HULL FORM OPTIMISATION OF FISHING VESSELS WITH RESPECT TO SEAKEEPING

by

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DECLARATION

Except where reference is made to the work of others,
this thesis is believed to be original.

DEDICATION

To my parents, my brother and sisters.

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CONTENTS

NOMENCLATURE

Symbols not included in the list below are only used at a specific place and are explained when they occur.

A_{jk}	Added mass coefficient for jk mode
a_j	Amplitude of j th response
AP	Aft Perpendicular
B	Ship breadth
B_{jk}	Damping coefficients for jk mode
BMT	British Maritime Technology
BSRA	British Ship Research Association
BSHC	Bulgarian Ship Hydrodynamics Centre
BTTP	British Towing Tank Panel
C_B	Block coefficient of ship
C_F	Frictional resistance coefficient
C_{jk}	Restoring coefficient for jk mode
C_M	Midship section coefficient
C_P	Prismatic coefficient
C_R	Residuary resistance coefficient
C_T	Total resistance coefficient
C_V	Viscous resistance coefficient
C_{VPA}	Vertical prismatic coefficient aft of amidships
C_{VPF}	Vertical prismatic coefficient forward of amidships

C_W	Wave making resistance coefficient
C_{WP}	Waterplane area coefficient
C_{WPA}	Waterplane area coefficient aft of amidships
C_{WPF}	Waterplane area coefficient forward of amidships
c/L	Cut-up ratio, where c is the distance from the FP to the cut-up point
DREA	Canadian Navy's Defence Research Establishment Atlantic
ESPEC	Irregular Sea Computer Program
FAO	Food and Agricultural Organisation
F_j	Complex amplitudes of the exciting force and moment
F_n	Froude number
FP	Forward Perpendicular
GZ	Righting Arm
g	Acceleration due to gravity
H1/3	Significant wave height
I_j	Moment of inertia in j th mode
I_{jk}	Moment of inertia in jk mode
ILO	International Labour Organisation
IMO	International Maritime Organisation
ITU	Istanbul Technical University
ITTC	International Towing Tank Conference
k	Wave number
k_x, k_y, k_z,	Roll, pitch and yaw radius of gyration
KTU	Karadeniz Technical University
L	Ship length
LCB	Longitudinal centre of buoyancy
LCF	Longitudinal centre of floatation
LCG	Longitudinal centre of gravity
MARCHS	3D Ship Motion Program

M	Mass of ship
M_{jk}	Mass matrix element for jk mode
R	Seakeeping rank
$\hat{R}$, F_i	Estimated or predicted value of R
R_{AR}	Estimator of added resistance index
RAO	Response Amplitude Operator
R_{AW}	Added resistance in waves
$\overline{R}_{AW}$	Average added wave resistance
R_{CR}	Estimator of calm water resistance index
R_F	Frictional resistance
RMS	Root Mean Square
R_n	Reynolds number
R_R	Residual resistance
R_S	Estimator of seakeeping index
R_T	Total resistance
R_V	Viscous resistance
R_W	Wave making resistance
S, A_{WA}	Wetted surface area
SDP	Seakeeping Design Package
SFOLDS	Ship Form on-Line Design System
SHIPMO-PC	2D Ship Motion Program
SMP	Navy Standard Ship Motion Program
SMSL	Ship Motion and Sea Load Computer Program
S_ζ	Wave spectrum
T	Ship draught
T_o	Modal wave period
V	Forward speed of ship
WL	Waterline of ship
x, y, z	Cartesian coordinate system

$\overline{ZG}$	Vertical location of centre of gravity
ε_j	Phase angle of the j th response
λ	Wave length
β	Ship heading angle relative to the wave direction
ζ_w, ζ_o	Wave amplitude
$(\zeta_w)_{1/3}$	Significant wave height
ζ^*	Modified incident wave amplitude
ξ_j	Six degree of freedom ship motions (surge, sway, heave, roll, pitch and yaw
ξ_k	Vertical relative displacement
σ_{AW}	Added resistance coefficient
σ_{LC},σ_{SC}	Long-crested/short-crested response root mean square values
ω, ω_ω	Wave frequency
ω_e	Encounter wave frequency
ω^*	The wave frequency above which ship responses are considered negligible
∇	Displacement volume
Δ	Displacement tonnage

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APPENDIX C

SUMMARY

The aim of this thesis is to formulate a relationship between the geometrical characteristics of a series of fishing vessel hull forms and the seakeeping qualities of these vessels. In addition a statistical relationship between these hull forms and added resistance and calm water resistance characteristics was developed.

The selection of ship motion theory is an important task to determine the seakeeping performance of fishing vessel hull forms. The first motion prediction method considered is a two-dimensional strip theory which predicts the motion responses in six degrees of freedom for a ship advancing at a constant speed with arbitrary heading in both regular and irregular seas. The second option considered is a three-dimensional translating pulsating source distribution technique associated with a cross-flow approach for taking viscous effects into account. Numerical computations were carried out using both theories for five chosen fishing vessels. It is found that the two-dimensional theory gives results with reasonable accuracy and with less Central Processing Unit (CPU) time compared with three dimensional theory.

Experiments were carried out to determine the seakeeping and resistance characteristics of a typical Black Sea fishing vessel. These experiments yielded a useful set of data for the validation of theoretical methods. The strip theory results, in general, show good agreement with the experimental data as well as with the three-dimensional theory. It is concluded that the strip method is a reliable tool to predict the dynamic motion response values of a fishing vessel hull form. In comparison with the three-dimensional source distribution method, this procedure has an advantage in that less computer time is required.

The generation of a systematic series of geometrically similar hull forms is of fundamental importance when seeking an optimal design with respect to the seakeeping characteristics. In this study a series of fishing vessel hull forms was generated from different parent hull forms. Numerical computations using the strip theory were carried out to determine the seakeeping performance of this series of hull forms. The main seakeeping parameters such as motions and accelerations were computed using the sea conditions specified for the Black Sea. The relative magnitude of these responses was related to hull form parameters by Bales' method. A regression equation with respect to hull form parameters was evaluated.

An optimisation procedure based on seakeeping assessment was developed, and used to obtain two optimum hull forms whose geometrical characteristics lay within the range of the investigated series. These two optimum hull forms give superior seakeeping performance compared with the corresponding parent hulls. The resistance characteristics of the optimised hull forms were also evaluated.

CHAPTER 1

INTRODUCTION

"In the past, fishing vessels constituted a much neglected sector of the fishing industry. Naval architects, boat designers, builders, and engineers took little account of fishing methods and the industry's special requirements at sea. Today conditions have changed. The fishing vessel has become the largest single investment in the industrial fishery of developed countries, greater than harbours, cannery plants, and retail stores. There exists therefore a strong incentive to produce highly efficient fishing vessels."

A. van B., Encyclopedia Britannica, 1982.

1.1 General

Fishing vessels of various kinds and forms exist in today's fisheries in all parts of the world. In the earlier times, fishing was done in inland waterways. With the advancement of knowledge, fisherman began to venture out into the open seas, first in simple dug out canoes and eventually using motor vessels as commonly seen in the present times. Due to its historic beginnings, almost all round the world, the profession of fishing is strongly influenced by tradition. In these circumstances, fisherman braved the hostile seas on fishing vessels known for their seagoing qualities after generations of modifications, based purely on experiences deriving from trial and error. However, in modern times, the rapid development in equipment and the demand for ever increasing returns necessitated tremendous changes to the techniques and methods of fishing. This affects the requirements for different types and sizes of fishing vessels. Attempting to accommodate the resulting large changes in design by the slow traditional approach of trial and error becomes rather cumbersome. In certain circumstances a lack of scientific judgement frequently leads to poor safety standards and to increased risk of loss of property and life at sea.

The fishing industry in Turkey is experiencing sudden changes in economical strategies so that the design and use of fishing vessels require new approaches that should produce a better efficiency in their exploitation. The renewal of the fishing vessel fleets requires new designs where the combination of higher productivity, fuel saving, safety and good working conditions will be a global and unique target. Traditionally, fishing is carried out by individuals owning their own boats, or by a group of individuals sharing a boat, and this is still the dominant pattern in inshore fisheries. The boat and ship builders traditionally act as technical consultants and advisers on all aspects of investment, and there are also some small firms with few specialist staff. Neither the individual owners and firms in the fishing industry, nor the vessel builders, have the resources in staff to cover the wide range of science and technology involved, or the capital to sustain the necessary programme of technical development. Over the past twenty years a considerable improvement in the design and construction of fishing vessels has been made in Turkey. One of the projects carried out at the Hydrodynamics Laboratory of the Technical University of Istanbul was to investigate possible improvements in the hull forms of existing designs. The aim of the project was to scientifically assess the traditional boat design and introduce guidelines for safe and optimum designs.

A modern fishing vessel is a complex technical system whose operation is affected by a number of random factors. In order to design the best hull form which will be highly cost efficient, safe and sea-worthy for given operating conditions, one has to optimise the different design requirements. It should be stressed that it is more difficult to optimise the characteristics of a fishing vessel than those of a transport ship. Firstly, this is due to the multipurpose activity of a fishing vessel that is to catch, process, store and transport fish. Secondly, operation of such a vessel strongly depends on random circumstances. Most of the parameters describing the process of exploitation of a fishing vessel are stochastic. For example, the amount of daily catch is random, and this requires estimation of the freezer's capacity to be considered as a stochastic problem. The same consideration applies to the capacity and the number of fish pre-cooling tanks, the size of refrigerated holds, fuel capacity and other parameters which are to be chosen by taking random circumstances into account. These problems are quite complicated to be handled simultaneously, thus the problem of optimisation of a fishing vessel is not a deterministic one. So far, it has not been possible to formulate and solve this stochastic problem at today's level of optimisation theory, which would adequately describe fishery activity of a ship.

The hull of a fishing boat has to perform many functions. Most important, it has to keep the sea on the outside, but it also has to be the right shape to negotiate rough seas and still be economical to drive through the water. It has to provide a platform for the fishing operations and be capable of withstanding the many stresses they impose. It has to be built to last for many years with a minimum of maintenance yet at the same time its cost has to be kept down to reasonable levels.

One of the most important design aspects of small ocean-going vessels, such as fishing vessels and offshore supply vessels, is good seakeeping characteristics. As Hutchison [1] notes *"The missions of ocean-going small craft are characterised by the* *need for the crew to perform complex functions and for vessels to perform intricate manoeuvres under hostile environmental conditions."* A fishing boat is one of the few types of craft which actually work at sea. Most vessels just carry cargo or people so that the design factors are considerably simplified. During fishing operations there are many factors which are difficult to assess during the design stage. This is one of the reasons why the design of fishing vessels is often conservative and slow to change.

The motions of a fishing vessel at sea should be of primary concern to the captain. The reactions of the fishing vessel to in-situ conditions is a result of the vessel's immediate static and dynamic stability. Also, the resulting motions of the vessel will impact the fishing effectiveness of the vessel, gear, and crew. Fishing vessels are one of a few types of craft which load at sea, making it extremely difficult to assess the stability of the vessel while fishing. Increasing the inherent stability of a fishing vessel generally increases the violence of the motions of the vessel. Since fishing vessels must be able to work at sea, the motions cannot be too severe. This restriction therefore requires a compromise between stability and comfortable motions.

For more than 30 years, researchers have investigated the equations governing the motions of vessels in waves. Some research has been a theoretical evaluation of the equations, while some research has incorporated the use of scale models to actually measure the motion of the vessels. Most of the research has been associated with container ships or the Series 60 hull, with only a limited amount of research conducted for fishing vessels. Nothing could be found, however, on the analysis of ship motions operating in a particular geographical location.

Stability Considerations-Stability is an often discussed problem of fishing vessels. The lack of sufficient stability has caused many owners to lose their vessels, and in some instances, their lives as well. As with other types of vessels, governmental authorities and regulatory bodies have to devise rules and regulations for the safe design and operation of fishing vessels. In 1945 the Food and Agricultural Organisation of the United Nations set up a Fishing Vessel Section which was the first international body to deal with the fishing problems [2]. This section was able to bring together all aspects which were connected with the fishing industry and to contribute to its advancement through the research and development work on fishing vessel and gears. Common interest on safety between shipping nations led to the establishment of the International Maritime Organisation, a body that recommends safety guidelines which may be ratified later as regulations by the individual governments. Resulting from the joint work by the Food and Agricultural Organisation (FAO), International Labour Organisation (ILO) and International Maritime Organisation (IMO), a document, in two parts, was drawn up and published under the title "Code of Safety for Fishermen and Fishing Vessels" [3, 4]. Part A of the Code provides information designed to promote the safety and health of fisherman, and part B information on design, construction and equipment of fishing vessels.

The first IMO stability criteria for fishing vessels above 24m in length was endorsed at the International Convention for the Safety of Fishing Vessels held in 1977 at Torremolinos, Spain [5]. This is based on an extensive survey of various national stability regulations; on statistical and other analyses on intact stability records and the experience of the different fishing fleets throughout the world. In essence they derive from the general criteria for large vessels modified for the purpose. The safety requirement is expressed in terms of minimum values for certain key features of the righting arm curve. These features include the initial stability given by the metacentric height (initial slope of GZ curve), the maximum GZ and the angle at which it occurs, and the specified area under the GZ curve up to an angle of 40 degrees heel. A detailed description of the development of these criteria is given by Nickum [6].

Fishing vessels must operate in continually changing sea conditions, encountering seas from varying directions. If the vessel has inadequate stability, specific operating scenarios could result in disaster. Even with adequate stability, operations in beam seas or following seas must be carried out with care. When operating in beam seas, water can be shipped on deck more readily. Should this water become trapped on deck, a significant reduction in vessel stability can result. Also, if the frequency of roll induced by beam seas is equivalent to the natural frequency of roll of the fishing vessel, the vessel could possibly roll beyond its range of positive stability with the ultimate outcome: capsizing [7].

The greatest concern for operating in following seas occurs when the fishing vessel is travelling at a speed very near or equal to the speed of the wave form. In this situation, the fishing vessel will experience a time when it is fixed on a wave crest with the crest located amidships. Whenever a fishing vessel (or any vessel) is in this situation, it experiences a reduction in its righting energy. The righting energy will be reduced even further by the dynamic effects of the vessel moving through the water. Another detrimental result of operating in following seas is the loss of steerage due to emergence of the rudder and propeller as the vessel travels over a wave crest. In addition to a loss of steerage, another problem with operating in following seas is broaching. This occurs whenever a vessel travelling over a wave crest looses its directional stability and turns parallel to the wave front. At this point if the wave height is sufficiently large, or the stability of the vessel is marginal, the wave will capsize the vessel.

Vessel/Gear Limitations-The motions of a fishing vessel impact the fishing effectiveness of the vessel and gear. Tupper [8], identified six categories of motion interference based on observations, interviews, and surveys of New England fisherman.

These categories are:

(1) Gear does not fish,

(2) Vessel can not stay on gear,

(3) Direct danger to the vessel,

(4) Loose gear on deck poses threat,

(5) Water on deck poses threat, and

(6) Motions impact crew's ability to work

From this study, the most frequently stated reasons for vessel motions interfering with fishing were (1) the gear did not fish properly, (2) the vessel could not stay on the gear, (3) the crew was being jerked around by the motions of the vessel, and (4) the crew would become exhausted from fighting the motions. The crew slipping and sliding on deck, and the threat posed by water on deck were also reasons stated for motion related fishing interference, but were not stated as frequently. The least frequently stated reasons for motions interfering with fishing were loose gear on deck posing a threat to the crew, and a direct danger to the vessel.

Human Limitations-Motion interactions with, and effects on, vessel stability and fishing effectiveness of the vessel and gear are problems faced by fisherman whenever experiencing less than ideal conditions. Designing fishing vessels for greater stability and developing fishing gear that can fish in adverse conditions are logical solutions to these problems. However, a third factor, the Human Factor, must be included whenever analysing and discussing fishing operations in adverse conditions. In the list presented previously, two of the four most frequently given reasons for interference of fishing due to motions dealt with crew performance, while only one related to the vessel and one related to the gear. With all things being equal, crew performance in adverse conditions is the one factor with the most variability. Therefore, a perception of how motions affect human performance is necessary to understand why the knowledge of a fishing vessel's reaction in various sea conditions would be beneficial to the captain. With that knowledge he would be able to choose the proper speeds and course headings so as to minimize the performance degradation of his crew while maintaining a maximum level of safety for his crew and vessel.

1.2 Background to the Fishing Vessel Studies and Layout of Thesis

A variety of data and references exist for the design of fishing vessels. Doust [9, 10, 11], carried out a considerable amount of work on the design optimisation of trawler forms. In 1962, he developed an equation for the estimation of resistance of trawler forms by a statistical analysis. The optimum trawler forms were derived by minimising the resistance coefficients given by the equation. In this equation, six form parameters (length-breath ratio, breath-draft ratio, maximum section area coefficient, prismatic coefficient, longitudinal position of centre of buoyancy and half angle of entrance) were used. By varying the parameters, using a computer program, the best combination of the parameters for minimum resistance was determined.

Engvall and Engstrom [12], described a method for the selection of an optimum fishing vessel. A mathematical model using simple operational research technique was presented for the selection of an optimum hull form. The size of the vessel, the hold capacity and the engine power were considered as the most important parameters and these were used as decision variables. A computer program was developed to compare the economical aspects of alternative designs which were generated by varying the parameters systematically.

Pal [13], described a methodology to determine at the pre-contract design stage the main design parameters of an optimum trawler for a specified fish-hold volume, some particulars of the fishing ground and the operating port. The results of a sensitivity analysis carried out with a particular fish-hold volume and installed horsepower to study the effect of the variation of some of the particulars of the fishing ground and the operating port on the optimum solutions as well as that of the variation of the installed horsepower on the optimum solutions for a particular fish-hold volume were also included in the study.

Sheshappa et al [14] developed a computer design model for the preliminary design of fishing vessels for the given fishery in question using the techno-economic calculations so as to get operational benefits. The model contains the relationship/submodels for determining the main dimensions of capacities, propeller calculations, installed engine power, fish catching power, supplies required for a given trip, economic free running speed, fuel consumption and investment calculations. Fish hold volume which is related to the vessel's main dimensions, is the main decision variable considered in the model. The design model can be used to determine the best possible match between vessel size, gear size and operation for the given fisheries.

Allievi [15] described an experimental and numerical investigation to determine the motions and stability of two fishing vessels in longitudinal and transverse seaway conditions. Heave, pitch, roll, yaw and sway responses due to regular and breaking waves of predetermined characteristics were obtained experimentally. The numerical analyses of fishing vessel motions in a longitudinal seaway was carried out using the strip theory. The velocity dependent coupling terms, responsible for a major part of the non-linear behaviour of the fishing vessel, were included. A parametric study of fishing vessel stability was carried out by considering the dynamic response in waves of varying characteristics. Fishing vessel stability tests were conducted for the seiner and trawler in longitudinal and transverse seaways. The purpose of this work was to give some insight into the mechanisms of capsizing of fishing vessels and to present a preliminary parametric analyses of the vessel's stability in different seaway conditions to complement current stability guidelines. A numerical investigation was also carried out to correlate the predictions with experimental results.

Karppinen [16] carried out motion computations based on the linear strip theory and three-dimensional linear sink-source method for very wide and short fishing vessels. Motion transfer functions and phase lags computed by linear strip theory for the vessels were compared with model test data and theoretical results determined by the three-dimensional linear sink-source method. Results were presented for beam and head seas at various speeds and it was concluded that the strip theory gives either a much better or at least equally good fit to the model test data than the three-dimensional method.

Frostad and Jullumstro [17] performed research in the Norwegian project "Modern Hullforms of Fishing Vessels". The aim of the project was to develop a new generation of hullforms for fishing vessels. In particular, small vessels of approximately 20 meters in length, medium size vessels of approximately 40 metres length and larger vessels with approximately 60 metres length were investigated. The seakeeping characteristics, such as motions and accelerations, were evaluated and related to the hull form and main dimensions. Through criteria of acceptable levels of ship motions, the working conditions and safety for personnel on board and thus the total operability of the vessel were derived.

Goren et al [18] developed a numerical approach to find optimum hull forms with minimum total resistance of fishing vessels. Two of the optimal forebodies were obtained and numerical results indicate that more than 10% reduction in total resistance is theoretically possible for fishing vessels with side-bulbs. Experimental results were presented for comparison and they show that the optimisation procedure may be useful as a design tool.

Ivanov et al [19] described a software to simulate operation of a fishing vessel. The simulation model used is a package of computer programmes which, by modelling a ship's activity through randomly changing fishing conditions, enables one to predict the technical and operational characteristics of a fishing vessel. The model assists designers to obtain the best characteristics of a fishing vessel by examining their possible variants. A variant is regarded as the best design in accordance with a certain criterion. In ship design for fisheries profitability, single cost, pay-back time etc. are usually suggested as economic and operational criteria. The model is to be used at the earliest stages of ship design. Using this method the following problems can be solved:

- optimisation of the main characteristics of a fish catching vessel at the earliest stage of her design evolution
- comparison of economic and operational characteristics of different versions of a ship or her design in order to meet the shipowner's requirements
- prediction of economic and operational characteristics of vessels in accordance with the shipowner's requirements

The simulation model consists of two blocks. The technical block generates the vessel's parameters which are used to simulate the operational aspects, and to calculate the technical and economical indices in accordance with the input data by solving a set of design equations. The set of equations includes the equation of masses, floatation, capacity, propulsive quality, the conditions of agreement between the ship's rolling and her stability, etc. The operational block simulates the process of the vessel's operation and calculates the technical and economic indices. Using this model results in not only reduction in the total time-period of fishing vessel design, an improvement of the quality of designs but also a substantial increase in the effectiveness of investments in building fishing vessels and a reduction of the risk to shipbuilders and fishing fleet operators.

Traditionally, the design procedure has been based on still water performance of the vessel. In fact a successful vessel design depends on its overall characteristics and performance at sea in various operating conditions. In the early design stage the designer must have a sufficient knowledge of predicting vessel characteristics from which he will be able to estimate the overall performance of the vessel at sea, e.g. resistance-propulsion characteristics, structural requirements, vessel motions as well as dynamic effects due to waves and wind. Extreme vessel motions and environmental effects can make the vessel duties hazardous, reduce crew comfort and the performance of the vessel. Thus the dynamic requirements have a vital importance on vessel's design considerations. The dynamic requirements are investigated by carrying out a seakeeping evaluation, by which the ability of a vessel to remain safe in a seaway and to perform its service in all real conditions, is determined. In a design process, seakeeping plays a great role to determine the trends in seakeeping variables linked with the modification of the hull geometry. Typical seakeeping performance analyses require either sophisticated numerical methods or expensive and time consuming scale model tests. In the ship synthesis and concept stages of design, large numbers of variations in her parameters are investigated. Precise definition of her form characteristics required by seakeeping prediction computer programs for all ship variations is impractical. Consequently, a simplified approach, or algorithm is necessary in the early design stages: however, the accuracy of this approach must also be sufficiently reliable so as to make its use worthwhile.

Recently, as the reliability of the techniques to predict ship motions increased, computational tools based on these techniques are more frequently used in comparing the candidate hull forms for their seakeeping qualities before deciding on a final hull form. Availability of such computational tools naturally enhance the design capability considerably. As the capability of computing the responses of a ship form to waves increases and characterisations of the wave environment become refined, a visible movement has been taking place in the last few years toward incorporating the seakeeping performance goals into the early stage of ship design process. Bales [20] provided the essential technique for the early stage estimate of seakeeping performance with the development of seakeeping index. The Bales approach used regression analysis to develop a relationship between certain hull form parameters and a general seakeeping estimator:

$$R[D] = R^{*}[G]$$

Where D is a set of significant responses forming the general ship behaviour in waves, and G is a set of geometric parameters most influencing ship seakeeping.

The seakeeping index R integrates a number of ship motion characteristics and it can be used for the evaluation and comparison of seakeeping qualities of various designs. Bales quantified this by using existing destroyer type hull forms. He then used the resulting optimum combination of these parameters to design an "optimum" seakeeping hull form. His methodology was validated by the fact that the resultant hull form had excellent seakeeping performance characteristics compared with similar ships of ordinary design. The concept was later used, among others, by van Wijngaarden [21] who developed an optimum small hull form for the North Sea, taking into account of both seakeeping and calm water resistance. In his work, van Wijngaarden modified the original concept by incorporating the probabilities of occurrence of particular wave periods in the index calculated for a given significant wave height.

In the study reported in this thesis a regression equation was developed to estimate the correlation between the hull forms and the seakeeping qualities by applying the Bales' procedure to the series of fishing vessels. The content and order of presentation of this thesis are briefly summarised below.

In Chapter 2 the operational consequences of seakeeping performance are discussed. A review of ship hull form design efforts is briefly given. It is noted that, during the last few decades, a large number of different attempts, both experimental and analytical, have been made to establish a general relationship between hull form characteristics and seakeeping performance. With greater use of analytical methods, particularly in the 1980s, several seakeeping design methodologies have been developed. These methodologies are reviewed in the last section of this chapter.

Chapter 3 contains the description of equations of motions and solution of these equations as well as comparisons between the predictions of two ship motion programs SHIPMO-PC, based on the two-dimensional potential flow theory, and MARCHS, based on three-dimensional translating pulsating source distribution technique. A numerical analysis was carried out for five different fishing vessels which consist of one existing Black Sea vessel [22], and four vessels chosen from Istanbul Technical University (ITU) series [23], and the results of the analysis are presented in the form of figures. The figures present the added mass and damping coefficients as well as surge, sway, heave, roll, pitch, and yaw motion amplitudes. The purpose of this comparison is to decide which program is most suitable to carry out seakeeping calculations for a large series of hull forms. In addition to the motion response predictions the added resistance, vertical acceleration and relative motion calculations were carried out. This chapter also describes a series of model tests with the Black Sea fishing vessel used in the numerical study, which were carried out in regular head seas, following seas and beam seas. Added resistance, heave and pitch motions, relative motions, and deck accelerations at the fore perpendicular were measured at different speeds. A series of resistance tests were also carried out in calm water for different Froude numbers. The results of the experimental measurements were used to validate the theoretical results.

Chapter 4 describes a systematic series of hull forms generated by a linear distortion method from different parent fishing vessel hull forms. This chapter presents the motion calculations obtained from the two-dimensional strip theory. The motion calculations were carried out for a family of fishing vessel hull forms in order to obtain their motion response characteristics, absolute vertical accelerations and relative motions in different sea states. This chapter details the generation of a data base containing the results of seakeeping calculations for the series of fishing vessel hull forms. A seakeeping index based on the seakeeping ranking procedure developed by Bales was calculated using the results contained in the data base. The results of a linear regression analysis to define the seakeeping rank as a function of various design variables are illustrated. This chapter also includes the development of a regression equation based on added resistance values which were calculated for head seas by the Joosen method.

Chapter 5 gives a brief review of the current calm water resistance prediction methods. A resistance algorithm developed by using a regression analysis of the published experimental data for the ITU series of hull forms and experimental measurements which were carried out by the author at the Hydrodynamics Laboratory, is described. The regression analyses used in the study are based on the techniques developed by van Oortmerssen [24] and Bulgarian Ship Hydrodynamics Centre (BSHC) [25]. Calm water resistance calculations were also carried out using Holtrop-Mennen [26, 27] method. The Oortmerssen and BSHC's methods were compared with Holtrop method and experimental measurements. A calm water resistance data base was generated for the series of hull forms using the BSHC method. The calm water resistance index was then calculated from this data base and a regression equation with respect to hull form parameters was derived.

In Chapter 6 a seakeeping optimisation procedure based on Hooke and Jeeves' [28] direct search method is presented. In this procedure, the seakeeping regression equation developed and detailed in the fourth chapter was taken as an objective function with related geometric and functional constraints to generate a final "optimum" design which is the best form within the geometric and functional limits. The effect of different hull geometrical parameters on the three regression equations based on seakeeping, added and calm water resistance are presented. Two seakeeping optimum hull forms were obtained from two parent fishing vessel hull forms. Finally ship responses, calm water resistance and added resistance predicted using a numerical method for these hull forms are presented.

Finally, main conclusions are given in Chapter 7.

CHAPTER 2

REVIEW OF INVESTIGATIONS ON SEAKEEPING ANALYSIS FOR DESIGN

2.1 Introduction

Marine vehicles are designed and built for different services, e.g.carrying people, transporting cargo and performing special services at sea. Marine services for a sea country take a wide range in the volume of industrial and economical sources. They also play a significant role for the development of the national economy. In the competitive world this always forces designers to design marine vehicles as high efficient performance, good stability and seakeeping as possible. The ship designer must carry out such an evaluation of marine vehicle geometry that would satisfy various requirements related to the vehicle's characteristics in a seaway. During the design stage of a marine vehicle the investigation of ship motions is particularly essential in order to obtain the best possible design from the seakeeping point of view and to reduce motions to an acceptable level both for men and cargo.

2.2 The Design Process

The starting point for a design is a given set of requirements concerning the ship type, speed, payload, range and operating conditions. The determination of the total design task occurs when the design definition embraces both the needs of the customer and the designer's criteria of technical acceptability. Figure 2.1 shows a hierarchical design sequence, starting with the outcome of the feasibility study.

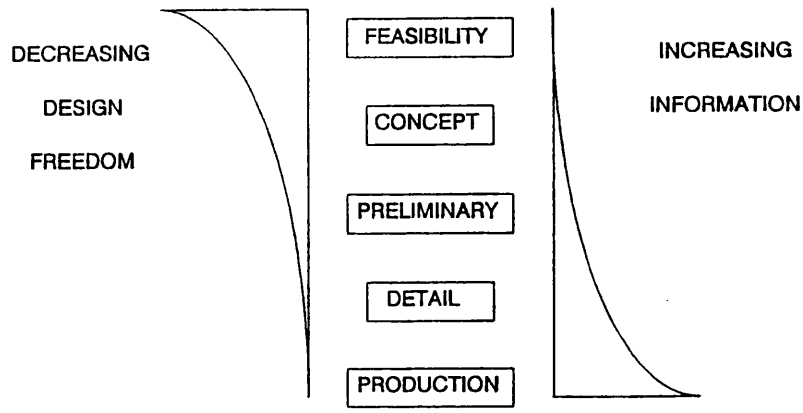


Figure 2.1 Hierarchy of the Design Process Steps

As the design process goes forward, the scope for change eventually decreases; at the same time more information becomes available about the design.

The ship design process may be summarized as consisting of the following steps:

- Feasibility Study
- Concept Design Stage
- Preliminary Design Stage
- Detailed Design Stage
- Production Stage

The first step in the ship design process is the generation of a clear definition of the design objectives. A fundamental aim of a ship owner is to make a profit on his capital investment. From market research the owner needs to decide on the type of trading in which to indulge and estimate the amount of the goods to be transported annually on his chosen routes and the required rates of delivery. It is necessary to carry out various economic examinations to decide not only the best size of the ship, but it's speed and the attainable level of profitability over an acceptable period of time.

Concept design translates the mission requirements into naval architectural and engineering characteristics. During the conceptual design stage, the Naval Architect would typically want to compare the merits of a range of alternative ship designs. In the earliest stages of the design, the designer seeks various ways of fulfilling the customer's requirements by matching the operations envisaged to the design and investment that would be necessary to perform them. The effectiveness of a ship design is subsequently determined by the quality of the conceptual design process and yet this stage of the design and production sequence often attracts poor resources in relation to its importance. The designers at the concept stage therefore require to have at their disposal computer-based systems which will allow them to generate, modify and detail, designs in one way or another. Once the principal particulars of the ship are selected the designer would proceed to more detailed analyses using specialist tools, for example seakeeping, resistance, powering, maneouvering, stability, propeller design, strength and vibration analysis, noise, mooring etc.

The preliminary ship design stage includes early concept formulation through the preparation of plans and specifications that form the basis of building contract. This phase of the design is the most significant of the whole design process. It is this stage of design where the major characteristics are determined, the dimensions have become firm, the requirements and the mission have come into focus. At this stage designer must answer many questions concerning speed, power, seakeeping, wave making resistance, stability etc.

In the detailed design stage every necessary detail is worked out so that material may be ordered and construction may begin. The members of the detailed design team are not necessarily the same as those which completed the conceptual and preliminary design stages. The nature of the work has now changed significantly as its directed towards the definition of the ship for contract and production.

2.3 Hull Form Development in Ship Design

One of the major elements of vital importance for a successful ship design is the hull form itself. Producing a hull form for a new ship design is one of the fundamental tasks in naval architecture. It is inevitable an iterative procedure and therefore its specification continues throughout the design process, progressing from a simple geometric description, through to a fully detailed structural form.

There are an infinite number of shapes satisfying the displacement equation for any set of values of length, beam, draught, block coefficient, and displacement. The challenge lies in developing an optimum hull form or, at least, one having acceptable performance. Hydrodynamic characteristics are very sensitive to even minor changes in the hull form. Therefore, the selection of ship lines requires great care in order to avoid unacceptable results.

A number of different methods of deriving a hull shape exist in ship design, and they can be classified as follows:

- The most commonly used approach is to select a previous successful design as the parent hull and to distort it to give the new hull form with desired mix of features. Although thousands of ships have been designed and built, and a great number of ship models have been tested and studied, a thorough understanding of ship hydrodynamics is still lacking. What quality or qualities a good hull form must possess to have superior resistance, seakeeping, propulsive and manoeuvring characteristics is still not quite known. Under such circumstances, a ship designer would normally try to find an existing ship with a good performance record to use as a basis for his new design.

- The use of a particular, successful parent, tends to lead to the families of designs that are apparent in the products of most design organisations. There are a number of well-known ship forms such as the Taylor Series, the Series 60, the BSRA Methodical Series etc. They are specified in a form which allows hull offsets to be readily generated for specified hull form parameters. Having selected possible approximate parameters it is possible to use the lines of series forms with similar design parameters as a basis ship in the design studies.

- The designer may develop a rough, faired set of lines without any parent, relying solely on his/her eye and past experience.

- For simple shapes such as barges, the hull forms can be created through the use of geometrical or mathematical equations. For more complicated shapes, direct generation of hull forms is possible with the aid of interactive computer graphics and fairing procedures.

- It must be recognised that the design of the hull form is strongly dependent on hydrodynamic requirements. Besides calm water performance factors, seakeeping and manoeuvring characteristics are becoming more and more important. This implies that direct hull form generation should, preferably using appropriate analytical tools, optimise the hull form with respect to specified hydrodynamic characteristics.

2.3.1 Hydrodynamic Considerations in Hull Form Design

The prediction of the hydrodynamic performance of a ship can be undertaken by one of the following approaches:

- Model Tests
- Standard Series Tabulations
- Statistical Methods
- Analytical Methods

Model tests involve a one-off scale model representation of the design and currently is regarded as the most reliable hydrodynamic performance prediction approach. Most tests can provide resistance, propulsion, seakeeping and manoeuvring data. However, model tests are relatively expensive and time consuming, and are therefore normally undertaken at the final stage of design. At this stage the designer have little freedom to change the hull form unless there are significant problems.

Standard series tabulations are generally large collections of data either tabulated or presented graphically from the results of systematic model tests or systematic computations based on a standard series hull form and its systematic variations. This approach is useful when determining basic performances, however, these series are type specific and modern design concepts are not necessarily embodied in the available standard series data.

Statistical Methods correspond to presentations of performance data gathered from the analysis of non-systematic model tests and computations. The principal technique employed is multiple regression analysis where an attempt is made to reduce the variations in basic parameters and eventual performance to an equation which relates them in some form. These equations only valid within the range of data over which there are reliable results. In addition the method of regression analysis has been shown to be extremely sensitive to the parameters used in the formulations of equations.

Traditionally, the hydrodynamic design of ships, tends to rely upon the largely idealized model of the smooth ship moving on a straight course at constant speed on a calm water surface. This model of an ideal ship's trial can be well approximated in the common towing tank tests. However, the ability of modern computers and computational methods allows the designer to perform the traditional calculations more quickly and more reliably, and also provides the capability to undertake such aspects of hydrodynamic design problems which could have been treated before only by intuition.

Seakeeping came of age as a discipline of applied hydrodynamics in the mid 1950s with the emergence of strip theory and linear superposition for the analytical prediction of ship motion in irregular seas. Subsequent advancement led to the development of technologies which are useful in the later stages of ship design. These technologies are now being introduced into the earlier stages of ship design and into ship operations.

The design of ships or any other floating systems intended to operate on or close to the surface of the sea is controlled to a large extend by what is usually referred to as seaworthiness, or, in more common terminology, safety at sea. Safety of a ship naturally includes the crew, cargo and the hull itself. Seaworthiness is a generalized term and reflects the ship's capability to survive all hazards at sea such as collision,grounding, as well as heavy-weather effects related to the environment in general and waves in particular.

While seaworthiness deals with the extreme, seakindliness usually refers to those qualities of the ship related to the less violent responses due to wind and waves. The notation of seakindliness appears to have been introduced by Mcdonald and Telfer [29]. They did not define the term but gave a specific examples of how a ship is likely to handle well or poorly in rough weather because of one or another feature of design. Later, Kent [30] gave a definition of a seakindly ship as *"A Seakindly ship is one which rides the seas in rough weather, with decks free of seawater: that is, green seas are not shipped and little spray comes inboard. No matter in which direction the wind and waves meet the ship, she will stay on her course with only an occasional use of helm, she will respond quickly to small rudder angles and maintain a fair speed without slamming, abnormal fluctuations in shaft torque, or periodic racing of her engines. Open decks will be easy to traverse in all weathers, without danger or discomfort to her passengers and crew, and her behaviour in a seaway - i.e. her rolling, pitching, yawing, heaving, surging and leeway drift - will be smooth and free from baulks or shocks."* St.Denis [31] proposed to adopt a simpler and more restricted definition of seakindliness as *"A seakindly ship is one which responds in a non-violent and non-dangerous manner to the environment of wind and waves."*

2.4 Seakeeping in Ship Design and Operation

The success of a ship design depends ultimately on its performance in a seaway. However, the prediction of ship motions, resistance and propulsion characteristics, structural loads, and dynamic effects like deck wetness and slamming in a realistic seaway is such a complex problem that ship designers are generally forced to select their hull forms and ship dimensions on the basis of calm water performance without much consideration of the sea and the weather conditions. Only very recently sophisticated experimental techniques and computer applications in ship motion theories have made it possible for the designer to consider the seakeeping qualities of his ship at an early stage.

Seakeeping characteristics of a ship can be divided into three major categories. These are Habitability, Operability and Survivability. In principle, a seakeeping hull design should be carried out to achieve the criteria encompassing all three of these categories. However, there is no distinct universal set of criteria for seakeeping performance. The criteria can vary vastly from ship to ship depending on the mission of the ship.

Habitability deals with the environment in which the crew can effectively perform their duties so that there is no degradation in performance due to the behaviour of the ship in a seaway. The habitability requirement depends considerably on the type of mission for the particular ship. A much higher degree of habitability is to be sought for a passenger vessel than for other types of merchant ships. The ride comfort of the passengers or the effective physiological and psychological functions of the crew under rough motions have to be considered in the design stage. The human tolerance level under a steady oscillating condition of a linear motion is shown in Figure 2.2.

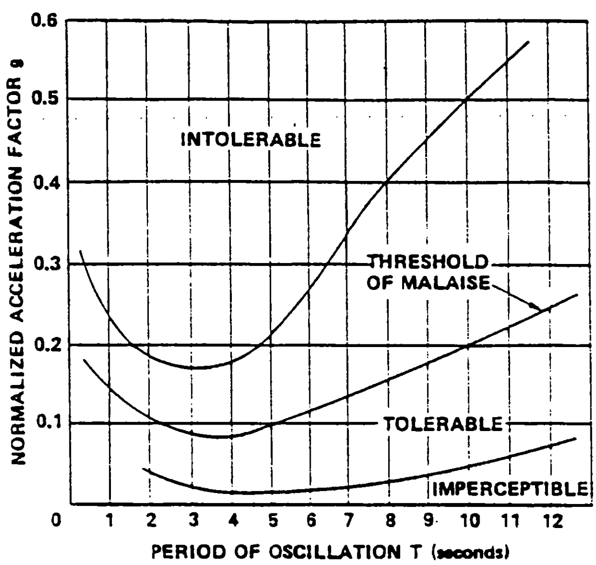


Figure 2.2 Human Tolerance for Vertical Acceleration [32]

It is shown by St. Denis [32] that a key factor affecting the body function is the acceleration level which the human is subjected to. The region where the periods of oscillation are 3 or 4 seconds shows the minimum level of tolerance. Particularly, when the acceleration level is high and persistent, the tolerance limit of the human body is significantly reduced.

Operability of a ship from the seakeeping standpoint is the capability of the ship with its crew and mechanical and electrical equipment to perform its assigned mission in the seaway environment, e.g. to continue fishing, maintain course and speed, continue operating helicopters etc. If the habitability is more directly related to the physiological response of human body, the operability is more oriented toward the ship's response to the seaway environment. In this category, the seakeeping performance has a direct relationship. Defining the criteria of operability of a ship is always an extremely difficult subject since they vary significantly from one type of ship to another.

In general, the displacement, velocity and acceleration of a ship from its equilibrium position are the factors governing the operability of the ship. Specifically, the major factors governing the seakeeping performance of a ship are deck wetness, slamming, propeller and rudder emergence, velocities and accelerations at local points on the ship, and roll motion among other modes of motion. The deck wetness, slamming, propeller and rudder emergence are the phenomena caused by the relative vertical motion between the ship and the free surface. The vertical motion at a point on the hull is the result of the heave, roll and pitch motion, while the transverse horizontal motion at a point on the hull is the result of the sway, roll and yaw motions.

The ultimate requirement of an acceptable ship design is whether or not the ship can effectively carry out its mission under all severe sea conditions. Survivability is concerned with what happens to the ship when conditions become so rough that the ship or any of its major subsystems such as the hull or machinery are in danger of damage or destruction. The environment is now one of the very severe storms experienced by a ship only once or twice in its life time. Habitability is no longer of primary concern, and operability is important only with respect to most essential subsystems. The primary structural strength of ships, the righting moment for roll and the floodable lengths are based on the survivability criteria. Historical design practices, classification society rules and safety regulations all emphasize the survivability of ship in extreme sea conditions. Compared with the habitability and operability criteria, the survivability criteria to be met in hull designs seems to be better defined and well exercised.

2.5 Seakeeping Performance Criteria

Seakeeping performance criteria describe the particular characteristics of a ship's seakeeping which degrade its habitability, operability or survivability. However, while theoretical and model test techniques have made possible the prediction of a ship's seakeeping characteristics, there is as yet no rational and widely accepted method for relating these to habitability, operability and survivability, except in the intuitively obvious statement that lower motions are better. For instance, it is at present impossible to evaluate a design which pitches badly but does not often slam, against another which pitches less but slams more frequently. The concept of seakeeping criteria was developed to assist this understanding.

Seakeeping performance criteria may classified as:

- Ship's criteria: which relate to the probability of damage to the hull, failure of the ship's engines, movement of cargo, intake of water, capsize etc. These primarily define the ship's operability and survivability.

- Ship/crew system criteria: which relate to the operational effectiveness of the ship and its crew, including the ability to navigate the ship, maintain the engines etc. These define the ship's habitability and operability.

Limits for the criteria are numerical values which define the worst seakeeping performance for acceptable habitability, for operability and for survival.

2.5.1 Methods of Determining Seakeeping Criteria

The methods which have been used to determine seakeeping criteria, for use in evaluating a ship's seakeeping performance near to limits of its operability, are:

- Special seakeeping trials in which ships are driven as fast as their captain dares in rough seas, and the performance characteristics at the point the captain decides to reduce speed are taken to be critical responses (Andrew and Lloyd [33]).

- Prolonged seakeeping monitoring in which the maximum responses over a long period, including typical rough weather conditions, are taken to be the critical values, assuming that the captain will operate near to the limits on occasions, but will never exceed them (Aertssen [34]).

- Questionnaires of ship's captains, asking for the conditions which cause them to reduce speed or change heading, and taking a statistical average of their answers (Hadler and Sarchin [35]).

2.5.2 Existing Performance Criteria

Various sets of performance criteria and limits have been proposed, some derived from full-scale data and others proposed arbitrarily from general experience. The limits are generally observed captain's limits which are assumed suitable for use as design limits. Vertical and Lateral accelerations are of major importance for ship habitability because of their strong association with the incidence of seasickness.

Daidola and Griffin [36] present sets of seakeeping criteria that have been included in the statements of requirements for the design of two Canadian oceanographic vessels. They also show a set of criteria used by Spouge [37] for predicting seakeeping performance of a British fisheries protection vessel.

Table 2.1 Limiting Criteria For Vertical Acceleration [Karpinnen, 1987]

Vertical Acceleration RMS	Description
0.275 g	Simple light work. Most of the attention must be devoted to keeping balance. Tolerable only for short periods on high speed craft.
0.20 g	Light manual work by people adapted to ship motions. Not tolerable for longer periods. Quickly causes fatigue.
0.15 g	Heavy manual work by people adapted to ship motions: for instance on fishing vessels and supply ships.
0.10 g	Intellectual work by people reasonably well adapted to ship motions. (i.e., scientific personnel on ocean research vessels. Cognitive/manual work of a more demanding nature. Long term tolerable for the crew. The International Standard for half an hour exposure period.
0.05 g	Passengers on a ferry. The International Standard for two hours exposure period. Causes symptoms of motion sickness in approximately 10 per cent of unacclimatized adults.
0.02 g	Passengers on a cruise liner. Older people. Close to the lower threshold below which vomiting is unlikely.

In a Nordic Co-operative project criteria have been established for different ship types, operations and activities on the basis of an extensive literature review and the experience of four Nordic ship laboratories. A selection of Nordic seakeeping criteria, Nordforsk [38], is given in Table 2.1 and Table 2.2. Karppinen [39] gives a tentative scale for vertical accelerations (see Table 2.1) which may be used for estimating the maximum acceptable magnitude for different activities on board and for the comfort of the crew and the passengers.

Table 2.2 Criteria for Vertical Acceleration and Roll Motion

RMS		Description
Vertical Acc.	Roll	
0.20 g	6.0 Deg.	Light manual work
0.15 g	4.0 Deg.	Heavy manual work
0.10 g	3.0 Deg.	Intellectual work
0.05 g	2.5 Deg.	Transit passengers
0.02 g	2.0 Deg.	Cruise liner

2.6 Seakeeping Design Parameters

The magnitude of ship motions will depend upon the interacting effects of speed, wave spectrum, dominant wave direction and the characteristics of the response RAO, which depend mainly upon the geometrical and dynamic characteristics of the ship. The geometric properties which determine the behaviour of a ship in a seaway can be studied in two groups. The first group consists of the simplest parameters such as length, beam, draft, displacement and position of the longitudinal centre of buoyancy that must be determined before a hull form is designed. The second group consists of parameters such as longitudinal moment of inertia, waterplane area, and longitudinal centre of flotation which from fundamental dynamics are likely to have a significant influence. A ship's size, particularly its length and displacement, has the greatest single influence on its seakeeping performance. Generally, a large ship reacts less violently in a given sea state than a smaller ship. However, other design criteria, mainly economical, force the designer to reduce ship size. A considerable number of studies have been published on the influence of design and operational parameters on seakeeping performance. An important feature of these investigations is that many apparent contradictions exist between the findings because of the differences between the sets of parameters which are kept constant and between those which are allowed to vary.

The influence of a ship's hull form on its seakeeping characteristics can be best understood by separately considering its underwater and above water characteristics. It is the underwater hull form that principally influences the heave, pitch and roll motions of a ship as it reacts to a given seaway. Such hull form features as waterplane area coefficient, and longitudinal centres of buoyancy and floatation influence a ship's motion to varying degrees. Once the size and the underwater hull form of a ship have been selected motion characteristics of the vessel in a seaway have largely been predetermined. Nevertheless, the ship's above water form, while it does not significantly influence the ship's motion, does strongly affect the deck wetness characteristics.

2.6.1 Influence of Underwater Hull Form on Seakeeping Characteristics

Lewis [40] investigated the influence of ship size on seakeeping by expanding the predicted pitching response spectra worked out for a Series 60 model to shorter and longer length values. Predicted pitch values clearly indicated the advantage of a larger ship size.

Lloyd [41] investigated the effects of the hull form on seakeeping characteristics using a simple mathematical frigate hull form. Different hull forms were obtained by specifying the length, forward waterplane area coefficient, midship area coefficient, block coefficient, and the ratios of midships draught to length, midship beam to length, transom draught to midship draught and transom beam to midship beam. The sectional area, waterplane and profile curves, and section forms were defined using simple mathematical formulae and distorted the parent hull systematically in three different ways, namely;

- by keeping the length constant and varying each of the seven nondimensional parameters in turn,
- by keeping all form parameters the same while varying the length, and
- by varying midships draught to length and midships beam to length ratios to maintain the ship mass constant while varying the length.

It was assumed that forms having the best performance in long crested head seas would also have the best or at least an adequate performance at other headings. The effect of forward speed on seakeeping responses was ignored and the study was limited to a single speed. A seakeeping rank which consists of heave, pitch and relative motions was evaluated. It was concluded that, seakeeping for a given length will generally be improved by adopting a large waterplane area coefficient, wide transom, full midship section and low block coefficient.

Lewis [42] reported the results of a comparative testing, in order to investigate the influence of length on ship motions. Two cargo ship models were tested in irregular seas. The variant model was obtained from the parent by increasing length by 10 percent with corresponding reductions in beam and draught so that the displacement remained the same. Freeboard/length ratio at the bow was kept constant for both models.The main conclusions of the study were that at equal speeds a considerable reduction in pitching amplitude, in vertical acceleration at the bow, and in shipping of water forward was observed for the longer hull. For comparable wetness characteristics in a particular sea state, the speed of the parent model was limited to 8 to 10 knots, while the longer variant can travel at a much higher speed.

Beukelman and Huijser [43] investigated the effects of ship form on seakeeping qualities using a strip theory based computer program. The parent hull was selected from Series 60 and the influence of length, speed, forebody section shape, block coefficient, position of the centre of buoyancy and radius of inertia was studied. All the calculations were carried out for irregular head seas based on the ITTC two parameter spectrum to obtain heave and pitch displacements, vertical bow accelerations, relative bow motions, slamming probability and added resistance in waves. The following conclusions were deduced from the computed results:

- Out of all parameters investigated the length has the greatest influence on the motions, accelerations, slamming probability and added resistance. With increase of the length the motions, accelerations and the probability of slamming decrease while the added resistance increases with length up to a certain value depending on the sea state, speed and block coefficient.
- V shaped forebody sections result in reduced responses above a certain length limit U shaped forebody sections are preferable with respect to the added resistance in waves.
- An increase of the block coefficient causes a strong reduction of all responses.
- Influence of the position of LCB is of minor importance.

Muntjewerf [44] investigated the effect of hull form and length using a series of five destroyer models. Tests were carried out in regular head and bow seas and the results of heave, pitch and power increase in waves were used to compute the behaviour in long and short crested irregular seas corresponding to sea state 5. The main finding of the study was that a large increase of length at constant displacement offers the best possibility for improving the seakeeping qualities of destroyer forms in head and bow seas.

Abkowitz et al. [45] reviewed the recent developments in seakeeping research and applied the available knowledge to some preliminary designs. A set of Series 60 ship forms with a fixed displacement was obtained by varying the length, beam, draught, prismatic coefficient and the midship section coefficient successively. For each form heave, pitch, vertical accelerations at selected points, and relative bow motion and velocity values were evaluated using the strip theory. The results of the investigations were presented in a form of three dimensional plots in which the ordinate is the RMS value of the chosen response, and the abscissas are the mean ship speed and the varied hull form parameters. The results indicated that:

- The effect of varying a given parameter on ship responses is strongly dependent on how the variation is performed. For example, increasing length is beneficial only when draught is decreased. Increasing length by decreasing other parameters leads to an increase of most of the responses examined.
- Variation of the midship section coefficient has negligible effects on ship responses.
- Variation in the longitudinal prismatic coefficient considerably affects the magnitudes of ship motions.
- When the draught is increased, most responses increase and the most effective way of reducing the responses examined is to decrease draught and to adopt a higher longitudinal prismatic coefficient or a longer length.

Vossers et al. [46] carried out systematical experiments on the Series 60 models to investigate the influence of main dimensions and displacement on seakeeping characteristics. To restrict the number of variables they kept the section shapes, and secondary hull form parameters such as LCB and C_M constant. Experiments were carried out in regular waves. Measured responses included heave, roll, pitch and relative bow motions in addition to thrust, torque and power increase in waves. They concluded that the influence of the block coefficient is negligible on motions and propulsive characteristics in waves while motion amplitudes and propulsion values generally decrease with the increase of the L/T ratio for the larger waves and increase for the smaller waves.

Robson [47] described the status of the international project on high speed displacement hull forms, first reported by Blok and Beukelman [48]. Following the selection of a parent form for the series, a "magic cube" of twenty seven different designs was obtained by systematically varying L/B, B/T and C_B. Transformation from the parent form was achieved by a simple linear transformation for breath and draught. For models with different C_B to the parent form, the ordinates of the sectional area curve were multiplied by a constant ratio of the actual C_B to the parent C_B. It was assumed that C_P and LCB were always the same as the parent hull. All models were tested with constant freeboard ratio and longitudinal radius of gyration. To compare the seakeeping performance of different forms, Bales' regression equation was utilized. Test results indicated that, seakeeping characteristics represented by a seakeeping rank in terms of vertical seakeeping responses could be improved by increasing L/B, B/T ratios. The effect of C_B on seakeeping was found negligible.

Moor [49] tested a series of sixteen models derived from the form of a large twin screw ship with block coefficient 0.573, to investigate the influence of secondary hull form parameters (LCB, LCF, C_{WP} and C_B) on motion and propulsive characteristics in waves. All models were tested in regular waves with constant radius of gyration and measurements were made of heave, pitch, vertical acceleration at the fore and aft peaks, propeller thrust and torque. Estimates of performance in irregular waves were made by using the ITTC spectrum. To compare the accuracy of these predictions, four of the models were run in irregular seas using the same spectrum. The correlation between calculated and measured significant responses was found to be satisfactory.

The results of experiments indicated that, pitch decreases significantly as the centre of buoyancy moves forward, increases as the centre of flotation moves forward, and tends to decrease as the bow sections become more U shaped. The trends of heave were the reverse of the trends of pitch, increasing as the centre of buoyancy moves forward, decreasing as the centre of flotation moves forward, and increasing as the bow sections become more U shaped. Relative bow motions and vertical accelerations at the bow reflected the trends in pitch.

Schmitke and Murdey [50] carried out a methodical series of model tests on frigate type hull forms and presented results showing the effect of hull form parameters on calm water resistance and seakeeping characteristics. Parameters to be varied were selected as block coefficient, waterplane area coefficient, B/T ratio and a slenderness parameter, L^2 / BT, to relate the beam and draught to the length of the hull. Experiments for ten models out of the total twenty four were carried out in regular head seas. The prediction of heave, pitch, relative bow motion and vertical acceleration at 0.25L were made for ships of 3500 tons in irregular head seas, using the measured response curves and a two dimensional spectrum. The results showed that heave, pitch and acceleration values were reduced by increasing L^2 / BT, B/T and C_{WP}. Increasing C_B resulted in an increase in these motions. Relative bow motions were relatively insensitive to hull form variations and reduced by increasing B/T and increased by increasing C_B. The following conclusions were drawn from the investigation:

- increasing ship length and B/T reduces ship motions and accelerations,
- increasing C_{WP} generally improves seakeeping performance,
- increasing C_B tends to increase ship motions,
- increasing L^2 / BT at constant displacement has a beneficial effect due to the associated increase in length,
- increase in beam and draught at constant length have a small detrimental effect.

In order to take into account resistance considerations another model, which combines the aftbody of the resistance optimum model and the forebody of seakeeping optimum model was tested for seakeeping and resistance measurements. It was concluded that bow form was of major importance for seakeeping and that stern might be optimised for performance in calm water with little effect on seakeeping.

Blok and Beukelman [48] reported the results of a systematic subseries of high speed displacement ship models. The aim of the study was to investigate the influence of secondary hull form parameters on seakeeping and calm water resistance and hence to select a parent form to be the basis of a wider systematic series in which L/B, B/T and C_B are varied. In addition to the model experiments, a series of predictions were carried out with the strip theory based programs and the results were correlated with the experimental measurements to determine the reliability of predictions. In order to reduce the number of form parameters to be varied, LCB and C_P were kept constant at their optimum values based on the results of previous research.

Six models of constant radius of gyration were all tested in regular head waves. The results of the experiments indicated that a large waterplane area and forward position of LCF reduce heave, pitch and relative bow motions and vertical accelerations. The tests results also indicated a very close correspondence between the vertical motions and added resistance in waves. The agreement between experiments and predictions was found satisfactory as far as the heave and pitch motions and the vertical accelerations were concerned even for the highest speeds. In order to obtain more realistic comparisons of the seakeeping behaviour between different models, vertical responses in irregular seas were predicted by using measured transfer functions and a two parameter wave spectrum. Bales' regression model for destroyer type of ships was selected as a seakeeping figure of merit and a seakeeping rank value for each model was calculated.

2.6.2 Influence of Forebody Shape on Seakeeping Characteristics

Swaan and Vossers [51] tested six models with the same principal dimensions and displacement, but with different section form in the forebody and prismatic coefficient. Measurements were made of heave, pitch, relative bow motions, power increase and bending moments in regular head and bow waves. In the first variation four models including the parent Series 60 model were tested. All these models had the same displacement, principal dimensions, sectional area curve and mass distribution but the forebody section shapes varied from extreme U to extreme V shape. Tests in regular waves indicated that V shaped forebody sections lead to a decrease in heave and pitch amplitudes, particularly in head seas. However, measured relative bow motion amplitudes were not completely decisive. A tendency for a higher power increase and bending moments for the more V shaped sections was detected.

Ewing [52] carried out predictions for four Series 60, 0.70 block coefficient forms with different forebody form which were similar but not identical to those experimentally investigated by Swaan and Vossers [51]. All the forms had the same Series 60 aftbody. The motion responses under consideration, namely heave, pitch relative bow motion and acceleration of bow and stern, were calculated using a computer program based on the strip theory with added mass and damping coefficients calculated according to Grim [53]. From the computed results, it was concluded that V shaped sections result in smaller motions.

Yourkov [54] investigated the influence of forebody form on seakeeping characteristics of a cargo ship using a strip theory based computer program. For this purpose, nine ship forms were generated from three groups of constant block coefficient. Within each group, aftbody form was kept identical and forebody form was varied from extreme U form to extreme V form. All the forms had the same main dimensions and sectional area curve, hence the only parameter varied was the forebody vertical coefficient.

All calculations were carried out in regular waves for three different speed values using a computer program based on the Gerritsma-Beukelman version of strip theory. The results of these calculations indicated a strong dependence of heave motion on the forebody form for all block coefficients and speed values. V shaped sections in the forebody resulted in smaller heave amplitudes for the whole range of wavelengths whilst the pitch motions were less sensitive to the changes in section shapes and the advantage of V shaped forebody form was limited to low speeds and longer waves.

2.6.3 Influence of Mass Distribution on Seakeeping Characteristics

Vossers and Swaan [55] experimentally investigated the influence of the weight distribution on motion and propulsive characteristics of a Victory ship model. A small longitudinal radius of gyration was found to cause a smaller power increase in waves of lengths exceeding the ship length in which the power increase is greatest. It was also concluded that a weight distribution giving the ship a relatively small longitudinal radius of gyration in general leads to a decrease of pitching and heaving, particularly at low speeds.

Similar conclusions were reached by Swaan and Rijken [56] from comprehensive tests with a Series 60 model in irregular seas. It was concluded that a decrease in radius gyration will increase the absolute vertical acceleration of the bow.

2.6.4 Influence of Above Water Form on Seakeeping Characteristics

An important criterion of seakeeping performance is the probability of bow submergence and hence of shipping water on deck, particularly in head seas, since this greatly affects attainable speed and operational performance of the ship. Predicting the shipping of water involves the comparison of the relative bow motion with the available bow freeboard. Therefore, shipping water depends not only on the relative bow motion but on the above water form and section shapes. The effect of above water form on relative motion, and hence on bow submergence has been investigated by several researchers.

Lloyd [57] presented an extensive account of systematic deck wetness experiments. He concluded that for very severe sea states only freeboard is important for reducing wetness. However, in moderate sea states the above waterline hull form also affects wetness. In this case a high overhang of the bow profile and moderate flare angle were found to reduce the frequency of deck wetness and its severity.

Lloyd [58] conducted model experiments to study the deck wetness process and to investigate the effects of systematic variations in above the water form. A model of a frigate was tested with nine alternative bows in irregular head waves corresponding to commonly occurring conditions in the North Atlantic. Measurements of relative bow motions were made and deck wetness frequency was recorded by pressure arrays on the model forecastle. A very fine raked bow with very little flare was found to have the best performance in all aspects. More heavily flared forms experienced grater relative motions and more frequent freeboard exceedences and deck wetness.

Mizoguchi [59] tested a model of S175 container ship in regular head seas and measured the wave heights at 40 points on the forecastle deck and the impact pressure acting on a breakwater. The freeboard and ship speed were varied systematically and results showed that the amount of deck wetness and the impact pressures acting on the breakwater reduce sharply when the freeboard is raised up or the speed is reduced.

One of the major criticisms of the application of linear ship motion theories in the investigation of the influence of hull form on seakeeping characteristics is that these theories cannot reflect the effects of above water form on motions. This question has been experimentally investigated by several researchers. Abkowitz [60] concluded from some tests with model of the Series 60, block coefficient 0.70 form, that although increased sheer, and therefore freeboard forward, reduces wetness, it does not materially affect pitch motions. Swaan and Vossers [51] carried out model tests with Series 60 forms having similar underwater forms but different above water characteristics. It was concluded that even an extreme flare above water at the bow has only a small influence on motions. Lloyd [57], who investigated the effects of above water forms on destroyer motions, found negligible influence on ship rigid body motions.

2.7 Seakeeping Design Methodologies

Over the past few decades several seakeeping design methodologies have been developed ranging from simple parameter ranking to optimisation procedures. These methodologies are analysed in detail in the following sections.

2.7.1 Regression Equation Based on Model Test Results

Moor and Murdey [61] presented the results of experiments in waves with 34 models of practical ship designs. These were in the form of regression equations of significant pitch and heave and mean power increase in irregular head waves as a function of different hull form parameters and speed. The models covered a wide range of single screw ocean going cargo liners and tankers with block coefficients from 0.55 to 0.88. All experiments were carried out with self propelled models and measurements were made of pitch, heave, propeller thrust and torque. In order to make useful comparisons between the performance of the various forms, significant motion and mean propulsive values were calculated for wave heights corresponding to Beaufort numbers of 5,6,7, and 8 by using the British Towing Tank Panel (BTTP) spectrum. Thirteen of the models were in fact run in irregular waves and the comparison of the values of pitch, heave and power increase measured in irregular waves against values predicted for the same spectrum using the regular response curves showed an excellent agreement. Three linear multiple regression equations for heave, pitch and power increase were obtained as a function of length to breath ratio, length to draught ratio, block coefficient, waterplane area coefficient, longitudinal position of centre of buoyancy, longitudinal radius of gyration and speed. The results of experiments indicated that the pitch response increases with block coefficient, draught and radius of gyration and decreases as length, waterplane area coefficient and breadth increase and as the centre of buoyancy moves forward. The heave response increases with block coefficient, draught, radius of gyration and as the centre of buoyancy moves forward, and decreases as length, breadth and waterplane area coefficient increases. Similar conclusions for power increase were that it increases with length, block coefficient, breath, radius of gyration and as the centre of buoyancy moves forward, and decreases as draught increases. The goodness of fit of the estimating equations to the model data was predicted to be within the limits of 5% for heave and pitch and 18% for the power increase.

2.7.2 Seakeeping Tables

Bales and Cummins [62] developed a computational design tool to predict the trends in seakeeping variables with changes in hull geometry. The methodology consisted of a hull form generator, a mathematical model to calculate ship motions in a specified sea environment, and a response surface representation of the trends in hull form geometry. It was assumed that a simplified cargo hull series could be defined by seven defining hull form parameters including length, beam, draught, waterplane area coefficient, and nominal values of sectional area coefficient at the forward and aft perpendiculars. The profile was assumed to be rectangular and waterlines had a parallel midship segment together with fourth degree polynomials in the fore and aft bodies. All calculations were carried out for head seas with a constant radius of gyration for all forms. In order to compare the seakeeping performance of different hull forms a seakeeping efficiency criterion which takes into account heave, pitch, relative motions and accelerations was utilized.

Comparisons are presented by Loukakis and Chryssostomidis [63] of responses obtained from their tables and results for six specific hulls given by Bales and Cummins [62]. A good agreement was found for heave, pitch, and accelerations while relative motion was generally overpredicted.

2.7.3 Ranking of Seakeeping

Bales [20] developed an analytical model relating ship underwater hull geometry to an index of seakeeping merit and quantified it using twenty existing destroyer type hull forms scaled to 4300 metric tone displacement. He calculated eight seakeeping responses in long crested head waves according to Bretschneider spectrum for a range of modal periods and ship speeds. The responses selected were heave, pitch, ship-to-wave relative motion at stations 0 and 20, slamming at station 3, absolute vertical acceleration at station 0, heave acceleration, and absolute vertical motion at station 20. To establish a comparative measure of seakeeping performance in head waves, a seakeeping rank, R, was defined as the unweighted summation of selected responses averaged over five model wave periods per significant wave height and five Froude numbers. To facilitate comparison, numerical values of the seakeeping rank, R, were normalised within the database population. According to this normalised scale, the R values ranged from 1 to 10 representing the worst and the best performing hulls, respectively. To develop an early stage design tool, Bales further postulated that the R value of a given hull design may be closely approximated by an equation of six hull form parameters that are readily available in the early stages of design development. Selected hull form parameters were as follows:

Waterplane coefficient forward of amidships, C_{WPF}

Waterplane coefficient aft of amidships, C_{WPA}

Draught to length ratio, T/L

Cut-up ratio, c/L, where c is the distance from the FP to the cut-up point

Vertical prismatic coefficient forward of amidships, C_{VPF}

Vertical prismatic coefficient aft of amidships, C_{VPA}

By applying a linear regression analysis to the six hull form parameters and to the R value of each hull in the database, an equation for the $\hat{R}$ was obtained as follows:

$$\begin{aligned}\hat{R} &= 8.422 + 45.104C_{WPF} + 10.078C_{WPA} - 378.465(T/L)\\ &\quad + 1.273(c/L) - 23.501C_{VPF} - 15.875C_{VPA}\end{aligned}$$

Using this equation he developed an optimum hull form which is constrained by the limits of the database. This hull form was designated as Hull 21 and extensive theoretical calculations and experimental analysis were performed to predict its seakeeping performance. The results indicated that Hull 21 had superior seakeeping performance characteristics compared with similar ships of ordinary design. This fact was initially established by extensive theoretical calculations, and later confirmed by model experiments.

Later Walden [64], using a similar methodology, added a term to the seakeeping rank equation by defining the effect of displacement as follows:

$$a_7(\Delta - 4300)/4300$$

From the numerical values of the coefficients of the seakeeping rank given by Bales, it can be concluded that superior seakeeping performance requires C_{WPF} and C_{WPA} should be as large as possible and T/L, C_{VPF} and C_{VPA} to be as small as possible within the permissible ranges of values. The effect of c/L was found to be minor.

McCreight [65] extended the original Bales data base to include 45 different hull forms with displacements of 4300, 5800, 7300 and 8800 tonnes. In addition to considering several alternative definitions of R, she carried out a stepwise regression analysis on the resulting 180 hull form data base using 73 hull form parameters and combination of parameters. An equation for the $\hat{R}$ was given as follows:

$$\begin{aligned}\hat{R} &= a_0 + a_1 BM_L \nabla + a_2 C_{VPF} + a_3 C_{VPA} + a_4 BM_L/(BL^3) \\ &\quad + a_5 L + a_6 (T/B) + a_7 A_{WA}/\nabla^{2/3} + a_8 (LCB - LCF)\nabla \\ &\quad + a_9 (L/2 - LCB)/\nabla^{1/3} + a_{10} L^2/(BT)\end{aligned}$$

The following values for the a_i coefficients obtained from the regression analysis are,

$$\begin{array}{ll} a_0 = 9.43595 & a_6 = -57.3460 \\ a_1 = 3.10450\text{x}10^{-6} & a_7 = -6.08436 \\ a_2 = -8.42980 & a_8 = 9.18775\text{x}10^{-5} \\ a_3 = -37.5995 & a_9 = -6.03225 \\ a_4 = 590.435 & a_{10} = -6.41495\text{x}10^{-3} \\ a_5 = 0.287418 & \end{array}$$

She concluded that for a given displacement, long ship with large waterplane area have the largest positive impact on the responses of a ship in a seaway.

Wijngaarden [21] investigated the seakeeping performance and the calm water resistance of a systematic series of 17 small ship hulls which were derived from a continental-shelf research vessel form. The variant forms were obtained by systematic variations of the main dimensions, prismatic coefficient and the longitudinal position of buoyancy while the displacement was kept fixed for each hull. He used the ITTC fetch limited spectrum to represent the seaway in the North Sea and calculated ship responses for heave, pitch, absolute vertical acceleration and the relative vertical motion at the forward perpendicular by using a computer program based on the linear strip theory. Calculations were carried out for only head seas and a single speed. In order to assess the seakeeping performance of each variant hull, each response was weighted with the probability of occurrence of each wave height and a seakeeping rank which was assumed to be a function of the following parameters;

Prismatic coefficient, C_P

Longitudinal centre of buoyancy, LCB

Waterplane coefficient, C_{WP}

Length to beam ratio, (L/B)

Length to draught ratio, (L/T)

Longitudinal centre of floatation, LCF

An equation for the $\hat{R}$ was obtained as follows:

$$\begin{aligned}\hat{R} = &-11.624 + 111.409 C_P^{\,4} + 5.042\,\mathrm{LCB} - 20.064\,C_{WP} \\ &- 3.236(L/B) + 1.743(L/T) - 5.663\,\mathrm{LCF}\end{aligned}$$

He concluded that a higher value of the prismatic coefficient and a forward location of the longitudinal centre of buoyancy have the largest positive impact on the responses of a ship in a seaway.

The Bales ranking approach has been applied recently by many authors. In these investigations the number and the type of the responses considered varied according to the particular ship project and her operational mission. The responses having prevailing effect on ship performance in realistic operational conditions are selected according to basic ship assignments. Most frequently introduced characteristics are listed in Table 2.3. One can notice that mainly heave, pitch, relative motion and vertical acceleration response amplitudes are utilized. This is reasonable if behaviour in head seas solely is considered. Design variables are selected among those ship parameters, which are known to have considerable influence on ship performance in realistic environment. Most frequently introduced values, besides L, B, T and their ratios, are C_B, C_M, C_{WP}, C_P, LCB, LCF as well as some local parameters. Usually the volume displacement is kept constant or varied slightly, and is involved indirectly by the $L/\nabla^{1/3}$ ratio.

In the work of Enerhaugh [66] the seakeeping performance in head seas of a series of four fishing vessel hulls was investigated. The parent vessel of the series was a modern Norwegian fishing vessel with an overall length of 19.80m, which was lengthened in three different ways. The seakeeping performance was determined by model tests carried out both in regular and irregular waves. The irregular waves represented the sea conditions typical for the North Sea/Norwegian coast. The main seakeeping responses (heave, pitch, accelerations) and added resistance were presented and evaluated both in dimensional and nondimensional forms. The relative magnitude of the responses were related to hull form parameters by the model of Bales/Wijngaarden.

Zborowski et al. [67] applied the concept of seakeeping index to the BSRA trawler hull form series. In their study they considered only the vertical motion responses to waves of 0.9m significant wave height. Their seakeeping index was composed of heave, pitch and the corresponding accelerations, and was weighted with the probability of occurrence of four wave modal periods found from the statistics of the Cape Canaveral coastal waters.

Takaki [68] derived the regression equation to estimate the correlation between the hull forms and the seakeeping qualities by applying the Bales' procedure to container ships. He provided the guidelines to optimise the hull form for the seakeeping performance and the added resistance in irregular waves. Ship responses for heave, pitch, absolute vertical acceleration and the relative vertical motion at specified points were calculated using a computer program based on the linear strip theory. Added resistance calculations were also calculated by using Gerritsma and Beukelman method. He defined a seakeeping rank which he assumed to be a function of the following parameters;

Waterplane coefficient forward of amidships, C_{WPF}

Waterplane coefficient aft of amidships, C_{WPA}

Vertical prismatic coefficient forward of amidships, C_{VPF}

Vertical prismatic coefficient aft of amidships, C_{VPA}

Length to beam ratio, (L/B)

Length to draught ratio, (L/d)

By applying a linear regression analysis to the series of ship hull forms, an equation for the F_i was obtained as follows:

$$\begin{aligned} F_i = &\ 23.563C_{WPF} + 15.105C_{WPA} + 3.740C_{VPF} - 20.070C_{VPA} \\ &- 1.747(L/B) + 0.453(L/d) - 6.732 \end{aligned}$$

He concluded that long ship with larger waterplane area have the positive impact on the responses of a ship in a seaway. He also concluded that this method is very useful in the early stage of ship design for determining the dimensions of a new ship with a good seakeeping performance and a small added resistance.

With a similar goal, simple sum of seakeeping and stability rank factors was used by Kishev et al. [69] and Nabergoj [70]. Kishev et al. [69] formed a common objective function consisting of seakeeping, resistance and stability terms. At the basis of the evaluation method it is assumed that the ship behaviour can be sufficiently represented by approximation as a function of a certain set of ship form parameters, which are known to have considerable influence on ship dynamics, resistance and stability. The method for rank evaluation of ship operability at seas was applied to a series of 12 form variants of a 1400 tonnes fast containership. The variants were generated with a view to ensuring significant differences in the geometrical characteristics at constant displacement. An equation which approximated a rank was assumed to be a function of the following parameters;

Length to displacement ratio, $(L / \nabla^{1/3})$

Block coefficient, C_B

Waterplane coefficient, C_{WP}

Draught to length ratio, (T/L)

Beam to draught ratio, (B/T)

Distance between the centre of buoyancy and centre of flotation, (LCB-LCF)

Shifting of the two centres, (LCB+LCF)

Depth to draught ratio, (d/T)

Midship sectional coefficient, C_M

By applying a linear regression analysis to the series of ship hull forms, an equation for the $\hat{R}$ was obtained as follows:

$$\begin{aligned}\hat{R} = {} & 129.9 - 6.78(L/\nabla^{1/3}) - 49.28C_B + 31.37C_{WP} - 516.0(T/L) \\ & - 2.93(B/T) - 54.51(LCB - LCF) + 38.9(LCB + LCF) \\ & - 38.61(d/T) + 18.97C_M\end{aligned}$$

They then developed an optimum hull form which is based on this equation. Seakeeping computations were performed for this hull and the results showed that the optimum hull has better or at least equal seakeeping characteristics in comparison with the other hulls in the series.

Following this work, Bogdanov and Kishev [71] proposed a simplified seakeeping ranking index based solely on total resistance, which has been proven to correspond closely to the general Bales seakeeping estimator.

2.7.4 Optimisation of Hull Form for Seakeeping

The first attempt at a seakeeping optimisation method was undertaken by Bales [20]. Bales used motion data for twenty existing destroyer type hull forms and linear regression analysis techniques to correlate averaged seakeeping performance, in head seas and at various speeds, to certain empirically selected hull form parameters. He then used the resulting optimum combination of these parameters and conventional lines drawing methods to design an "optimum" seakeeping hull form.

In Table 2.3, numerous optimisation studies are given [68-79] and ways of formulation of goal function as direct relation between ship geometry and generalised ship responses are tabulated.

Table 2.3 Design Variables and Characteristic Responses

AUTHOR(S)	SHIP TYPE	DESIGN CONSIDERATIONS	GEOMETRY PARAMETERS	RESPONSES	TYPE OF OBJECTIVE FUNCTION
Bales [20]	Destroyer	Seakeeping	C_{WPF}, C_{WPA}, T/L, c/L, C_{VPF}, C_{VPA}	Pitch, Heave, RM at FP and AP, Vert. Acc. at FP, Slamming, Vert. Mot. at AP	Criteria-free, based on averaged and ranked response
Wijngaarden [21]	Research Vessel	Seakeeping Resistance	L/B, L/T, LCB, LCF, C_P, C_{WP} L, B, T, $L/\nabla^{1/3}$, C_B, C_P, C_M, LCB	Heave, Pitch, RM at FP, Vert. Acc. at FP Calm Water Resistance	Criteria-free, weighted, averaged and ranked response Separate control
Loukakis et al. [74]	Any Type	Seakeeping	L, ∇/L^3, T/L, C_{WP}, B/L, $(LCB+LCF)/2$, $(LCB-LCF)$, K_B	Heave, Pitch, RM at the Bow, Vert. Acc. at FP and AP, Vert. Mot. at Stern, Raw	Criteria-free, based on averaged and ranked response
McCreight [65]	Destroyer	Seakeeping	L, T/B, L^2/BT, C_{VPF}, C_{VPA}, $(LCF-LCB)\nabla$, $LCB/\nabla^{1/3}$, $A_{WA}/\nabla^{2/3}$, $BM_L\nabla$, BM_L/BL^3	Pitch, Heave, RM at FP and AP, Vert. Acc. at FP, Slamming, Vert. Mot. at AP	Criteria-free, based on averaged and ranked response
Guliev et al. [75]	Dry Cargo Ship	Seakeeping	L, B, C_B	Slamming, Deck Wetness, Raw, Vert. Acc., Screw Racing	Proportional to the attainable speed in waves
Grigoropoulos, Loukakis [72]	Any Type	Seakeeping	L, B, T, C_B, C_{WP}, LCB, LCF, K_B	Heave, Pitch RM at FP, Vert. Acc., Raw	Criteria-free, based on averaged peak responses in regular waves
Hearn et al. [76], [77]	Any Type	Seakeeping Stability Resistance	L, B, T, C_{WP}, C_B, LCF, LCB	RMS Motion, Velocity or Acc., Event Occurrences, Raw IMO Criteria Calm Water Resistance	Single or combined max. responses Constrains Constrains
Lloyd [73]	Frigate	Seakeeping	L, B, T, ∇, B, T at stem, LCG, C_{WPF}, C_M, GM, freeboard	Vert. Acc. on Bridge, Vert. Acc. on Flight Deck, Deck Wetness at FP, Slamming at St.16	Deviation from target values
Takaki [68]	Container Ship	Seakeeping	L/B, L/T, C_{WPF}, C_{WPA}, C_{VPF}, C_{VPA}	Heave, Pitch, Raw, Vert. Acc. at FP, AP, M, RM at FP and AP	Criteria-free, based on averaged and ranked response
Nabergoj [70]	Fishing Vessel	Seakeeping Stability	L, B, T, C_B, C_P, $L/\nabla^{1/3}$, LCB	Heave, Pitch, RM at FP and AP Strathclyde Criterion	Single or global averaged response Separate rank
Zborowski, Liu [78]	Trawler	Seakeeping	L, B, T, C_B, $L/\nabla^{1/3}$, GM	6-D of Freedom Motions, Velocities and Accelerations	Criteria-free, based on averaged and ranked response
Boote, Bruzzone [79]	Ro-Ro	Seakeeping	L/B, B/T, C_B	Heave, Pitch, Raw, Wave Bending Moment, RM, Velocities and Acc. at FP and AP	Criteria-free, based on averaged, weighted and ranked response
Kishev et al. [69]	Container Ship	Seakeeping Stability Resistance	B/T, T/L, D/T, $L/\nabla^{1/3}$, C_B, C_{WP}, C_M, LCB, LCF, Trim, S_F, S_A	Heave, Pitch, Roll, Roll Period, Slamming, Deck Wetness, Raw, Screw Racing, Vert. Acc. Stability Diagram Elements, Weather Criterion Still Water Resistance	Criteria-free, based on partial or total sum of averaged, weighted and ranked responses
Bogdanov, Kishev [71]	Bulker	Seakeeping Resistance	B/T, LCB, LCF, C_B, $L/\nabla^{1/3}$, C_{WP}	Raw Still Water Resistance	Weighted total resistance

Grigoropoulos and Loukakis [72] presented a new method for analytical seakeeping optimisation. The method was based on a computer code which predicts seakeeping performance when the ship profile, the design waterline, the sectional area curve and the distribution along the ship of the centroid $K_B(x)$, of the cross sections are prescribed. Since the methodology was developed for use in the preliminary design stage, main dimensions and the displacement were kept constant and section forms were obtained using a three parameter Lewis form representation. To obtain variant hull forms from the parent hull, Lackenby's linear transformation methods were used. The code can automatically generate variant hull forms differing from a parent in the main dimensions and in one or more parameters such as C_{WP}, LCF, LCB, K_B distribution, C_P , etc. An optimisation problem with the objective being the weighted sum of the peak values of a prescribed set of ship responses in regular waves was stated and solved by using Hooke and Jeeves' algorithm. To investigate the validity of this approach, the hull form of a reefer vessel was selected and optimised in head seas with respect to vertical accelerations and relative motions. The variant hull form had the same main dimensions and displacement as the parent, but a considerably improved seakeeping behaviour was analytically predicted. Two-meter models of the parent and the optimised hull forms were subsequently built and tested for resistance in regular and random head seas for the vertical ship responses and added resistance. The experimental results verified the analytical predictions with respect to the seakeeping performance, whereas only minor differences between the two hull forms in calm water resistance were observed.

Lloyd [73] developed a Seakeeping Design Package (SDP) which automatically creates a destroyer type hull form to achieve a specified seakeeping performance. The objective of the optimisation process is defined as to design a hull form having the closest match between the given probabilistic criteria and their corresponding target values. The optimal values of specified hull form parameters are obtained by searching a database consisting of regression equations for each response in terms of the selected form parameters. Having determined the optimal form parameters, the optimal lines plan is obtained by using polynomial representation.

2.8 Conclusions

The above considerations indicate that there are various operational consequences of seakeeping performance characteristics which require the attention of the ship designer. In order to address these consequences the designer needs to be able to assess the seakeeping performance characteristics of a given ship design. The conventional methods of seakeeping performance assessment include full scale trials and model tests. However, these methods are not available in the early stage of design where the designer should decide on different form parameters.

A number of studies have attempted to establish the effect of size, main dimensions, and hull form on seakeeping. Detailed comparisons of the results of these studies have been summarised. In the last section several existing seakeeping design methodologies have been presented. It has been shown that these methodologies attempt to link hull form parameters of a vessel to its seakeeping performance. These methodologies are based on regression equations derived from experimental or computational data.

CHAPTER 3

ASSESSMENT OF EXISTING PREDICTION TOOLS FOR MOTION RESPONSE CALCULATION

3.1 Introduction

Considerable progress has been made in the theoretical modelling of ship motions and related dynamic effects over the last forty years. Modern computational methods allow the designer to apply seakeeping theory at the earliest possible stages in the design process. The process of evaluating ship motions can now be carried out rapidly and with a high degree of reliability. Both of these features are necessary at the concept design stage, where large numbers of alternatives need to be examined.

Prediction of ship responses in a seaway involves dynamics (the determination of the forces imposed by the seaway on the ship) and kinetics (the determination of the motions resulting from the forces imposed by the seaway). The forces and moments acting on the ship in the direction of each degree of freedom are the seaway induced excitations, and the "forces" associated with the reactions of the ship to the wave excitation, as measured through the ship motions.

Modern seakeeping theory originates from the pioneering work of Korvin-Kroukovsky and Jacobs [80] who provided the first usable method for calculating the coupled heave and pitch motions of a rigid ship in regular sinusoidal waves. Their approach contains many of the basic ingredients adopted in subsequent ship motion theories; that is to use slender body theory and representation of the rigid ship hull by a series of two-dimensional transverse elements or strips. The so-called strip theory has been developed theoretically [81] to a point where, in general, adequate predictions are obtained of the motions of a ship in a seaway.

In the application of strip theory, the total added mass and damping coefficients of the ship are obtained by numerically integrating the 2D based values determined for different transverse sections along the ship length, L. For example, the strip theory approximation for the global heave added mass is

$$A_{33} = \int_L a_{33}(x)\,dx$$

Where,

$a_{33}(x)$ is the sectional added mass

L denotes that the integration is taken over the ship length

The first step in computing the ship motions by strip theory is to determine the two dimensional added mass and damping coefficients for each ship section. The earliest theoretical results on added mass are those due to Lewis [82]. In his classical paper, Lewis showed how the added mass of an infinitely long cylinder of ship related cross section, oscillating at very high frequency could be obtained from the knowledge of the behaviour of a unit-radius circular cylinder through use of the conformal transformation. The work of Lewis was subsequently extended by many researches. Grim [83] applied a two parameter conformal mapping and provided extensive tables of added mass and damping for Lewis sections as a function of sectional area coefficient, beam-draught ratio, and nondimensional frequency. Given enough sectional form parameters, one can approximate any form to any degree of satisfaction.

Frank [84] proposed a Close-fit method consists of dividing the ship section into a series of straight line segments. At the centroid of each segment, fluid sources with constant, but unknown, strengths are located. The unknown source strengths then found by satisfying the body boundary conditions at the centre point of each segment. Knowing the source strength distribution, the velocity potential and hence the sectional added mass and damping coefficients can be determined. The main advantages of Frank Close-fit method are that it is computationally fast and any ship cross-section can be approximated with as much accuracy as desirable.

While it provides good results in general, due to some of the assumptions inherent in the strip theory approach, the method is less successful when the ship has forward speed or a detailed distribution of the hydrodynamic forces along the length of the hull is required. In order to remove these limitations three dimensional panel methods for ship motions at non zero forward speed were developed [85, 86, 87]. In these methods the hull surface is divided into number of panels on which sources are assumed to be constant. The velocity potential is expressed by the Green function satisfying a linear free surface condition as well as a radiation condition.

In this chapter, the motion characteristics of fishing vessel hull forms investigated by two different theoretical methods and their validation with experimental measurements are presented.

3.2 Existing Computer Programs for Motion Response Calculation

Two different computer programs to assess the ship motions were available to the author. The first program is based on the strip theory, and the second program is based on a three-dimensional translating pulsating source distribution technique.

3.2.1 Computer Program Based on the Strip Theory

In 1972, the David Taylor Naval Ship Research and Development Centre began utilizing a ship motion computer prediction program called the Ship Motion and Sea Load Computer Program, SMSL. This program provided predictions of the motions and loads in six degrees of-freedom for a ship advancing at a constant speed with an arbitrary heading in regular waves. For motion predictions in irregular seas, a second computer program was developed in 1975 called ESPEC. This program provided the motion Root Mean Square (RMS) values in long-crested and short-crested seas described by the two-parameter (significant wave height and modal wave period) Bretschneider wave spectrum.

In 1977, a need was recognized for a user orientated, state-of-the-art ship motion prediction tool that could be easily used and maintained. This program would facilitate the incorporation of seakeeping considerations by the ship designers into the hull design at the earliest possible stage. Work began immediately on a revision and rewrite of the Ship Motion and Sea Load program. Improvements to the SMSL included a new theory associated with hull and appendage lift damping to improve the roll motion predictions at speed, as well as refinements in ship response prediction methods, current mathematical modelling, and more extensive ship performance calculations. This new program, the Standard Ship Motion Program (SMP) [88], provided motion predictions in both regular and irregular seas for any location on a ship.

The Ship Motion Program SHIPMO-PC used in this study is a PC-based program modified from SHIPMO developed by the Canadian Navy's Defence Research Establishment Atlantic (DREA) [89] which is equivalence of the Standard Ship Motion Program (SMP). It predicts ship motions in six degrees of-freedom in both irregular and regular seaways, or for a sea spectrum specified by the user. In addition, SHIPMO-PC includes algorithms for predicting deck wetness and slamming occurrences, slamming pressures, and motion criteria based on human tolerance to vertical motions.

3.2.1.1 Theoretical Basis

The general approach used in SHIPMO-PC for the basic calculation of ship motions in irregular seas follows standard practice. Linear equations of rigid body motion in regular waves are formulated and solved in the frequency domain, and the results are extended to irregular seas by the superposition principle. This approach was first advanced by St. Denis and Pierson [90]. The algorithms for calculating the pitch and heave responses are taken from Frank and Salvesen [91]. Algorithms from Ochi and Motter [92] were adapted in order to calculate the slamming pressure and deck wetness. Details for SHIPMO-PC can be found in [93, 94].

3.2.1.2 Rigid Body Motions

The theoretical model of ship rigid body motions in regular waves has four basic facets:

(1) Strip theory for computing hull added mass, wave making damping and exciting forces.

(2) Lifting surface contributions to lateral motion damping and exciting forces.

(3) Viscous roll damping, principally from bilge keels.

(4) Hull circulatory effects.

Since the model is based on the strip theory, the standard assumptions made in applying the strip theory to a displacement hull can be given as follows:

(1) Ship response is a linear function of wave excitation.

(2) Ship length is greater than either beam or draft.

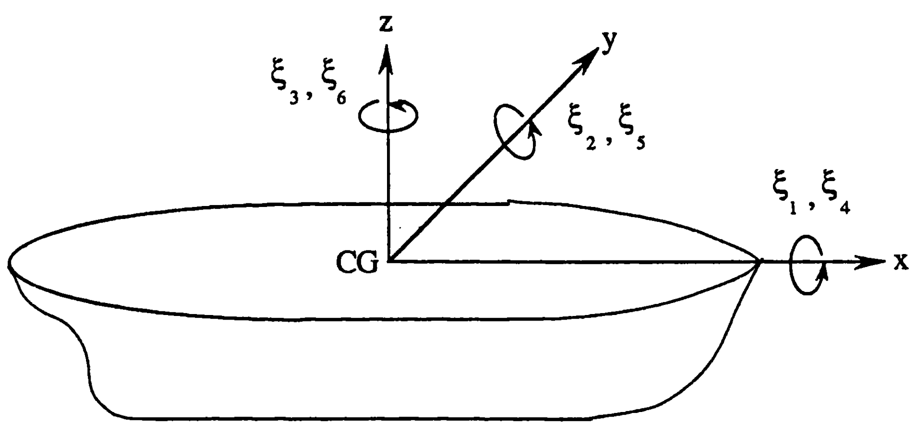
(3) All viscous effects other than roll damping are negligible.

(4) The hull does not develop appreciable planing lift.

In the following pages, a review of the theory used to predict the responses of a ship in regular as well as irregular seas is presented. A description of the required input data and the output capabilities of the program are also given.

3.2.1.3 Equations of Ship Motion

The strip theory presented by Salvesen et al. [81] is used by the Ship Motion Program to calculate a ship's six degree of-freedom response as it advances through regular sinusoidal waves at a constant mean forward speed with an arbitrary heading. The calculated responses are assumed to be linear and harmonic.



ξ_1 : Surge ξ_3: Heave ξ_5: Pitch
ξ_2 : Sway ξ_4: Roll ξ_6: Yaw

Figure 3.1 Definition of Coordinate System

The axis system is illustrated in Figure 3.1 where (x,y,z) is a right-handed orthogonal coordinate system with the origin fixed at the centre of gravity. The positive x axis points forward in the direction of the forward motion, the positive y axis to port, and the positive z axis vertically upward.

For a given speed, heading angle and frequency of encounter, ω_e, the motion displacements, ξ_j, are defined as:

$$\xi_j = a_j \cos(\omega_e t + \varepsilon_j) \qquad ; j = 1,2,\ldots,6 \tag{3.1}$$

where

a_j = Motion amplitude

ε_j = Phase lead of the j th motion with respect to the maximum wave elevation at the origin,

and where,

j=1 refers to surge motion,

j=2 refers to sway motion,

j=3 refers to heave motion,

j=4 refers to roll motion,

j=5 refers to pitch motion, and

j=6 refers to yaw motion.

Using subscript notations, the six linear coupled differential equations of motion can be written as:

$$\sum_{k=1}^{6}\left[\left(M_{jk} + A_{jk}\right)\ddot{\xi}_k + B_{jk}\dot{\xi}_k + C_{jk}\xi_k\right] = F_j e^{i\omega_e t} \qquad ; j = 1,2,\ldots,6 \tag{3.2}$$

where

M_{jk} : Generalized mass matrix components

A_{jk} : Added mass matrix components

B_{jk} : Damping coefficients matrix components

C_{jk} : Hydrostatic restoring coefficients matrix components

F_j : Complex amplitudes of the exciting force and moment given by the real part of $F_j e^{i\omega_e t}$ where

F_1, F_2, F_3 : Amplitudes of the surge, sway, and heave exciting forces, and

F_4, F_5, F_6 : Amplitudes of the roll, pitch, and yaw exciting moments

with ξ_k, $\dot{\xi}_k$, and $\ddot{\xi}_k$ representing displacement, velocity, and acceleration terms respectively.

With the assumptions that the ship has lateral symmetry (symmetric about the x-z plane), and the centre of gravity is located at $(0,0,\overline{ZG})$ where the origin is on the centreline of the vessel in the still water plane, the generalized mass matrix (M_{jk}), added mass matrix (A_{jk}), damping coefficient matrix (B_{jk}), and hydrostatic restoring coefficient matrix (C_{jk}) can be written in the following form:

$$M_{jk} = \begin{bmatrix} M & 0 & 0 & 0 & M\overline{ZG} & 0 \\ 0 & M & 0 & -M\overline{ZG} & 0 & 0 \\ 0 & 0 & M & 0 & 0 & 0 \\ 0 & -M\overline{ZG} & 0 & I_4 & 0 & -I_{46} \\ M\overline{ZG} & 0 & 0 & 0 & I_5 & 0 \\ 0 & 0 & 0 & -I_{64} & 0 & I_6 \end{bmatrix} \tag{3.3}$$

where

M : Mass of the ship

$\overline{ZG}$: Vertical centre of gravity

I_j : Moment of inertia

I_{jk} : Product of inertia

$$A_{jk}\ (\text{or } B_{jk}) = \begin{bmatrix} A_{11} & 0 & A_{13} & 0 & A_{15} & 0 \\ 0 & A_{22} & 0 & A_{24} & 0 & A_{26} \\ A_{31} & 0 & A_{33} & 0 & A_{35} & 0 \\ 0 & A_{42} & 0 & A_{44} & 0 & A_{46} \\ A_{51} & 0 & A_{53} & 0 & A_{55} & 0 \\ 0 & A_{62} & 0 & A_{64} & 0 & A_{66} \end{bmatrix} \tag{3.4}$$

Furthermore, for a ship geometry, the only non zero linear hydrostatic restoring coefficients are:

$$C_{33}, C_{35}, C_{44}, C_{53}, C_{55} \quad \text{with } C_{35} = C_{53} \tag{3.5}$$

If the generalized mass matrix, Equation (3.3), the added mass and damping coefficients, Equation (3.4), and the restoring coefficients, Equation (3.5), are substituted in the equation of motion, Equation (3.2), it is seen that for a ship with lateral symmetry, the six coupled equations of motion, Equation (3.2), reduce to two sets of equations. One set of three coupled equations of motion for surge, heave, and pitch can be written as:

$$\begin{aligned}(A_{11} + M)\ddot{\xi}_1 + B_{11}\dot{\xi}_1 + A_{13}\ddot{\xi}_3 + B_{13}\dot{\xi}_3 \\ + \left(A_{15} + M\overline{ZG}\right)\ddot{\xi}_5 + B_{15}\dot{\xi}_5 = F_1 e^{i\omega_e t}\end{aligned} \tag{3.6}$$

$$\begin{aligned}A_{31}\ddot{\xi}_1 + B_{31}\dot{\xi}_1 + (A_{33} + M)\ddot{\xi}_3 + B_{33}\dot{\xi}_3 \\ + C_{33}\xi_3 + A_{35}\ddot{\xi}_5 + B_{35}\dot{\xi}_5 + C_{35}\xi_5 = F_3 e^{i\omega_e t}\end{aligned} \tag{3.7}$$

$$\begin{aligned}\left(A_{51} + M\overline{ZG}\right)\ddot{\xi}_1 + B_{51}\dot{\xi}_1 + A_{53}\ddot{\xi}_3 + B_{53}\dot{\xi}_3 + C_{53}\xi_3 \\ + (A_{55} + I_5)\ddot{\xi}_5 + B_{55}\dot{\xi}_5 + C_{55}\xi_5 = F_5 e^{i\omega_e t}\end{aligned} \tag{3.8}$$

and another set of three coupled equations for sway, roll, and yaw can be written as:

$$\begin{aligned}(A_{22} + M)\ddot{\xi}_2 + B_{22}\dot{\xi}_2 + \left(A_{24} - M\overline{ZG}\right)\ddot{\xi}_4 \\ + B_{24}\dot{\xi}_4 + A_{26}\ddot{\xi}_6 + B_{26}\dot{\xi}_6 = F_2 e^{i\omega_e t}\end{aligned} \tag{3.9}$$

$$\begin{aligned}\left(A_{42} - M\overline{ZG}\right)\ddot{\xi}_2 + B_{42}\dot{\xi}_2 + (A_{44} + I_4)\ddot{\xi}_4 + B_{44}\dot{\xi}_4 \\ + C_{44}\xi_4 + (A_{46} - I_6)\ddot{\xi}_6 + B_{46}\dot{\xi}_6 = F_4 e^{i\omega_e t}\end{aligned} \tag{3.10}$$

$$\begin{aligned}A_{62}\ddot{\xi}_2 + B_{62}\dot{\xi}_2 + (A_{64} - I_{46})\ddot{\xi}_4 + B_{64}\dot{\xi}_4 \\ + (A_{66} + I_6)\ddot{\xi}_6 + B_{66}\dot{\xi}_6 = F_6 e^{i\omega_e t}\end{aligned} \tag{3.11}$$

For a vessel with lateral symmetry, the surge, heave, and pitch motion equations constitute one set of coupled equations and the sway, roll, and yaw motion equations constitute a second set of coupled equations. These two sets of equations are independent of each other.

The coefficient matrix components presented in equations (3.3), (3.4), and (3.5) are the zero speed matrix coefficients. Modifications to include the forward speed effects are made to the zero speed heave-pitch and pitch-heave cross coupled added mass and damping coefficients, as well as the pitch added mass and damping coefficients, as shown in Table 3.1, and exciting force terms. Similar modifications are also made to the zero speed sway-yaw and yaw-sway cross coupled added mass and damping coefficients and exciting force terms [89].

Having modified these matrix components for the forward speed effects, a coordinate system transformation was applied to the lateral motion equations (3.9)-(3.11) to move the origin from the LCG in the waterplane to the vertical centre of gravity (VCG). The shift in origin results in a more consistent coordinate system whereby the empirically-obtained modifications to the lateral force coefficients can be included. The coefficients of the lateral motion equations were then modified to include the nonlinear viscous roll damping effects, as well as the speed-dependent lift effects on the hull and its various appendages. These transformed lateral equations and corresponding coefficients, as well as the forward speed affect modifications, are presented in the SHIPMO User Manual [93]. After the modification of the coefficients of the lateral motion equations, the equations were re-written in a reference system whose origin was at the waterplane. These equations yield all the rigid-body displacements values as measured from the same origin.

Detailed expressions for the added mass and damping coefficients are given in Table 3.1. Ship Motion Program, assumes that the terms $A_{13}, B_{13}, A_{15}, B_{15}, A_{31}, B_{31}$,

A_{51} and B_{51} are zero. Therefore, with these cross coupled terms equal to zero, the only coupling between the surge and pitch equations is in the $M\overline{ZG}$ term. There is no surge-heave coupling in the heave equation.

Table 3.1 Added Mass and Damping Coefficients

A_{33}	$\int a_{33}dx$	B_{33}	$\int b_{33}dx$
A_{35}	$-\int xa_{33}dx - \frac{V}{\omega_e^2}B_{33}$	B_{35}	$-\int xb_{33}dx + VA_{33}$
A_{53}	$-\int xa_{33}dx + \frac{V}{\omega_e^2}B_{33}$	B_{53}	$-\int xb_{33}dx - VA_{33}$
A_{55}	$\int x^2a_{33}dx + \frac{V^2}{\omega_e^2}A_{33}$	B_{55}	$\int x^2b_{33}dx + V^2B_{33}$
A_{22}	$\int a_{22}dx$	B_{22}	$\int b_{22}dx$
$A_{24} = A_{42}$	$\int a_{24}dx$	$B_{24} = B_{42}$	$\int b_{24}dx$
A_{26}	$\int xa_{22}dx + \frac{V}{\omega_e^2}B_{22}$	B_{26}	$\int xb_{22}dx - VA_{22}$
A_{44}	$\int a_{44}dx$	B_{44}	$\int b_{44}dx$
A_{46}	$\int xa_{24}dx + \frac{V}{\omega_e^2}B_{24}$	B_{46}	$\int xb_{24}dx - VA_{24}$
A_{62}	$\int xa_{22}dx - \frac{V}{\omega_e^2}B_{22}$	B_{62}	$\int xb_{22}dx + VA_{22}$
A_{64}	$\int xa_{24}dx - \frac{V}{\omega_e^2}B_{24}$	B_{64}	$\int xb_{24}dx + VA_{24}$
A_{66}	$\int x^2a_{22}dx + \frac{V^2}{\omega_e^2}A_{22}$	B_{66}	$\int x^2b_{22}dx + \frac{V^2}{\omega_e^2}B_{22}$

The above coefficients of the six degree of-freedom motion equations are calculated for given speed, heading, and wave frequency values supplied by the user. Once these coefficient values are determined, solutions to the two sets of coupled equations are obtained by matrix inversion. The resulting solutions of $\ddot{\xi}_k$, $\dot{\xi}_k$, and ξ_k for k=1, 2,..., 6 are then stored in a data file to be used later. These values are the six degree of-freedom ship motion response transfer functions (response per unit wave amplitude) used in the calculation of the Response Amplitude Operators (RAO) for the ship in regular waves. These RAO values are in turn used to predict the final motions of the ship in irregular seas.

3.2.1.4 Ship Responses in Regular Waves

As stated previously, the response of a ship in regular sinusoidal waves forms the data base from which the ship's responses to irregular waves are calculated. In the SHIPMO-PC, various assumptions are made in the calculation of the regular wave response. A right-hand coordinate system is used with the origin located on the undisturbed free surface at the longitudinal centre of gravity. The positive z-direction is upward thus making the x-direction positive forward and the y-direction positive to port. This coordinate system is assumed to be moving at the same speed as the ship. The ship is assumed to be moving at a constant forward speed and arbitrary heading and the waves are assumed to be regular sinusoidal waves with unit amplitude. The resulting six degree of-freedom responses surge, sway, heave, roll, pitch, and yaw are assumed to be small, linear, and harmonic with respect to a wave whose maximum elevation is located at the origin of the coordinate system. The ship is then moved through the regular waves. The wave frequency of encounter, ω_e, is defined as

$$\omega_e = \omega - (\omega^2 V / g)\cos\beta \tag{3.12}$$

where

V : Mean forward speed of the ship

β : Ship heading angle relative to the wave direction

ω : The wave frequency

With this heading angle description, $\beta = 0°$ corresponds to following seas, $\beta = 90°$ corresponds to starboard beam seas, and $\beta = 180°$ corresponds to head seas.

Even though the ship's responses are assumed to be linear, ship model experiments have shown that the roll response becomes nonlinear with increasing wave amplitude. Also, experiments have shown that the roll damping coefficient of the equations of motion at the natural frequency tends to be nonlinear as the roll angle increases. Because the roll motion is generally lightly damped, it is considered a narrow-banded response, being most sensitive to changes in damping at frequencies near the natural roll frequency of the ship. In SHIPMO-PC program, roll damping consisted of a linear potential term as well as nonlinear viscous terms due to skin friction, hull shape, and bilge keels. The program includes speed dependent lift damping terms due to the dynamic lift generated by appendages such as rudders, skegs, propeller, shaft brackets, passive fins and bilge keels. The nonlinear viscous damping of the rudders, ship, fins, and propeller shaft brackets are included in the SHIPMO-PC. For ships without bilge keels, the program incorporates an empirical formula to reduce the zero speed nonlinear viscous damping as the vessel's speed increases. This is because measurements have found that roll tends to become more linear with increasing speed for vessels without bilge keels.

When a ship is moving within quartering or following seas, the ship's frequency of encounter becomes less than the wave frequency as the ship speed increases. At certain combinations of speed, heading and wave frequency, this encounter frequency approaches zero. At this point, the surge, sway and yaw motions become unrealistically large because of a lack of restoring terms in their respective equations of motion. In these situations, the SHIPMO-PC imposes empirically derived numerical limits on the predicted motion transfer functions.

The six degree of-freedom transfer functions (response per unit wave amplitude) required for irregular sea motion predictions are obtained as solutions to two independent sets of three coupled equations of motion of surge, heave, pitch and sway, roll, yaw. This separation of equations is based on the assumption of lateral symmetry of the ship as explained in the previous section.

3.2.1.5 Ship Responses in Irregular Waves

Two basic assumptions are used in the prediction of ship motions in irregular seas [90], namely:

(1) The irregular sea waves can be represented as a sum of simple sine waves whose amplitudes are obtained from specified spectral densities and whose phases are random with a uniform distribution, and

(2) The responses of a ship to the irregular sea waves can be obtained as the sum of the ship responses to the individual sine waves.

Once the program has calculated the previously discussed values and parameters for a unit wave size, the response of the ship in irregular seas can be accomplished. The irregular sea response calculations for a particular ship are performed in the frequency domain using the products of Response Amplitude Operators (RAO), Sea Spectrum and Frequency Mapping. Within the program, the response amplitude operators for a particular ship is defined as the square of the regular wave transfer function amplitude at each frequency. These RAO's have the units of [Response Physical Unit/Wave Physical Unit]^2.

There are three types of wave spectra available for the motion calculations in irregular seaways. Namely, quadratic regression spectrum suitable for open ocean, such as the North Sea, Bretschneider two-parameter spectrum also suitable for open ocean and measured spectrum. If a measured wave spectrum is used, the frequency and corresponding spectral density are required.

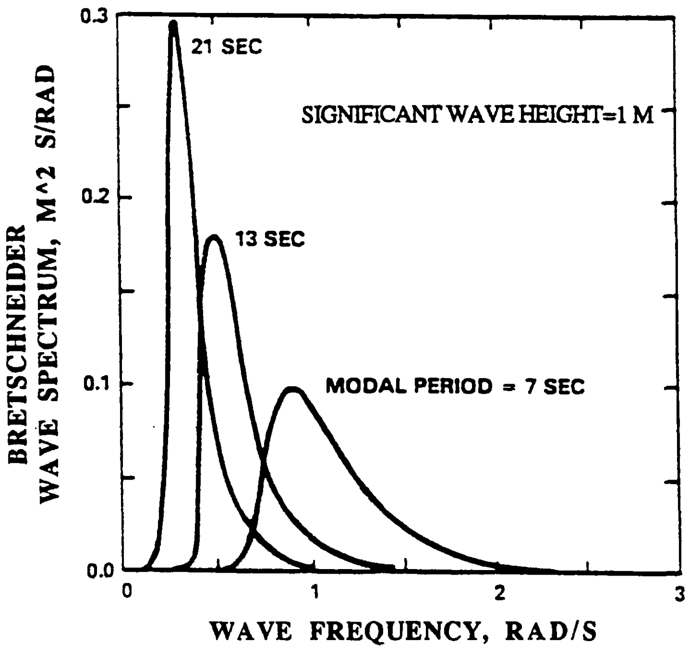


Figure 3.2 Bretschneider Energy Spectrum for Different Sea States

The Bretschneider two-parameter spectra [95], examples of which are shown in Figure 3.2, are used in the SHIPMO-PC to cover wide range of sea conditions. The two parameters are by definition, significant wave height, $(\zeta_w)_{1/3}$, and modal wave period, T_0. The wave spectral density, $S_\zeta(\omega)$, is defined as:

$$S_\zeta(\omega) = A\omega^{-5}\exp(-B/\omega^4) \tag{3.13}$$

where

$A = 487.0626(\zeta_w)_{1/3}^2 / T_o^4$

$B = 1948.2444 / T_o^4$ and,

ω is the wave frequency in radians per second

Long-crested and short-crested response variances are obtained by a frequency domain calculation for a given sea condition ($((\zeta_w)_{1/3}$ and $T_0)$ and a given ship speed V as:

$$\sigma_{LC}^2(\beta) = \int_0^{\omega^*} RAO(\omega,\beta)\, S_\zeta(\omega) d\omega \tag{3.14}$$

where

ω^* : The wave frequency above which ship responses are negligible

$RAO(\omega,\beta)$: Response Amplitude Operator for a specific wave frequency and unidirectional incident wave heading

$S_\zeta(\omega)$: Wave spectral definition

Short-crested response variances, σ_{SC}^2, are also computed for a given sea condition and ship speed as:

$$\sigma_{SC}^2(\beta) = \int_{\beta-\pi/2}^{\beta+\pi/2} \int_0^{\omega^*} RAO(\omega,\nu)\, S_\zeta(\omega,\nu) d\omega\, d\nu \tag{3.15}$$

The short-crested wave spectrum, $S_\zeta(\omega,\nu)$, is defined as:

$$S_\zeta(\omega,\nu) = \frac{2}{\pi}\cos^2(\nu-\beta) S_\zeta(\omega) \tag{3.16}$$

where

$S_\zeta(\omega)$: Long-crested wave spectrum

In the short-crested wave spectrum definition, β is the predominant heading of the waves containing the principal amount of wave energy over an area ±90 degrees from the predominant heading.

3.2.1.6 Operation of the Motion Program SHIPMO-PC

The basic computational structure of SHIPMO-PC is divided into three principal sections:

(1) Data Entry

(2) Analysis

(3) Results Output

In section (1), all necessary data for the execution of the program covering ship geometry, appendages, control systems, speed, heading and sea state are read in. Point locations other than the origin define where motions will be computed. Points may also be selected for calculating relative motion and the frequency of occurrence of slamming and emergence of these locations. Irregular sea calculations are controlled by inputting wave periods and significant wave heights.

In section (2), ship motions and seakeeping parameters are computed for all specified ship speeds, sea directions and sea states. In each case, frequency response to regular waves is first determined by solving the equations of motion. The computed frequency response to regular waves is then used to determine RMS motions in a specified seaway spectrum.

In section (3), when results have been accumulated for all specified sea directions and sea states, motions and calculated seakeeping parameters such as slamming and deck wetness are output for unidirectional seas.

The program permits the user to run the hydrostatics calculation routines prior to execution of the motions computations. This has the advantage of allowing the user to verify the hydrostatic results, and hence verify the input data, before the computationally intensive motion calculations are performed. Operating details of SHIPMO-PC can be found in the User's Manual [96].

3.2.1.7 Input Description

A complete data file contains all the input data required for the execution of the program, which is all the information that was entered by the user during the data input section. A brief description of the input items as follows:

Data Base-This section permits the user to select data from the database. A file selected from this section will be loaded into the program. The user may then proceed to edit the file by using the SHIPMO-PC interface.

Units-In this section the unit system to be used is defined. Two Unit systems are available in the program, either British (Imperial) or Metric (SI). The user should ensure that input data is entered consistently, based on the selected unit system.

Operating Conditions-The operating conditions to be used in the analysis such as the speed and the water density are defined in this session. The speed at which the motions are to be calculated are specified in terms of a minimum and maximum speed and a speed increment.

Ship Description-In this section the characteristics of the vessel to be investigated are entered. The user has the option of defining the hull using Hull Offsets or Sectional Areas methods. To obtain meaningful ship motion predictions, SHIPMO-PC relies heavily on the user-supplied description of the hull configuration. The maximum number of stations that may be selected by the user is twenty one. The station numbering starts at the bow

(Station 0) and terminates at the stern. The OFFSETS METHOD for entering hull section data uses horizontal (y-axis), and vertical (z-axis), offsets at each station. The user can enter up to twelve offsets per station. Ideally, the user should input eight offsets below the design waterline and four offsets above it. Figure 3.3a shows a visual explanation as to how the data is to be entered for each station.

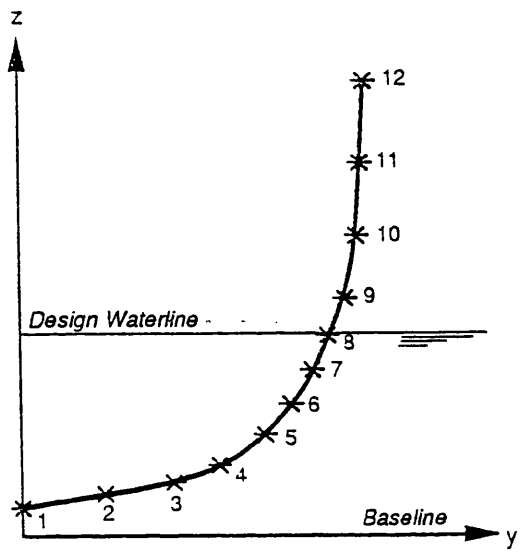


Figure 3.3a Example of Station Offsets for SHIPMO-PC

The SECTIONAL AREAS method is an alternate method based on the immersed hull section as defined by area coefficients. This method is particularly efficient when the sectional area data is available. When the sectional area data are entered, offsets will be generated using Lewis forms. The loading condition parameters are required only if the hull geometry is specified using the OFFSETS method. These values will be ignored if SECTIONAL AREAS method is subsequently specified to define the hull. The loading condition for the vessel can be specified as either displacement or draft at midships. Ship particulars such as the length, vertical centre of gravity, metacentric height, roll gyradius must also be specified in this section. If the user intents to investigate the influence of the hull appendages on the motion characteristics, the geometry of the various appendages (bilge keel, roll stabilizer, propeller, rudder) is defined through a series of sub-sections. Definition related to appendages type can be found in SHIPMO-PC User's Manual.

Wave Definition-In this section the characteristics of the sea states to be used in the analysis are entered. As mentioned previously there are three types of wave spectra available for the motion calculations in irregular seaways. The user may select one of three types of spectra namely Quadratic Regression spectrum, Bretschneider Two-Parameter spectrum or Measured spectrum for the motion calculations in irregular seas.

For the wave frequency or the encounter frequency entry, the user must provide the upper and lower frequencies as well as a frequency increment. The frequency increment is important because it effectively determines the accuracy of the motion response calculations in irregular waves. The maximum number of frequencies which may be specified is forty. The vessel response will be computed at the wave frequencies specified, therefore, in irregular seas, care must be taken to ensure that the frequency range of interest is adequately covered. At full scale, realistic limits on the frequency interval are $0.2 \leq \omega_{\omega} \leq 2.0$ rad/sec.

The principal sea directions (maximum 19) are to be specified with respect to the ship's heading where 0 degrees is defined as following seas and 180 degrees is defined as head seas. The vessel response will be calculated for each sea direction specified. The number of seaways (maximum 10), the significant wave height and the wave period must be specified for motion calculations in irregular seas.

RAO Method-The computation of the sectional added mass and damping coefficients is the most time consuming part in solving the equation of motion. These coefficients must be quite accurately computed in order to get satisfactory motion results. In this section either the Close-Fit or Conformal Mapping method in obtaining these quantities will be chosen. The Close-Fit method uses hull offsets, while the Conformal Mapping method uses the sectional area information for each station. For the Close-Fit method the geometrical shape of the section is mathematically represented by a given number of offsets points (about 8-12) with straight line segments between the points. The velocity potential is then obtained for a distribution of source singularities over the submerged surface of the hull with constant strength over each of the straight segments.

Seakeeping Calculations-This section permits the user to select the types of seakeeping calculations required for each run. If local motions at specified points along the centreline plane of the hull are required, the station number and the vertical position will be entered. The program will then provide the motion response values for these specified points.

3.2.1.8 Hydrostatics and Seakeeping Analysis

The execution of the hydrostatics and seakeeping analysis may be performed separately. It is primarily a check-out procedure which helps the user identify and correct obvious input errors prior to making a production run. Since it requires little execution time, it is an efficient as well as economical method of assuring proper input data. If the user is performing a parametric analysis of a particular ship and is confident that the ship is correctly described in the input, he/she then will proceed to run the hydrostatics and the ship motions analysis in a single step. The amount of time necessary to execute the program is directly related to the number of speeds, point locations, and sea states desired. Depending on the scope of the analysis, execution of the program can be quite time consuming. A typical run of the program takes about 20 minutes on a 80486 IBM compatible computer.

3.2.1.9 Output Description

The output from a SHIPMO-PC run is stored as a series of output files, which allows the user to be specific in his/her selections and avoid extremely long outputs. The outputs files consists of the following options:

Hydrostatic Summary-This is a text file which presents the output of the Hydrostatics analysis. It can be accessed prior to running the motions calculations to check that the vessel parameters are correct.

RAO(s)-This file contains the data for the Response Amplitude Operators (RAO) used to calculate the vessel responses. A sub-menu allows the user to view either amplitudes or phase angles.

RMS Responses-This file contains the data describing the vessel response in the irregular seaway, at the centre of gravity and specified locations in the centre line planes. The responses are presented as root-mean square (RMS) values.

Motions and Deck Wetness-This file contains the data describing the absolute and relative motions as well as the deck wetness characteristics of a specified position on the vessel in irregular seaways. The motion responses are presented as root-mean square (RMS) values; they include both absolute and relative motion responses. The deck wetness data is presented as a probability of occurrence and as the number of deck wetness per hour.

Slamming/Keel Emergence-This files contains the data describing the slam characteristics of a particular position on the vessel in irregular seaways. The motion responses include both absolute and relative RMS motion responses. Keel emergences are reported as a probability of occurrence and the number of deck wetness per hour.

Roll Damping Coefficient-This option allows the user to view the roll damping coefficients. The general format of the output is similar to the RAO output.

Motion Summary-This is a text file which summarises the inputs used in the motions calculations in the program. This file can be accessed prior to running the motions calculations, to check that the parameters are correct.

3.2.2 Computer Program Based on a Three-Dimensional Translating Pulsating Source Distribution Technique

A computer program to asses the motions of monohull ships based on a three-dimensional translating pulsating source distribution technique associated with a cross-flow approach for taking viscous effects into account is used to calculate the motion responses of the parent fishing vessel hull forms.

The motion program called MARCHS developed by Chan [97], is based on the assumption that the frequency of oscillation is greater than the differential operator on the free surface boundary condition and that the mean wetted surface can be represented by an oscillating source distribution over the discretised body surface. An empirical method based on a steady cross-flow assumption is used to calculate the fluid forces and moments due to viscous effects. The lift and drag coefficients used in the cross-flow formulation are assumed to be constant values along the length of the ship hull.

The program was written on the IBM 3090 mainframe at the University of Glasgow's Computer Centre. The wave excitation and hydrodynamic force and resulting motion values of a given hull form is calculated using MARCHS in association with three other pre-processor programs. The program HULSUR is used for the discretisation of the underwater form of a vessel and the program HULPLOT is used for a graphical display of the discretised hull form. The geometrical characteristics of the vessel is generated by the HULDAT routine. The output data which comprises the motion response and wave force amplitudes in six-degrees of freedom is written to a file for further processing.

The required Central Processing Unit (CPU) time to run the MARCHS program for a single wave heading and twenty five regular wave frequencies is about 4 hours. The total CPU required also depends on the number of panels of the hull facets. Details of MARCHS are given in Chan [97].

3.3 Added Resistance

The added resistance is an important factor in estimating the power of a ship advancing in a seaway. Techniques to predict the total ship resistance in calm water have been well established, either by experimental or numerical methods. Generally the horsepower needed for a ship can be well estimated by considering the friction, wave-making, viscous, air and appendages resistance in calm water. However, the ship speed reduces in waves for a given engine power output due to her motions. Traditionally the power required to attain a certain speed in a seaway has been determined from the still water performance of the vessel after making allowance of 15% to 30% for wind and waves [98].

Added resistance of a ship in waves in generally maximal in head seas and may be considered to be made up of three components [99];

(1) One corresponding to that experienced by a ship forced to oscillate in calm water, generating damping waves that dissipate energy,

(2) One caused by the phase shift between wave excitation and ship motions,

(3) One resulting from the diffraction of oncoming waves by the ship.

The transfer function for the added resistance in waves can be obtained by measurement or prediction of the added wave resistance values in regular waves as:

$$R(\omega_e) = \frac{R_{AW}}{\zeta_w^2} \tag{3.17}$$

Where ζ_w is the wave amplitude.

In irregular seas, principle of superposition may be applied to obtain the average added wave resistance, $\overline{R}_{AW}$:

$$\overline{R}_{AW} = 2\int_0^\infty R(\omega_e)S_\zeta(\omega_e)d\omega_e \tag{3.18}$$

where $S_\zeta(\omega_e)$, is the the spectral density function representing the seaway.

Analytical methods and experimental techniques for determining the added resistance of a ship running in a seaway have now been developed quite well and can be used for design purposes. The sectional hydrodynamic coefficients and RAO's can be used to evaluate the added resistance in regular waves. These values can also be combined with the sea state data to obtain added resistance in an irregular seaway.

Many researches have investigated the added resistance in waves, both experimentally and analytically. Havelock [100] provided one of the earliest analysis of added resistance in regular waves. He expressed the added resistance, R_{AW}, in terms of heave amplitude, ξ_3, and pitch amplitude, ξ_5, as follows:

$$R_{AW} = -\frac{k}{2}[F_3\xi_3 \sin\varepsilon_3 + F_5\xi_5 \sin\varepsilon_5] \tag{3.19}$$

Where k is the wave number, F_3 is the heave exciting force amplitude and F_5 is the pitch exciting moment amplitude. An alternative way of writing this equation is in terms of the pure fluid damping coefficients, that is

$$R_{AW} = \frac{\omega_e^3}{2g}[B_{33}\xi_3^2 + B_{55}\xi_5^2] \tag{3.20}$$

Where ω_e is the wave encounter frequency, and B_{33} and B_{55} are the damping coefficients for heave and pitch respectively.

The Havelock method should be regarded as a first approximation, particularly since it neglects the effects of heave and pitch coupling. Nonetheless, two important observations can be made from the Havelock equations. First, added resistance is independent of the still water resistance, and secondly it is proportional to the square of the wave amplitude.

Maruo [101] developed a theoretical analysis method based on the linear theory to predict added wave resistance. He derived an expression in terms of the geometric characteristics of the ship and her motions. The geometric characteristics that enter into the computation of the added resistance, according to Maruo's method, include the sectional area, beam and draft, and the vertical centroid of the sectional area at each station. The ship motions must be obtained either from analysis, from model tests, or from full-scale measurements.

The total added wave resistance is partitioned into a number of different components as follows:

$$R_{AW} = R_{11} + R_{22} + R_{33} + R_{12} + R_{13} + R_{23} \tag{3.21}$$

These terms may be identified with physical processes as follows:

R_{11} : radiation due to heaving motion
R_{22} : radiation due to Pitching motion
R_{33} : diffraction (reflection) of the incident wave
R_{12} : coupling between heaving and pitching motions
R_{13} : coupling between heaving motion and the resistance associated with wave diffraction
R_{23} : coupling between pitching motion and the resistance associated with wave diffraction

Joosen [102] used a slender body expansion to develop an extension of Maruo's analysis of the wave drift force. The theory was extended to include the forward speed by substituting a wave encounter frequency which is a function of velocity for the wave frequency appearing in the analysis. Joosen's method is valid only for short waves and is similar to that of Havelock except for an additional term to account for the heave-pitch coupling.

$$\sigma_{AW} = E_1 + E_2 + E_3 \tag{3.22}$$

Where

σ_{AW} is the nondimensional added resistance coefficient given by

$$\sigma_{AW} = \frac{R_{AW}}{[\rho g(B^2 / L)\zeta_o{}^2]} \tag{3.23}$$

the three components of σ_{AW} have the following form

$$\begin{aligned} E_1 &= C_0 B_{33}\xi_3^2 \\ E_2 &= C_0 (2\pi L / \lambda)^2 B_{55}\xi_5^2 \\ E_3 &= -2C_0 (2\pi L / \lambda) B_{35}\xi_3\xi_5 \cos(\varepsilon) \\ C_0 &= (1/16)(L^2 / B^2)\omega_e^3 (L/g)^{3/2} (\nabla / L^3) \\ \varepsilon &= |\varepsilon_3 - \varepsilon_5| \end{aligned} \tag{3.24}$$

where L is the ship length, B is the ship beam, λ is the regular wave length and ε_3 and ε_5 is the phase difference between the exciting forces and motions for heave and pitch respectively. The damping coefficients B_{33}, B_{55} and B_{35} correspond to heave, pitch and heave-pitch coupling. In particular the damping coefficients are defined as follows:

$$B_{33} = \frac{1}{\omega_e \nabla}(g/L)^{1/2}\int_0^L b_{33}(x)dx$$
$$B_{35} = \frac{1}{\omega_e \nabla}(g/L)^{1/2}\int_0^L b_{33}(x)xdx \qquad (3.25)$$
$$B_{55} = \frac{1}{\omega_e \nabla}(g/L)^{1/2}\int_0^L b_{33}(x)x^2dx$$

where ∇ is the displaced volume of the body and $b_{33}(x)$ is the sectional fluid damping coefficient.

Gerritsma and Beukelman [103] computed added resistance by calculating the energy flux radiated from the hull. The energy radiated during one wave encounter period T_e is given by

$$E = \int_0^{T_e}\int_{x_a}^{x_f} b(x)V_z^2(x,t)dxdt \qquad (3.26)$$

where $V_z(x,t)$ is the vertical velocity of the ship section relative to the disturbed water surface elevation. The longitudinal coordinate position x is now defined as the distance forward of the longitudinal centre of gravity of the ship. Hence x_a and x_f are the respective positions of the aft and fore perpendiculars. Since the relative velocity V_z is a harmonic function of time, which can be expressed as

$$V_z = V_{za}\cos(\omega_e t + \varepsilon) \qquad (3.27)$$

the time dependence integration yields

$$E = \frac{\pi}{\omega_e}\int_{x_a}^{x_f} b(x)V_{za}^2(x)dx \qquad (3.28)$$

Referring to the work of Hanaoka et al. [104], Gerritsma and Beukelman have shown that the added resistance of the ship is proportional to the radiated energy in the form

$$E = \lambda R_{AW} \tag{3.29}$$

where λ is the regular wavelength. This yields

$$R_{AW} = \frac{k}{2\omega_e}\int_{x_a}^{x_f} b(x) V_{za}^{2}(x)dx \tag{3.30}$$

This elegant and simple result only requires an accurate knowledge of the distribution of the $b(x)$ to obtain the added resistance for various motion conditions. Expanding the equations of motion for heave and pitch, Gerritsma and Beukelman have shown that the term $b(x)$ is given by

$$b(x) = b_{33}(x) - V[a_{33}(x) / dx] \tag{3.31}$$

where $a_{33}(x)$ and $b_{33}(x)$ are the zero-speed sectional added mass and damping coefficients, respectively. The vertical relative velocity V_z is determined from the relative displacement equation

$$\xi = \xi_3 - x_b\xi_5 - \zeta^* \tag{3.32}$$

as

$$V_z = \dot{\xi}_3 - x_b\dot{\xi}_5 + V\xi_5 - \zeta^* \tag{3.33}$$

where x_b is the station position measured positively forward from the centre of gravity, ξ_3 is the positive upwards, ξ_5 is defined positive for bow-down motion, and ship speed is given by V. The effective vertical wave displacement ζ^* is the incident wave amplitude modified by the radiation and diffraction wave profiles.

Loukakis and Sclovounos [105] extended the method of Gerritsma and Beukelman to calculate added resistance and drift force in oblique waves including the effect of lateral motions.

3.4 Numerical Computations

In order to choose the most efficient program to generate seakeeping information for a large number of hull forms used in this study, both the strip theory based computer program SHIPMO-PC and the three-dimensional translating pulsating source distribution technique based program MARCHS are considered. During the calculations, five different fishing vessel hull forms were used to predict the motion response values for various Froude numbers and wave headings.

3.4.1 Predictions Based on the Three-Dimensional Source Distribution Technique

In order to investigate the effect of hull form on seakeeping characteristics, the computer program, MARCHS, based on the three-dimensional translating pulsating source distribution technique was run for five different fishing vessel hull forms for various Froude numbers and wave headings. The fishing vessel hull forms chosen for this investigation consist of an existing Black Sea fishing vessel having a cruiser stern [22] and four fishing vessels chosen from Istanbul Technical University series with transom sterns defined by Kafali [23]. The body plans and the principal particulars of the five parent hull forms are shown in Appendix A. Each hull was modelled by a total of 244 rectangular and triangular panels as shown in Figure 3.21. A program called SHIP-RMA was written on the IBM 3090 mainframe to calculate vertical acceleration and relative motion amplitudes from the output produced by MARCHS. The output format for the hydrodynamic coefficients, and the response amplitude operators are non-dimensionalised as defined in Table 3.2.

Table 3.2 Non-dimensional Forms of Hydrodynamic Coefficients and Ship Responses

	Non-dimensional Form	
Added mass coefficient, A_{jk}	$a_{jk} = A_{jk} / \rho\nabla$	for $j,k = 1,2,3$
	$a_{jk} = A_{jk} / \rho\nabla L^2$	for $j,k = 4,5,6$
Damping coefficient, B_{jk}	$b_{jk} = B_{jk} / \rho\nabla\sqrt{(g/L)}$	for $j,k = 1,2,3$
	$b_{jk} = B_{jk} / \rho\nabla L^2\sqrt{(g/L)}$	for $j,k = 4,5,6$
Motion amplitude, ξ_k	$\xi_k' = \xi_k / \zeta_o$	for $k = 1,2,3$
	$\xi_k' = \xi_k / \upsilon\zeta_o$	for $k = 4,5,6$

3.4.1.1 Hydrodynamic Coefficients

Numerical computations were carried out for the fishing vessel KTU/1-K for four Froude numbers ($Fn = V / \sqrt{gL}$) 0.0, 0.22, 0.3 and 0.43 at infinite water depth at the non-dimensional frequency of encounter ($= \omega_e\sqrt{L/g}$) ranging from 0.0 to 5.0. The non-dimensional coefficients for the added mass and damping in six rigid modes of motion are illustrated in Figures 3.22 and 3.23. As can be seen from these figures, the hydrodynamic coefficients in surge, sway, heave and roll modes of motion are speed independent since the oscillating source model implemented in the program takes into account the speed dependent term via the encounter frequency only. The hydrodynamic coefficients of pitch and yaw motions are more speed dependent in the low frequency region whereas the coefficients merge into a single curve in the high frequency region where the effect of encounter frequency is greater than that of the speed.

Figures 3.24 through to 3.27 illustrate the added mass and damping coefficients for five fishing vessel hull forms and two Froude numbers of 0.0 and 0.3. It is observed that for the zero speed case increasing the ship length and B/T ratio increase the values of hydrodynamic coefficients in heave, roll and pitch modes of motion but decrease those values in sway and yaw modes of motion since a shallow draught results in low sway fluid reactive forces and wider beam results in high heave fluid reactive forces. Meanwhile a decrease in the C_M coefficient decreases the values of surge hydrodynamic coefficient because the more slender the hull form the less the fluid forces acting in longitudinal direction. Increasing C_{WP}, and the forward position of the LCB increases the hydrodynamic coefficients in heave and pitch modes of motion but decrease the roll mode of motion. Same characteristics, which were observed in the zero speed case, can be found for the forward speed case as well. For example increasing the ship length and B/T ratio increase the values of hydrodynamic coefficients in heave, roll and pitch modes of motion but decrease those values in sway and yaw modes of motion.

3.4.1.2 Ship Responses

The zero speed motion responses of the vessel KTU/1-K in deep water at various angles of wave heading are illustrated in Figure 3.28. The sway, heave and roll motion responses of the vessel in beam waves are larger than those in oblique and head waves because of stronger wave forces in beam waves for these modes of motion. In particular, the roll motions in beam and oblique waves become large around the resonance frequency due to weak wave damping. The amplitudes of sway and roll motions decrease both from beam waves to head waves and from beam waves to following waves. Eventually, there are no responses in sway, roll and yaw motions in head and following waves due to the longitudinal plane of symmetry. The surge, pitch and yaw motion responses in beam waves are smaller than those at other angles of wave incidence. On the other hand, the amplitudes of surge and pitch responses increase at lower frequencies as the wave heading changes from beam waves to following waves. In the long wave regime the amplitudes of motion responses in stern waves are the same as those in bow waves, because wave exciting forces are the same.

The motion response values of the vessel KTU/1-K at various angles of wave heading at Froude number of 0.3 are illustrated in Figure 3.29. Some characteristics, which were observed in the zero speed case, can be found for the forward speed case as well. For example, the amplitudes of the sway and roll responses in beam waves for all wavelengths are larger than those in other wave directions because of stronger wave excitation in beam waves for these two modes of motion. The peak amplitudes of the heave and pitch response values decrease as the wave angle of attack decreases from 180° to 0°.

The motion response values of the vessel KTU/1-K with different forward speeds at four wave heading angles are illustrated in Figures 3.30 through to 3.34. It is observed that the amplitudes of surge and sway responses decrease in bow waves but increase in stern waves as forward speed increases. An increase in the forward speed causes an increase in the resonant peaks of heave and pitch response curves in bow and head waves but the opposite occurs in stern and following waves. The response values in beam waves are less sensitive to the forward speed.

The motion response values for five different fishing vessel hull forms at Froude numbers of 0.0, and 0.3 in head seas are illustrated in Figures 3.35 and 3.36. Since all the ITU series hull forms had the same L/B and B/T ratio, the analysis did not predict any significant differences between the responses of these forms. It is observed that increasing ship length and B/T reduce the motion responses particularly in the surge and heave modes. Increasing C_{WP} and forward position of the LCB reduce the heave and pitch motions. The heave and pitch motions increase as the C_B values increase. It should be pointed out that during the investigation reported above the variations in the response values were not very large since the vessels' dimensions were not altered significantly.

3.4.2 Predictions Based on the Strip Theory

The strip theory based computer program SHIPMO-PC was used to carry out motion response predictions, for various Froude numbers and wave headings, of the same hull forms as mentioned in the above section. In describing the hull shape as input to this program, data was input for twenty-one sections equally spaced over the waterline length. The predictions were made using the Close-Fit method which computes the hydrodynamic properties of the hull sections. The body plan and an example of the computer representation of hull sections are shown in Figure 3.3b.

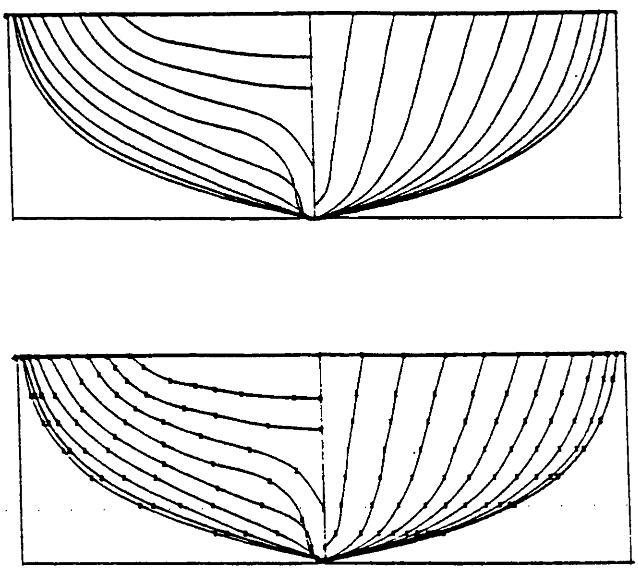


Figure 3.3b Computer Presentation of Body Plan

In order to decode the added mass and damping coefficients from the SHIPMO-PC output, a program called SHIP-AMD was written. In addition to the motion response predictions the added resistance calculations were carried out for the form KTU/1-K in head seas. The sectional hydrodynamic coefficients and RAO's generated by the motion program SHIPMO-PC are used to evaluate the added resistance in regular waves. For this analysis a computer program SHIP-AR based on the Joosen Method described in the previous section was written on an IBM compatible PC.

3.4.2.1 Added Mass and Damping Coefficients

The added mass and damping coefficients of KTU/1-K for heave and pitch motions in regular waves were obtained by the strip theory (Frank close-fit method) and the three-dimensional source distribution technique for zero speed. The results are presented in the usual non-dimensional form in Figures 3.37 through to 3.40.

As shown in Figures 3.37 and 3.39, the agreement between the strip theory and the three-dimensional source distribution technique is good for the heave and pitch added mass coefficients, especially in the high frequency range. On the other hand, correlations for the heave and pitch damping coefficients as shown in Figures 3.38 and 3.40 are poor. The discrepancy should mainly be due to the inclusion of viscous effects in the program SHIPMO-PC. As a result the values of heave and pitch damping coefficients obtained from the program SHIPMO-PC are larger than those obtained from the three-dimensional potential flow based program.

3.4.2.2 Added Resistance

Added resistance in waves can be measured as the difference between the time averaged resistance in waves and the calm water resistance at the same speed. In Figure 3.43 the non-dimensional values of the added resistance measurements for Froude numbers of 0.22 and 0.3 are presented as a function of the non-dimensional encounter frequency. The line in this figure represents the results of calculations of the added resistance carried out by using the Joosen method described in the previous section. As can be seen from this figure the magnitude of the added resistance increases with increasing model speed. The correlation between the measured and predicted added resistance by the Joosen method in conjunction with a linear strip theory is poor for the peak value of the added resistance. It was found that the predicted peak value of the added resistance is higher than the measured peak value. The curves for added resistance coefficients follow the same trend as for the motion responses. This is because added resistance in waves is dependent on the heave and pitch motion responses.

It may be concluded that the program SHIP-AR based on the Joosen method can only predict the added resistance experienced by a vessel in waves in an approximate manner.

3.4.2.3 Ship Responses

The motion response predictions were carried out for the fishing vessel KTU/1-K at different wave headings for Froude numbers of 0.0, 0.22, 0.3 and 0.43. The results were compared with experimental data and 3-D results wherever possible. The results of these predictions are presented in Figures 3.44 through to 3.50. The motion response values at zero speed for beam and quartering seas are illustrated in Figures 3.51 through to 3.53. A detailed discussion about these predictions are given in section 3.5.

3.5 Experimental Investigation of Dynamic Motion Response Characteristics of a Fishing Vessel Model

In order to validate the two numerical methods used in this study, a Black Sea fishing vessel model KTU/1-K was tested in regular waves. The experiments were conducted in the towing tank of the Hydrodynamics Laboratory which is 77m long, 4.6m wide and 2.7m deep. The model was towed with the main carriage where the speed can be electronically controlled. Regular waves are created by a plunger type wave maker driven by an electronically controlled hydraulic pump. There is an absorber beach at the other end of the tank. There is practically no limitation to the wave heading that can be generated in the towing tank as far as the motion tests at zero speed is concerned. However, due to allowable laboratory time considerations, the test program was restricted to wave headings which were considered to be most important, i.e. head, following, quartering and beam waves. Heave and pitch motions, relative motion and vertical acceleration measurements were carried out at the fore perpendicular (0.25L) in head and following seas for forward speed , in addition zero speed measurements were carried out for head seas only. Measurements of heave and roll motions were performed for beam and quartering seas at zero speed. Resistance in waves was also measured when measuring the motions in head seas. Experiments were also carried out to measure the calm water resistance in two loading conditions. Table 3.3 gives a summary of the test programme. The general instrumentation set up and the tests are detailed in the following.

Table 3.3 Particulars of the Test Programme

PARTICULARS		FREE-RUNNING IN STILL WATER	FREE-RUNNING IN WAVES					
Wave Heading		—	Head Seas		Following Seas	Quartering Seas 45 Deg.	Beam Seas 90 Deg.	Quartering Seas 135 Deg.
Regular Waves	Frequency Range [rad/s]	—	2.51 - 7.53	2.51 - 7.53	2.51 - 7.53	2.51 - 7.53	2.51 - 7.53	2.51 - 7.53
	L/λ	—	0.22 - 1.99	0.22 - 1.99	0.22 - 1.99	0.22 - 1.99	0.22 - 1.99	0.22 - 1.99
Draught	[m]	0.16, 0.2	0.16	0.16	0.16	0.16	0.16	0.16
Speed	[m/s]	0.5 - 2.5	Zero Speed	1.0, 1.4, 2.0	1.0, 1.4, 2.0	Zero Speed	Zero Speed	Zero Speed
	Fn	0.10 - 0.54	0.0	0.22, 0.3, 0.43	0.22, 0.3, 0.43	0.0	0.0	0.0
Measurements		Resistance	Heave, Pitch	Added Res. Heave, Pitch, Rel. Mot. at FP, Vert.Acc. at FP	Heave, Pitch, Rel. Mot. at FP, Vert.Acc. at FP	Heave, Roll	Heave, Roll	Heave, Roll

3.5.1 Construction of the Model

The body plan of the model is depicted in Figure 3.4. In order to construct the model, the lines plan of a Black Sea fishing vessel is produced from a previously developed lines plan of a traditional vessel.

Length between perpendiculars	27.0 m
Breath	8.0 m
Draught	2.0 m
Displacement	197.3 t
Block coefficient	0.446
Prismatic coefficient	0.704
Longitudinal centre of buoyancy	0.184 m (aft of amidships)

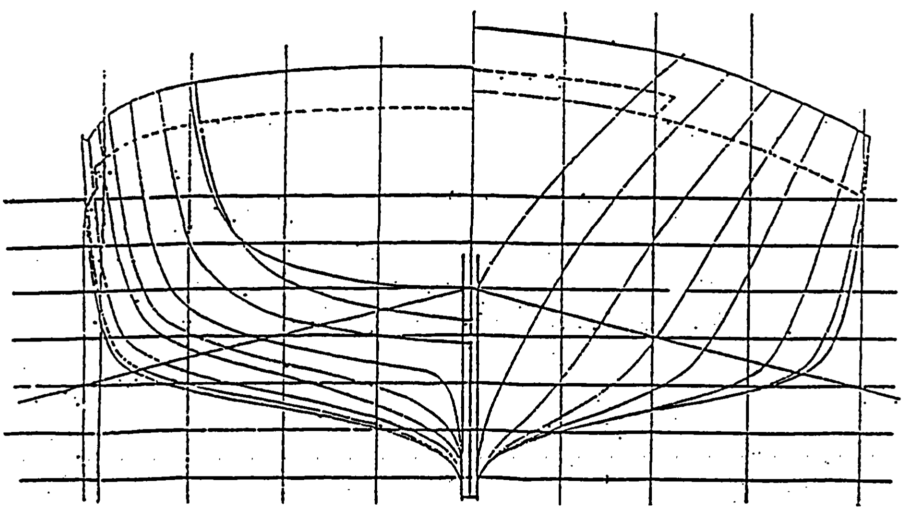


Figure 3.4 Body Plan of the Model Used in Experiments (Scale: 12.5)

The material used in the construction of the model is glass-reinforced plastic. The model was constructed in three stages as follows:

- The wax hull model was built
- The glass-reinforced plastic mould was made
- The final hull model was built by laying the finely chopped, strand-matt reinforcement fibres inside the mould using epoxy resin.

3.5.2 Measurement Devices

Uni-axial watertight force transducers were used to measure the model resistance in calm water and resistance in waves was measured using the dynanometer. Principal instruments for the measurement of model motions were either linear vertical displacement transformers (LVDT) or the Selspot motion detection system incorporating infra-red light emitting diodes (LED) and cameras, or a combination of both. A gravity type accelerometer was used to measure the vertical acceleration. The wave elevations generated by the wavemaker were measured by wave probes which generates electronic signals based on the submergence of the capacitor metal bar in the water. Three wave probes were placed on the bridge across the tank between the model and the wavemaker. The spreading of the wave probes was made at B/2, B/3 and B/4 from the tank side wall where B is the tank width, so that any change in the wave form across the tank could easily be identified. Three wave probes were situated on the model to measure relative motions and another one was mounted on the carriage to measure wave elevations during forward speed experiments.

Before the first run of the day was commenced, calibrations were conducted on each device to eliminate any changes in signal levels caused by the atmospheric state surrounding the devices, i.e.temperature, humidity, static current, etc. The calibration factor generated is automatically stored in the computer to convert the electronic signals from any measuring device during experiments. This gives the resulting quantity of the measured motion or wave elevation as the actual magnitude with an appropriate unit. In the following sections several important points regarding the experimental procedures and the data analysis are described. Some instrumentation used in the model tests are also described.

3.5.3 The Experiments in Calm Water

Calibration of Force Transducers-A uni-axial watertight force transducer was used to measure the model resistance. A calibration procedure was carried out by applying static weights in increments and recording the corresponding electronic signal into the micro computer.

The calm water resistance tests which covered a range of model speeds from 0.5 to 2.5 metres per second, were carried out for two loading conditions (the model speeds correspond to full scale speeds of 5 to 13 knots). The lightship draft is defined as the draft of the vessel when departing for the fishing grounds. The fish holds are assumed to be empty and a full supply of fuel and stores are assumed to be onboard. At the loaded draft, it is assumed that the fish holds would be full and a half supply of fuel and stores would be onboard.

Values of total model resistance and corresponding model velocity were obtained for each test run. Figure 3.41 and 3.42 shows the results of calm water total resistance of the model as function of the forward speed for two loading conditions. The temperature of the fresh water in the tank was also measured and recorded.

3.5.4 The Experiments in Waves-Head and Following Seas

Heave and pitch response measurements for head and following seas were carried out using two light emitting diodes on the model. Selspot cameras to trace the motions of the diodes were mounted on fixed points at the carriage. A wave probe mounted at the fore perpendicular was used to measure the relative motions and a gravity type accelerometer was used to measure the vertical accelerations. A wave probe was placed on the carriage to measure the wave height. Resistance in waves was measured using a dynanometer. The general layout of the experimental setup is shown in Figure 3.5. Calibration procedures are explained in the following:

Calibration of Selspot System-Calibration was carried out by moving the diodes a pre-determined distance in the vertical direction. The electronic signals corresponding to the displacement of the diodes were recorded by the micro computer.

Calibration of Wave Probes on Model-Calibration was performed by ballasting the model with a set of weights, one at a forward position and one at aft. These additional weights changed the model displacement by a pre-determined calibration distance. The electronic signal corresponding to the displacement of the model was recorded by the micro computer.

Calibration of the Wave Probe-The wave probe was submerged to 3/4 of its height in the tank when the water was calm and zero readings were taken on the wave probe amplifiers and the micro computer. The calibration process was continued by lifting the wave probe a pre-determined distance and the corresponding electronic signal was recorded by the micro computer.

Calibration of the Accelerometer-The acceleration due to gravity was concealed by lying the accelerometer on its side and a zero reading was taken. The Accelerometer was then returned to its operating position to induce an acceleration of 1g over the initial position, thus giving a known acceleration. The corresponding electronic signal of the accelerometer was recorded by the micro computer.

The model was tested in regular waves over a frequency range of 0.4 to 1.2 Hz at intervals of 0.1Hz at three different Froude numbers (0.22, 0.3 and 0.43). The sampling of the signals was set at 100 samples per second, per channel over a period of 15 seconds for each wave frequency.

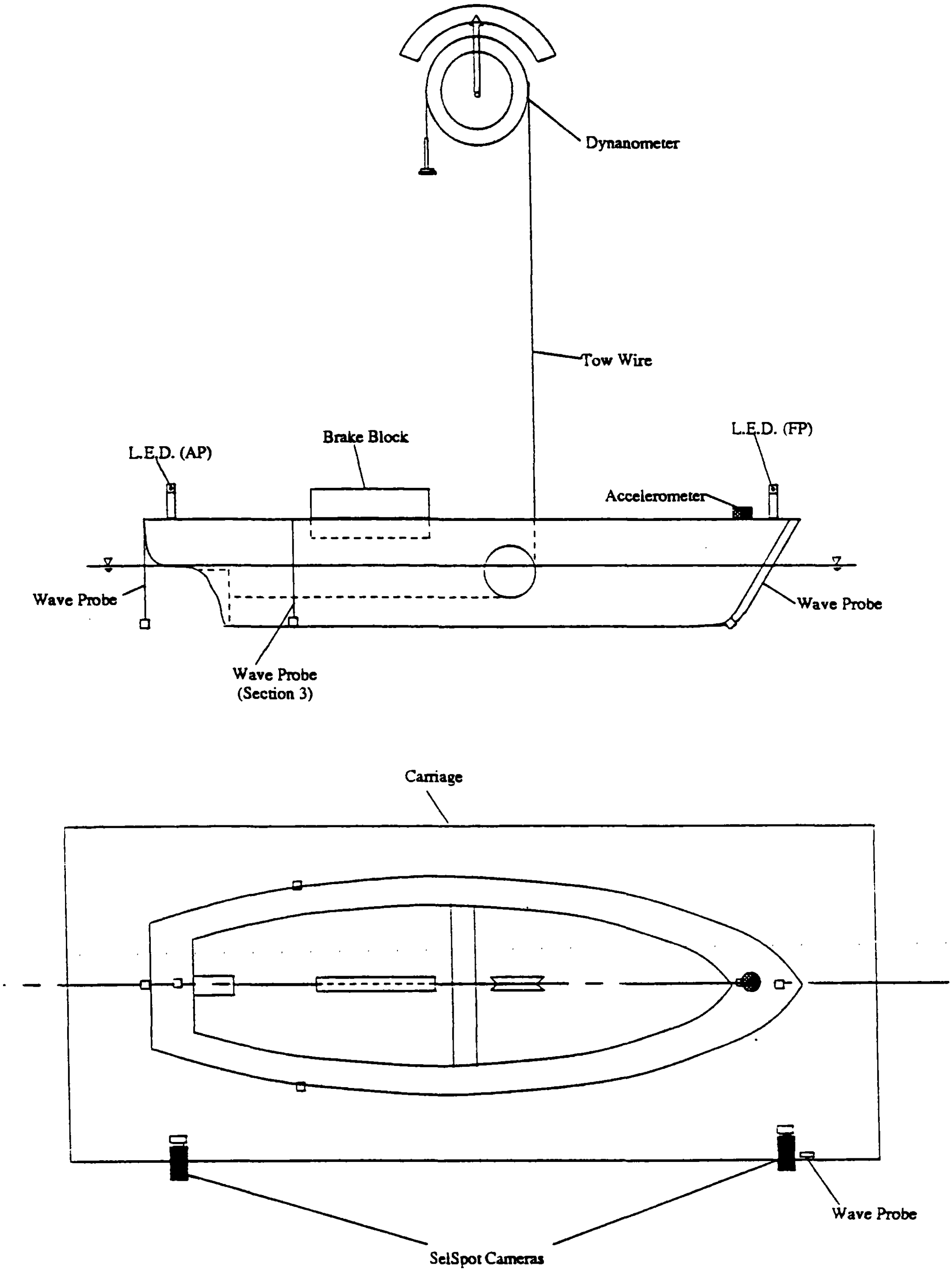


Figure 3.5 Experimental Test Set-up for Head Seas and Following Seas

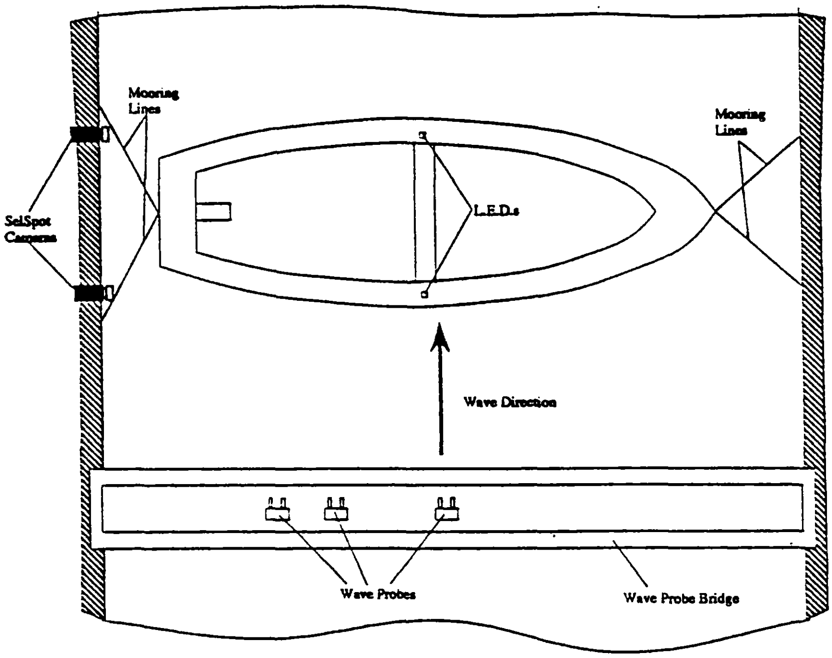


Figure 3.6 Experimental Test Set-up for Beam Seas

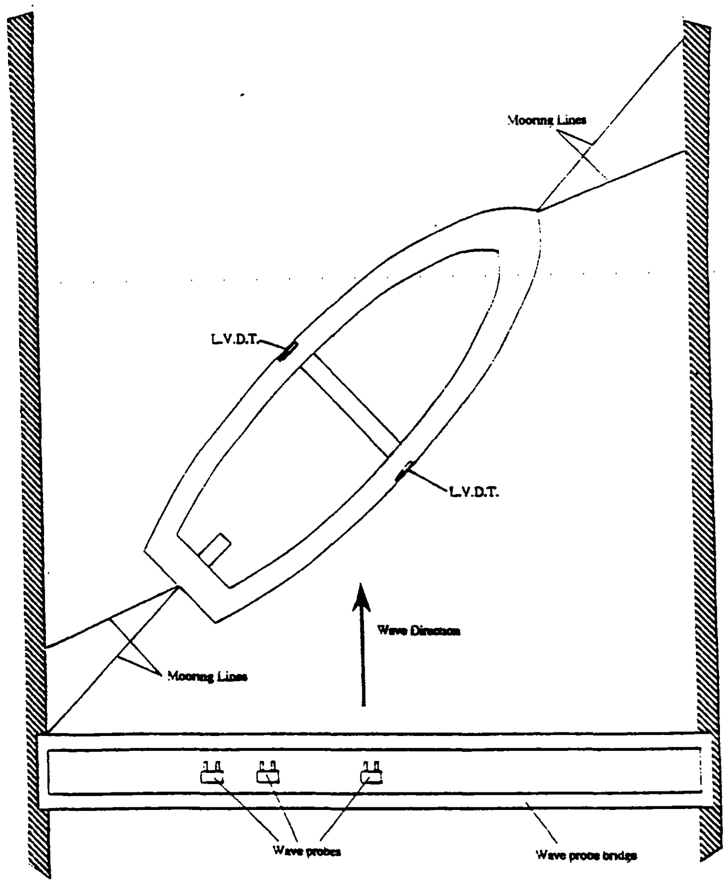


Figure 3.7 Experimental Test Set-up for Quartering Seas

3.5.5 The Experiments in Waves-Beam Seas

Two selspots (LED) were used to measure heave and roll modes of motion. The wave heights were measured by three resistance type wave probes. They were placed between the wave maker and the model. The Experimental layout is shown in Figure 3.6. A calibration of selspot system and the wave probes was carried out using the procedures described in the previous section.

The wave tests were carried out only at zero speed. The model was tested in regular waves over a frequency range of 0.4 to 1.2 Hz at intervals of 0.1Hz. The sampling of the signals was set at 100 samples per second per channel over a period of 15 second for each wave frequency.

3.5.6 The Experiments in Waves- Quartering Seas

Two LVDTs were used to measure heave and roll modes of motion. The wave heights were measured by three resistance type wave probes. They were placed between the wave maker and the model. The Experimental layout is shown in Figure 3.7. Calibration procedure is explained in the following:

Calibration of the LVDTs-The calibration process was performed by moving the LVDTs a pre-determined distance vertically. The signals corresponding to the displacement of the LVDTs were recorded by the micro computer.
The test programme was the same as the test programme for beam seas.

3.5.7 Amplifier and Data Acquisition Devices

Amplifiers were used to convert the signals from measuring instruments into voltages in the range of the data acquisition devices. There were two types of recording (data acquisition) devices used during the experiments, that is a pen recorder and a Macintosh IIci computer on which a software package named LabView is run. Although a pen recorder is a reliable device, its capability is limited by the number of the channels that can be connected to it.

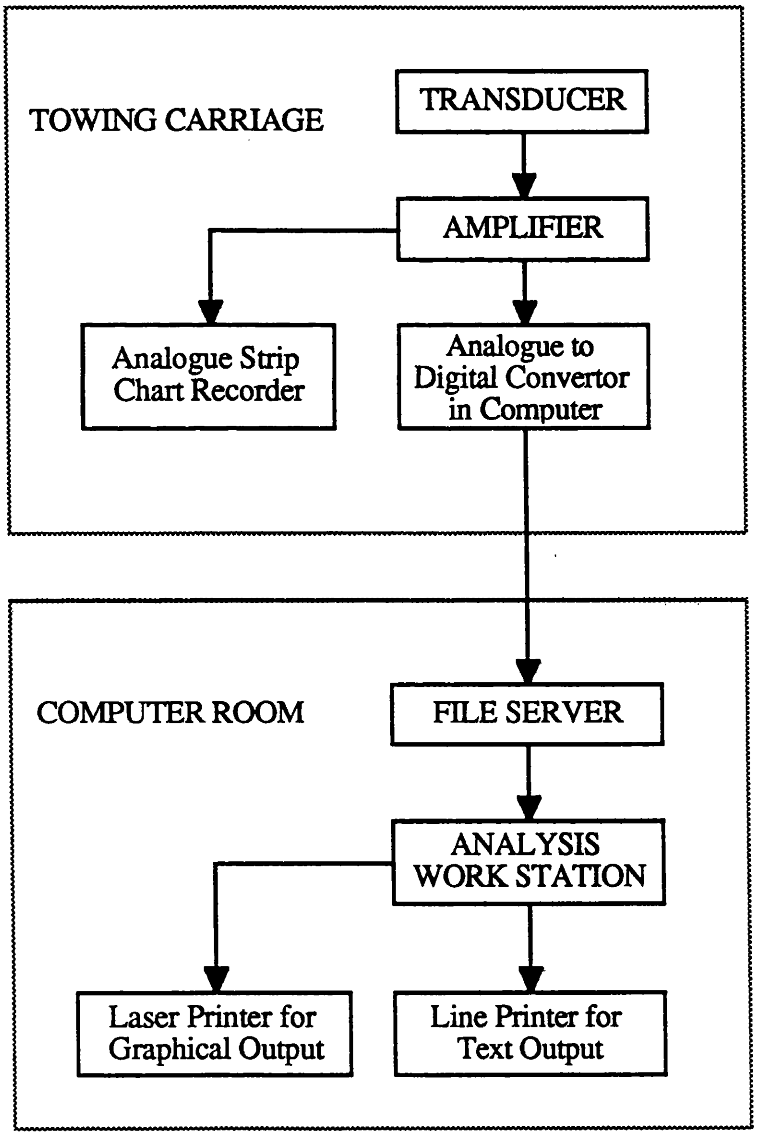


Figure 3.8 Data Acquisition Schematic Diagram

The use of a computer is more flexible when a relatively large number of electronic channels is required. Moreover, the use of a computer is more convenient when a complicated data analysis is to be carried out. Computer based data analysis is much less time consuming than the analysis performed using pen recorders. Figure 3.8 shows the data acquisition diagram. Figures 3.9 through to 3.12 show the model during a test run in calm water and in waves.

3.5.8 Analysis of Test Data

All experimental data acquired by the Macintosh IIci computer was analysed on the VAX 3100 workstation computer system. The VAX 3100 workstation is also the fileserver for the Macintosh network so the transfer of data from the Macintosh to the VAX 3100 is simple. A computer program written in FORTRAN for the analysis calculates the heave response at each sample by taking the average of the vertical motion detector (LVDTs or selspot) positions. The pitch or roll responses at each sample are calculated by taking the arcsine of the difference between the position of the vertical motion detectors divided by the distance between the detectors. The formulations are as follows:

$$\text{Heave} = \left(\frac{z_1 + z_2}{2}\right) \text{ and}$$

$$\text{Pitch or Roll} = \sin^{-1}\left(\frac{z_1 - z_2}{\Delta L}\right)$$

Where z_1 and z_2 are the position of the two vertical motion detectors and ΔL is the distance between the vertical motion detectors. All other signals were analysed without modification. The examination of the time series plots show the motions were of a sinusoidal form. Thus the data was analysed using simple statistical techniques. The calm water resistance data was analysed by calculating the mean of the time series.

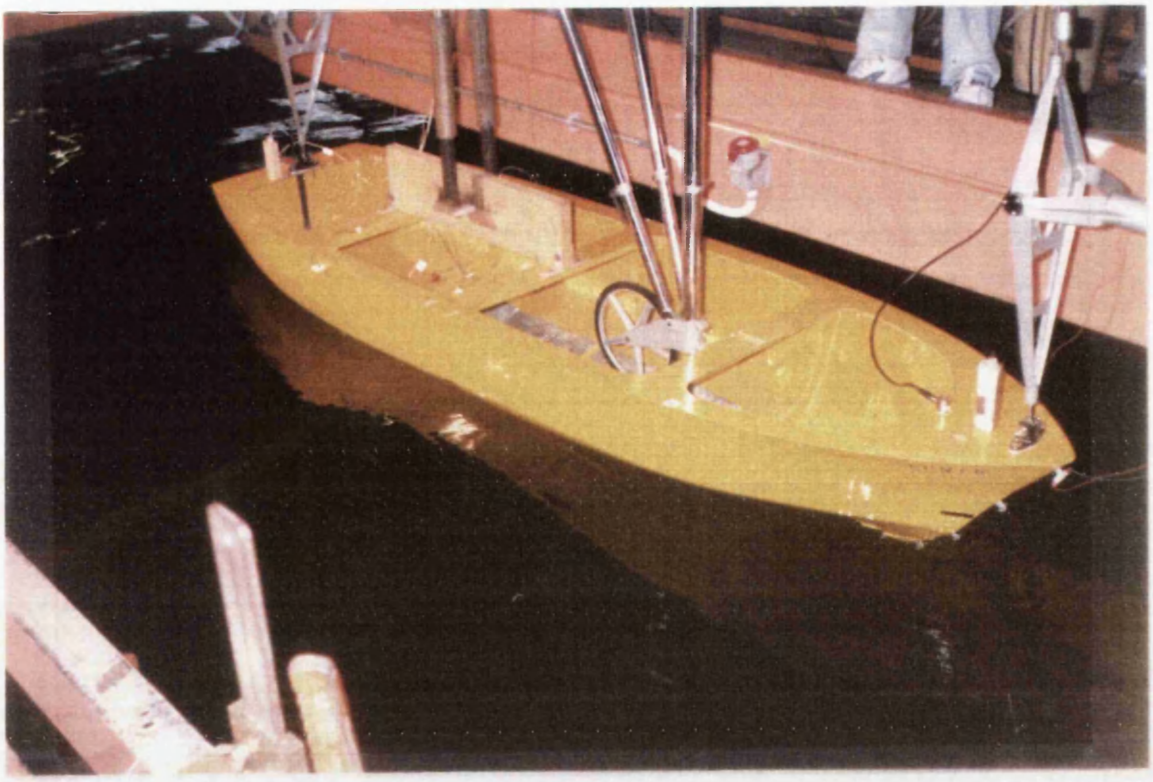


Figure 3.9 Fishing Vessel Model During a Test Run in Calm Water

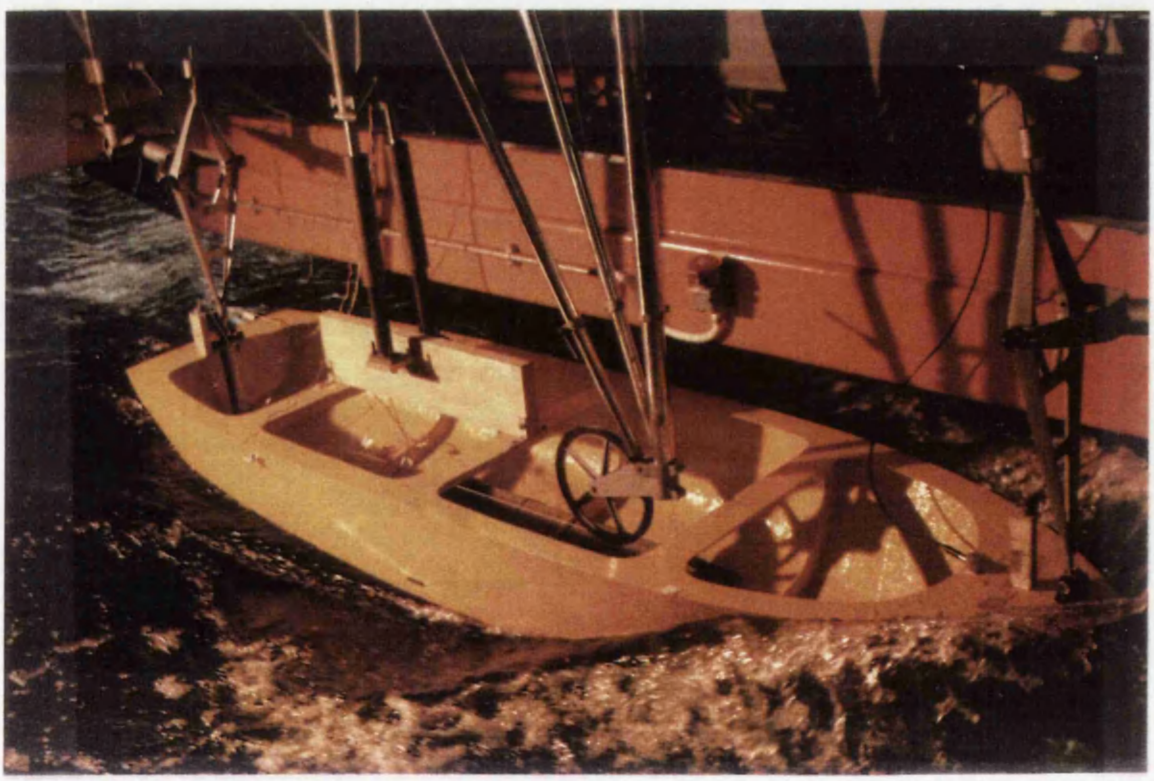


Figure 3.10 Fishing Vessel Model During a Test Run in Head Seas

Figure 3.11 Fishing Vessel Model During a Test Run in Following Seas

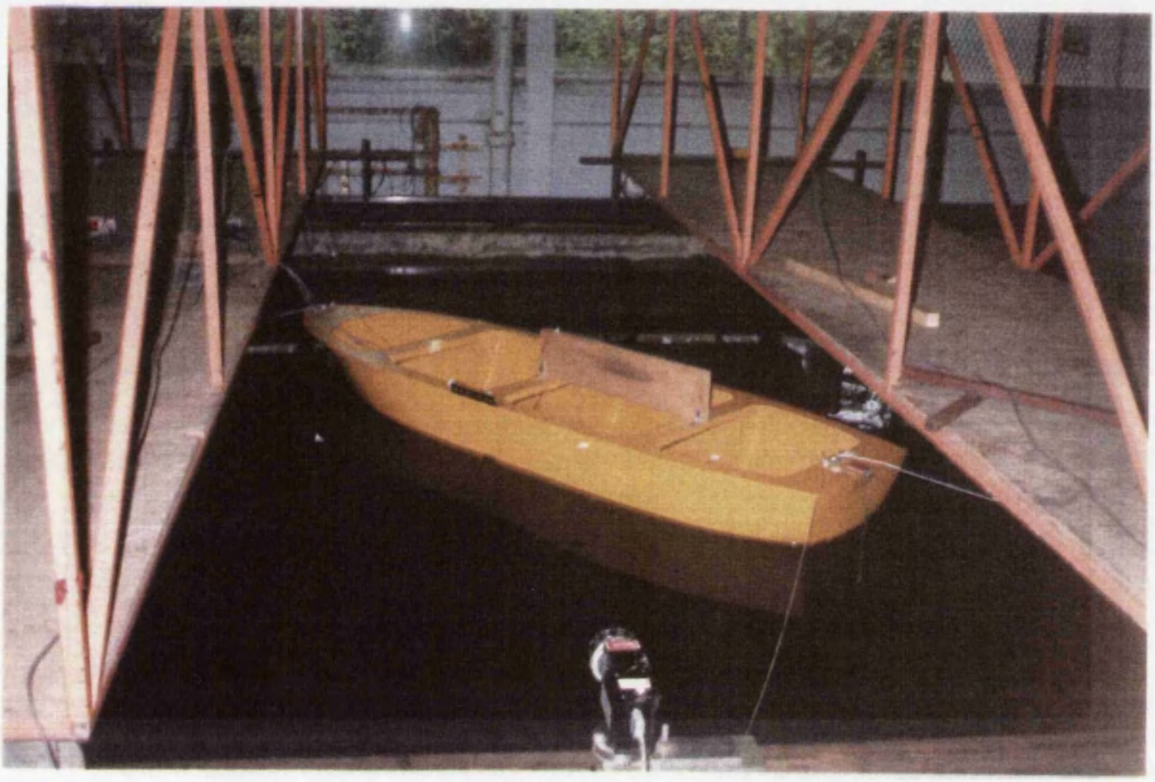


Figure 3.12 Fishing Vessel Model During a Test Run in Quartering Seas

The resistance in waves was obtained by measuring the output from the dynanometer. Typical plots of calm water resistance, motions and wave elevations as functions of time are shown in Figures 3.13 through to 3.20. Although the signals recorded in all headings with zero speed and in head seas with forward speed behaved in approximately a sinusoidal manner, following seas with forward speed records are not so sinusoidal and acceleration signal is distorted by signal noise.

The results of predictions are compared with experimental data wherever possible. To compare the test results with theoretical predictions it is more convenient to present the motion data in a non-dimensional form. The parameters used to non-dimensionalise the motion data are given in Table 3.2. In addition, the factors making the relative motion, vertical acceleration and added resistance values non-dimensional were chosen as follows:

relative motion	S_a / ζ_o
vertical acceleration	$\ddot{\zeta}_3 L / g\zeta_o$
added resistance	$\sigma_{AW} = \dfrac{R_{AW}}{[\rho g(B^2 / L)\zeta_o^{\ 2}]}$

The results are plotted against the wave or encounter frequency which is non-dimensionalised as:

$$\omega' = \frac{\omega}{\sqrt{g/L}} \quad \text{or} \quad \omega_e' = \frac{\omega_e}{\sqrt{g/L}} \tag{3.34}$$

Where ω', ω_e' are non-dimensional wave and encounter frequencies respectively, and L is the characteristic length of the model [m], g is the acceleration due to gravity ($=9.81\ m/s^2$).

3.5.9 Comparison of Experimental Results and Theoretical Predictions

In this section correlations between experimental measurements with the KTU/1-K model and theoretical predictions based on 2-D and 3-D are discussed.

3.5.9.1 Responses in Head Seas

Figures 3.44 through to 3.47 illustrate the comparisons between the calculated and measured response values of heave, pitch, relative motion and vertical acceleration at fore perpendicular of the model in head seas. In general the prediction of the heave and pitch motions obtained from both prediction methods show quite good agreement with the measurements at zero speed. The heave and pitch response values obtained from the two methods tend to diverge with the increase of forward speed. It seems that the strip theory has a general tendency to underpredict the responses at higher speeds. It is found that for heave and pitch motions at Froude number 0.22 and 0.3 the three-dimensional translating pulsating source distribution technique agrees better than strip theory with experimental results, agreement of 3-D with the experiments is especially good for Froude number of 0.3. At Froude number 0.43 heave comparison is good whereas pitch response is overpredicted by both theories. The measured pitch response is slightly below the prediction in low frequency. As shown in Figure 3.46b, relative motion and vertical acceleration predictions at fore perpendicular at Froude number 0.3 compares well with the measurements.

3.5.9.2 Responses in Following Seas

In following seas, Figures 3.48 through to 3.50 illustrate the comparisons between the calculated and measured response values of heave, pitch, relative motions and vertical accelerations at fore perpendicular. It seems that the 3-D theory yields smaller response values than the strip theory unlike the head sea case. At Froude number 0.22 the heave and pitch responses are underestimated by both theories with slightly better agreement in higher frequencies. It is found that for pitch motions at Froude number 0.3 and 0.43 the three-dimensional translating pulsating source distribution technique agrees better with experimental results than the strip theory. As shown in Figure 3.49b, the comparisons of relative motions and vertical accelerations at fore perpendicular at Froude number of 0.3 are not very good unlike the head sea case.

3.5.9.3 Responses in Beam Seas

In beam seas, as shown in Figure 3.51 the comparisons between both the prediction techniques and the measurements for the heave motion response are quite good. It is found that the calculated heave response agrees very well with the experiments. However the roll amplitude values predicted by both the three-dimensional translating pulsating source distribution technique and the strip theory are in poor agreement with measurements. The discrepancy may be due to the difficulty in theoretical evaluation of the viscous roll damping coefficient. For roll motion viscous roll damping is dominant factor for good correlations. Another could-be important factor is that the quality of measured data for the roll motion might not be too high.

3.5.9.4 Responses in Quartering Seas

The heave and roll amplitudes are presented in Figures 3.52 and 3.53 in stern (45 deg.) and bow (135 deg.) quartering seas for zero speed. As may be seen from these figures the correlation between the predictions and measurements for the heave motion is generally quite good. However the roll amplitude values predicted by both the three-dimensional translating pulsating source distribution technique and the strip theory are in poor agreement with measurements. Same comments as the beam sea case can be made for responses in quartering seas.

3.6 Conclusions

Numerical calculations for five different fishing vessel hull forms for various Froude numbers and wave headings have been carried out using the computer programs based on the two-dimensional strip theory and the three-dimensional translating pulsating source distribution technique. It is found that the results obtained using both theories are generally in good agreement with the predictions of heave and pitch added mass coefficients. However the prediction of heave and pitch damping coefficients are in poor agreement with each other.

The calculated hydrodynamic coefficients in translational modes of motion and the roll mode are speed independent whereas the curves representing pitch and yaw added masses and damping coefficients merge into a single curve in short waves since the effect of encounter frequency is greater than that of speed.

It is observed that increasing ship length and B/T ratio increases the values of hydrodynamic coefficients in heave, roll and pitch modes of motion but decreases those values in sway and yaw modes of motion. Meanwhile a decrease in the C_M coefficient decreases the values of surge hydrodynamic coefficient because the more slender the hull form the less the fluid forces acting in the longitudinal direction. Increasing C_{WP}, and the forward position of the LCB increases the hydrodynamic coefficients in heave and pitch modes of motion but decrease the roll mode of motion.

The influence of forward speed and ship heading plays an important role in defining the motion response characteristics. This has been demonstrated by the three-dimensional translating pulsating source distribution technique for five different hull forms at various forward speeds and wave headings. In general, the sway, heave and roll motion responses of the vessel in beam waves are larger than those in oblique and head waves because of stronger wave forces in beam waves for these modes of motion. The heave and pitch amplitude values increase with increase in forward speeds.

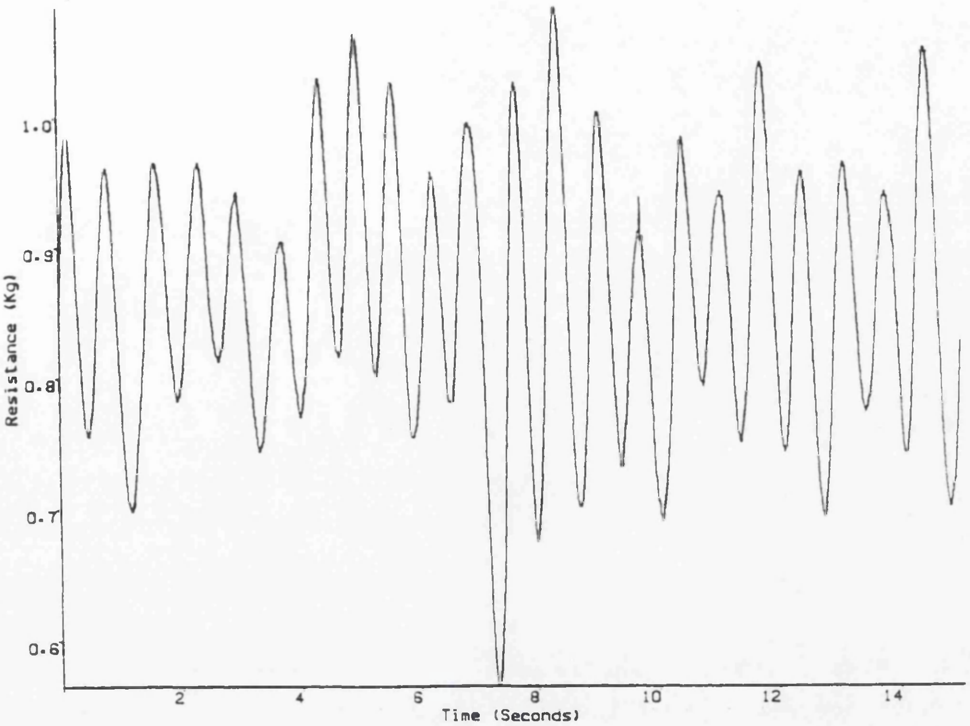
Numerical calculations for five different fishing vessel hull forms in head waves show that increasing the ship length and B/T reduces the motions particularly in heave and yaw. Increasing C_{WP}, and forward position of the LCB reduces the heave, pitch motions. Heave and yaw motions are increased by increasing C_B.

In addition the added resistance calculations were carried out for the form KTU/1-K in head seas. The correlation between the measured and predicted added resistance by the Joosen method in conjunction with a linear strip theory is poor for the peak value of the added resistance. It was found that the predicted peak value of the added resistance is higher than the measured peak value. The curves for added resistance coefficients follow the same trend as for the motion responses. This is because added resistance in waves is dependent on the heave and pitch motion responses. It may be concluded that the program SHIP-AR based on the Joosen method can only predict the added resistance experienced by a vessel in waves in an approximate manner.

In order to validate the two numerical methods, a Black Sea fishing vessel model KTU/1-K was tested in regular waves for different headings and forward speeds. For the head sea case, in general the prediction of the heave and pitch motions obtained from both prediction methods show quite good agreement with the measurements at zero speed. It is found that for heave and pitch motions at Froude number 0.22 and 0.3 the three-dimensional translating pulsating source distribution technique agrees better than the strip theory with experimental results. The 3-D theory agrees well with the experimental measurements at Froude number of 0.3. In following seas, the 3-D theory yields smaller response values than the strip theory, unlike the head sea case. It is found that for pitch motions at Froude number 0.3 and 0.43 the three-dimensional translating pulsating source distribution technique agrees with experimental results better than the strip theory.

In beam seas, the comparisons between both theories and experimental measurements for the heave motion response are quite good. However the roll amplitude values predicted by both the three-dimensional translating pulsating source distribution technique and the strip theory are in poor agreement with the measurements. The same comments as the beam sea case can be made for quartering seas.

The strip theory results, in general, show good agreement with the experimental data as well as with the corresponding three-dimensional analysis.



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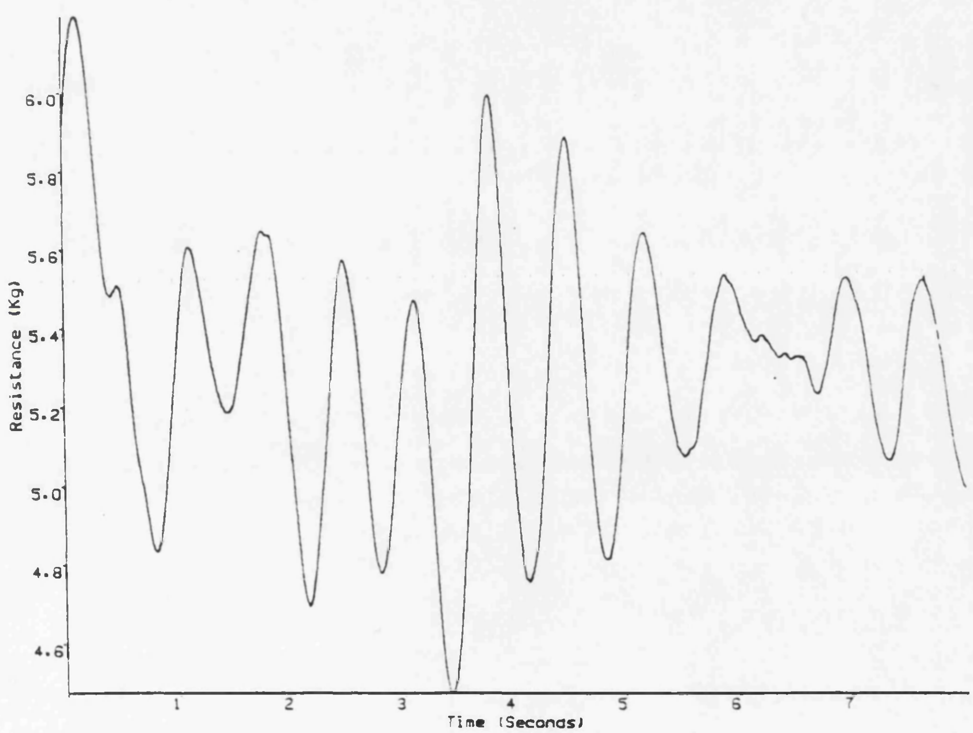
Speed : 1.3 m/s



Run Number : TS26123
Speed : 2.0 m/s

Figure 3.13 Typical Model Test Run Record Taken in Calm Water

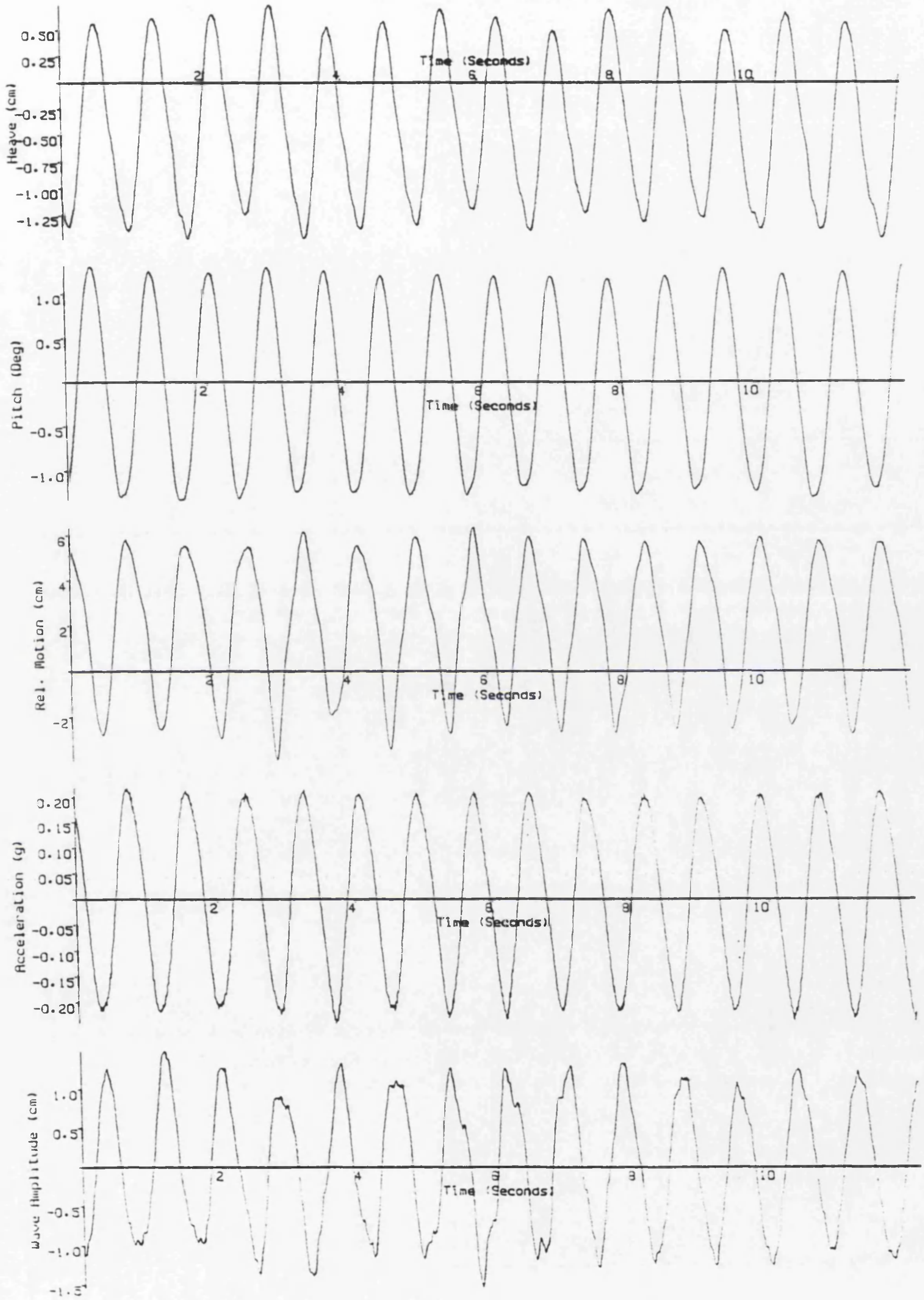


Figure 3.14 Typical Model Test Run Record Taken in Regular Waves. α=180 Deg., Fn=0.22, L/λ=0.88

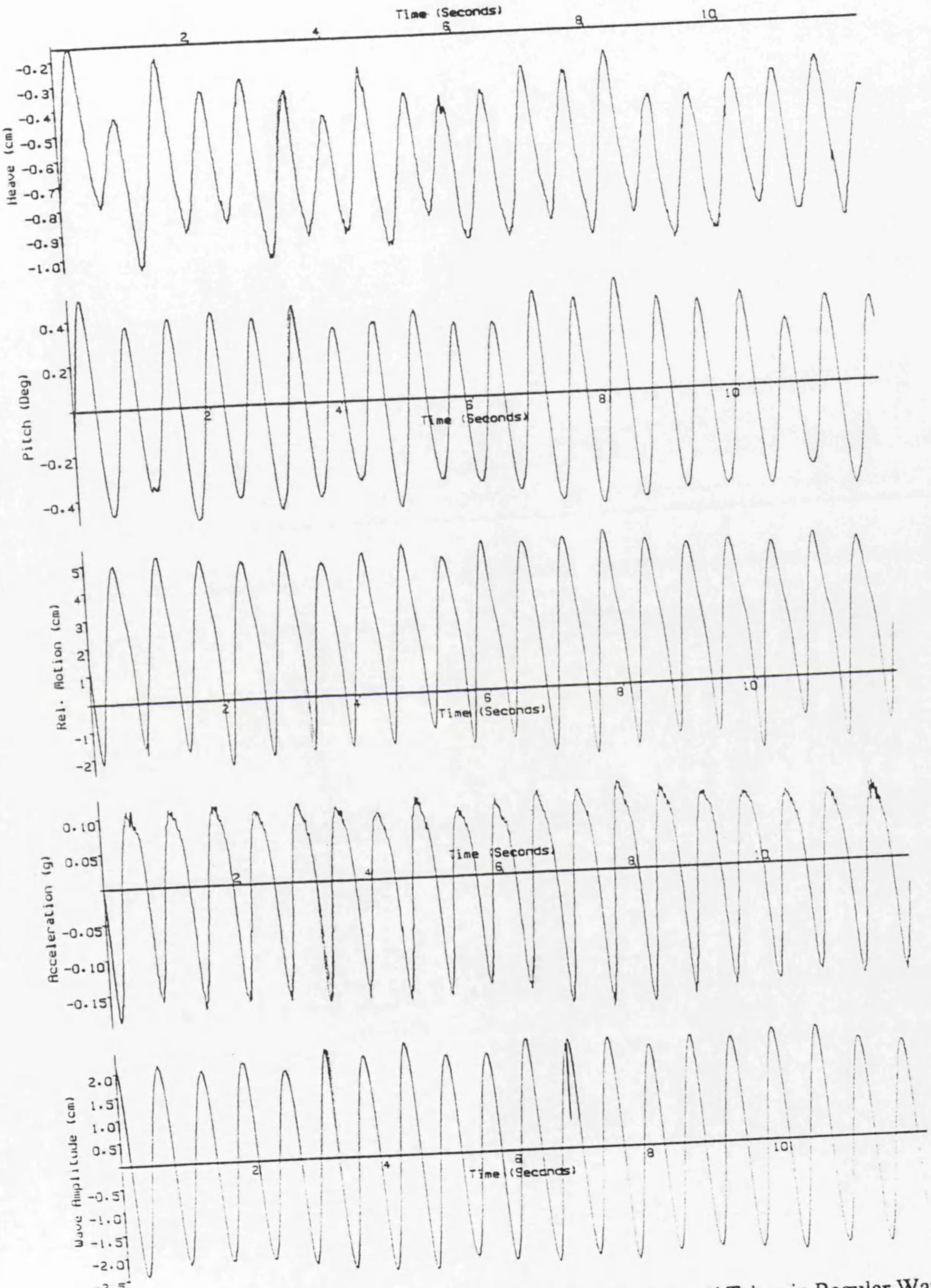


Figure 3.15 Typical Model Test Run Record Taken in Regular Waves, α=180 Deg., Fn=0.22, L/λ=1.38

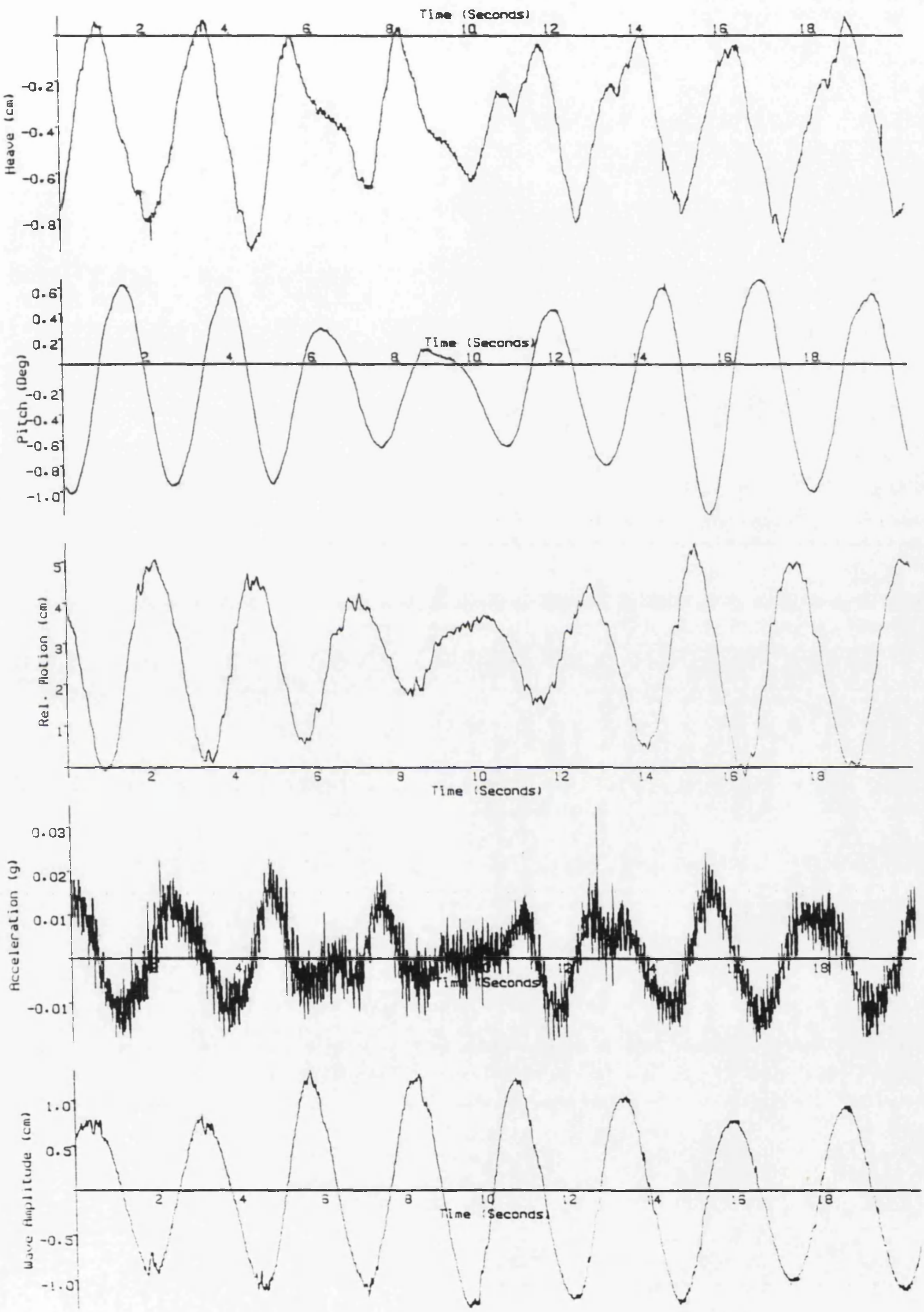


Figure 3.16 Typical Model Test Run Record Taken in Regular Waves. α=0 Deg., Fn=0.22, L/λ=0.88

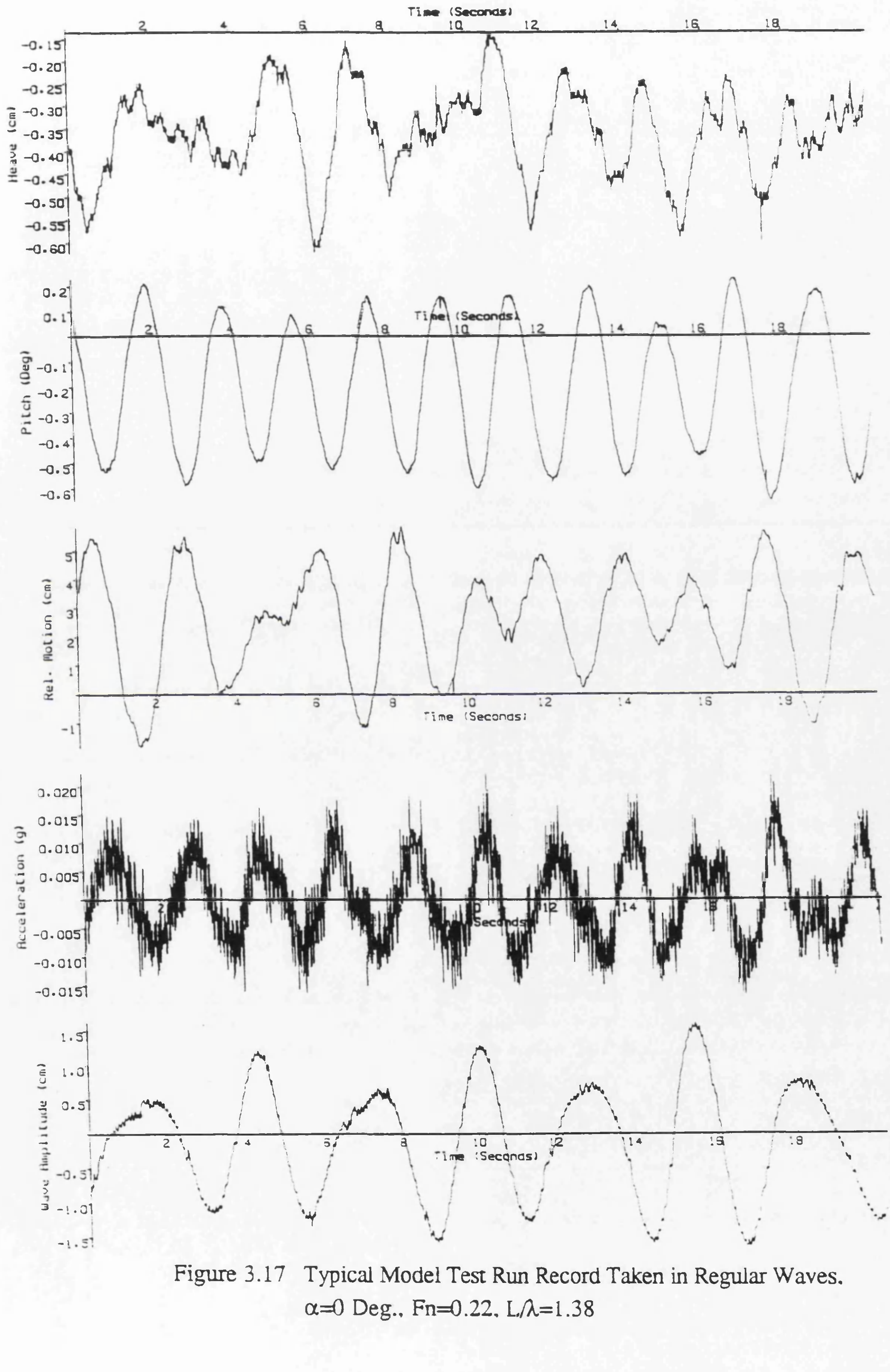


Figure 3.17 Typical Model Test Run Record Taken in Regular Waves. α=0 Deg., Fn=0.22, L/λ=1.38

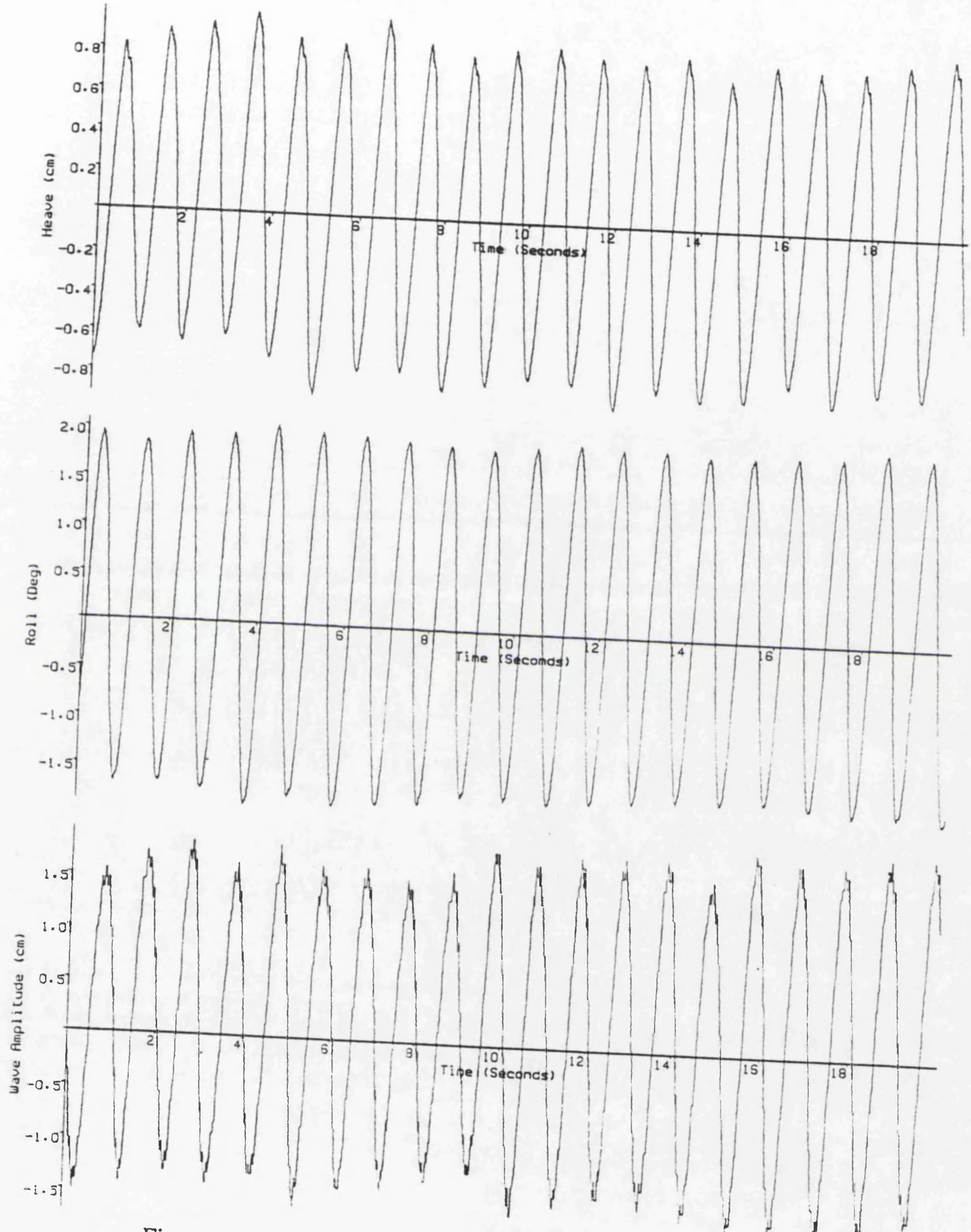


Figure 3.18 Typical Model Test Run Record Taken in Regular Waves, α=45 Deg., Fn=0.0. L/λ=1.38

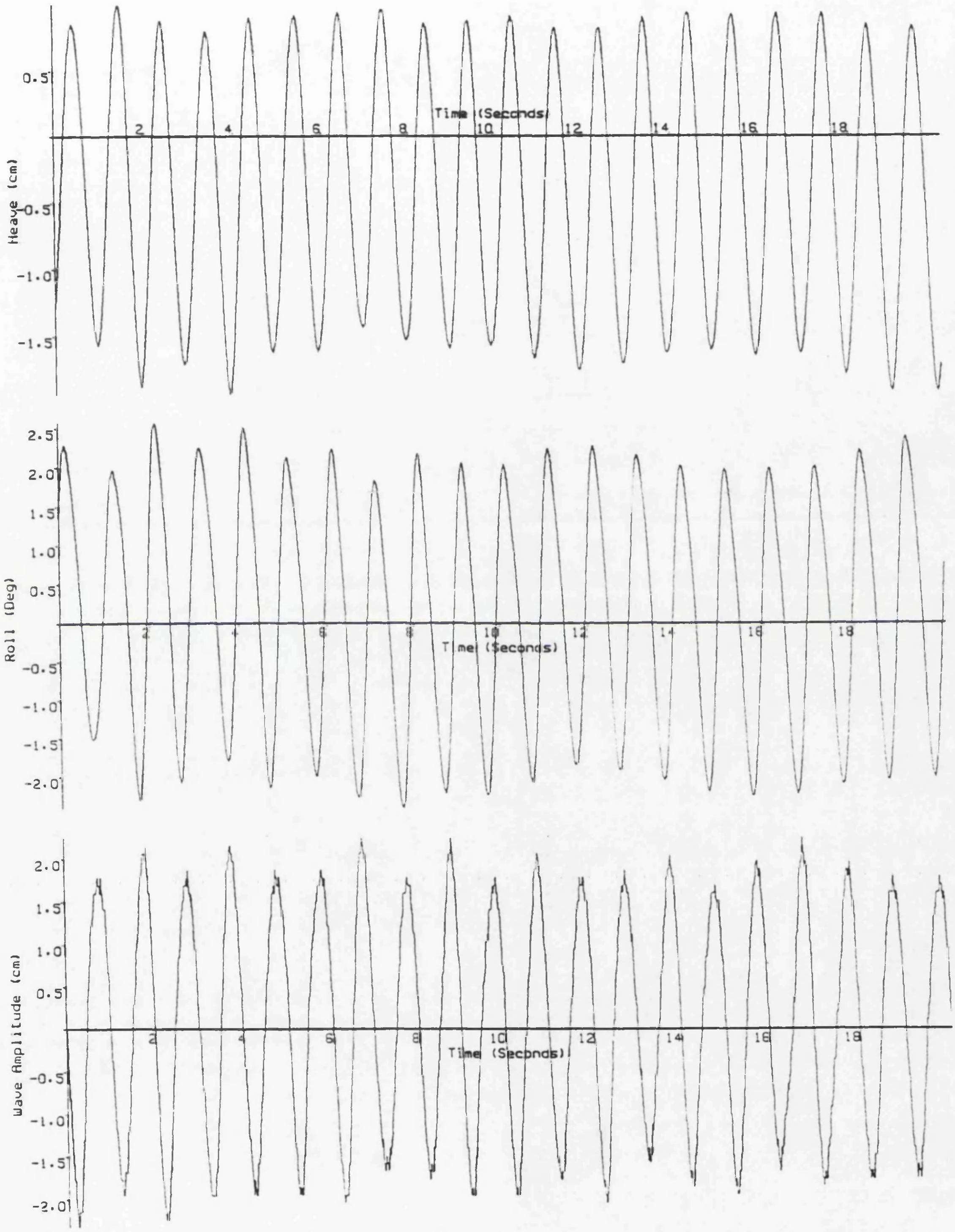


Figure 3.19 Typical Model Test Run Record Taken in Regular Waves, α=90 Deg., Fn=0.0, L/λ=1.38

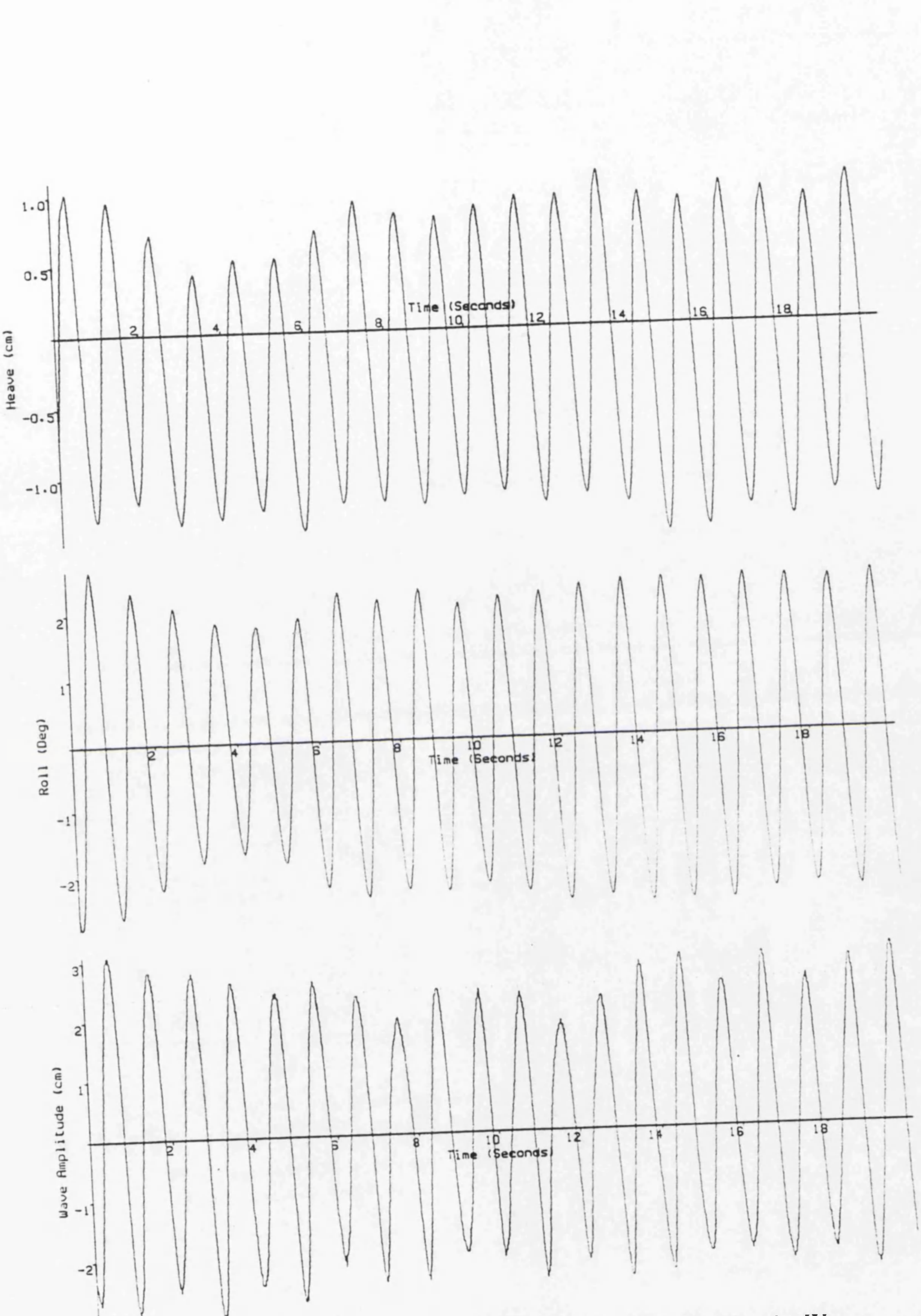


Figure 3.20 Typical Model Test Run Record Taken in Regular Waves, α=135 Deg., Fn=0.0, L/λ=1.38

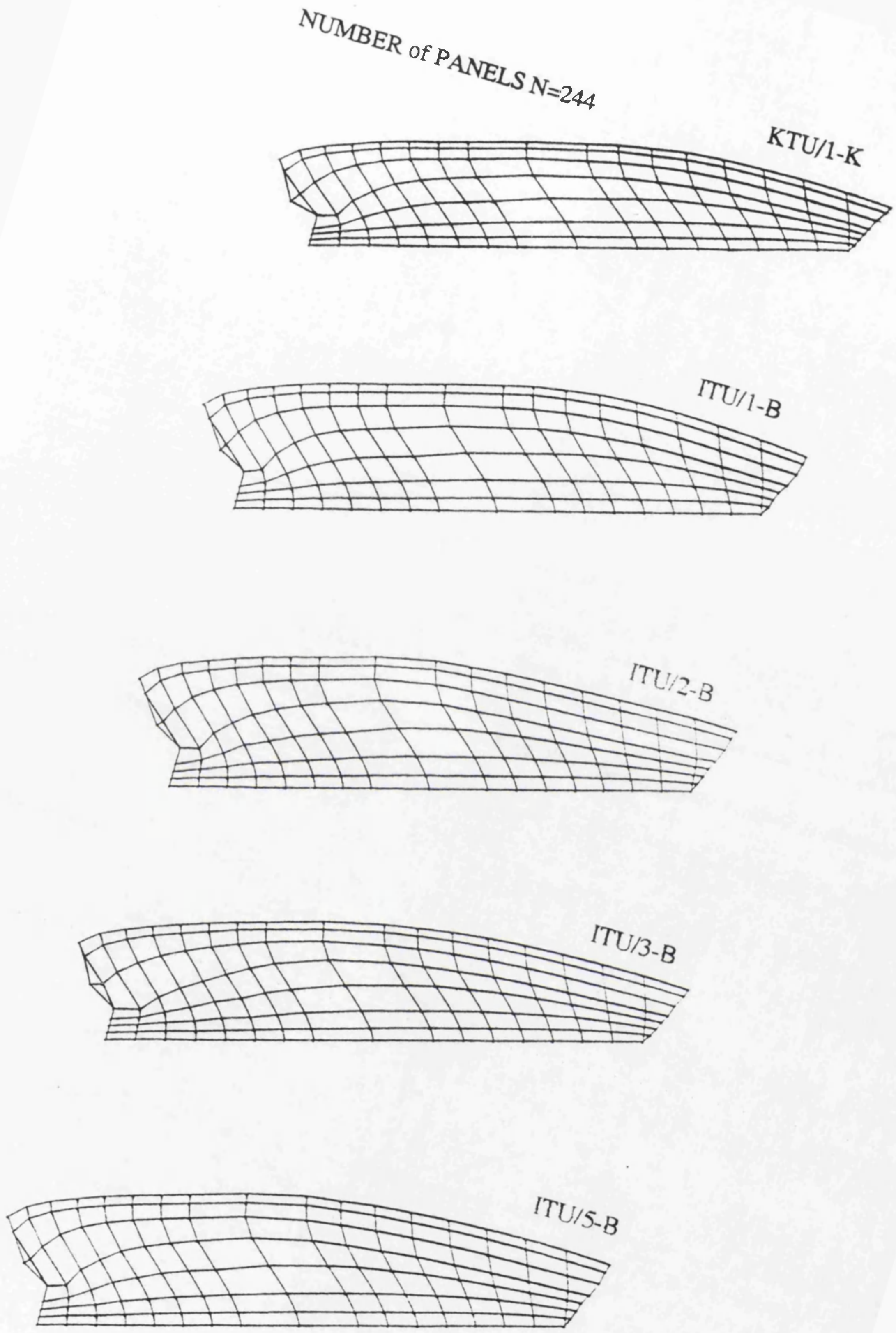


Figure 3.21 Surface Discretisation of Fishing Vessels

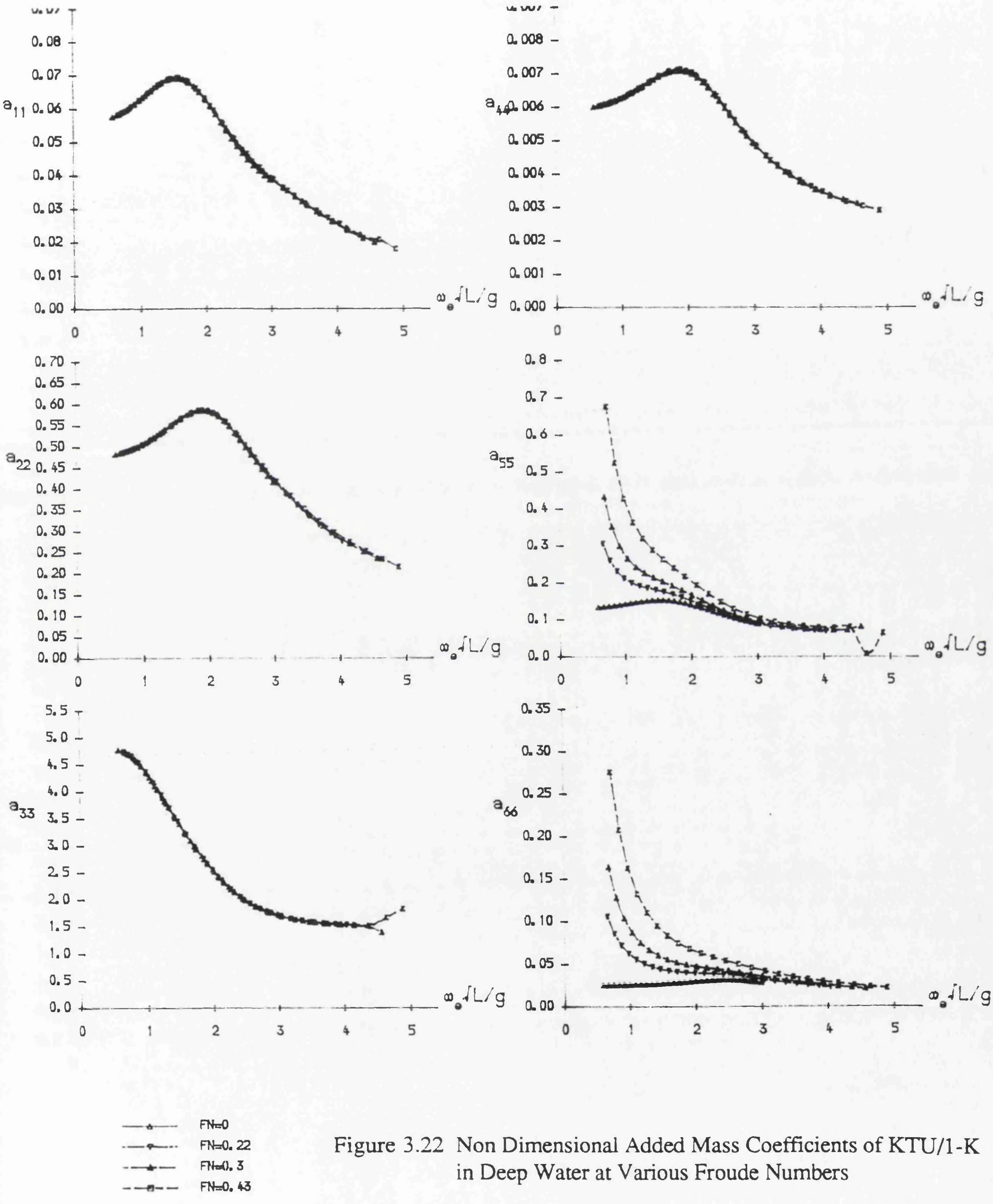


Figure 3.22 Non Dimensional Added Mass Coefficients of KTU/1-K in Deep Water at Various Froude Numbers

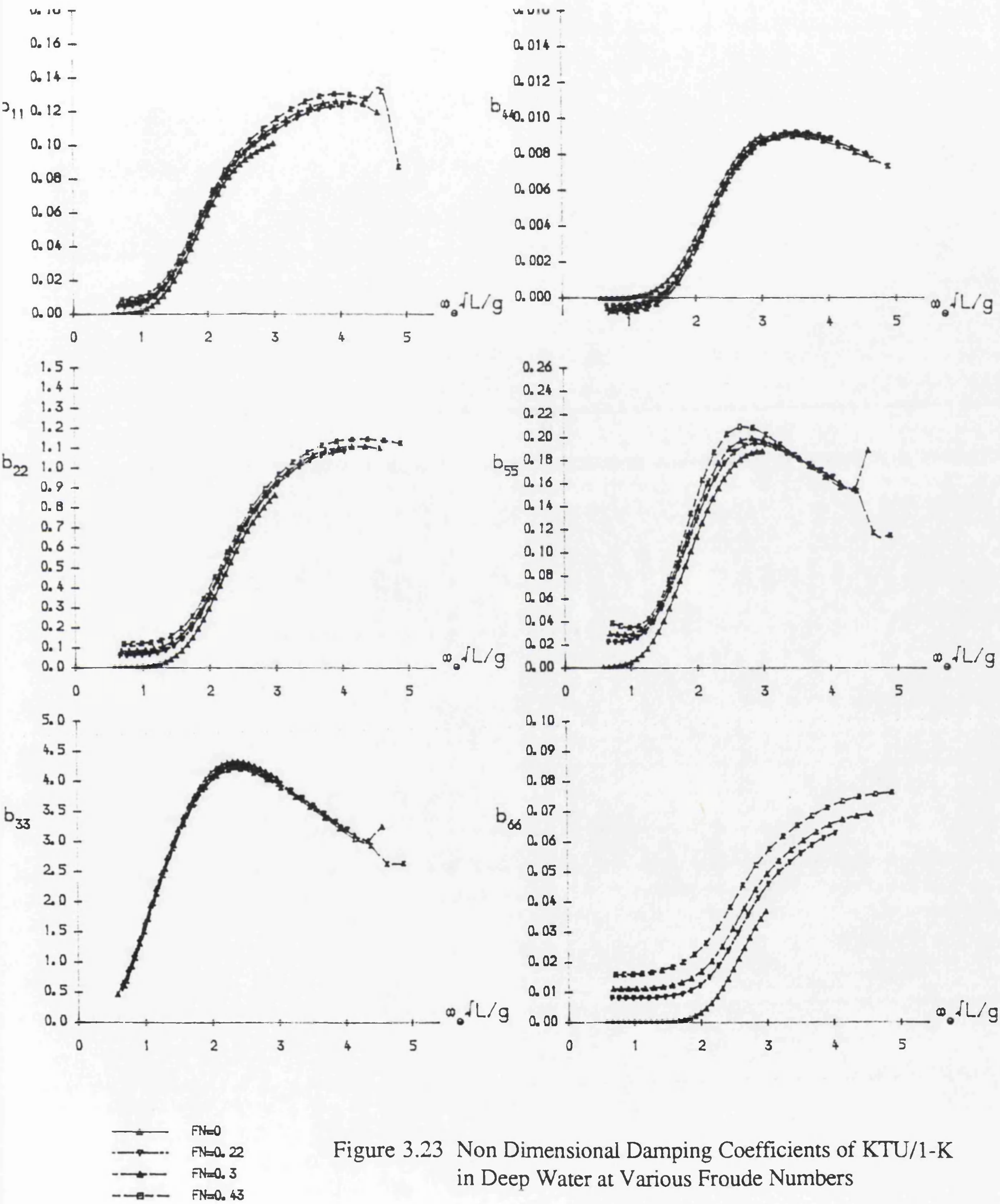


Figure 3.23 Non Dimensional Damping Coefficients of KTU/1-K in Deep Water at Various Froude Numbers

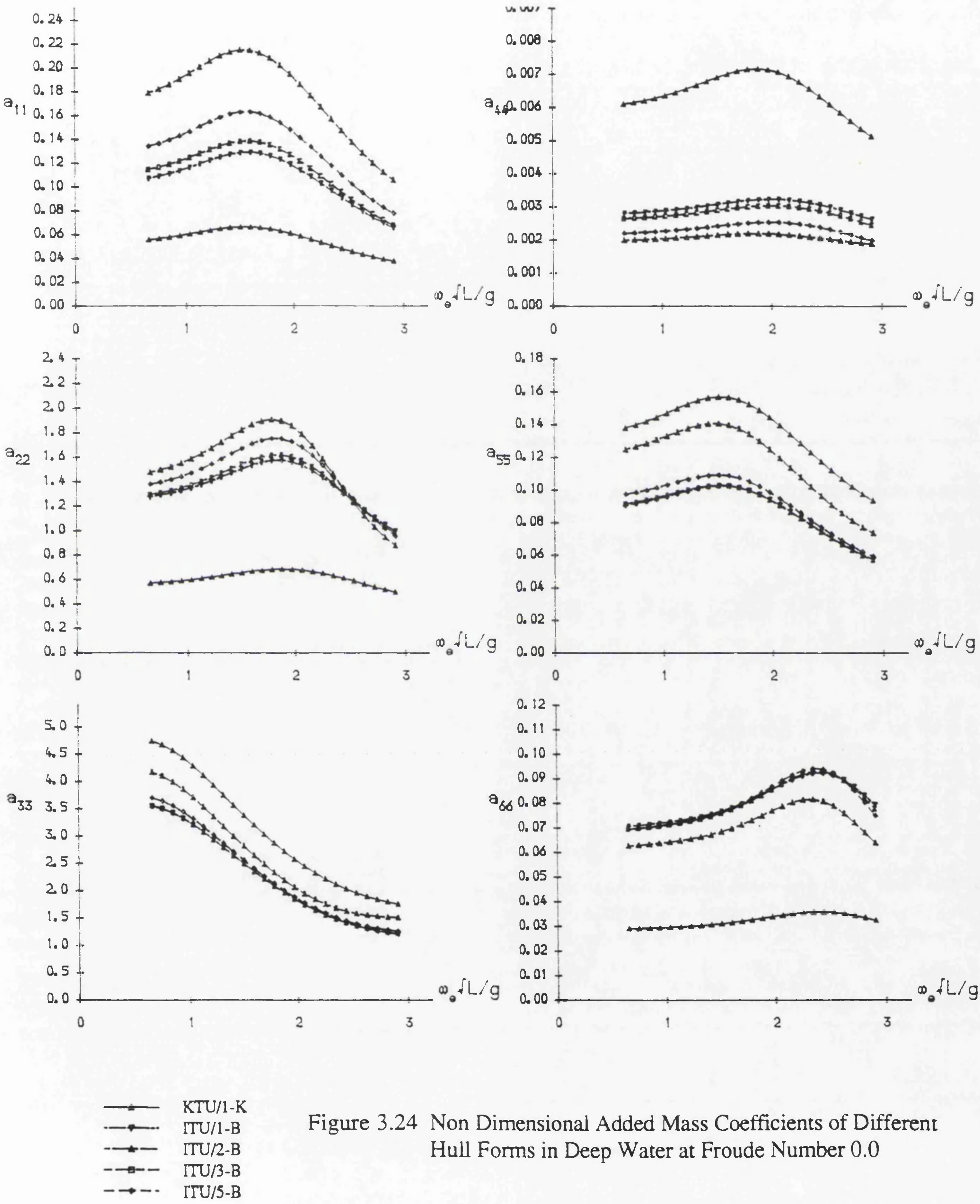


Figure 3.24 Non Dimensional Added Mass Coefficients of Different Hull Forms in Deep Water at Froude Number 0.0

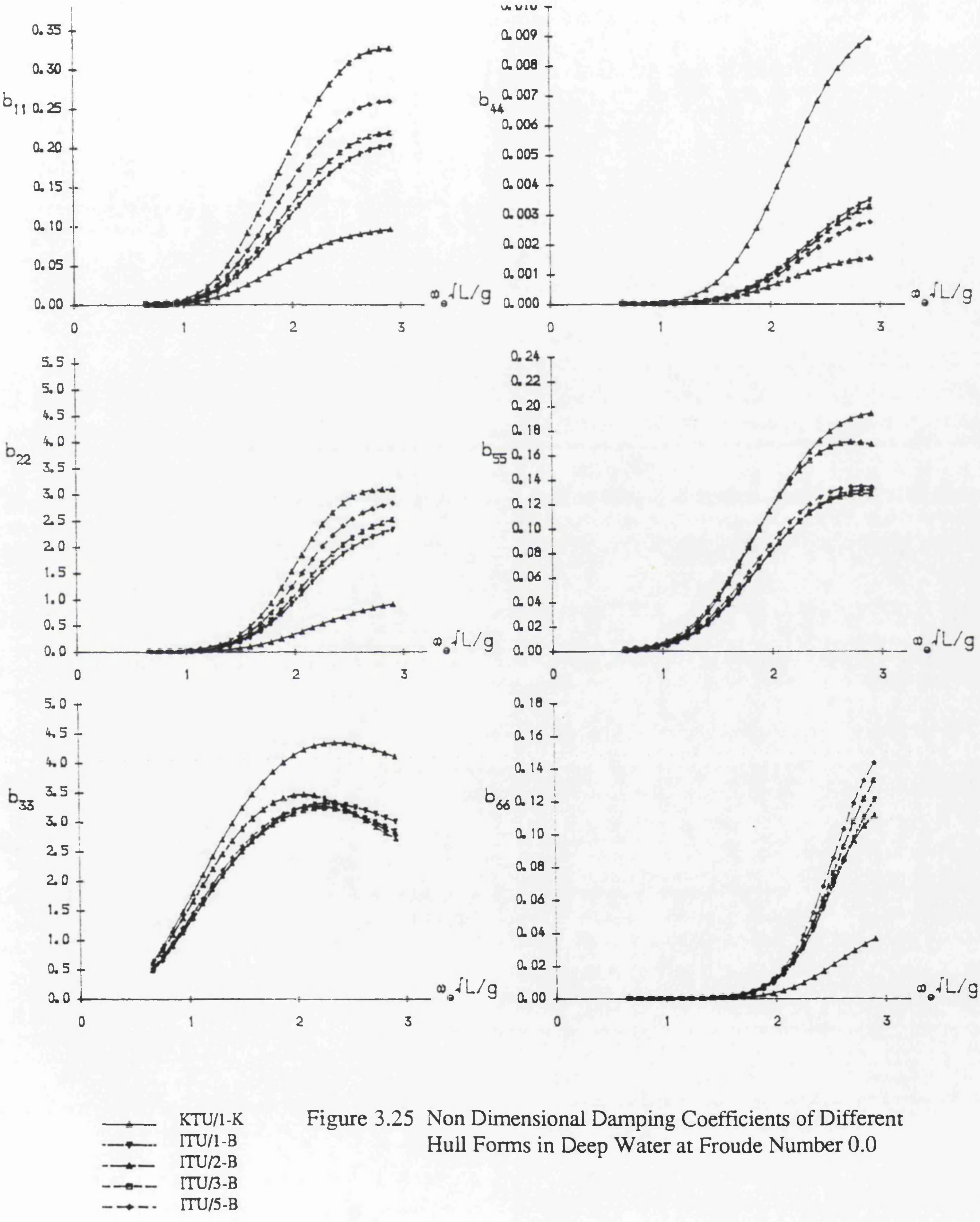


Figure 3.25 Non Dimensional Damping Coefficients of Different Hull Forms in Deep Water at Froude Number 0.0

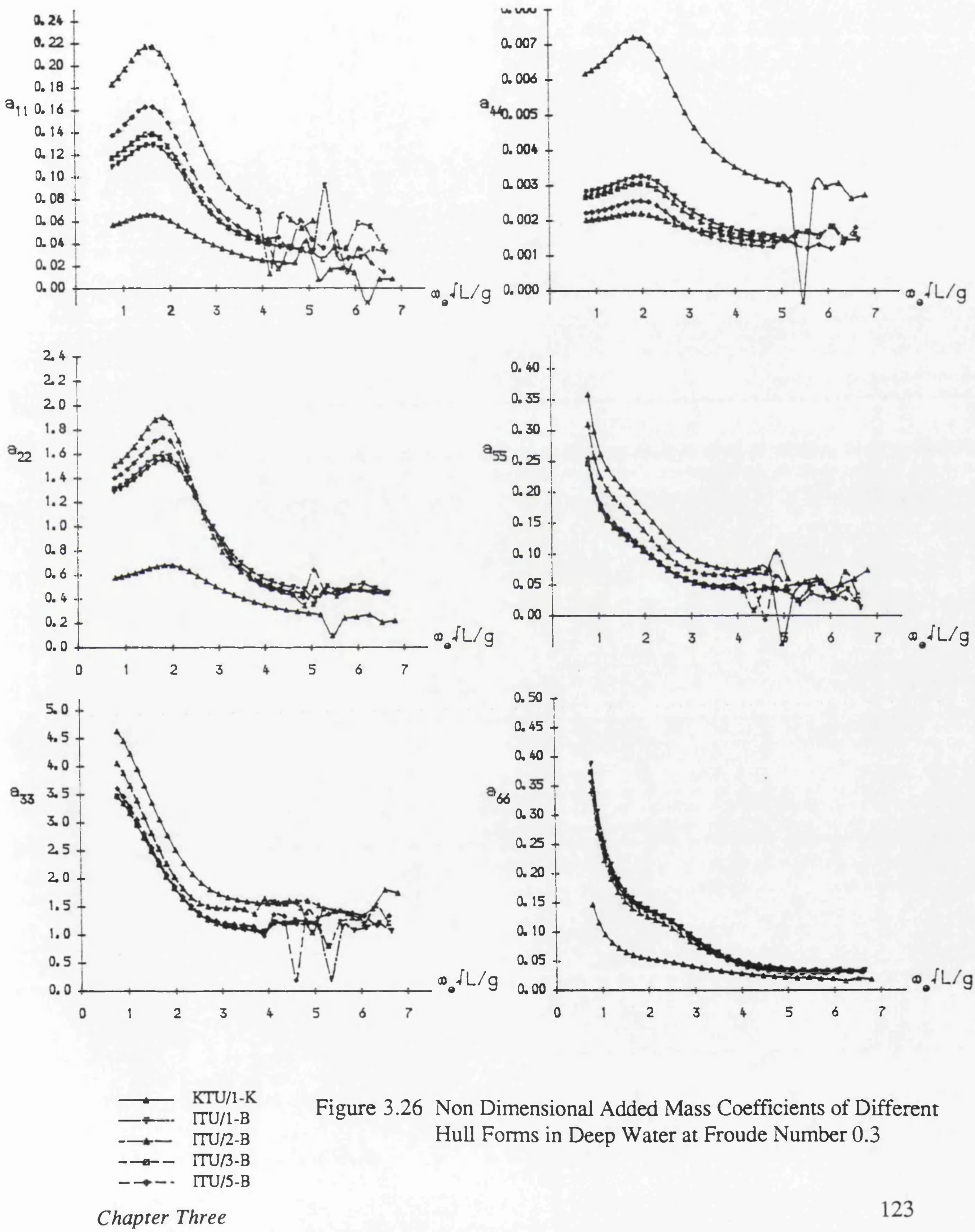


Figure 3.26 Non Dimensional Added Mass Coefficients of Different Hull Forms in Deep Water at Froude Number 0.3

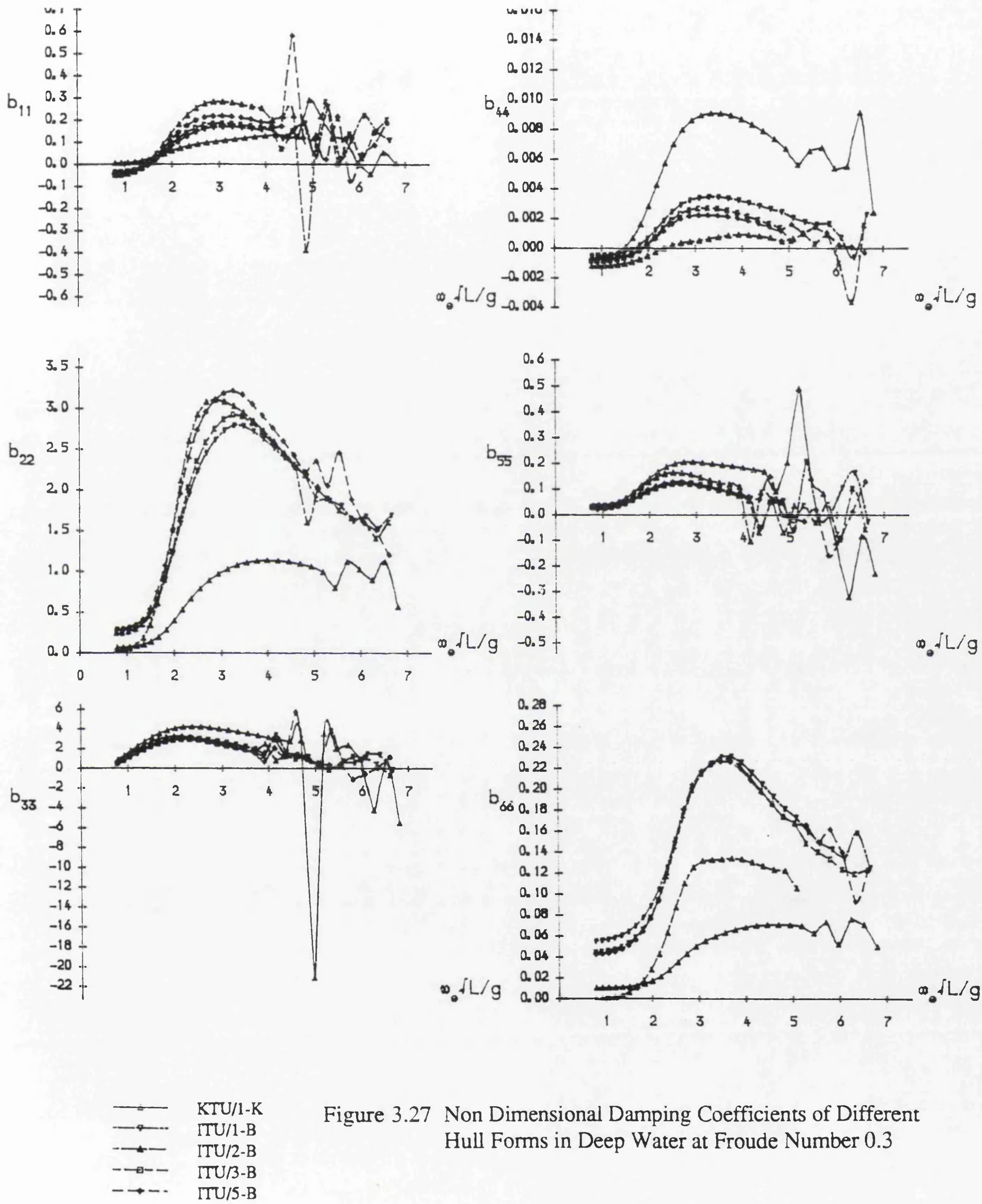
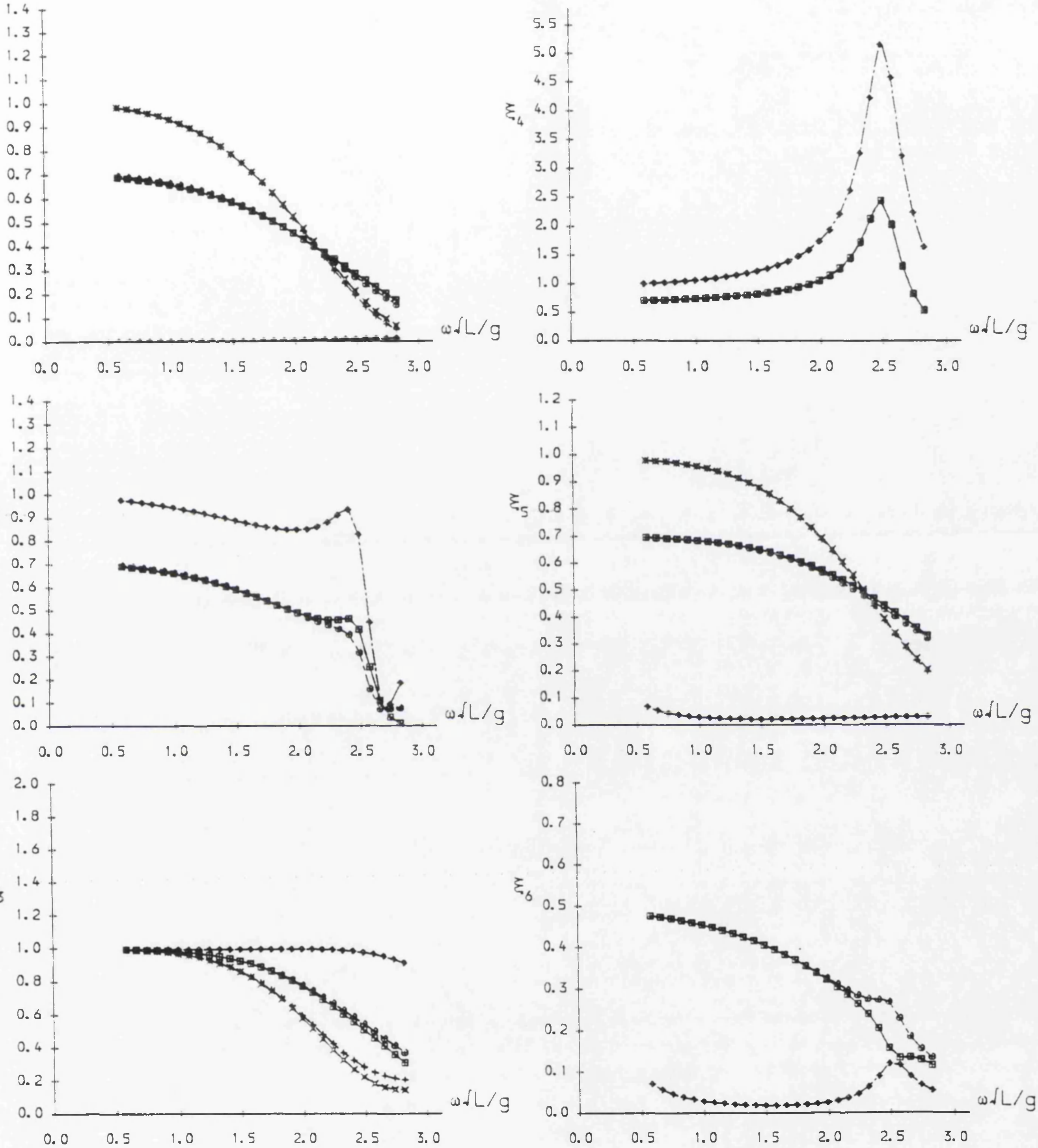


Figure 3.27 Non Dimensional Damping Coefficients of Different Hull Forms in Deep Water at Froude Number 0.3



45°
90°
135°
180°
0°

Figure 3.28 Motion Responses of KTU/1-K in Deep Water at Froude Number 0.0 in Various Angles of Wave Incidence

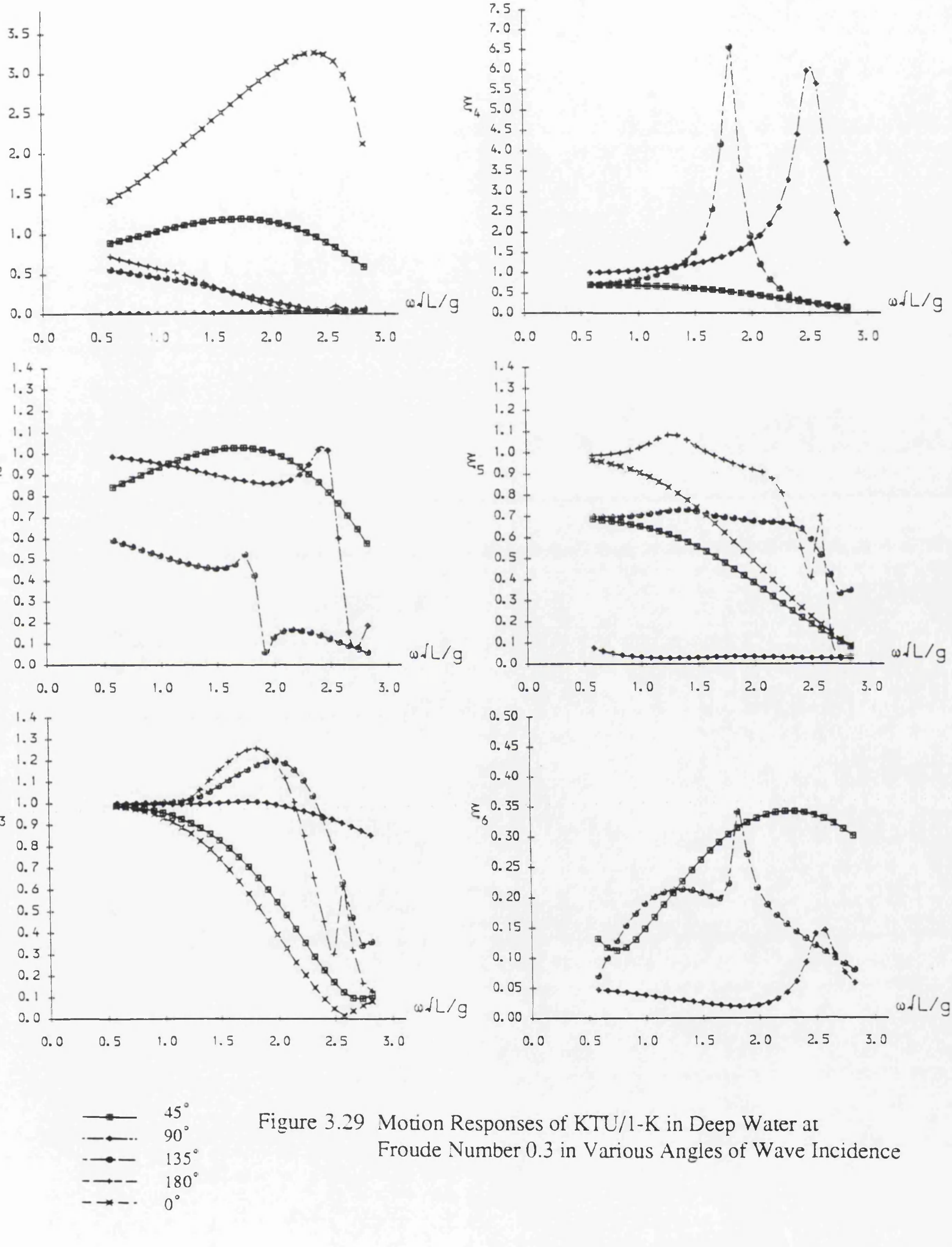


Figure 3.29 Motion Responses of KTU/1-K in Deep Water at Froude Number 0.3 in Various Angles of Wave Incidence

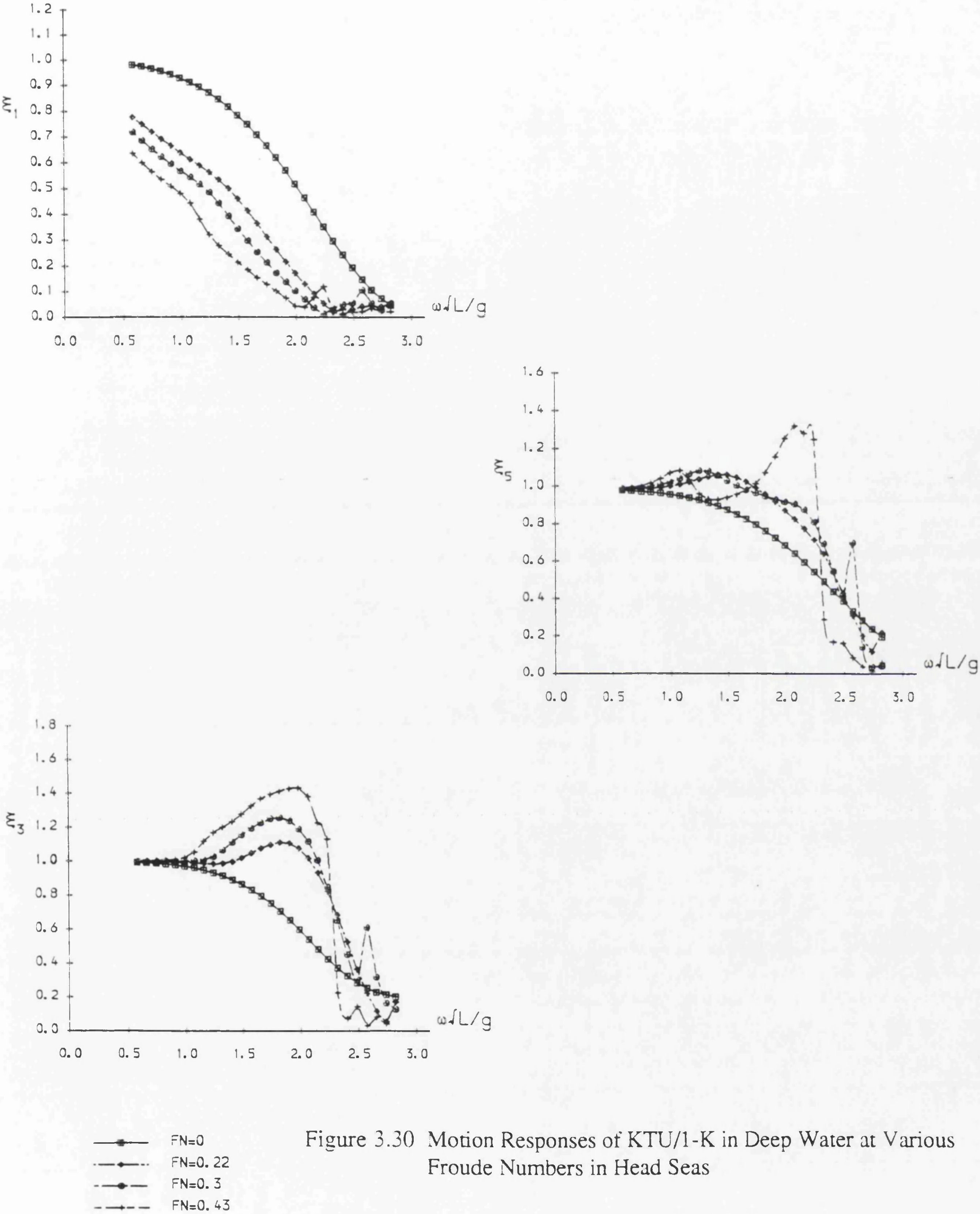


Figure 3.30 Motion Responses of KTU/1-K in Deep Water at Various Froude Numbers in Head Seas

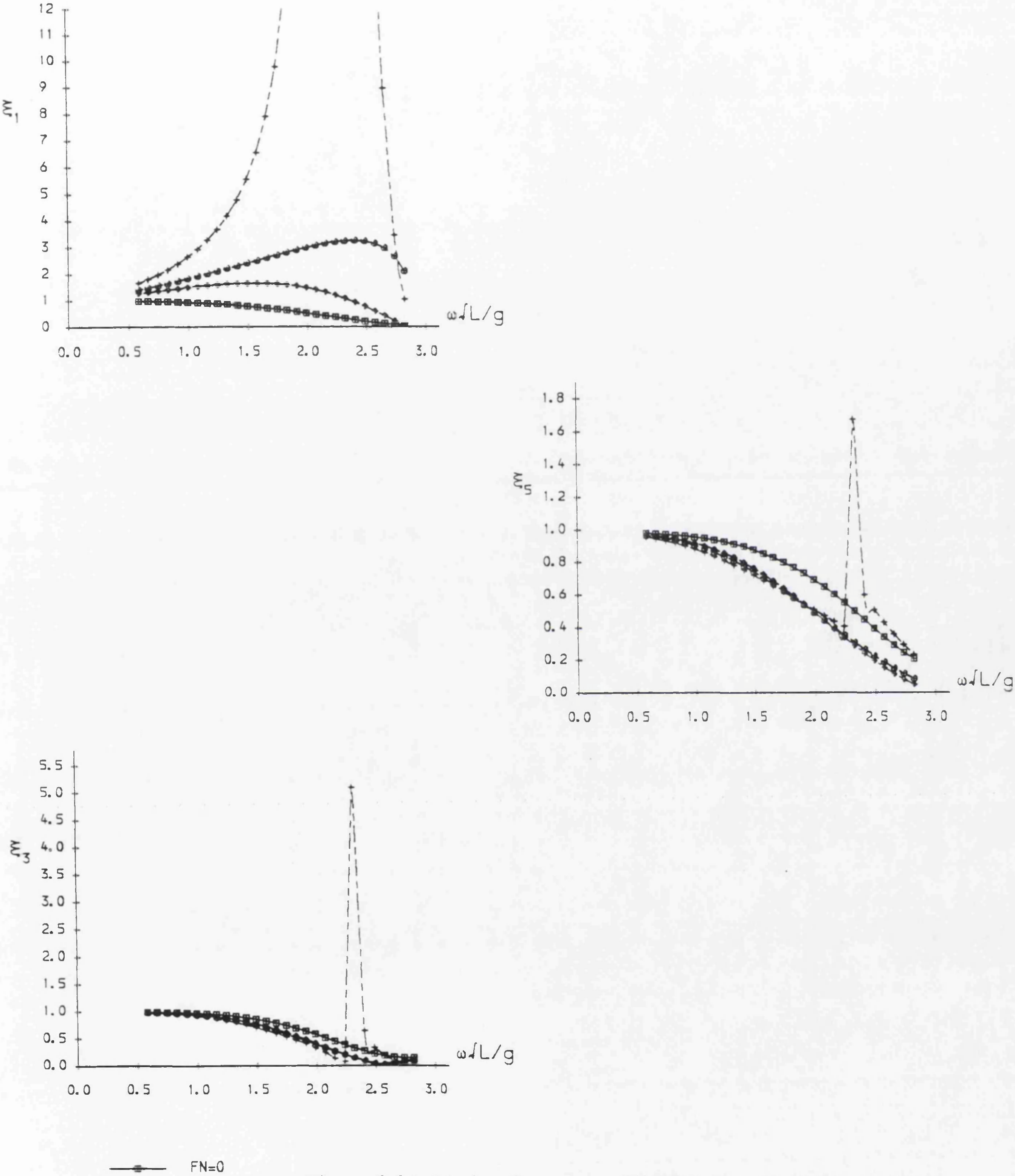


Figure 3.31 Motion Responses of KTU/1-K in Deep Water at Various Froude Numbers in Following Seas

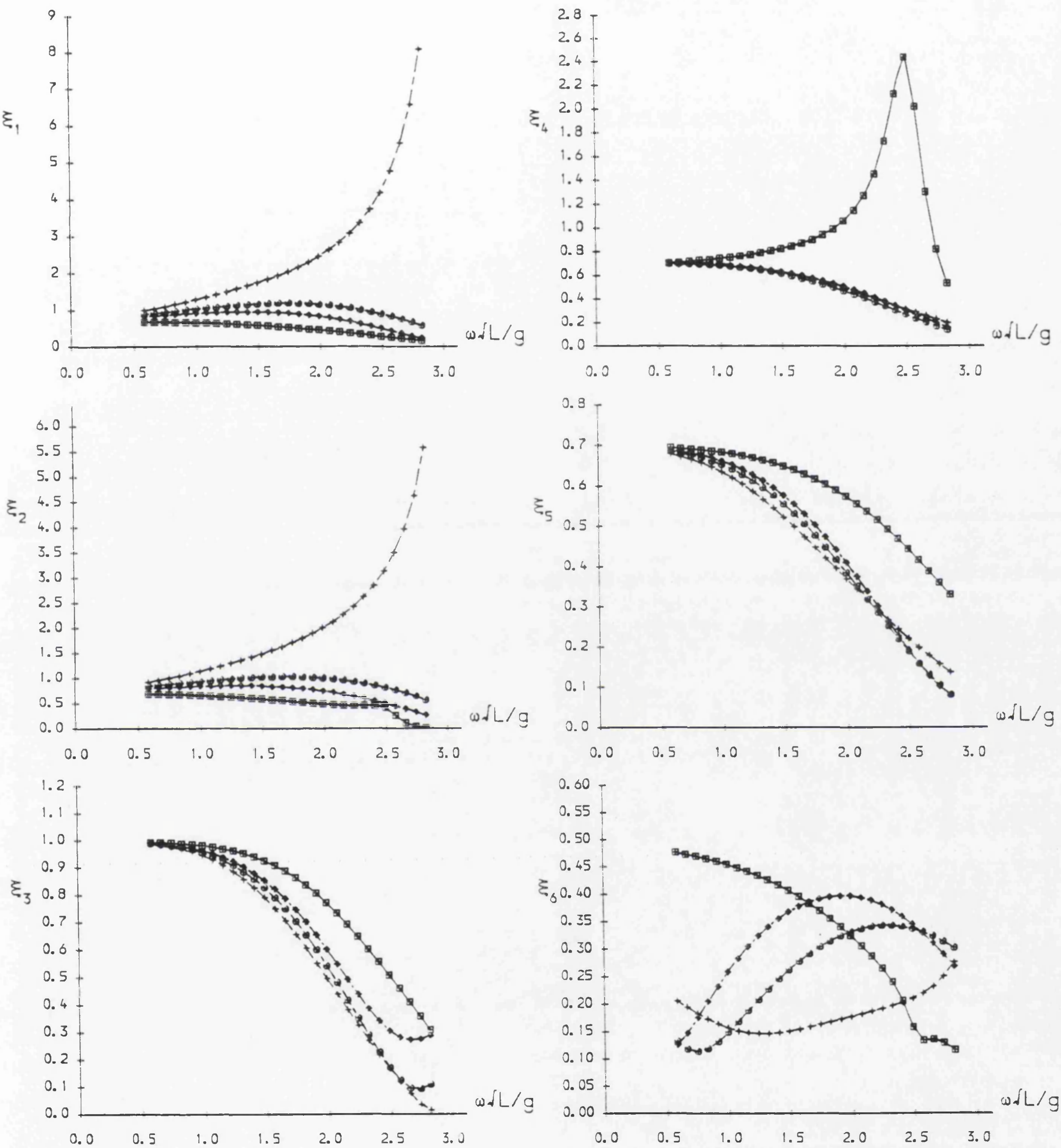


Figure 3.32 Motion Responses of KTU/1-K in Deep Water at Various Froude Numbers in Quartering Seas, α=45 Deg.

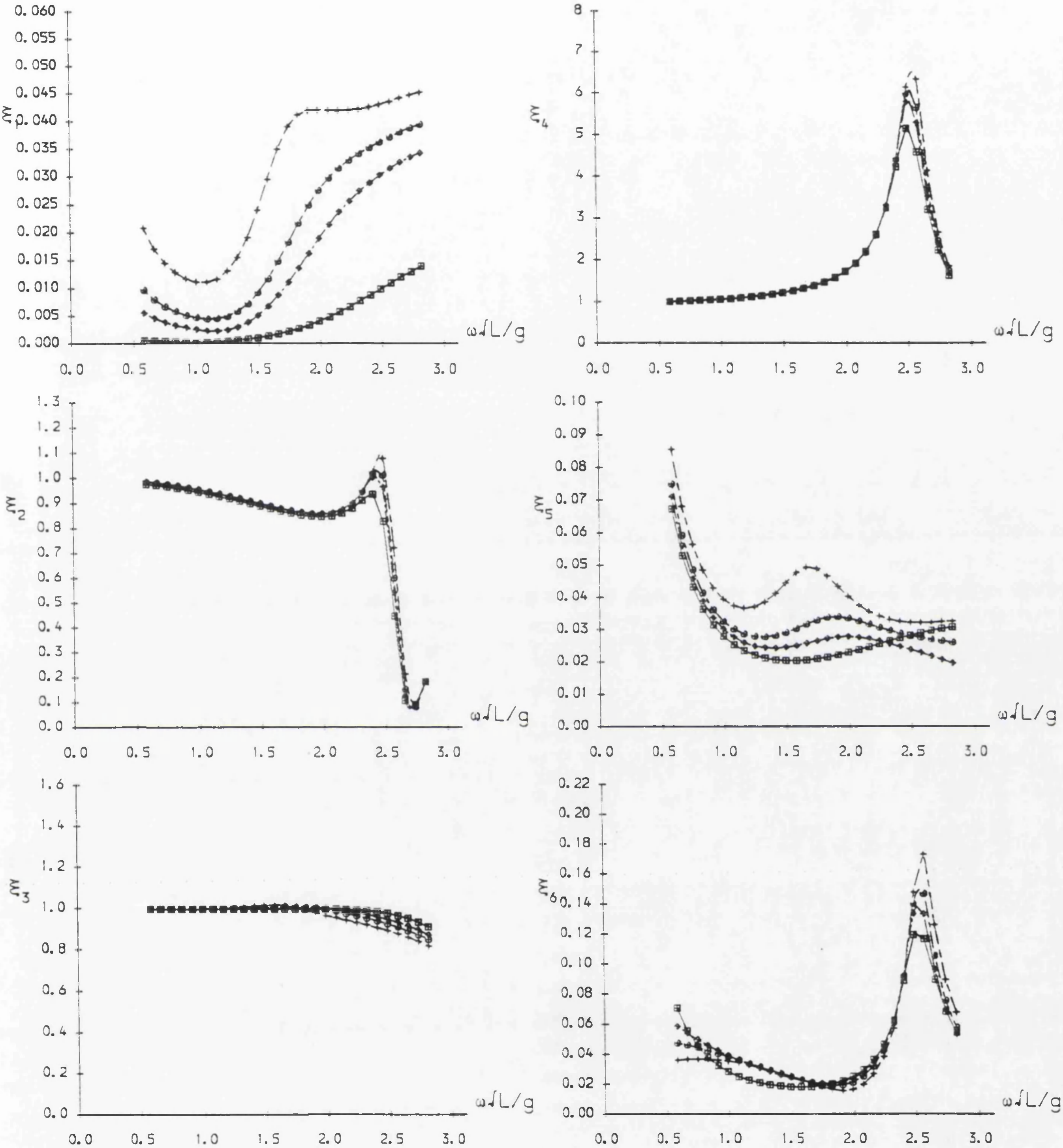


Figure 3.33 Motion Responses of KTU/1-K in Deep Water at Various Froude Numbers in Beam Seas, α=90 Deg.

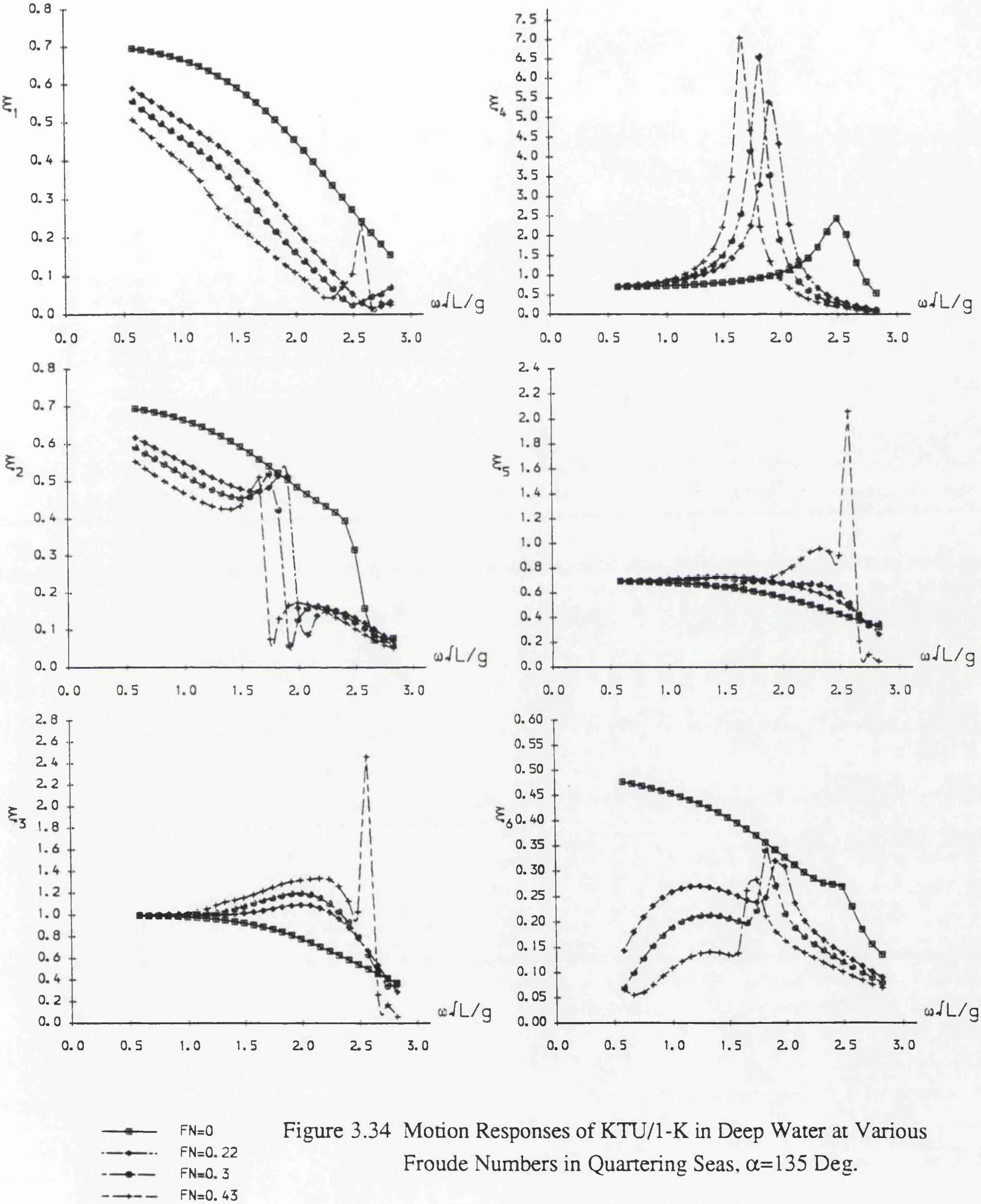
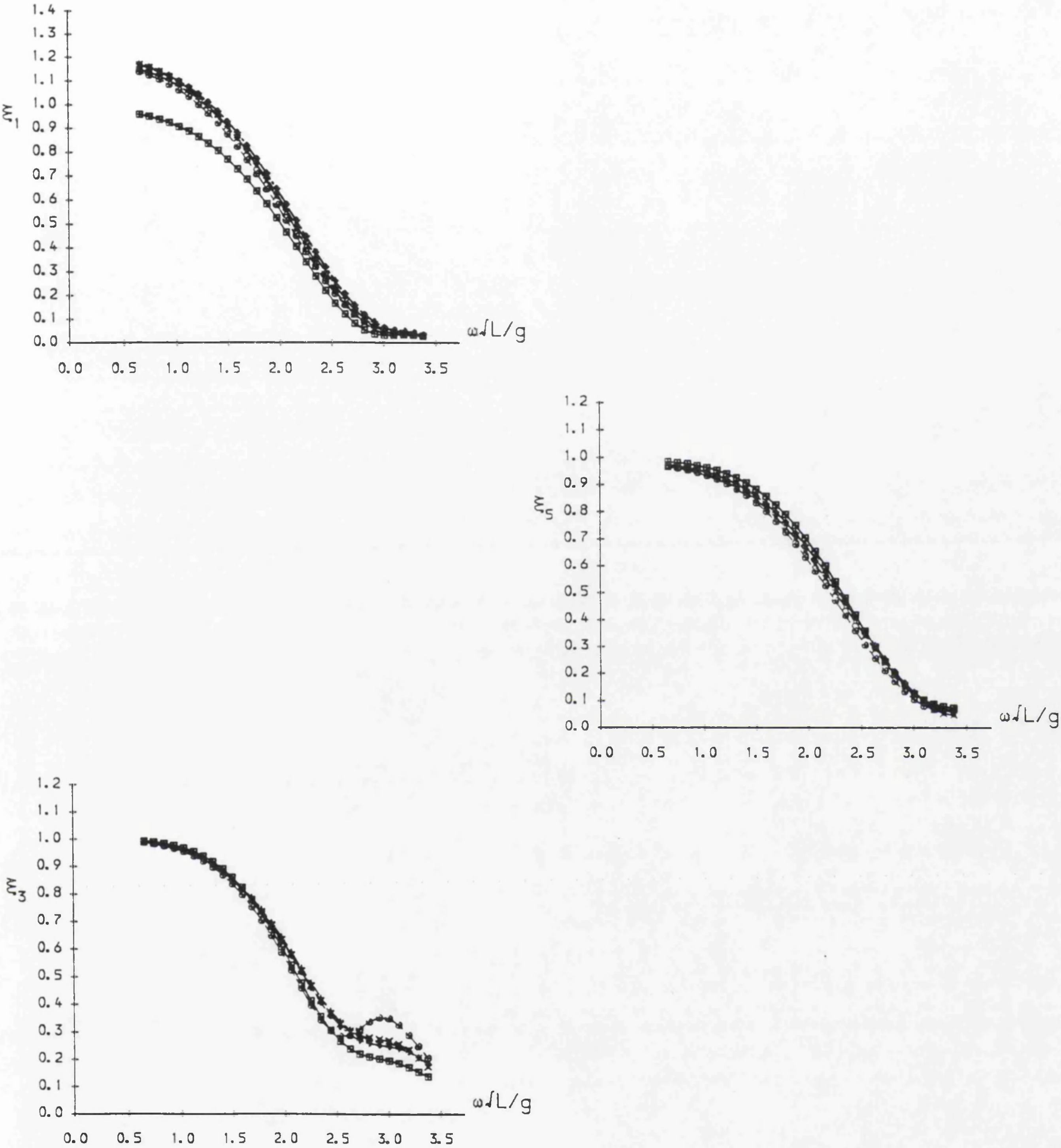


Figure 3.34 Motion Responses of KTU/1-K in Deep Water at Various Froude Numbers in Quartering Seas, α=135 Deg.



KTU/1-K
ITU/1-B
ITU/2-B
ITU/3-B
ITU/5-B

Figure 3.35 Motion Responses of Different Hull Forms in Deep Water at Froude Number 0.0 in Head Waves

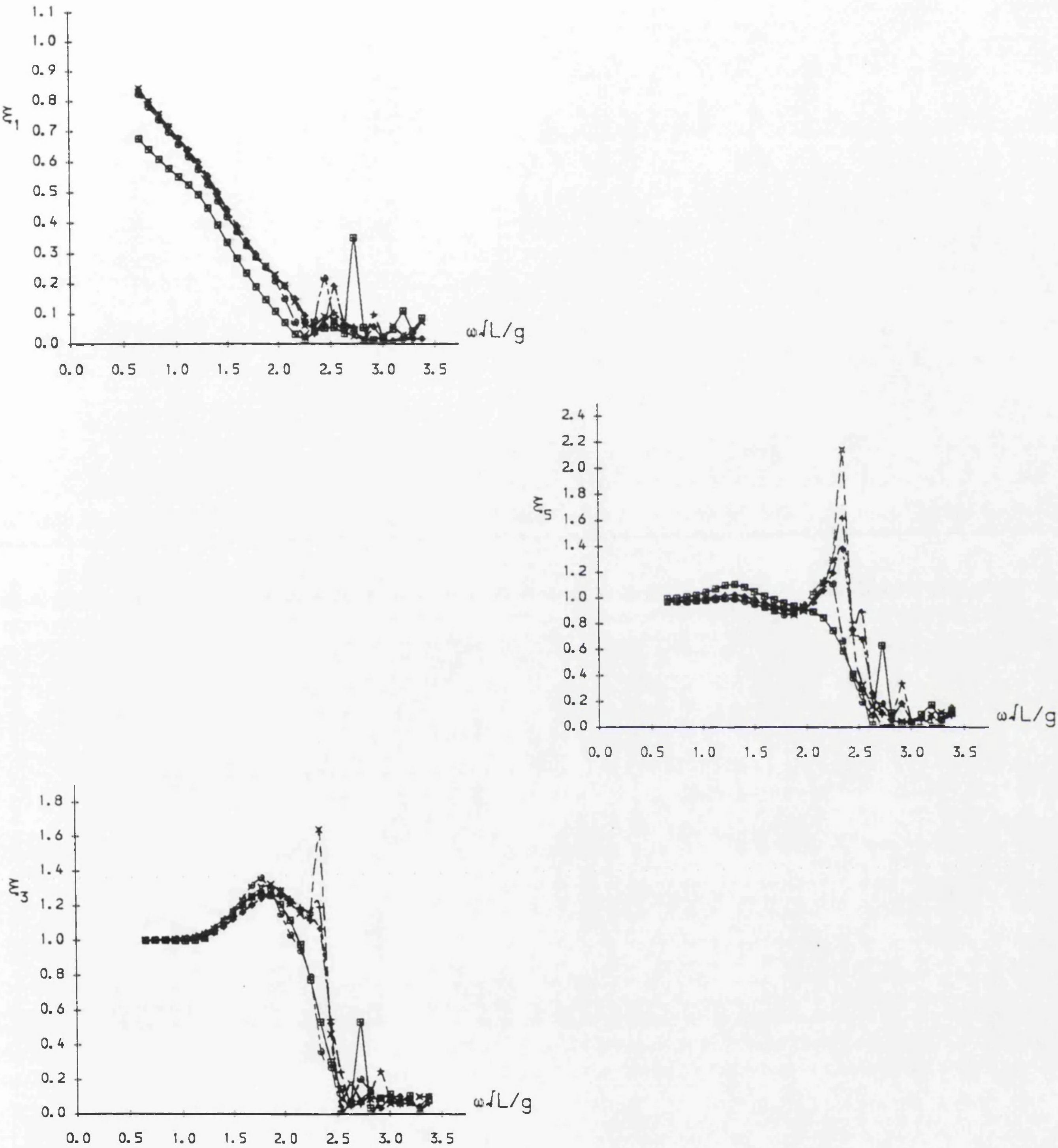


Figure 3.36 Motion Responses of Different Hull Forms in Deep Water at Froude Number 0.3 in Head Waves

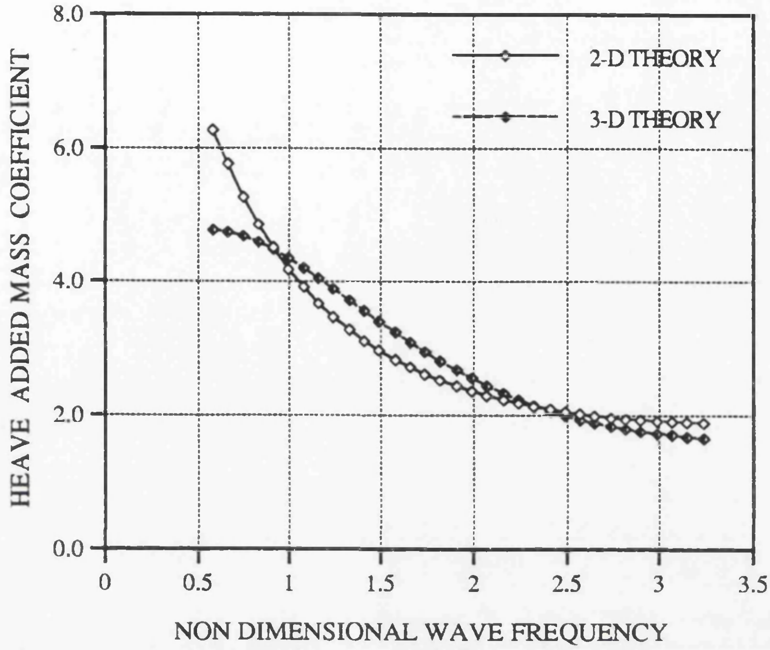


Figure 3.37 Heave Added Mass Coefficients at Fn=0.0

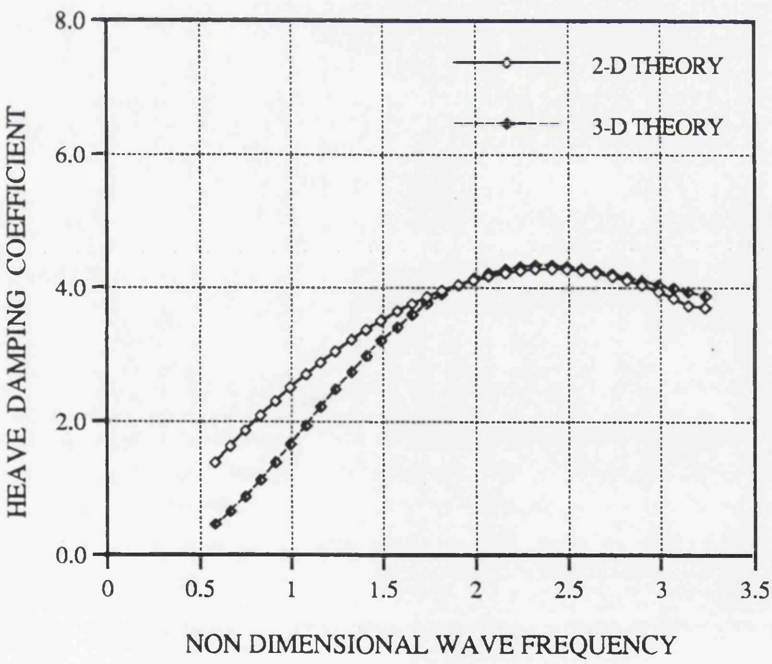


Figure 3.38 Heave Damping Coefficients at Fn=0.0

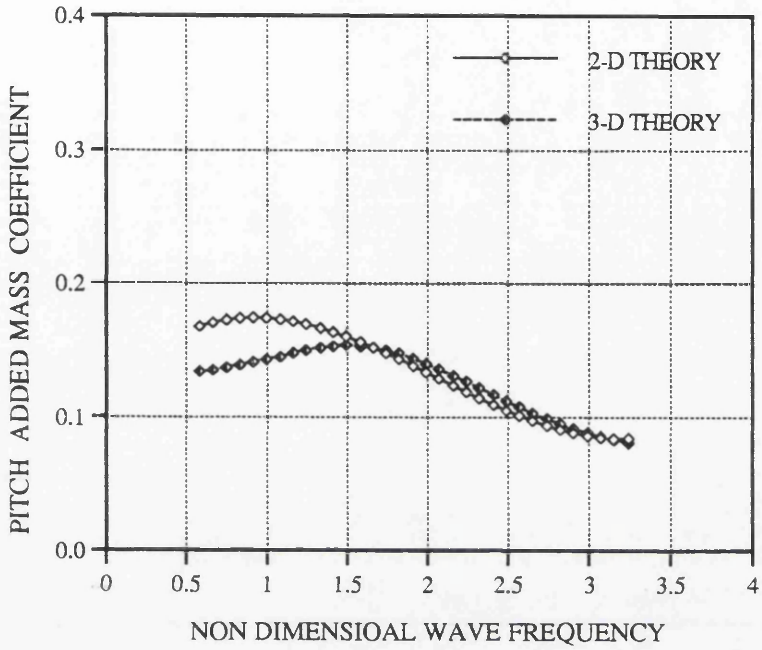


Figure 3.39 Pitch Added Mass Coefficients at Fn=0.0

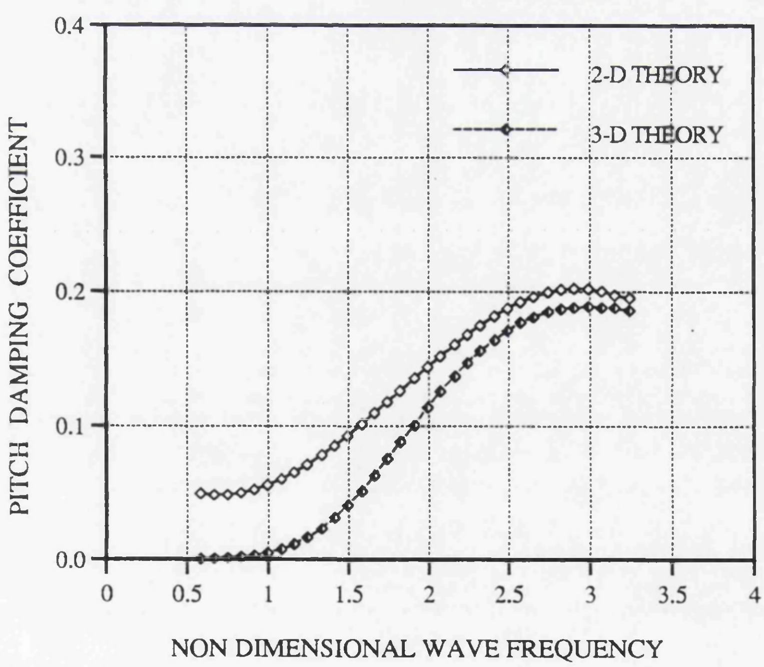


Figure 3.40 Pitch Damping Coefficients at Fn=0.0

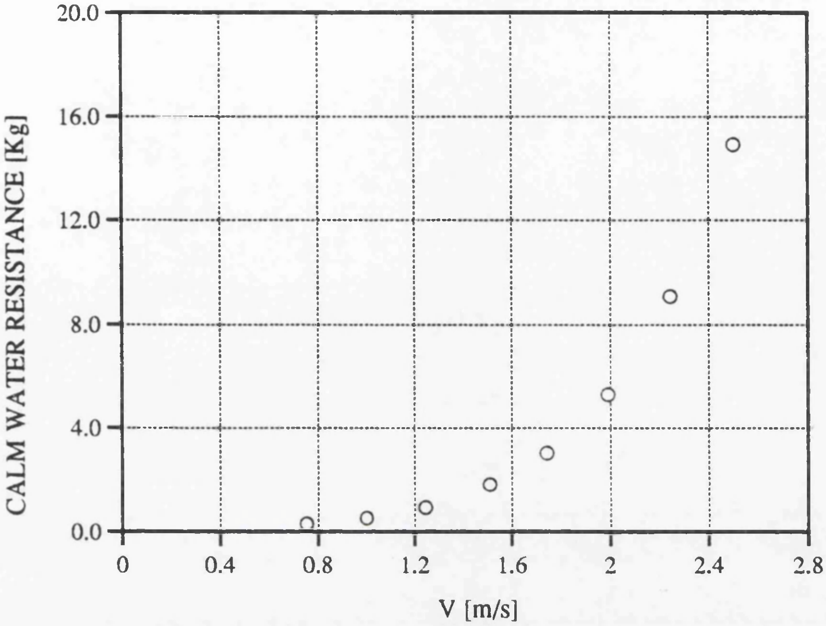


Figure 3.41 Calm Water Resistance at Lightship Draft

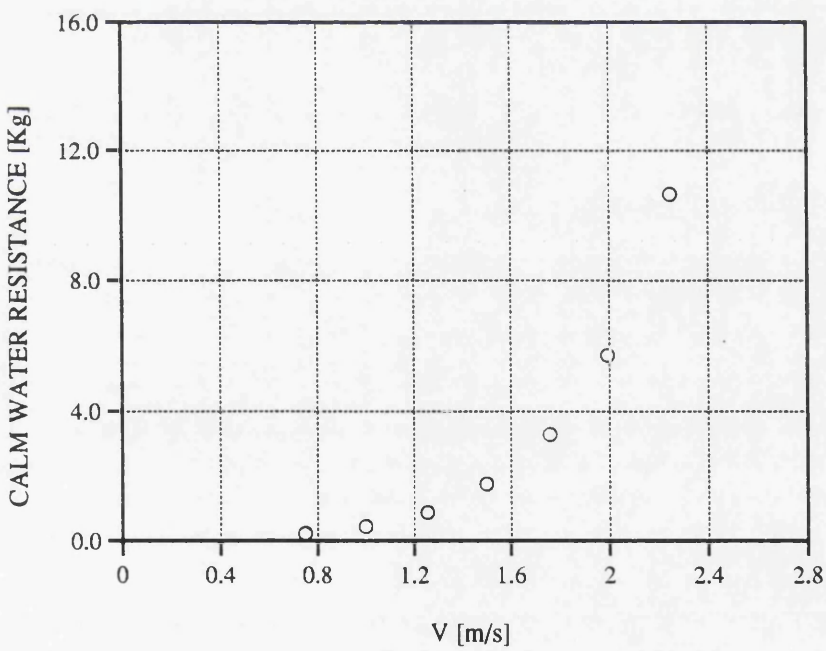
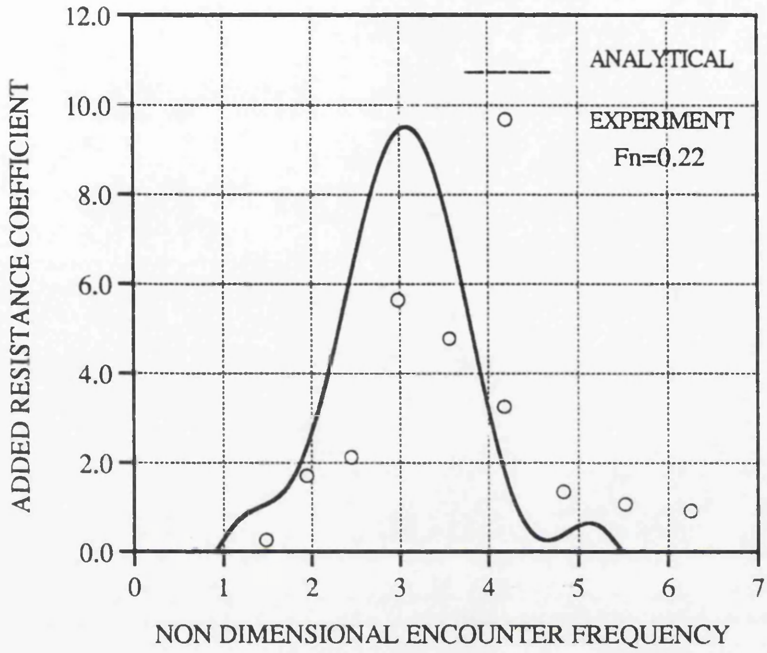


Figure 3.42 Calm Water Resistance at Loaded Draft



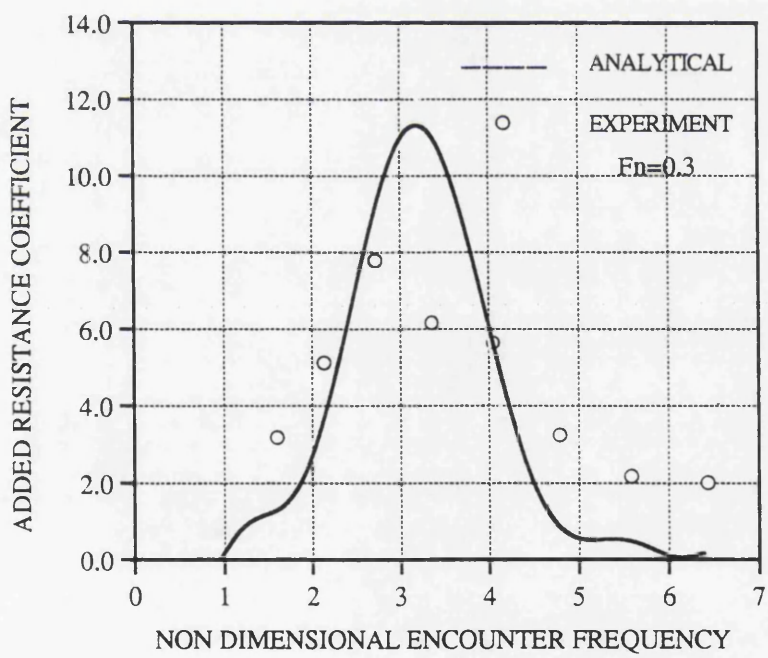


Figure 3.43 Comparison of Measured and Predicted Added Resistance in Head Seas

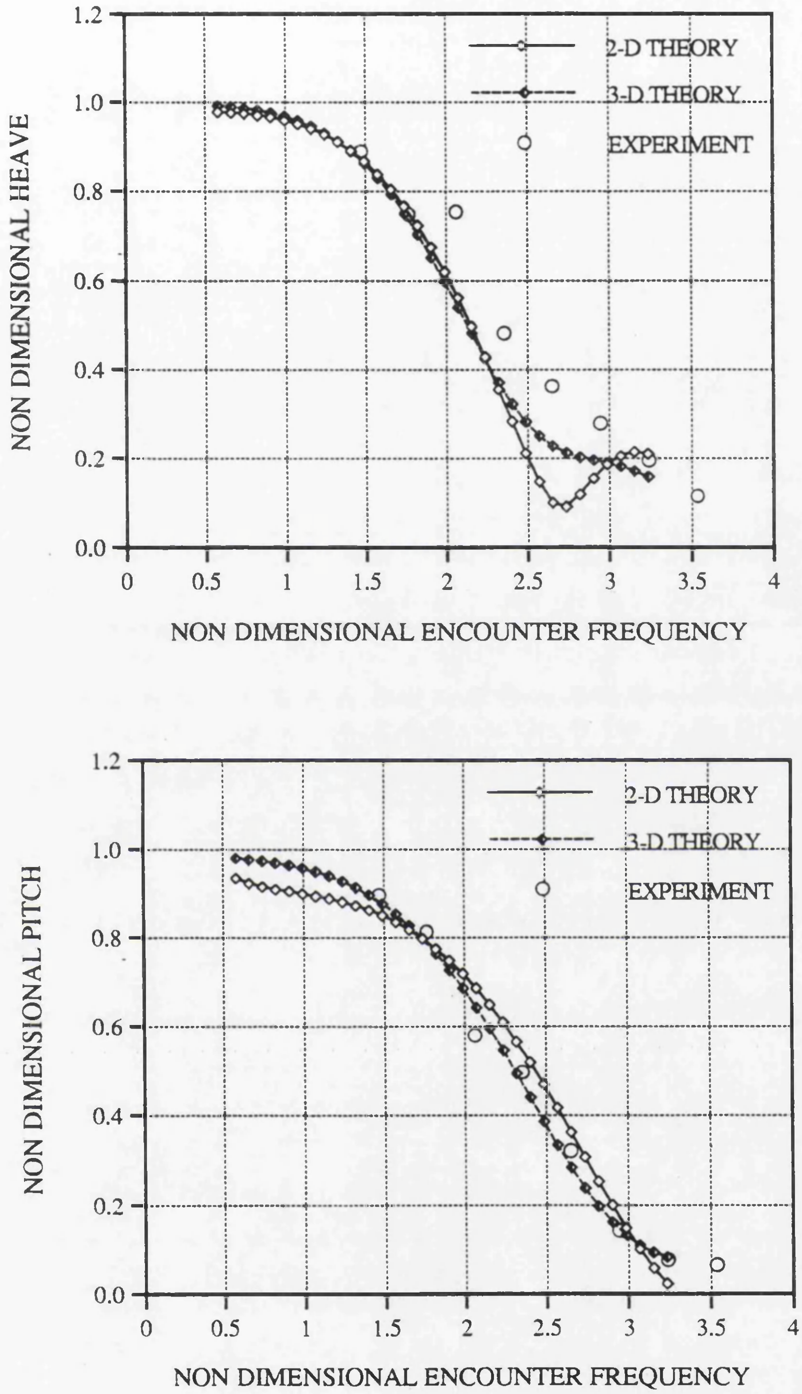
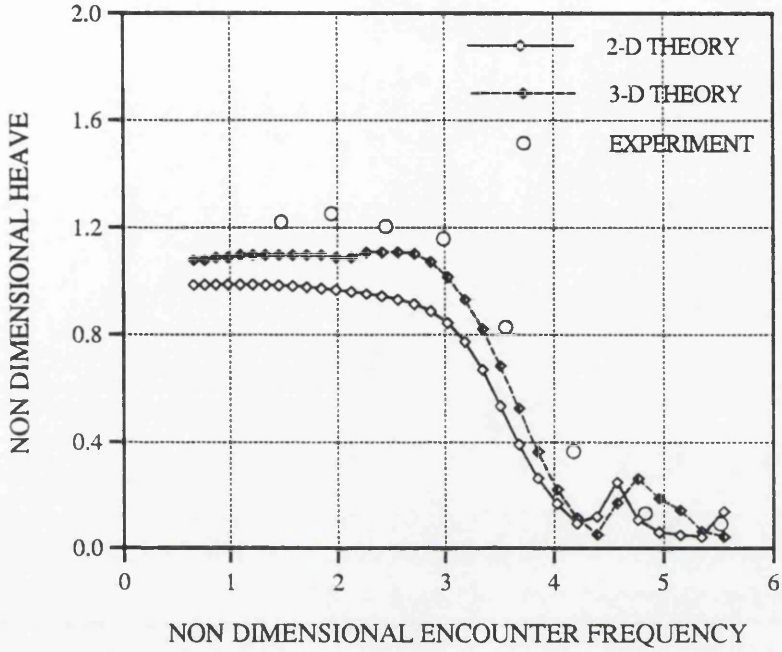


Figure 3.44 Comparison of Measured and Predicted Responses in Head Seas, Fn=0.0



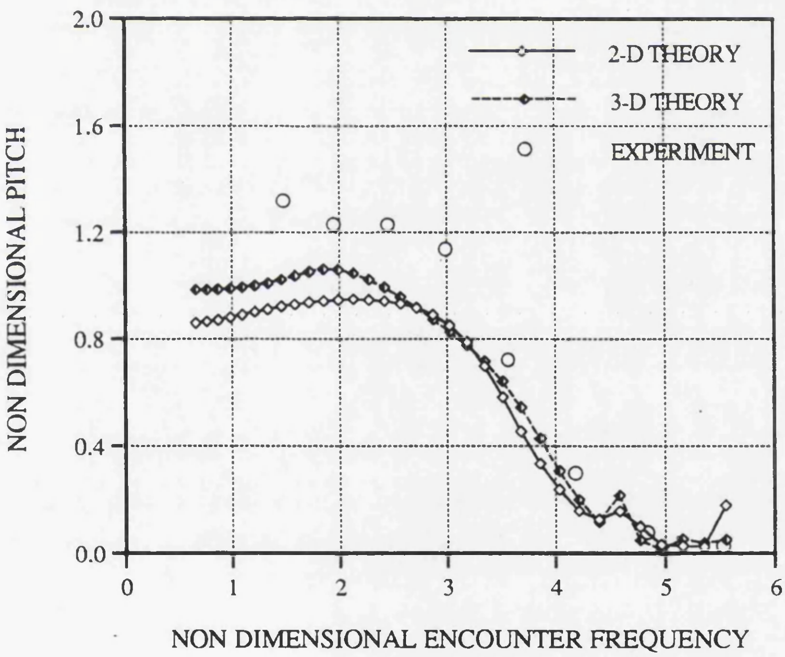


Figure 3.45 Comparison of Measured and Predicted Responses in Head Seas, Fn=0.22

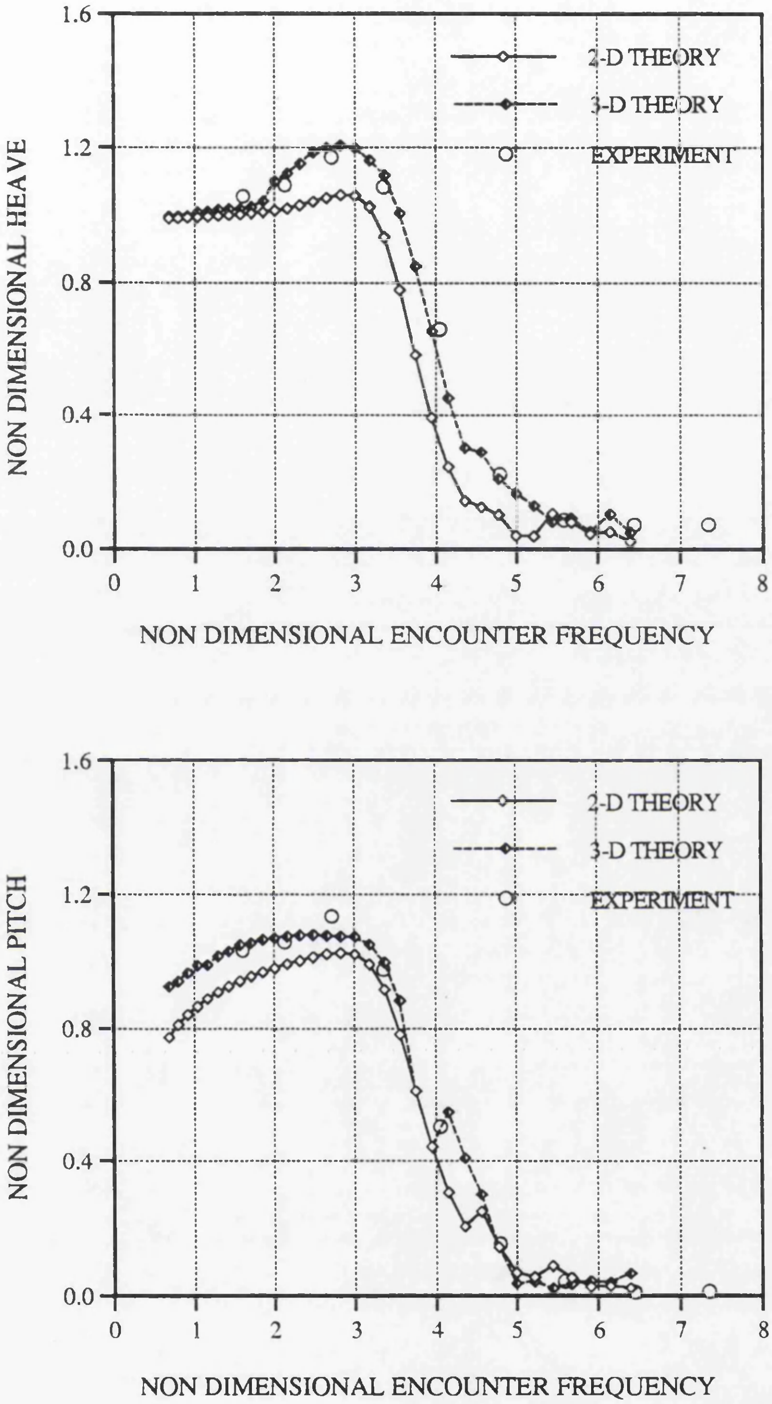
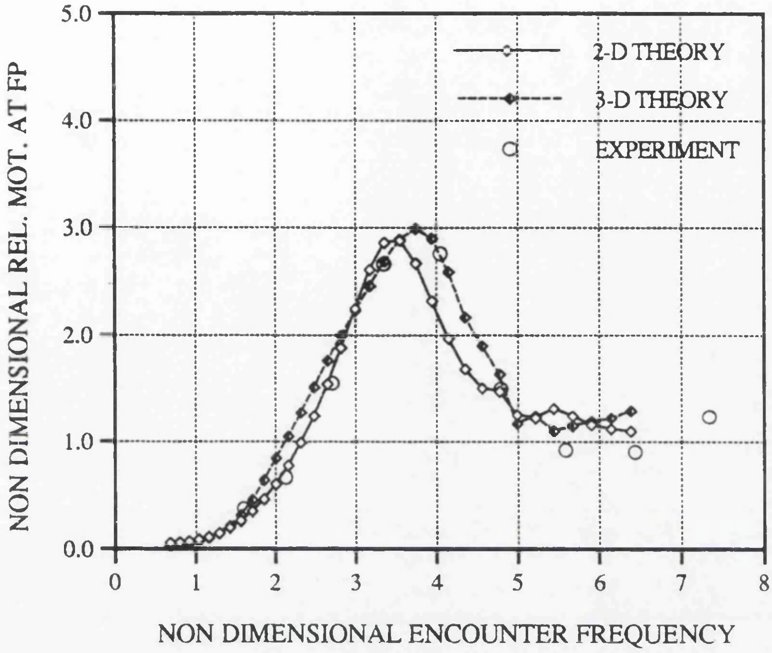


Figure 3.46a Comparison of Measured and Predicted Responses
in Head Seas, Fn=0.3



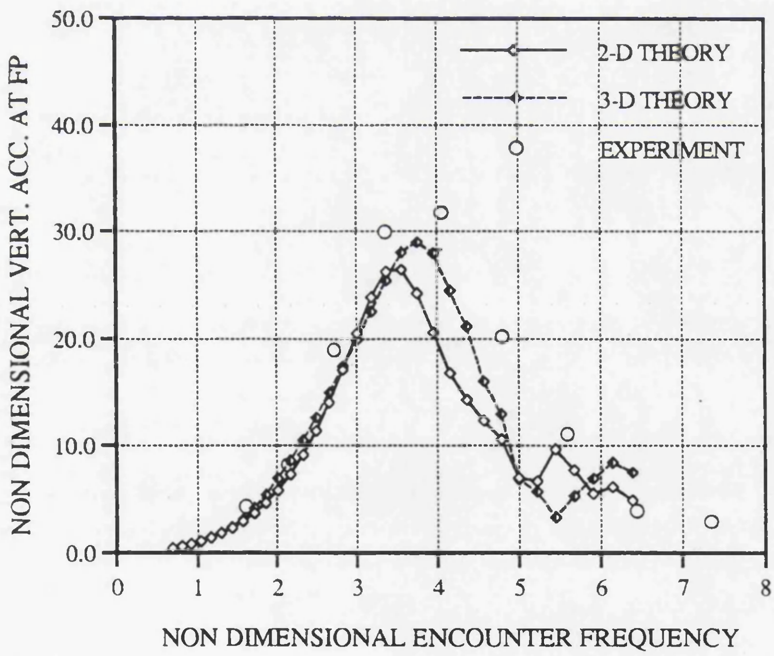


Figure 3.46b Comparison of Measured and Predicted Responses in Head Seas, Fn=0.3

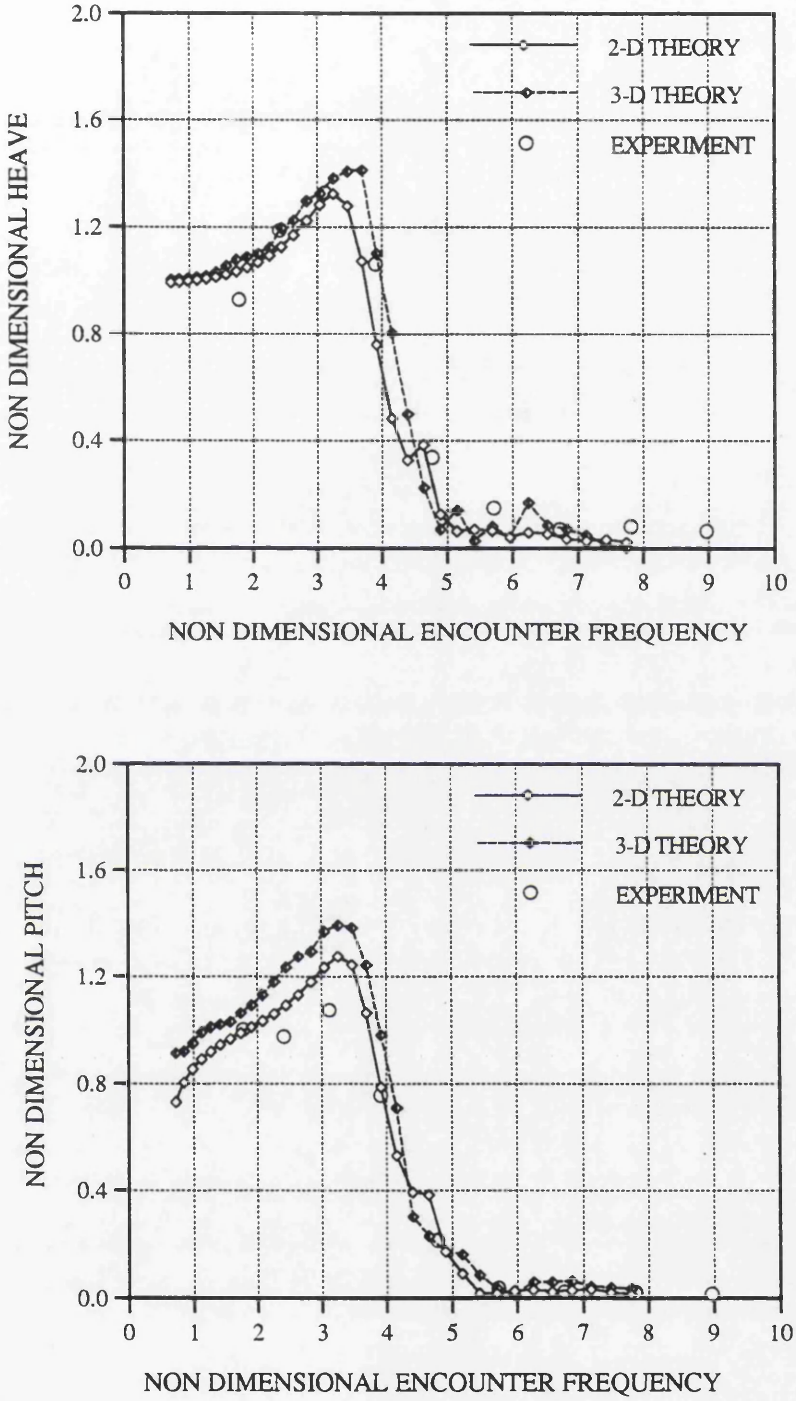
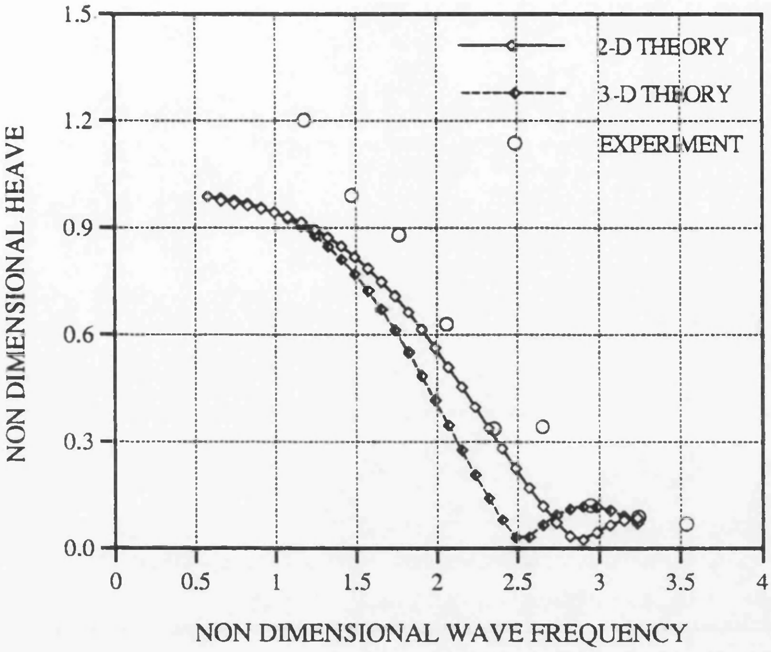


Figure 3.47 Comparison of Measured and Predicted Responses in Head Seas, Fn=0.43



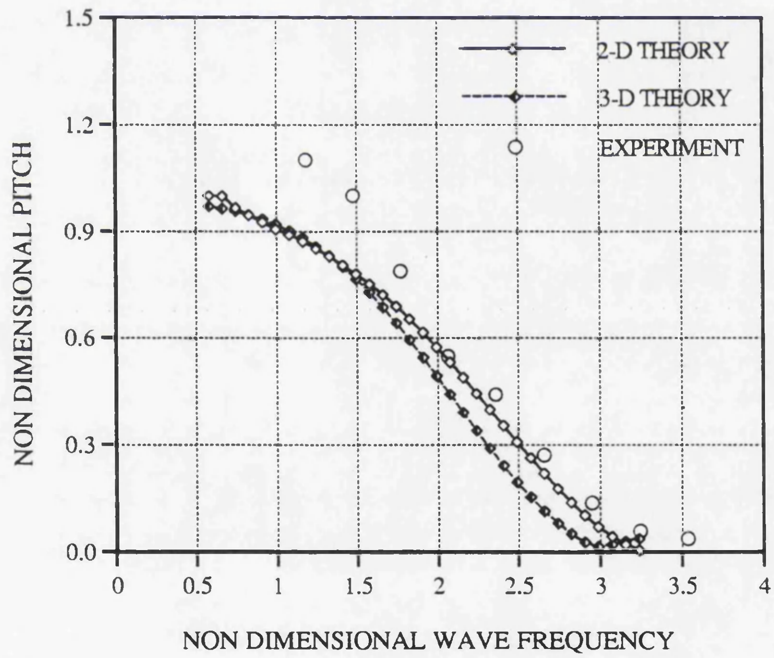


Figure 3.48 Comparison of Measured and Predicted Responses in Following Seas, Fn=0.22

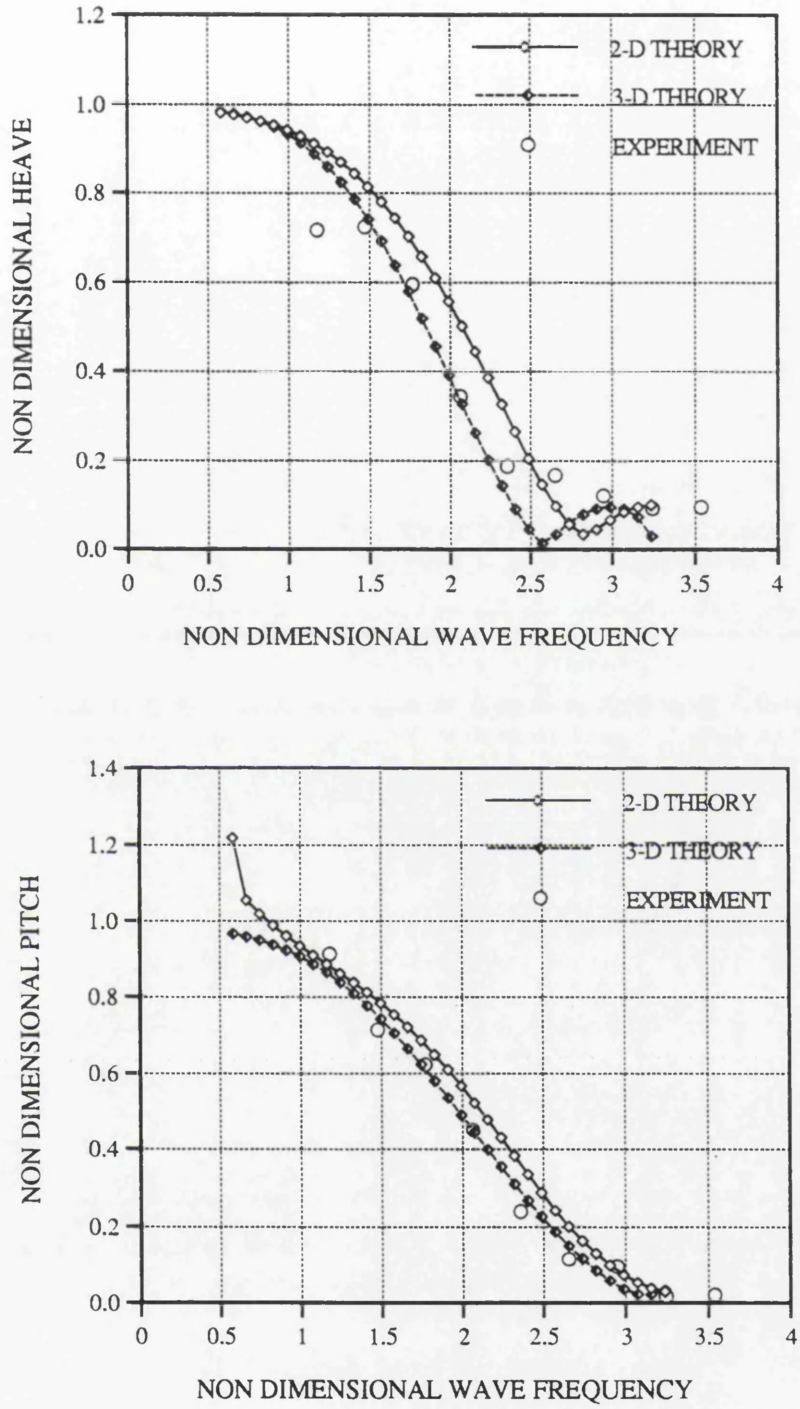
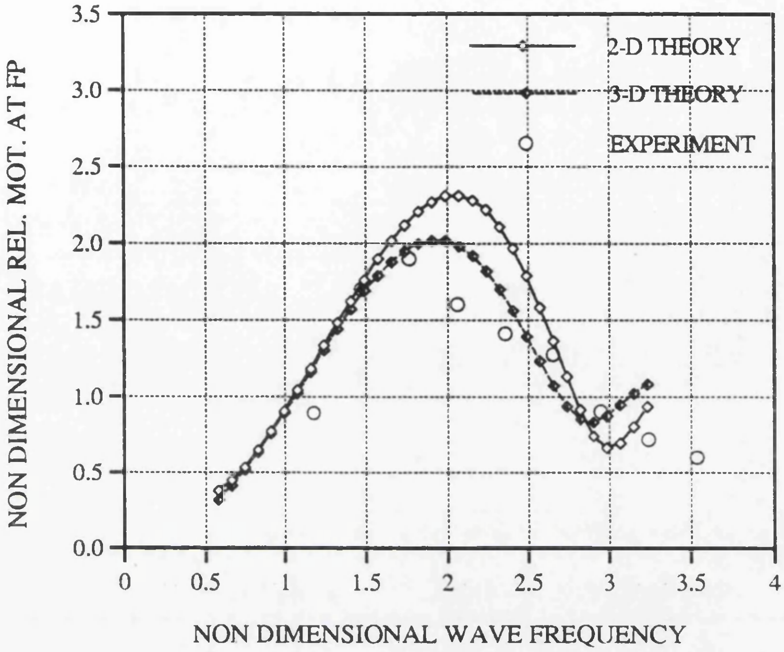


Figure 3.49a Comparison of Measured and Predicted Responses in Following Seas, Fn=0.3



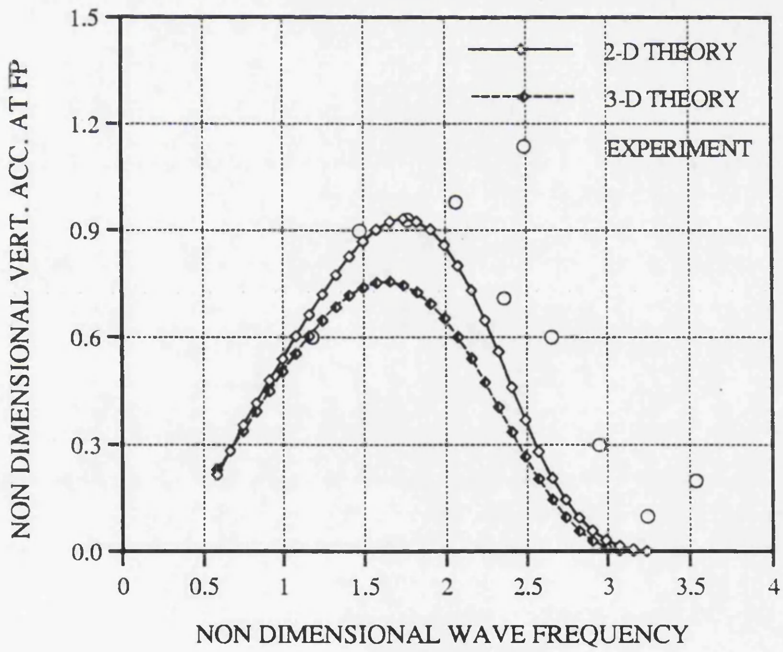
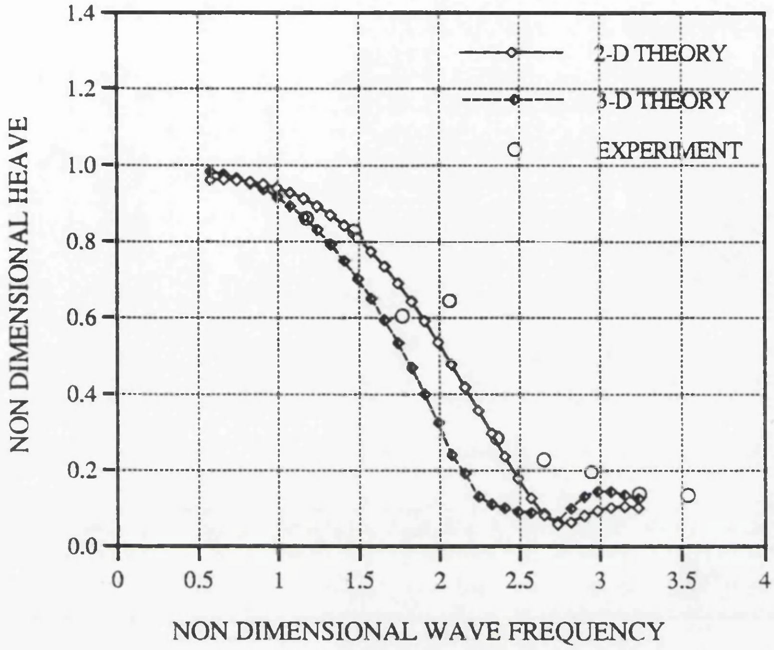


Figure 3.49b Comparison of Measured and Predicted Responses in Following Seas, Fn=0.3



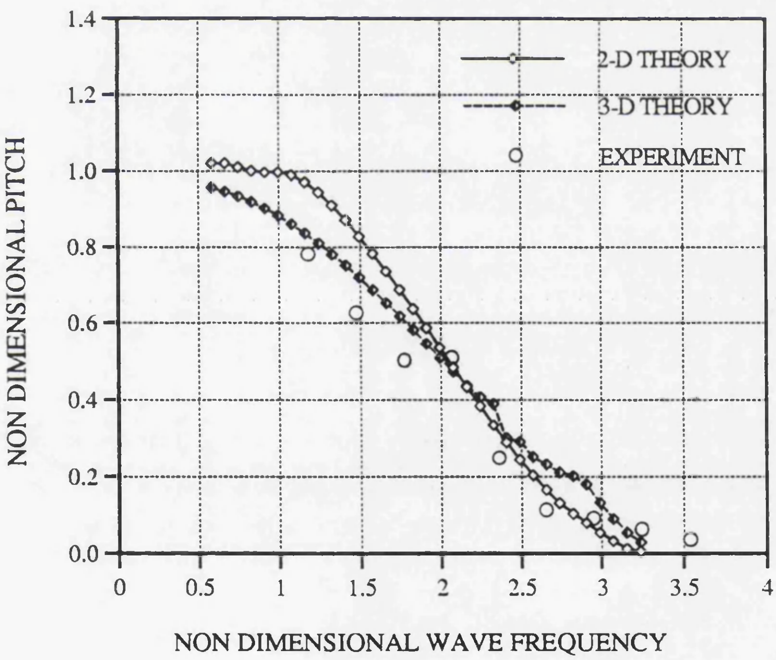
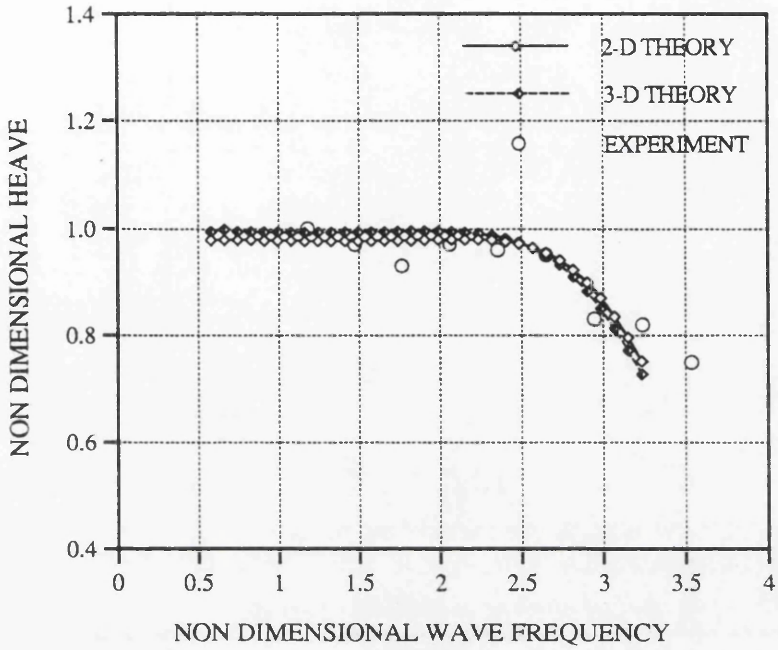


Figure 3.50 Comparison of Measured and Predicted Responses in Following Seas, Fn=0.43



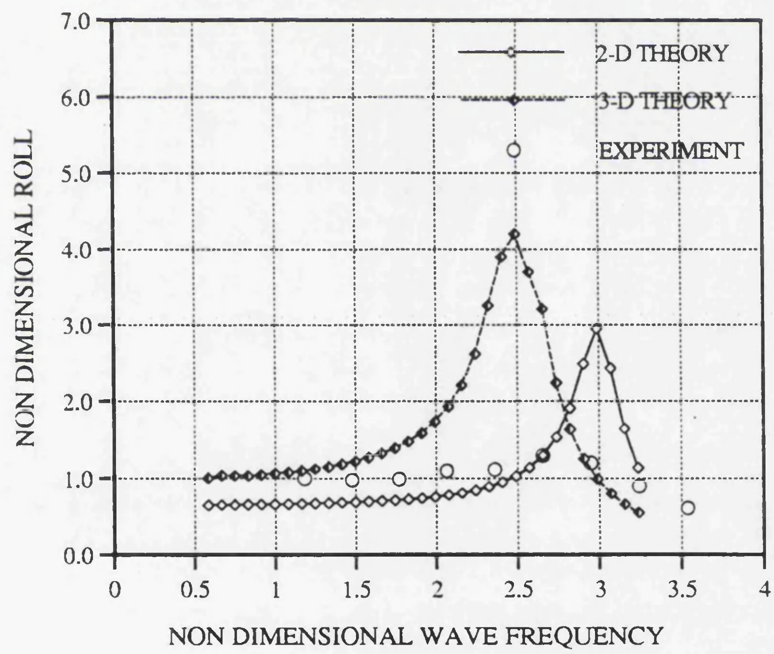
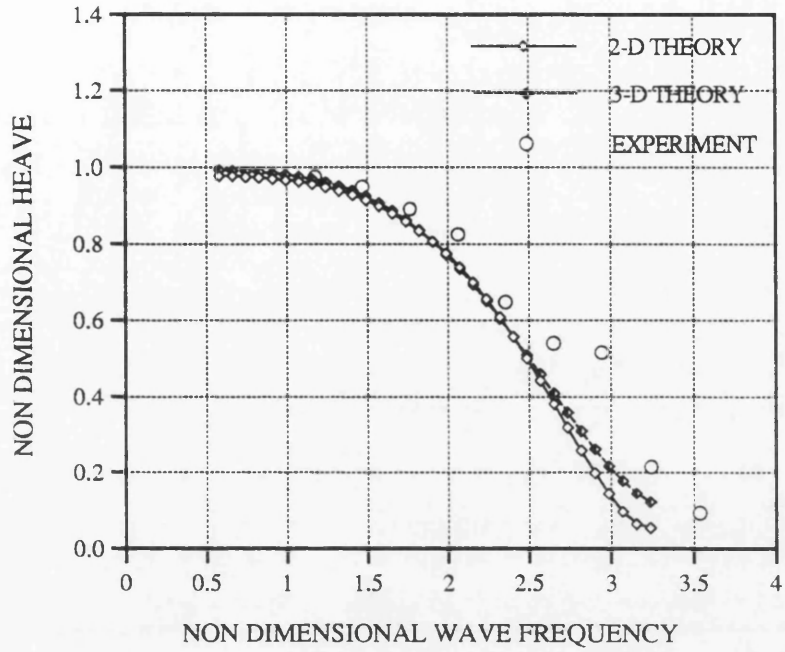


Figure 3.51 Comparison of Measured and Predicted Responses in Beam Seas, α=90 Deg., Fn=0.0



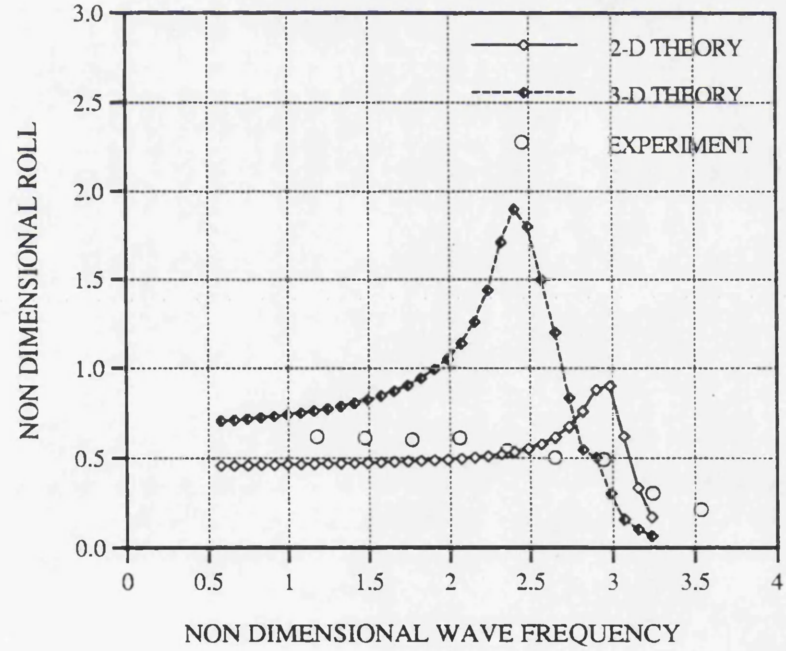
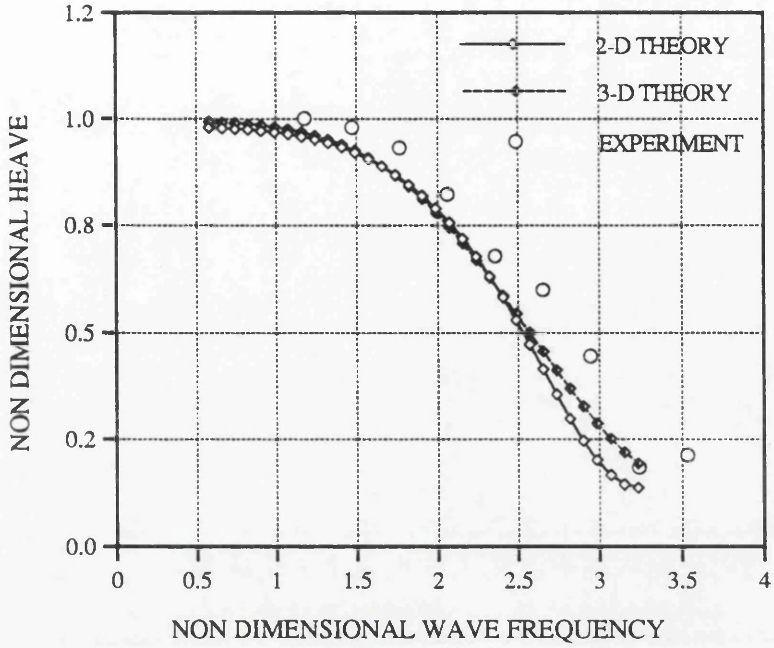


Figure 3.52 Comparison of Measured and Predicted Responses in Quartering Seas, α=45 Deg., Fn=0.0



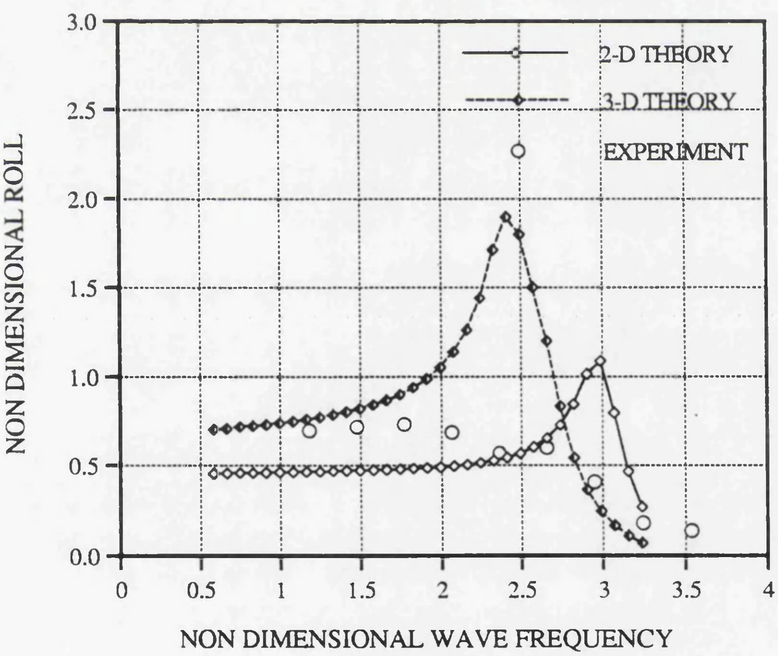


Figure 3.53 Comparison of Measured and Predicted Responses in Quartering Seas, α=135 Deg., Fn=0.0

CHAPTER 4

HULL FORM GENERATION AND SEAKEEPING PERFORMANCE ASSESSMENT

4.1 Introduction

In the ship's preliminary design phase, the designer usually faces two independent tasks. The first task is to perform a parametric study by which the ship's main dimensions can be optimised within the imposed constraints, and the best possible configuration satisfying the design requirements can be selected. The second task is to predict ship performance for the selected design using available prediction techniques relevant to a particular design level.

In developing a design procedure to assess the seakeeping characteristics of a hull form one needs to relate the dynamic response of the hull in waves to various form parameters of the hull design. In order to achieve this systematic theoretical or experimental investigations have to be carried out to determine the effect of varying form parameters on seakeeping performance of the hull.

A number of alternative designs can be produced using available software. The difficulty lies in handling the huge amount of output data from the computer simulation. For that reason, out of many combinations of wave directions, wave heights, ship speed, and a number of seakeeping characteristics, only a few are usually selected and compared at a time. A suitable option is then selected based on rather narrow foundations, despite the fact that a considerable effort has often been made in carrying out extensive computations. Having established a data bank which contains seakeeping values for different hull forms this information has to be processed via a statistical technique to relate the seakeeping characteristics to hull form parameters.

The purposes of the present study are to investigate the influence of the main particulars of the underwater hull form on seakeeping performance of small fishing vessels, and, to provide an answer to the question: what set of the main form parameters will ensure the best seakeeping performance in different modes of ship motion. For these purposes numerical computations using strip theory were carried out to determine the seakeeping performance of a series of fishing vessel hull forms. The main seakeeping parameters such as motions and accelerations were computed using the sea conditions specified for the Black Sea. The relative magnitude of these responses was related to hull form parameters by Bales' method. In addition to the motion response predictions, added resistance calculation based on the Joosen method was carried out for the series of hull forms. A regression equation based on added resistance values was developed. The outlined seakeeping performance prediction shown in Figure 4.1 includes:

- Generation of ship forms by varying the basic geometric characteristics
- Comprehensive seakeeping calculations for each ship form
- Statistical averages of the chosen ship responses
- Regression analysis to obtain a general seakeeping estimator as a function of the chosen basic geometric parameters

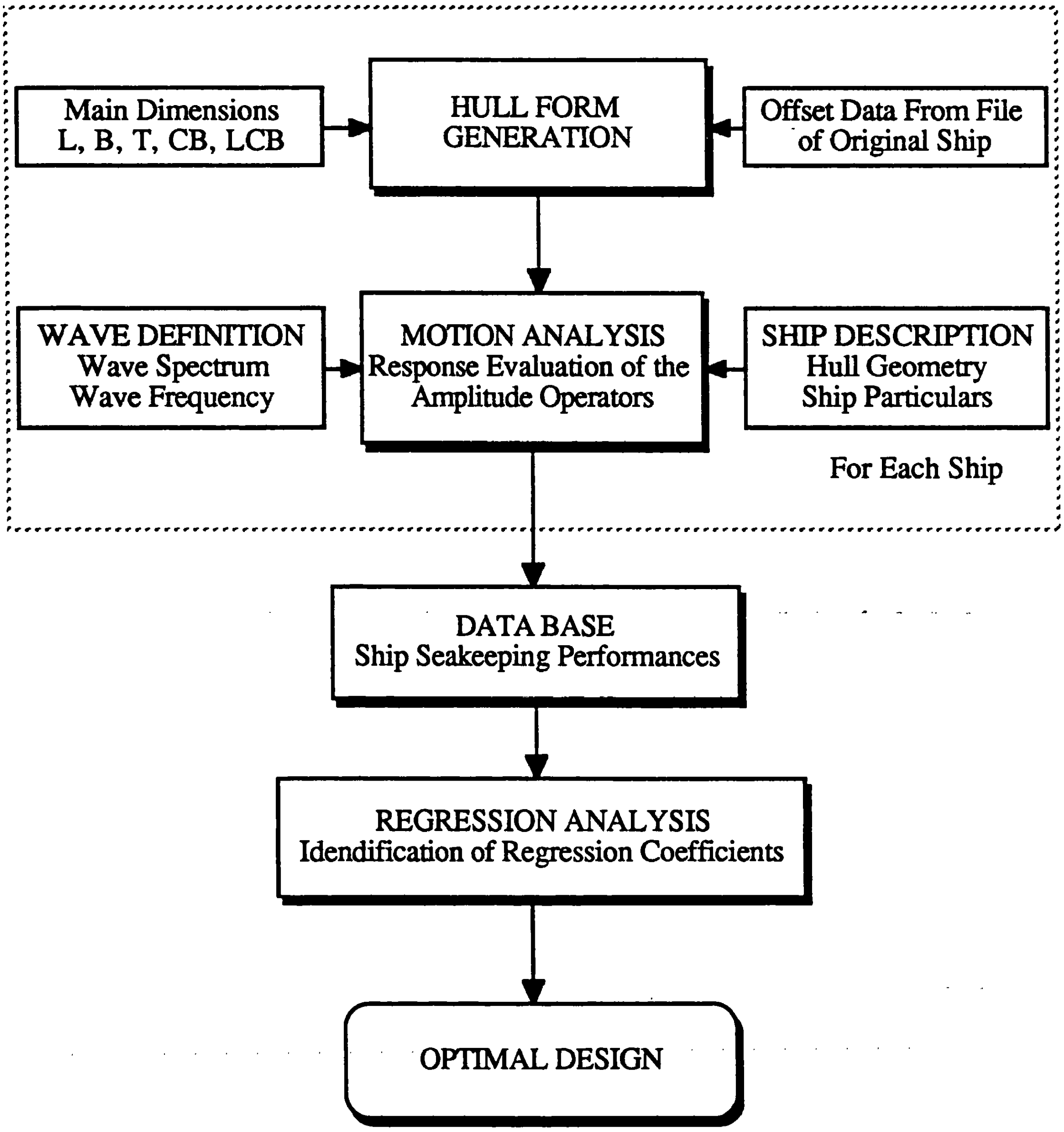


Figure 4.1 General Procedure for Seakeeping Performance Prediction

4.2 Hull Form Development

One of the major elements of vital importance for a successful ship design is the hull form itself. There are an infinite number of shapes satisfying the displacement equation for any set of values of length, beam, draught, block coefficient and displacement. The challenge lies in developing an optimum hull form or, at least, one having acceptable performance. Hydrodynamic characteristics are very sensitive to even minor changes in hull form. Therefore, the selection of ship lines requires great care in order to avoid unacceptable results.

A number of different methods of deriving hull shape exist in ship design, and they can be classified as follows:

- The most commonly used approach is to select a previous successful design as the parent hull and to distort it to give the new hull form with the desired mix of features. Although thousands of ships have been designed and built, and a great number of ship models have been tested and studied, a thorough understanding of ship hydrodynamics is still lacking. What quality or qualities a good hull form possesses to give superior resistance, seakeeping, propulsive and manoeuvring characteristics is still not quite known. Under such circumstances, a ship designer would normally try to find an existing ship with a good performance record to use as a basis for his new design.

- The use of a particular successful parent hull tends to lead to the families of designs that are apparent in the products of most design organisations. There are a number of well-known ship forms such as the Taylor Series, the Series 60, the BSRA (British Ship Research Association) Methodical Series etc. They are specified in a form which allows hull offsets to be readily generated for specified hull form parameters. Having selected possible approximate parameters it is possible to use the lines of series forms with similar design parameters as a basis ship in the design studies.

- The designer may develop a rough, faired set of lines without any parent hull, relying solely on his eye and past experience.

- For simple shapes such as barges, the hull forms can be created through the use of geometrical or mathematical equations. For more complicated shapes, direct generation of hull forms is possible with the aid of interactive computer graphics and fairing procedures.

It must be recognised that the design of the hull form is strongly dependent on hydrodynamic requirements. Besides calm water performance factors, seakeeping and manoeuvring characteristics are becoming more and more important. This implies that direct hull form generation should, preferably using appropriate analytical tools, optimise the hull form with respect to specified hydrodynamic characteristics.

4.2.1 Hull Definition and Generation

The generation of a systematic series of geometrically similar hull forms is of fundamental importance when seeking an optimal design with respect to seakeeping characteristics. The implied hull form modifications associated with the primary parameter changes can be achieved using linear distortion method. In the present study the Lackenby method of generating hull forms was used to produce a series of vessel hull forms.

In order to generate the different hull forms BMT's (British Maritime Technology) SFOLDS program was used [106]. SFOLDS is an acronym for the name of the suite of programs, i.e. Ship Form On-Line Design System, which was originally developed as a design tool. The suite is well tried, has a justifiable reputation for its versatility, and is regularly updated to keep pace with international regulations, advances in software engineering, advances in hardware technology and the continued growth in number of users worldwide.

The SFOLDS suite of programs is intended to be used as a preliminary design tool for marine vehicles. It provides a comprehensive tool kit for the Naval Architect to assess a particular hull form and manipulate that hull form in order to arrive at desired properties. The suite can be envisaged as being at three levels, according to the details of input information required and the degree of integration of programs within the suite. There are modules that require details of the hull geometry; and there are modules that require knowledge of both hull and compartment geometry. The hull geometry files from most of the major analysis systems can be used as input. All design evaluation data may be edited and entered interactively.

4.2.2 Use of the Module DEFORM

The longitudinal centre of buoyancy LCB, and block coefficient C_B, of the parent form were adjusted for a given set of values by the SFOLDS module called DEFORM. This module uses the traditional techniques adopted by Naval Architects for preliminary design, i.e. distortion of the sectional area curve at the level trim design waterline. The module provides the user with the option to scale the principal particulars of the parent hull form (length between perpendiculars, beam and draught) and to distort the parent hull form so that the required longitudinal centre of buoyancy and block coefficient are attained. After computing and printing the parent hull particulars at the load water line the user is given the opportunity to keep the principal dimensions of the new form same as the parent form or to type new values. The required block coefficient and longitudinal centre of buoyancy at the design load waterline are then input. Finally the parent hull form is modified by distorting the sectional area curve using Lackenby's linear distortion method.

The Lackenby method [107] is a well known method for deriving the amount by which each offset station should be moved to generate given changes in the total prismatic coefficient, forward and aft prismatic coefficients and longitudinal centre of buoyancy. In this method, for the transformation of a parent form to a desired ship form with different C_P and LCB position, the afterbody and the forebody of the parent hull are transformed separately to the calculated values of prismatic coefficients for the afterbody and the forebody. This approach can be used in the distortion of the sectional area curve and design waterline independently. Linear distortion methods such as Lackenby's method as described above, enables the designer to derive a series of hull forms by a systematic change in the locations of the stations at which the offsets are given.

4.2.3 Operational Procedure of the Module DEFORM

Hull Forms are defined through the use of offsets as in a conventional lines plan. The global coordinate reference system for the hull offsets is a three dimensional cartesian axis system (see Figure 4.2). The x-axis represents vessel length with the origin at the aft perpendicular. Hence distances forward of aft perpendicular are positive and astern of the aft perpendicular are negative. The y axis represents vessel breadth with the origin located on the ship's centreline. Half-breaths are defined as positive and symmetry is assumed. The z-axis represents vessel depth with the origin lying on the zero waterline i.e. baseline. Distance above the zero waterline are positive, and below are negative.

The numerically defined hull form is stored in a file called DESIGN. This is the principal data file for the program SFOLDS. The contents of the file can be summarised as follows:

- Principal Hull Dimensions-Parameters which define the principal dimensions of the ship, e.g. length between perpendiculars, beam, draught.
- Section Definition-There are 23 sections defined as the standard series of stations (see Figure 4.3).

- Waterline Definition-17 waterlines are used to define the cross section at the 23 standard displacement stations. The base line is chosen as the moulded keel line. The uppermost waterline is continuous with the vessel's upper deck. The first offset in the waterline data represents the flat of bottom line. The waterlines are more closely spaced in regions of rapid change (see Figure 4.4).
- Offset Definition-The offsets are defined on each station as half-breadths of the moulded hull at the waterline heights. The offsets on the base waterline are assumed to be zero.

The DESIGN file must be checked through the recommended checking module to ensure that there were no errors. Details for using the programs can be found in the SFOLDS User's Manual [106]. The SFOLDS program was run on a VAX 3600 computer system at Strathclyde University's Marine Technology Department.

4.2.4 Generation of a Series of Fishing Vessel Hull Forms

A series of fishing vessel hull forms were derived from an existing Black Sea fishing vessel (KTU) [22], and the Istanbul Technical University (ITU) series fishing vessels defined by Kafali [23]. The main parameters and the body plans of the parent hull forms are illustrated in Tables A.1 through A.8 and Figures A.1 through A.8 in Appendix A.

Using SFOLDS' DEFORM module, the geometrical characteristics of the parent forms were modified by varying the main hull dimensions, prismatic coefficients and longitudinal centre of buoyancy to give a displacement of 192.5 m^3 for each parent hull. Main particulars of these modified parent hull forms are given in Table 4.1.

Table 4.1 Main Particulars of the Parent Hull Forms

$\nabla = 192.5\ m^3$

HULL	L [m]	L/B	B/T	C_B	C_P	C_M	C_{VP}	C_{WP}	%LCB
KTU/1-K	27.00	3.375	4.000	0.446	0.704	0.633	0.558	0.798	-0.681
ITU/3-K	24.50	3.500	2.500	0.401	0.574	0.698	0.589	0.681	-3.306
ITU/4-K	22.78	3.499	2.501	0.499	0.558	0.893	0.666	0.748	0.009
ITU/1-B	24.97	3.501	2.499	0.379	0.573	0.661	0.518	0.731	-4.150
ITU/2-B	22.25	3.496	2.503	0.535	0.599	0.892	0.677	0.789	-0.049
ITU/3-B	24.38	3.499	2.488	0.405	0.606	0.668	0.557	0.727	-3.999
ITU/4-B	22.80	3.497	2.508	0.498	0.561	0.888	0.631	0.789	-0.096
ITU/5-B	23.68	3.500	2.506	0.445	0.618	0.720	0.597	0.745	-3.146

This procedure was repeated to generate a series of 159 hull forms, each with an displacement of $192.5\ m^3$, from these parent hull forms. The forms are divided into two groups, the first group of three parent hulls (KTU/1-K, ITU/3-K, ITU/4-K) and 81 generated hulls have a cruiser stern with breath-draft ratios of 2.17 to 4.0 and prismatic coefficients of 0.39 to 0.74. The main dimensions and hull form parameters for this group are given in Table B.1a. The second group of five parent hulls (ITU/1-B, ITU/2-B, ITU/3-B, ITU/4-B, ITU/5-B) and 70 generated hulls have a transom stern with breath-draft ratios of 2.12 to 4.0 and prismatic coefficients of 0.47 to 0.67. The main dimensions and hull form parameters for this group are given in Table B.1b. Within these lower and upper limits, the main dimensions were chosen arbitrarily. Examples of the variations between parent and derived hull forms are shown in Figure 4.5 through to Figure 4.8. The relationship between the various main parameters are presented in Figure 4.9 for the 159 hull forms. The hull forms generated from the parent hulls KTU/1-K and ITU/3-B are shown in Figure 4.10 and Figure 4.11.

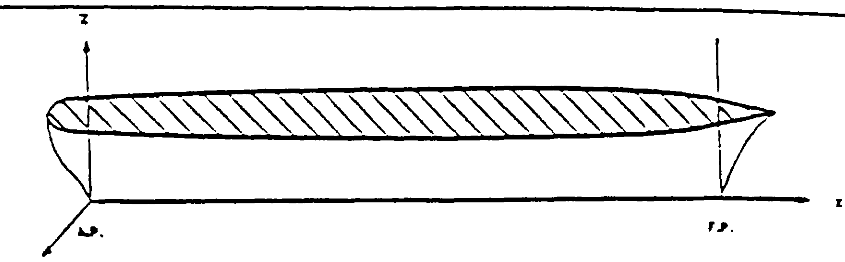


Figure 4.2 Three Dimensional Cartesian Axes

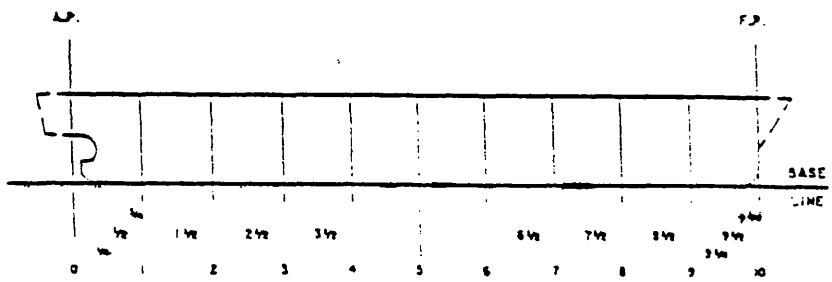


Figure 4.3 The 23 Standard Stations

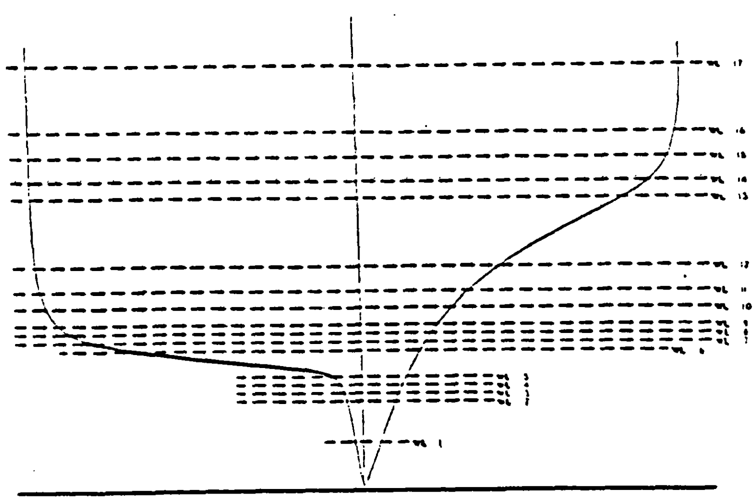


Figure 4.4 A Suitable Choice of Waterline Heights

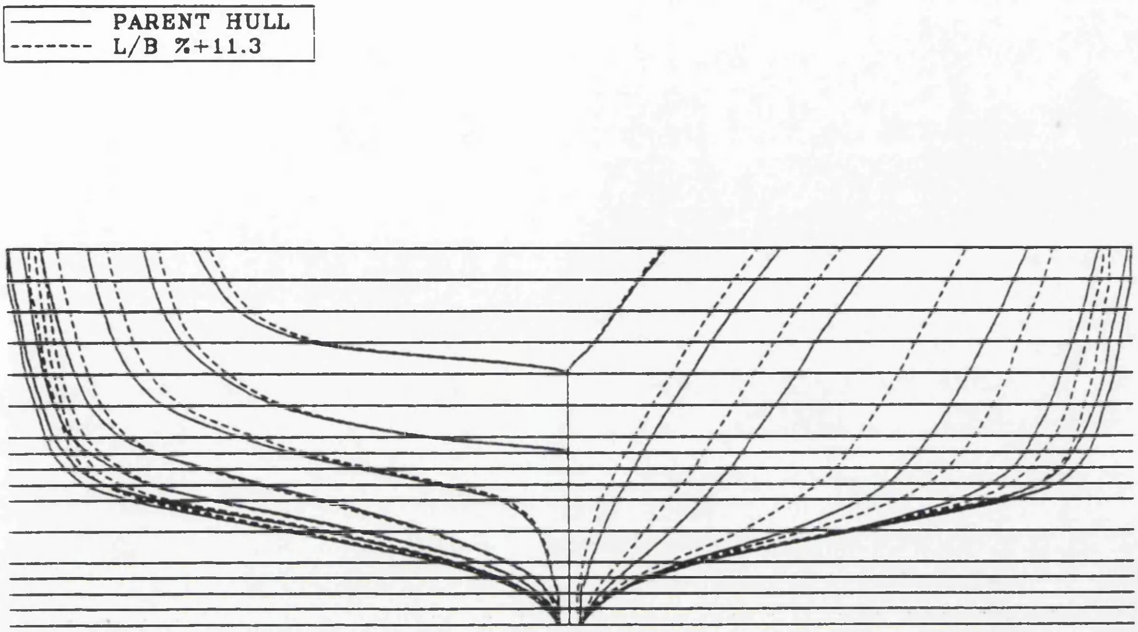


Figure 4.5 Variation of L/B by Linear Distortion Method, Parent Hull KTU/1-K

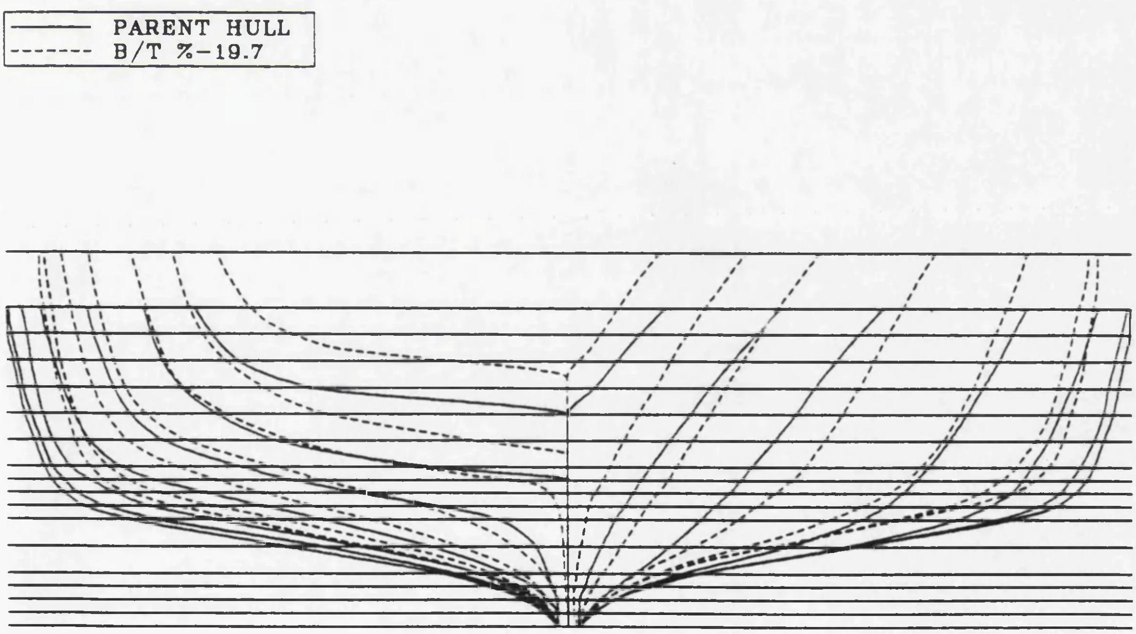


Figure 4.6 Variation of B/T by Linear Distortion Method, Parent Hull KTU/1-K

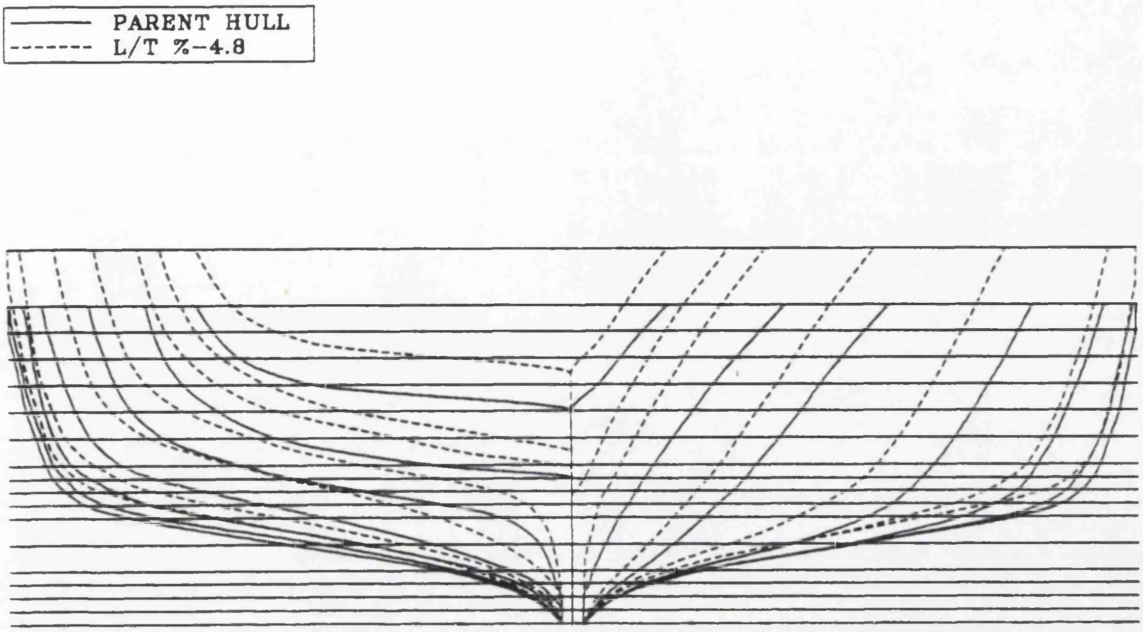


Figure 4.7 Variation of L/T by Linear Distortion Method, Parent Hull KTU/1-K

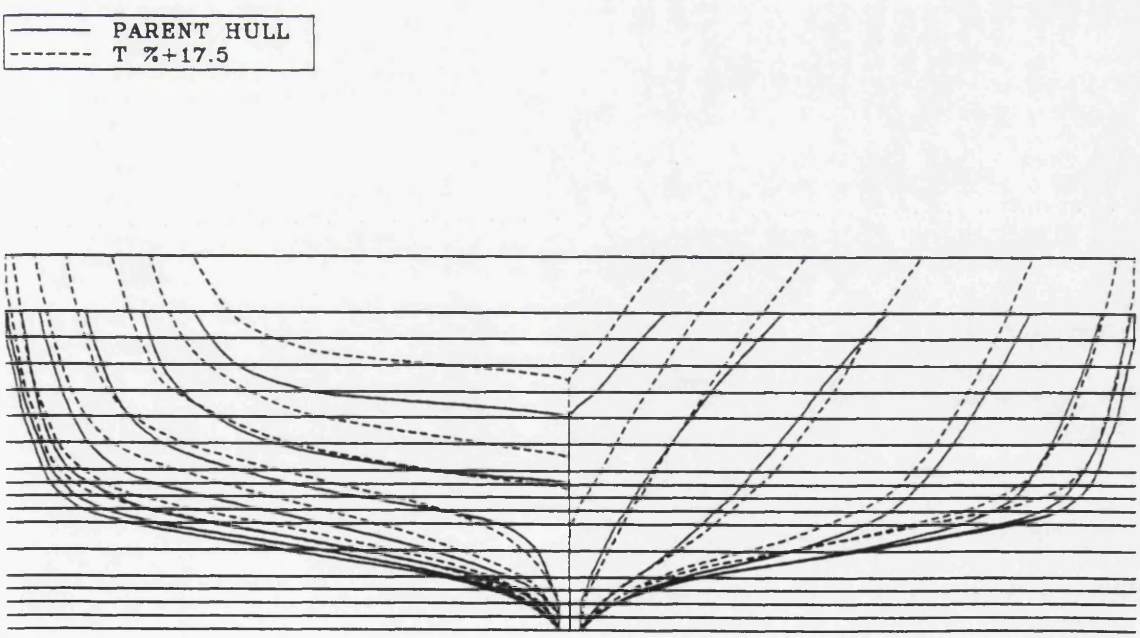


Figure 4.8 Variation of T by Linear Distortion Method, Parent Hull KTU/1-K

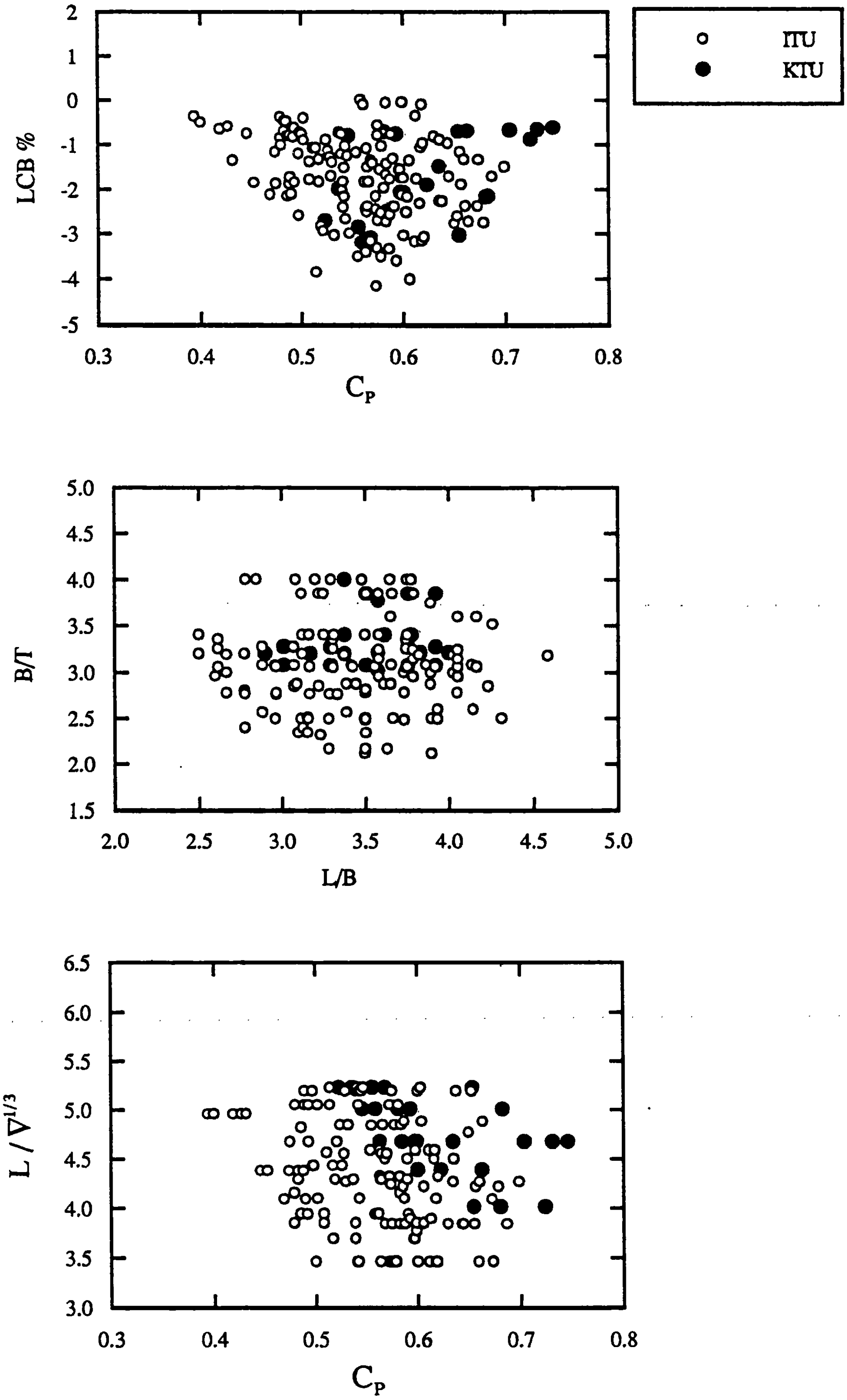


Figure 4.9 Form Parameters of the Series of Hull Forms

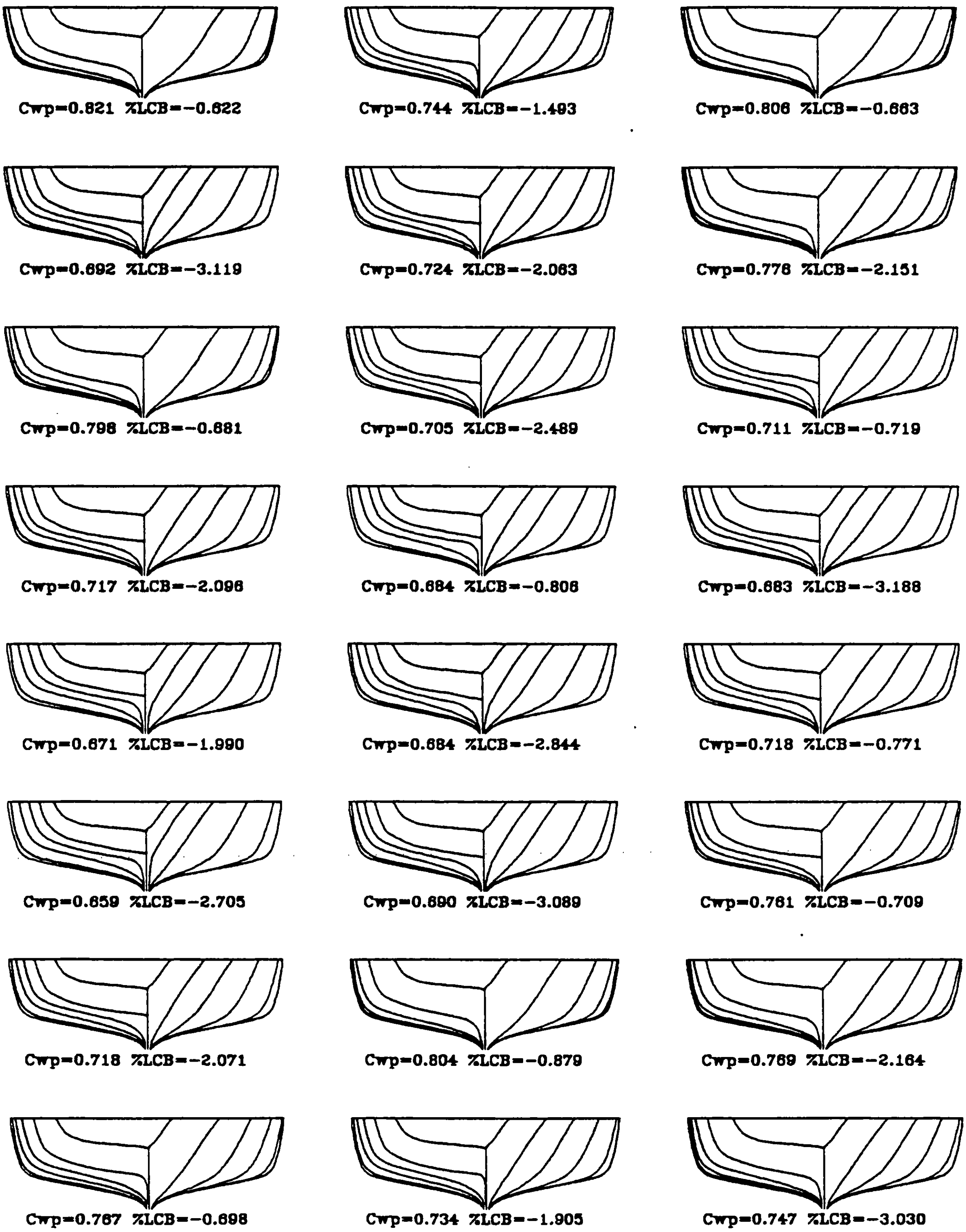


Figure 4.10 Hull Forms Adapted for Case Studies, Parent Hull KTU/1-K

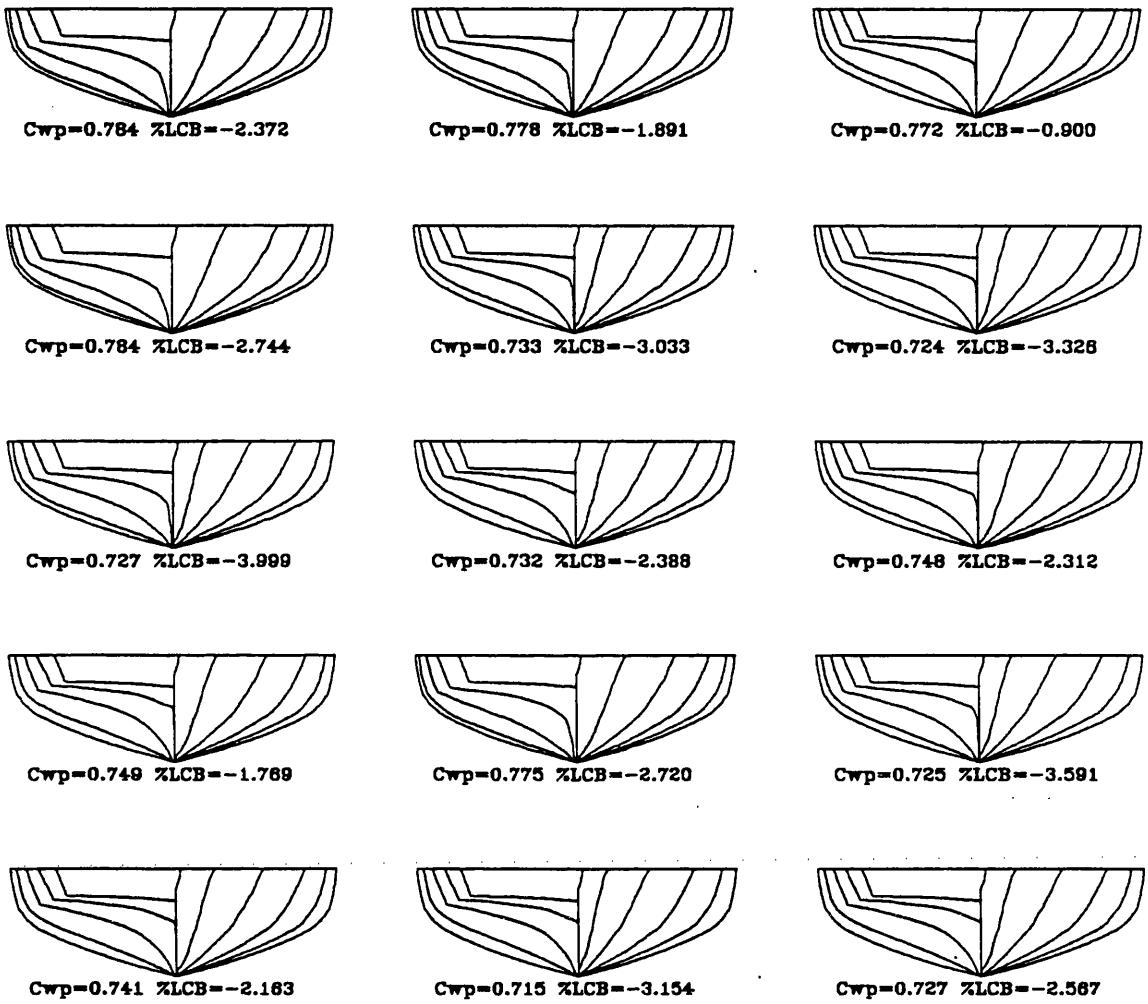


Figure 4.11 Hull Forms Adapted for Case Studies, Parent Hull ITU/3-B

4.3 Prediction of Motion Responses for the Series of Hull Forms Using SHIPMO-PC

The computer program SHIPMO-PC was used to calculate the seakeeping responses of the series of 159 hull forms described in the previous section. In order to compare the seakeeping performance of the series of hull forms it was decided to carry out calculations for the significant wave height of 1.3m which represents a typical value for fishing vessel operating conditions in the Black Sea. The input data to the program include the ship dimensions, the metacentric height and table of offsets. For all vessels the standard radius of gyration was selected to be $k_x = 0.35B$, and $k_y = 0.25L$. The hydrostatics, added mass and damping coefficients, response amplitude operators (RAO's) and phases, and responses in irregular waves were calculated. The predictions were carried out using four ship speeds of 0, 5, 10 and 15 knots and five ship headings from 0 degrees (following waves) to 180 degrees (head waves) at 45 degree increments. For each ship speed and heading, the responses were calculated according to the Bretschneider spectrum for four wave modal periods of 3.5, 4.5, 5.5 and 6.5 seconds.

The calculated responses in irregular seas, expressed in terms of significant values, were as follows: motions in six degree of-freedom (heave, pitch, roll, surge, sway, and yaw), velocities, and accelerations for all the motions. The content of the output file for each ship is as follows:

- Table of ship particulars,
- Added mass and damping coefficients,
- Response amplitude operators (RAO's) and phases for the following conditions:
  ship speed, V=0, 5, 10, and 15 knots
  Heading, β=0, 45, 90, 135, and 180 degrees

- Significant response values for long-crested waves for the following conditions:
  ship speed, V=0, 5, 10, and 15 knots
  heading, β=0, 45, 90, 135, and 180 degrees
  significant wave height, H1/3=1.3 metres
  wave periods, T_o=3.5, 4.5, 5.5, and 6.5 seconds
  motions, velocity and accelerations (surge, sway, heave, roll, pitch, and yaw)

4.4 Development of a Model Relating the Seakeeping to the Hull Form

To make the seakeeping concept useful in the hull design process the seakeeping index, R_S, could be closely approximated by the hull form parameters that are readily available in the early stages of design development. Parameters for the model were selected on the basis of the knowledge of the influence of hull form on seakeeping as stated in Chapter 2. An overall tendency for increases in waterplane coefficient to improve seakeeping is anticipated. A total of eight parameters were selected for the model are as follows:

Prismatic coefficient, C_P

Waterplane area coefficient, C_{WP}

Vertical prismatic coefficient, C_{VP}

Length to beam ratio, L / B

Beam to draught ratio, B / T

Length to displacement ratio, $L / \nabla^{1/3}$

Longitudinal centre of buoyancy, LCB

Longitudinal centre of flotation, LCF

It was decided to employ a simple, linear model as:

$$\begin{aligned} R_S &= a_0 + a_1 C_P + a_2 C_{WP} + a_3 C_{VP} + a_4 (L/B) + a_5 (B/T) \\ &\quad + a_6 (L/\nabla^{1/3}) + a_7 LCB + a_8 (C_P\, LCB) + a_9 LCF \end{aligned} \tag{4.1}$$

Where $a_i, i = 0,1,2,\ldots,9$ are constants to be determined.

The above equation was derived following a detailed study to decide the parameters to be used [108].

4.5 Seakeeping Index and Regression Analysis

Six responses, heave, roll, pitch and vertical motion, heave acceleration and relative motion at fore perpendiculars were used to calculate the seakeeping index. The computations produced 480 response statistics (4 modal wave periods x 4 speeds x 6 responses x 5 wave headings) for each of the 159 data-base hulls [108]. Because of the large amount of data generated, a computer program INDEX-MO was developed to convert SHIPMO-PC output into the seakeeping index for all the forms analysed. The flowchart of this program is shown in Figure 4.13.

In order to calculate the seakeeping index, a value for each response for each hull form, at each speed and wave heading was first calculated and normalised with the significant wave height. The responses used in the calculation of the seakeeping index correspond to wave periods T_o=3.5, 4.5, 5.5, and 6.5 seconds, which approximately cover the variation of the wave period found from the statistical data for the Black Sea [109]. Figure 4.12 shows the frequency distribution of the wave periods in the Black Sea. Since the calculation of the responses does not include the period of 7.5 sec, the evaluation of the seakeeping index does not take into account the corresponding probability of 4.76 per cent.

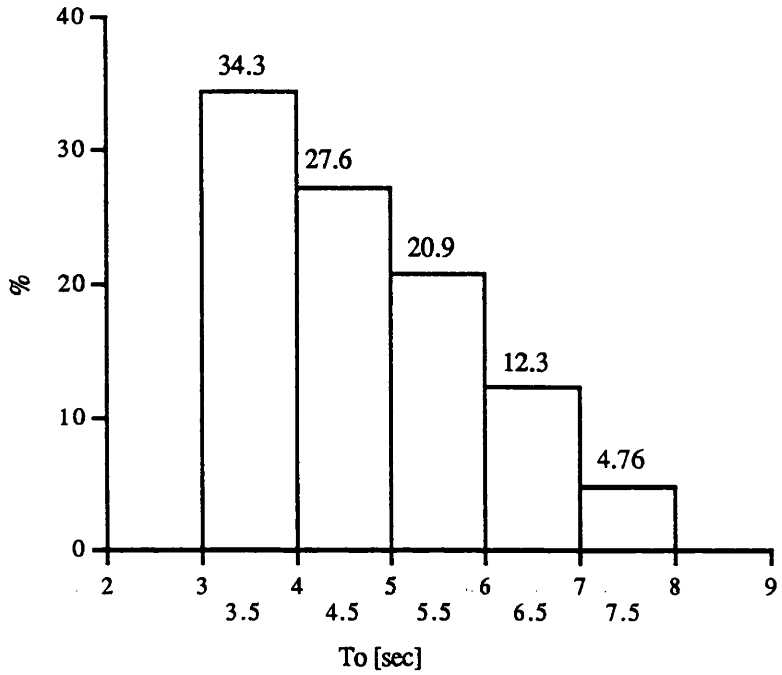


Figure 4.12 Frequency Distribution of the Wave Periods in the Black Sea

The average responses, weighted with the probabilities of occurrence for each wave period, were calculated for a significant wave height of 1.3m using the following formula:

$$Rw = [34.3\ R(3.5) + 27.6\ R(4.5) + 20.9\ R(5.5) + 12.3\ R(6.5)]\ /\ 95.1 \qquad (4.2)$$

Where R (i) is the response for i th wave period.

For a given mode of motion a set of normalised responses were than calculated by dividing the smallest response value by all the other response values of this particular mode. During this process the weighted value calculation according to (4.2) was made. This gives a normalised response value for a particular mode for each of the speeds and wave heading for each hull form. The six normalised responses were then summed to give a single value for each hull form at each speed and wave heading. The groups of summed normalised responses thus obtained were rearranged in a scale of 1 to 10 as a seakeeping index. The best ship, with the largest normalised average response value, was given number 10 and the worst, number 1. The index for other vessels falling in between the largest and smallest normalised response values were calculated with the following formula:

$$\text{Index (R)} = \frac{S_A - S_L}{S_U - S_L} x9 + 1 \tag{4.3}$$

where

S_L is the smallest value of the sum corresponding to 1

S_U is the largest value of the sum corresponding to 10

S_A is the actual value of the sum of the ship for which the index is calculated

The effect of variations in heading angle and speed on the seakeeping index for the parent forms is illustrated in Table 4.2. From this table it can be seen that hull KTU/1-K has the highest value of seakeeping index for the parent hulls in most of the speed/heading combinations.

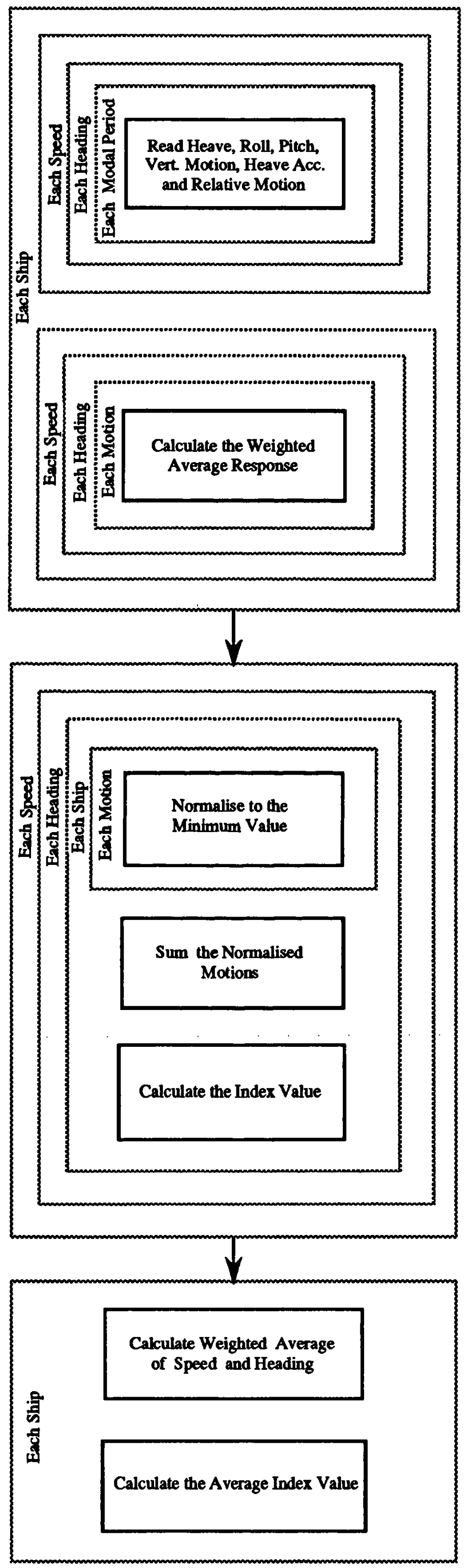


Figure 4.13 Flow Chart of the INDEX Program

Table 4.2 Seakeeping Index for Parent Forms

SPEED	HULL	0°	45°	90°	135°	180°
	KTU/1-K	8.58	7.54	7.91	8.29	9.27
	ITU/3-K	1.96	3.34	3.89	1.90	1.94
	ITU/4-K	3.94	5.98	2.43	5.62	4.50
0 Knots	ITU/1-B	3.76	4.45	5.22	2.86	3.51
	ITU/2-B	4.54	5.01	2.37	5.61	5.08
	ITU/3-B	3.15	4.22	4.42	2.45	2.85
	ITU/4-B	5.02	5.71	2.62	5.34	5.23
	ITU/5-B	3.50	5.63	4.04	3.21	3.26
	KTU/1-K	7.34	5.71	7.94	9.75	10.00
	ITU/3-K	2.32	3.48	3.71	1.38	1.41
	ITU/4-K	4.96	8.33	3.21	5.01	4.14
5 Knots	ITU/1-B	3.30	3.60	5.15	2.30	3.01
	ITU/2-B	5.33	6.58	2.74	5.91	5.25
	ITU/3-B	3.21	4.01	4.39	1.68	2.21
	ITU/4-B	6.04	6.85	2.75	5.19	5.40
	ITU/5-B	3.81	5.27	4.40	2.30	2.59
	KTU/1-K	5.82	3.91	8.29	9.67	10.00
	ITU/3-K	4.36	3.77	4.04	2.56	1.29
	ITU/4-K	7.07	8.21	2.87	4.31	3.80
10 Knots	ITU/1-B	5.15	3.47	5.21	3.41	2.82
	ITU/2-B	7.34	7.38	3.61	6.14	5.71
	ITU/3-B	5.68	4.28	4.86	3.12	2.39
	ITU/4-B	8.73	7.29	3.75	5.91	5.69
	ITU/5-B	5.75	5.03	4.80	3.18	2.65
	KTU/1-K	7.16	3.19	8.31	10.00	10.00
	ITU/3-K	1.73	4.52	4.36	2.87	3.81
	ITU/4-K	5.14	7.76	3.17	4.01	5.51
15 Knots	ITU/1-B	4.96	4.34	5.56	4.18	4.94
	ITU/2-B	7.57	7.75	3.84	6.62	7.26
	ITU/3-B	5.41	4.99	5.22	3.83	4.82
	ITU/4-B	8.01	7.38	4.05	6.10	6.95
	ITU/5-B	5.23	5.32	5.14	3.62	4.97

The six weighted seakeeping responses calculated for the series of hull forms for the combinations of four speeds, 0, 5, 10 and 15 knots, and five headings, 0, 45, 90, 135 and 180 degrees, are illustrated in Table B.2 through B.21 in Appendix B. The same tables contain the summed normalised responses and the seakeeping index as described above.

A main seakeeping index Rm was calculated for each hull form as a weighted average value based on the operating profile in a 24 hour working day as given in Table 4.3 [110].

Table 4.3 Operating Profile of a Fishing Vessel During a 24 Hour Working Day

Speed	Heading Angle				
	0°	45°	90°	135°	180°
0 Knots	-	1 hour	1 hour	2 hours	1 hour
5 Knots	-	1 hour	1 hour	1 hour	3 hours
10 Knots	5 hours	-	-	-	4 hours
15 Knots	3 hours	-	-	-	1 hour

The values of the main seakeeping index, Rm, for 159 hull forms are given in Table B.22a and Table B.22b. This table shows the data base hulls in order of index from best (Rm=10.00) to worst (Rm=1.00). This table also includes the hull form parameters on which Rm has been modelled. It can be seen that Hull 125, which was generated from ITU/1-B, has the best seakeeping index and Hull 52, which was generated from ITU/3-K, has the worst. It is evident that none of the parameters considered provide a reliable indication of the behaviour of the index, although gross tendencies toward increasing index with increasing C_{WP} and with decreasing C_P are discernible.

By applying a linear regression analysis using the hull form parameters as the independent variables and the main seakeeping index value Rm of each hull as the dependent variable in the database, an equation for the R_S was obtained as follows:

$$R_S = -57.728 - 21.181\ C_P + 76.313\ C_{WP} + 13.205\ C_{VP} - 6.581\ (L/B) - 3.257\ (B/T) + 10.434\ (L/\nabla^{1/3}) + 0.872\ LCB - 1.46\ (C_P\ LCB) + 0.403\ LCF \tag{4.4}$$

It can be seen from this equation that for the range of vessels considered in this study long vessels with a large waterplane area have the largest positive impact on the responses (see Table 6.1).

4.6 Prediction of Added Resistance for the Series of Hull Forms Using SHIPMO-PC

In order to compare the added resistance of the series of hull forms, in addition to the motion response predictions, the added resistance calculation based on the Joosen method [102] described in Chapter 3 was carried out for the series of 159 hull forms. The damping coefficients as well as information on the heave and pitch motions and phase relationships generated by the motion program SHIPMO-PC are used to evaluate the added resistance. The predictions were carried out for ship speeds of 5, 10 and 15 knots for head seas. For each ship speed, the added resistance were calculated using the Bretschneider spectrum for four wave modal periods of 3.5, 4.5, 5.5 and 6.5 seconds for one significant wave height of 1.3m. This analysis were performed in a modified version of the program SHIP-AR described in Chapter 3.

4.7 Added Resistance Index and Regression Analysis

In order to facilitate the comparison between the hull form concerned, the added resistance index for was calculated using a method similar to the seakeeping index described in previous section. Weighting calculations were carried for working hours spent in head seas. The analysis were performed with a computer program INDEX-AR. The main values of added resistance index for 159 hull forms are given in Table B.23a and Table B.23b. It was found that Hull 112, which was generated from ITU/4-B, has the best added resistance index and Hull 03, which was generated from KTU/1-K, has the worst.

It was decided that the calculated added resistance index could be approximated by the hull form parameters that are used in seakeeping calculations. By applying a linear regression analysis to the series of ship hull forms, an equation for the R_{AR} was obtained as follows:

$$\begin{aligned} R_{AR} = & -9.774 - 18.620\ C_P + 26.096\ C_{WP} + 8.811\ C_{VP} + 1.154\ (L/B) \\ & - 0.895\ (B/T) + 0.080\ (L/\nabla^{1/3}) + 0.897\ LCB \\ & - 1.808\ (C_P\ LCB) + 0.011\ LCF \end{aligned} \tag{4.5}$$

It can be seen from this equation that the waterplane area and vertical prismatic coefficient have the largest positive impact on the added resistance. The hull form parameters have the same effect on added resistance as they have on seakeeping with the exception of the L/B (see Table 6.1).

4.8 Conclusions

Bales' method was applied to develop a relationship between hull form parameters and a general seakeeping estimator. For this purpose the series of 159 fishing vessel hull forms were generated using the Lackenby linear distortion method from an existing Black Sea fishing vessel and the Istanbul Technical University series fishing vessels. Using the hull distortion module DEFORM in the program SFOLDS, the geometrical characteristics of the parent forms were modified by varying the main hull dimensions, prismatic coefficients and longitudinal centre of buoyancy while keeping the displacement constant for each vessel.

The numerical computations using strip theory were carried out to determine the seakeeping performance of the series of 159 fishing vessel hull forms. Six responses, heave, roll, pitch and vertical motion, heave acceleration and relative motion at fore perpendiculars were calculated using the sea conditions specified for the Black Sea. The main seakeeping index were calculated for each hull form as a weighted average value based on the operating profile of vessel in a 24 hour working day. A regression equation with respect to hull form parameters was evaluated. It was found that for the range of vessels considered in this study long vessels with a large waterplane area have the largest positive impact on the responses.

In order to compare the added resistance of the series of hull forms, added resistance calculations based on the Joosen method were carried out for head seas. To facilitate the comparison between the hull forms concerned, the added resistance index was calculated using a method similar to the seakeeping index. A regression equation with respect to same hull form parameters was evaluated. It was found that the hull form parameters have the same effect on added resistance as they have on seakeeping with the exception of the L/B.

CHAPTER 5

RESISTANCE CALCULATIONS

5.1 Introduction

The seakeeping performance characteristics are just one of the important items to be considered in the preliminary hull form design stage. The designer should, ideally, be able to generate similar design charts for each of the design considerations so that he can justify the selection of an "optimal" form with respect to all aspects of design considerations. One of the most important of these considerations are resistance characteristics. Prediction of ship resistance is a subject of fundamental interest to naval architects. Historically, hydrodynamicists have been interested in determining the physical law that relates ship resistance to ship speed and hull form characteristics. Due to the complicated nature of flow around a ship hull, a satisfactory analytical method relating speed and powering requirement to hull form has not yet been developed. Model testing is still regarded by naval architects as the most reliable method, while theoretical prediction is thought of only as a supplement to model testing.

In early stage design, hull form development and powering prediction are still largely based on inspection or statistical analysis on historical data. Regression analysis has been successfully used to analyse resistance data for both random forms and methodical series. The applicability of such programs, therefore, is usually limited to certain types of hull forms. However, naval architects have always experienced the situation where the hull form parameters of their designs lay outside the data range of the available resistance prediction programs. In the absence of data for similar ships, the naval architect will often select and use a standard series which encompasses the range of parameter chosen. The use of methodical series data is a subject covered in detail in a standard text such as Lewis [111].

5.2 The Original Problem

During the past hundred years ship resistance has been predicted from the results of model experiments on the basis of Froude's assumptions:

- The total resistance may be divided into two independent components, and each component follows its own scaling law.

- Skin friction resistance may be taken to be the same as that of a flat plate with the same length and the same wetted area as the model or the ship.

According to the first assumption, in smooth water where the added wave resistance is zero, the total resistance of a ship is composed of viscous and non-viscous components. The viscous resistance, R_V, is dependent on the Reynolds number while the non-viscous or wave making resistance, R_W, is dependent on the Froude number, i.e.;

$$R_T = (R_n, F_n) = R_V(R_n) + R_W(F_n)$$

where R_n and F_n are the Reynolds and Froude numbers respectively.

Figure 5.1 shows the comparison of the various components of resistance for a model and the ship. Nevertheless, the relationships between frictional, residuary, form, viscous, wavemaking and total resistance can be seen.

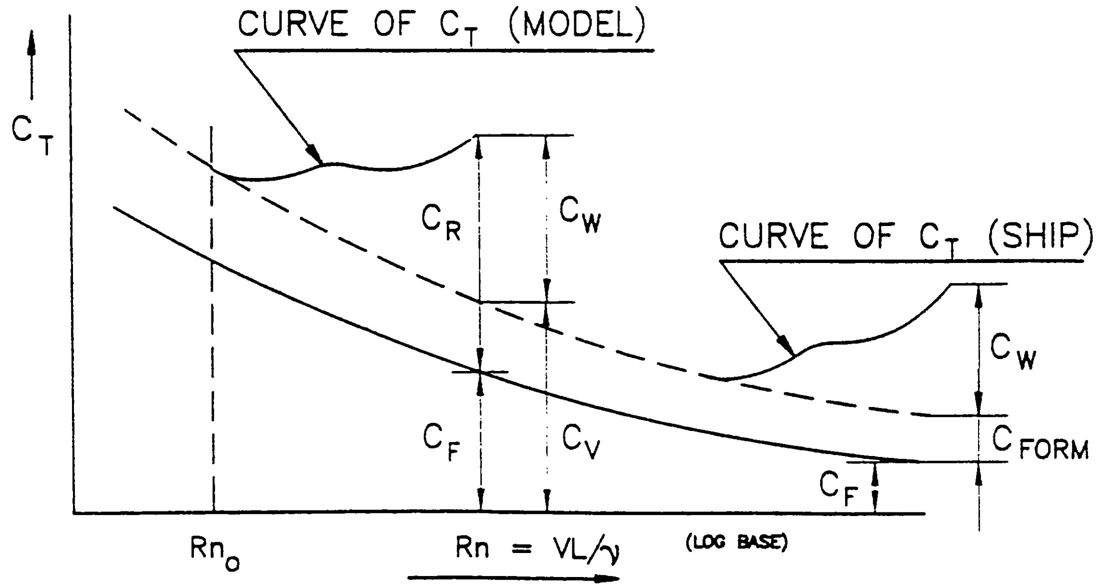


Figure 5.1 Elements of Total Resistance [112]

The second assumption has been shown to be not strictly correct and a three dimensional extrapolator should be considered. The most popular method of three-dimensional extrapolation which has been used for the prediction of ship resistance in practice is the form factor concept proposed by Hughes [113]. In this method it is assumed that the effect of form is taken into account by increasing the two-dimensional flat-plate friction coefficient by a constant percentage, and the constant percentage increase of resistance is called the form factor k.

At the 15th International Towing Tank Conference in 1978, a method called "1978 ITTC Performance Prediction Method for Single Screw Ships" was recommended for general application [114]. In this method the viscous coefficient, C_V, has been defined as:

$$C_V = (1+k)C_F$$

The form coefficient, C_{FORM}, can then be defined as $C_{FORM} = kC_F$

where k is a factor that accounts for the three-dimensional effects, and C_F is the frictional resistance coefficient as given by ITTC 1957,

$$C_F = \frac{0.075}{(\log 10 R_n - 2)^2}$$

Table 5.1 shows how each of the coefficients relates to the other, and how model results compare to full scale in both systems.

Table 5.1 Relationship of Resistance Coefficients

Displacement Vessel Resistance Components		Comparative Ship (s)-Model (m) Relationships	
Two-Dimensional	Three-Dimensional	Two-Dimensional	Three-Dimensional
Viscous $C_F = C_F$	$C_V = (1+k)C_F$ or, $C_{FORM} = kC_F$	$C_T = C_R + C_F$ Viscous $C_{Fs} < C_{Fm}$	$C_T = C_W + C_V$ $C_{Fs} < C_{Fm}$ $C_{Vs} < C_{Vm}$ $C_{FORMs} < C_{FORMm}$
Residuary $C_R = C_R$	$C_R = C_W + kC_F$ or, $C_R = C_W + C_{FORM}$	Residuary $C_{Rs} = C_{Rm}$	$C_{Rs} < C_{Rm}$ $C_{Ws} = C_{Wm}$
Total $C_T = C_R + C_F$	$C_T = C_W + C_V$	Total $C_{Ts} = C_{Fs} + C_R$	$C_{Ts} = C_{Fs} + C_{FORMs} + C_W$

The resistance components-residuary (C_R) for the two-dimensional case or wavemaking (C_W) in the three dimensional system-can be obtained from model or full scale testing and reduced into equations versus the Froude numbers. Studies have shown that use of the three-dimensional form factor method greatly improves the correlation of model results to full ship values [114]. The empirical derivation of the form factor is difficult to attain and often requires a subjective analysis of the test data. So far , no conclusive means to obtain or calculate the form factor exists. The contribution of form generally has a smaller magnitude than either wavemaking or friction, so a small error in estimating a form factor does not significantly degrade the overall prediction. Even with an inaccurate form factor, three-dimensional prediction results are generally superior to two-dimensional. An accurate analytical technique for computing the form factor is not yet available. However several empirical formulae for the estimation of form factor, as a function of ship form, have been suggested as listed:

Granville [115]

$$18.7(C_B \frac{B}{L})^2$$

Prohaska [116]

$$0.11 + 0.128\frac{B}{T} - 0.0157(\frac{B}{T})^2 - 3.10(\frac{C_B}{L/B}) + 28.80(\frac{C_B}{L/B})^2$$

Gross and Watanabe [117]

$$0.017 + 20.0\frac{C_B}{(L/B)^2(B/T)^{1/2}}$$

A more detailed list is given by Gross and Watanabe [117]

5.3 The Methods of Prediction of the Ship Wave Resistance

As stated in the previous section ship resistance mainly consists of viscous resistance and wave resistance. The viscous resistance is dependent on the area of wetted surface of the hull and not influenced so much by the form of the hull. On the contrary, wave resistance is influenced strongly by the hull form. Therefore one of the most important tasks in the initial design is to predict the wave resistance accurately. It has been one of the most important problems of ship hydrodynamics to find the laws of variation of wave resistance according to hull form and ship's speed. The wave resistance theory began with J.H. Michell's study reported in 1898 [118]. Since then many researchers have investigated the laws theoretically, and experimentally.

There are several methods at present to predict wave resistance or residual resistance for given ship forms and ship speed, which may be classified as:

(1) The method of estimation on the basis of comparison of the resistance characteristics of type ships.
(2) The method of estimation by charts derived from systematic series test results.
(3) The method of estimation by regression formulae based on tank test results of various ship forms.
(4) The method of estimation based on theoretical calculation of wave resistance.

The first method is most popular and is useful for the design of ships when appropriate type ship data are available. It is not easy, however, to find a way to improve a hull form better than type ships without enough information on the relation between the resistance and hull forms.

The second method are available the charts of Ridgley-Newitt [119, 120, 121], Todd [122] and so on. In these charts, residual resistance is represented graphically versus speed-length ratio with hull parameters.

The third method is applied for analysis of the results of model experiments of fishing boast by Doust and O'Brien [123], Doust [9, 10], Hayes and Engvall [124], and Tsuchiya [125]. Doust, compiled resistance data for 130 sets of trawler resistance data and successfully used multiple regression for resistance predictions. Later in 1962, he extended his research to cargo type ocean-going vessels based on two hundred models and proved certain capabilities in using regression analysis for trawler hull form optimization. The basic hull form parameters of the Doust's trawler regression equations were length-beam ratio (L/B), beam-draft ratio (B/T), midship section coefficient (C_M), prismatic coefficient (C_P), longitudinal buoyancy (LCB), and half entrance angle (α_e). Sabit [126, 127], reported the regression formulae obtained by the analysis of the Series 60 and BSRA Series. These regression formulae are generalised as follows:

$$\begin{aligned} C_t &= f(x_1, x_2, x_3, \ldots\ldots, x_n) \\ &= \sum_{i=0}^{m} a_i x_j^{\alpha} x_k^{\beta} \end{aligned}$$

where

C_t	:	Total resistance coefficient
a_i	:	Regression coefficient
α, β	:	0 or positive integer
m	:	The number of the terms of regression equation
x_j	:	Independent variable

The introduced independent variables are grouped into three classes

(1) Ratios of principal dimensions

$L / \nabla^{1/3}$, L / B, B / T, C_B, C_P, C_M

(2) Variables representing shapes of prismatic curves and water-lines

C_P, LCB, $\frac{1}{2}\alpha_e$, $\frac{1}{2}\alpha_r$, $\frac{1}{2}\alpha_{BS}$, trim

where

$\frac{1}{2}\alpha_e$: The angle which the water-line makes the centre line of the model at the stem.

$\frac{1}{2}\alpha_r$: The maximum angle of run up to and including the designed floating water-line. This angle is measured at a section 5 percent of the water-line length forward of the aft end of L.

$\frac{1}{2}\alpha_{BS}$: Maximum buttock slope of the 1/4 beam buttock measured relative to the floating water-lines.

(3) Others

Blockage correction term

Section area of a bar or wooden keel

In this prediction method, many model test data are used effectively, and the equation can be applied to improving ship hull forms. It was reported that the method was used in designing trawlers and they showed good performance relative to vessels designed by the previous methods (1) and (2).

The regression equations used in above method are determined with purely statistical analysis, each term of the equations has not always a physical meaning.

Therefore this method leaves some room for improvement by means of theoretical consideration.

The fourth method was first reported by Havelock [128, 129]. He replaced the wave making characteristics of the ship form by two-dimensional pressure disturbance and calculated the wave resistance of such a pressure disturbance. After some simplification, he found

$$R_W = \alpha e^{-\frac{m}{9c^2}} + \beta(1 - \gamma \cos\frac{n}{c^2})e^{-\frac{m}{c^2}}$$

where

R_W : Wave resistance of a ship

c : Speed length ratio

m, n : Universal constants

α, β, γ: Constants depend upon the form of the ship

He showed that despite of the limitations of theory and the difficulty of interpretation of experimental data, a good quantitative agreement was found in several cases with the published results of tank experiments on models when suitable numerical values were given to the coefficients in the formulae.

Numerous analytical approaches for ship resistance and performance predictions were created by Oortmerssen [24], Holtrop et al [26, 27], and instead of using the traditional least-squares fit for performance predictions, the researchers used Havelock's wave making formula as their theoretical basis (see Table 5.2). In order to simplify the required hull form inputs for performance prediction, Havelock's wave-making formula was further simplified for regression analysis.

Table 5.2 Resistance Methodologies for Displacement Hulls

NAME	SHIP TYPE	HULL FORM PARAMETERS	METHODOLOGY	SPEED RANGE
BSRA Cargo Ship Series [126]	Single screw, cruiser stern cargo ships	C_B, 0.59–0.80, B/T, 2.1–6.4	2-D C_R, ATTC, Model series	Fn 0.15-0.24
Series 60 Cargo Ship Series [127]	Single screw, cruiser stern cargo ships	C_B, 0.60–0.80, L/B, 5.5–8.5, B/T, 2.5–3.5	2-D C_R, ATTC, 67 Model series	Fn 0.10-0.27
Great Lakes Bulk Carrier Regression [133]	Single screw ships	C_B, 0.80–0.92, L/B, 6.5–10.0, B/T, 2.0–6.0	2-D C_R, ITTC-57, 50 Various models	Fn 0.11-0.18
University of Denmark Merchant Ship Method [134]	Single screw, cargo ships	C_B, 0.55–0.85, L/B, 5.0–8.0, $L/\nabla^{1/3}$, 4.0–6.0	2-D C_R, ITTC-57, Various models	Fn 0.05-0.33
UBC Trawler Series [135]	West coast fishing vessels	C_B, 0.53–0.61, L/B, 2.6–4.0, B/T, 2.0–3.0, $L/\nabla^{1/3}$, 3.0–4.5	2-D C_R (Havelock), ITTC-57, 13 Model series	Fn 0.20-0.43
BSHC Merchant Ship Method [25]	Single screw ships	C_B, 0.75–0.85, L/B, 5.0–8.0, B/T, 2.25–3.6	3-D C_W, ITTC-57, 140 Various models	Fn 0.10-0.20
Oortmerssen Small Ship Random Model Method [24]	Tugs and trawlers	C_P, 0.52–0.70, L/B, 3.4–6.2, B/T, 1.9–3.4, C_M, 0.73–0.98	2-D C_R (Havelock), ITTC-57, 93 Various models	Fn 0.05-0.50
Holtrop Random Model Method [26],[27]	Comprehensive variety of commercial and naval hulls	C_P, 0.55–0.85, L/B, 3.9–14.9, B/T, 2.1–4.0	3-D C_W (Havelock), ITTC-57, 334 Various hulls and models	Fn 0.05-1.0

Oortmerssen [24] reported the regression formulae for small ship like tugs and trawlers. He proposed a pressure distribution considering the stream-lines around a ship, and presented the wave resistance of a two-dimensional pressure distribution. After some statistical analysis of the resistance data of the tugs and trawlers, the final form of the resistance equation was presented as follows:

$$\frac{R_R}{\Delta} = C_1 e^{-\frac{m}{9}F_n^{-2}} + C_2 e^{-mF_n^{-2}} + C_3 e^{-mF_n^{-2}}.\sin F_n^{-2} + C_4 e^{-mF_n^{-2}}.\cos F_n^{-2}$$

where

$$C_i = f(\mathrm{LCB}, C_P, L/B, C_{WL}, B/T, C_M)$$

$$m = b_1 C_P^{-b_2}$$

Various Parametric studies showed that the low speed resistance prediction method developed at the BSHC [25] is a reliable resistance prediction tool. Using the three-dimensional method,

$$C_{Ts} = (1+k)C_F + C_W + C_A$$

where

C_F : ITTC-57 friction line

(1+k) : Form factor obtained from model tests by Prohaska's method [116], with C_W assumed to be proportional to $F_n^{\,6}$

$$C_A = \left[105\left(\frac{k_s}{L_{WL}}\right)^{1/3} - 0.64\right] \times 10^{-3}$$

with $k_s = 150 \times 10^{-6}$, ITTC-78 the roughness allowance

The method developed at BSHC is equivalent to the determination of 1+k by means of a curve-fitting process in which a regression equation is used:

$$C_{Tm} = (1+k)C_F + pF_n^{\ 6}$$

The frictional resistance coefficients are calculated from the ITTC-1957 formula. The form factor (1+k), representing the viscous resistance and the coefficient p is related to the wave resistance of the hull.

5.4 Hull Form Parameters and Resistance Data

In this study experimental resistance data for fishing vessels has been processed statistically. It was found that the resistance of the fishing vessels can not be predicted by existing model series data. These vessels typically have lower length-beam and length-volume ratios than previously reported model series such as the BSRA Trawler Series [130, 131], or the Webb Trawler Series [119, 120, 121]. Table 5.3 shows the comparison of vessel series parameters.

Table 5.3 Comparison of Fishing Vessel Series Parameter Ranges

SERIES	C_B		L/B		B/T	
	min	max	min	max	min	max
ITU	0.35	0.56	3.3	5.0	2.0	3.2
DOUST	0.30	0.52	4.4	5.8	2.0	2.6
BSRA	0.53	0.63	4.3	5.8	2.0	3.0
RIDGELY&NEVITT	0.40	0.53	4.4	5.8	2.0	2.6

A resistance prediction algorithms was developed by using the experimental measurements for the ITU series [23] of hull forms which were carried out at the Hydrodynamics Laboratory of the Technical University of Istanbul and experimental measurements using a Black Sea fishing vessel (KTU) as described in Chapter 3. The main geometrical particulars of the models for both lightship and loaded drafts are given in Table 5.4.

Table 5.4 Principal Dimensions of Series Models

Principal Dimensions of Series Models at Lightship Draft

MODEL	L [m]	L/B	B/T	C_B	C_M	C_P	C_{WP}	%LCB	S [m^2]	$L/\nabla^{1/3}$
ITU/1-B	2.00	3.50	2.50	0.378	0.661	0.572	0.731	-4.150	1.261	4.324
ITU/2-B	2.00	3.50	2.50	0.535	0.893	0.599	0.789	-0.049	1.398	3.853
ITU/3-B	2.00	3.50	2.50	0.406	0.669	0.607	0.727	-3.999	1.250	4.221
ITU/4-B	2.00	3.50	2.50	0.497	0.889	0.559	0.789	-0.096	1.341	3.949
ITU/5-B	2.00	3.50	2.50	0.444	0.721	0.616	0.745	-3.146	1.310	4.101
ITU/6-B	2.29	4.00	2.50	0.400	0.669	0.598	0.727	-3.980	1.455	4.639
ITU/7-B	2.29	4.00	2.50	0.491	0.888	0.553	0.789	-0.087	1.525	4.335
ITU/8-B	2.86	5.00	2.50	0.404	0.669	0.604	0.727	-3.990	1.794	5.366
ITU/9-B	2.86	5.00	2.50	0.493	0.888	0.555	0.789	-0.105	1.908	5.022
ITU/3-K	2.00	3.50	2.50	0.401	0.699	0.574	0.681	-3.306	1.215	4.243
ITU/4-K	2.00	3.50	2.50	0.499	0.894	0.558	0.748	0.009	1.299	3.946
KTU/1-K	2.16	3.38	4.00	0.446	0.634	0.704	0.798	-0.681	1.331	4.676

Principal Dimensions of Series Models at Loaded Draft

MODEL	L [m]	L/B	B/T	C_B	C_M	C_P	C_{WP}	%LCB	S [m^2]	$L/\nabla^{1/3}$
ITU/1-B	2.03	3.48	2.04	0.441	0.712	0.619	0.753	-5.801	1.502	3.829
ITU/2-B	2.03	3.56	2.00	0.581	0.915	0.635	0.836	-1.229	1.640	3.520
ITU/3-B	2.03	3.48	2.04	0.457	0.729	0.627	0.747	-5.359	1.500	3.785
ITU/4-B	2.03	3.56	2.00	0.564	0.911	0.619	0.836	-1.377	1.590	3.554
ITU/5-B	2.03	3.48	2.04	0.494	0.718	0.688	0.753	-4.474	1.568	3.688
ITU/6-B	2.32	3.97	2.04	0.455	0.728	0.625	0.749	-5.390	1.736	4.136
ITU/7-B	2.32	4.06	2.00	0.549	0.912	0.602	0.838	-1.370	1.815	3.913
ITU/8-B	2.89	4.95	2.04	0.458	0.728	0.629	0.751	-5.399	2.141	4.777
ITU/9-B	2.89	5.06	2.00	0.559	0.912	0.613	0.840	-1.385	2.266	4.505
ITU/3-K	2.06	3.54	2.04	0.436	0.748	0.583	0.709	-4.313	1.458	3.883
ITU/4-K	2.06	3.60	2.00	0.540	0.915	0.590	0.803	-0.834	1.563	3.634
KTU/1-K	2.22	3.38	3.29	0.477	0.663	0.719	0.806	-1.463	1.561	4.284

5.5 Resistance Prediction

Resistance prediction algorithms were developed by a regression analysis of the model test data for two loading conditions. The first algorithm is based on the method developed at the Bulgarian Ship Hydrodynamics Centre (BSHC) [25] for single-screw merchant ship hull forms and the second algorithm is based on the method developed by Oortmerssen [24] for the analysis of small vessels.

5.5.1 Resistance Prediction Using the BSHC Method

It was decided to develop a regression formula as a function of hull form coefficients and LCB. These parameters are usually used at the feasibility studies and initial design stages. As described in the previous section a regression equation is used:

$$C_{Tm} = (1+k)C_F + pF_n^{\ 6} \tag{5.1}$$

The relationship of the coefficients (1+k) and p was determined from regression analysis of the model test data for two loading conditions [132]. The coefficients obtained for lightship draft conditions are given in Table 5.5a and loaded draft conditions are given in Table 5.5b. The plots in Appendix C labelled as "Predict.[1]" refer to the predictions by BSHC method.

Table 5.5a Coefficients for Regression Formulae for Lightship Draft

1+k		P	
Term	Coefficient	Term	Coefficient
1	1.83981	1	-6.90736
$C_B/(L/B)^2 x(B/T)^2$	-1.51985	C_B	19.06449
$(B/T)xLCB$	0.05906	$C_B^{\ 2}xLCB$	2.23878
		C_PxLCB	0.27873
		$(C_BxLCB)^2$	1.53035

Table 5.5b Coefficients for Regression Formulae for Loaded Draft

1+k		P	
Term	Coefficient	Term	Coefficient
1	1.26689	1	-9.92956
$C_B/(L/B)^2 x(B/T)^2$	63.93207	C_B	20.36966
$(B/T)xLCB$	0.01702	$C_B^{\ 2}xLCB$	-1.40959
		C_PxLCB	-1.94611
		$(C_BxLCB)^2$	-0.86215

5.5.2 Resistance Prediction Using the Oortmerssen Method

The Oortmerssen method is based on Havelock's theory in which the wave resistance is represented as a two-dimensional pressure distribution. The equation developed by Oortmerssen is given as:

$$\frac{R_R}{\Delta} = C_1 e^{-\frac{m}{9}F_n^{-2}} + C_2 e^{-mF_n^{-2}} + C_3 e^{-mF_n^{-2}}.\sin F_n^{-2} + C_4 e^{-mF_n^{-2}}.\cos F_n^{-2} \qquad (5.2)$$

Where

$$C_i = d_{i,0} + d_{i,1}\frac{L}{B} + d_{i,2}\frac{B}{T} + d_{i,3}C_P$$

and

$$m = 0.14347 C_P^{-2.1976}$$

The coefficients $d_{i,j}$ were determined from regression analysis of the model test data. Two sets of coefficients were computed for different loading conditions. The coefficients obtained for lightship draft conditions are given in Table 5.6a and loaded draft conditions are given in Table 5.6b.

Table 5.6a Coefficients for Regression Formulae for Lightship Draft

i=	1	2	3	4
di,0	0.03821	2.69144	-0.09730	-0.68604
di,1	0.00200	-0.09159	0.02100	0.07257
di,2	0.00294	0.21021	0.16701	-0.07050
di,3	-0.08727	-4.13822	-0.86638	0.89574

Table 5.6b Coefficients for Regression Formulae for Loaded Draft

i=	1	2	3	4
di,0	0.00595	1.71004	-0.62381	-0.75875
di,1	0.00117	-0.05006	0.04846	0.03713
di,2	-0.00455	0.12285	-0.00636	-0.12473
di,3	0.00225	-2.42259	0.63588	1.38515

The results from the Oortmerssen method are labelled as "Predict.[2]". The predicted resistance values are found to match well with the experimental data for all models at lightship condition.

An algorithm for the estimation of the wetted surface areas is given below:

$$S = L(2T + B)\sqrt{C_M}(c_1 + c_2 C_B + c_3 C_M + c_4 \frac{B}{T} + c_5 C_{WP}) \tag{5.3}$$

Where

$c_1 = 0.719721$ $\quad$ $c_4 = -0.002813$

$c_2 = 0.521755$ $\quad$ $c_5 = 0.316401$

$c_3 = -0.601034$

The coefficients were derived using the data given for two different draft conditions.

The accuracy of the resistance algorithms is shown in Appendix C. The Oortmerssen method was found to give a better fit to the model test data which corresponds to the light ship condition whereas the algorithm based on the BSHC method agrees better with experiments in the loaded draft condition.

The experimental resistance values have been preliminary extrapolated to the full-scale ship. In addition resistance calculations were also carried out using the Holtrop-Mennen [26, 27] method for the parent hull form KTU/1-K. Figure 5.2 show the comparison of total resistance coefficient obtained by the predicted and measured values for the loaded draft.

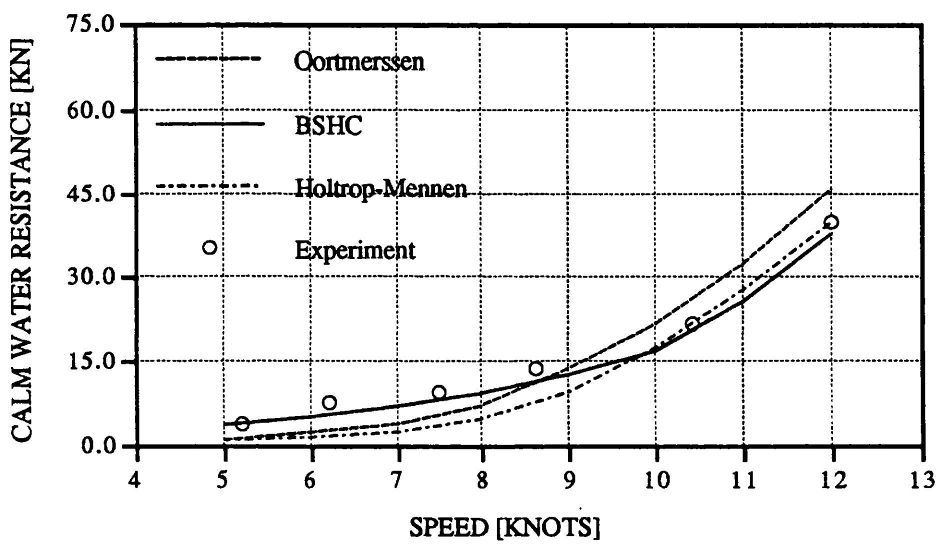


Figure 5.2 Comparison of Measured and Predicted Resistance for KTU/1-K

5.6 Resistance Index and Regression Analysis

Using the coefficients for the regression formula obtained by using the BSHC method for the loaded draft (see Table 5.5b), the calm water resistance calculation was carried out for the series of 159 hull forms at 5, 10 and 15 knots. The values obtained were then indexed using a method similar to the method described in the previous chapter. A computer program called INDEX-CR was developed to calculate the calm water resistance index for all the forms analysed. The results are given in Table B.24a and Table B.24b.

It was decided that the calculated calm water resistance index could be approximated by the hull form parameters that are used in seakeeping calculations. By applying a linear regression analysis to the series of ship hull forms, an equation for the R_{CR} was obtained as follows:

$$\begin{aligned} R_{CR} = {} & 34.404 - 3.658\ C_P - 19.607\ C_{WP} - 26.156\ C_{VP} + 1.342\ (L/B) \\ & + 1.075\ (B/T) - 1.159\ (L/\nabla^{1/3}) - 1.242\ LCB \\ & + 1.613\ (C_P\ LCB) + 0.135\ LCF \end{aligned} \tag{5.4}$$

It was found that as the L/B, B/T values become larger and the position of LCF gets closer to the midship the calm water resistance becomes smaller.

5.7 Conclusions

Experimental resistance data for fishing vessels have been processed statistically and resistance prediction algorithms developed. It was found that the algorithm based on Oortmerssen's method gives better agreement with the experiments in the lightship condition whereas the algorithm based on the BSHC method agrees better with experiments in the loaded draft condition. The resistance algorithm will be useful for estimating the resistance of small size displacement vessels.

CHAPTER 6

OPTIMISATION

6.1 Introduction

The development of high-speed computers has made possible significant changes in the ship design process. One of these is the availability of various mathematical programming methods for use in design optimisation. In order to obtain the best engineering solutions combined with high efficiency of ships expected to operate in severe conditions their design requires optimisation. The optimisation procedures are numerical methods by which the design alternative that yields a maximum or minimum (optimum) value of a specified criterion (objective function) can be selected from all those which satisfy a design model under the prescribed constraints.

Optimisation procedures in design for seakeeping have been used for some years. The first complete seakeeping optimisation method was defined by Bales [20]. By that time the analytical tools available to the profession were shown to be reliable enough to be used for optimisation purposes, whereas seakeeping experiments could not be used for the same purpose due to the excessive time and cost involved. van Oortmerssen and Oossanen [136] presented a modern computer aided ship design methodology and reported the need for a compact hydrodynamic design tool in such methodologies: *"Presently a series of new programs for the direct generation of a hull form have become* *available on the market. Most of these programs can be described as very user-friendly draughting tools to define arbitrary three-dimensional forms. The design of the hull form, however, is strongly dependent on hydrodynamic requirements. Besides still water performance, seakeeping and manoeuvring characteristics are becoming more and more important (elements such as sustained speed in waves, restrictions on acceleration levels, dynamic stability, etc.). This implies that direct hull form generation should preferably be coupled in an iterative process with analytical tools to calculate and preferably optimise the hull form with respect to these hydrodynamic characteristics, at least with respect to complying with a specific sectional area curve, pre-set values of the prismatic coefficient, longitudinal centre of buoyancy, entrance angle of the design waterline, etc."*

The major factor hindering the application of optimisation techniques to the design of a ship for seakeeping is the complexity of the mathematical representation of the hydrodynamic forces and motions. Therefore, it is not surprising that little work can be found in naval architecture literature relating the application of optimisation techniques in the design of vessels in waves. In the present study a seakeeping optimisation procedure based on the regression equation with respect to hull form parameters derived in Chapter 4 was developed to obtain hull forms which have better seakeeping performance than the initial specification.

6.2 Outline of the Optimisation Procedure

An optimal solution can be found if a measure of merit function is defined. Such a function is called the objective function. The objective function must provide some comprehensive figure of merit to allow selection between the alternative designs. Similarly constraints, which may be regarded as limits to be imposed on the design, need to be specified. The optimisation problem as outlined is amenable to solution by nonlinear programming techniques. For this analysis a computer program OPTI-HULL based on the Hooke and Jeeves' direct search method was written on the VAX 3100 workstation. This method is described in the following section.

6.2.1 Direct Search Method of Hooke and Jeeves

Hooke and Jeeves [28] method is one of the most widely used direct search methods. It attempts in a simple though ingenious way to find the most profitable search directions. The method is based on two types of step-by-step searches alternating in turn, a "local search", which is unidirectional variation of each design variable resulting in the direction of steepest descent, and a "pattern move" which represents a rotation of the search direction which accelerates the search by the aid of increasing the step widths.

If we consider the problem of minimising/maximising $f(x_1,x_2,x_3,...,x_n)$, the general procedure, which is shown in Figure 6.1, can be described as follows:

(1) Start with an arbitrarily chosen initial base point $(b_1,b_2,b_3,...,b_n)$ and step lengths $(h_1,h_2,h_3,...,h_n)$ for the respective variables $(x_1,x_2,x_3,...,x_n)$.

(2) The method proceeds by a sequence of exploratory and pattern moves. The procedure for an exploratory move about the point $(b_1,b_2,b_3,...,b_n)$ is as follows:

- Evaluate $f(b_i+h_i)$. If the move from b_i to b_i+h_i is a success, replace the base point b_i by b_i+h_i. If it is a failure, evaluate $f(b_i-h_i)$. If this move is a success, replace b_i by b_i-h_i. If it is another failure, retain the original point b_i.
- Repeat the above procedure for each variable in turn finally arriving at a new base point after $(2n+1)$ function evaluations at most.
- If $b_{i+1}=b_i$, halve each of the step lengths h_i and return to first step. The calculations terminate when the step lengths have been reduced to some prescribed level. If $b_{i+1}\neq b_i$, make a pattern move from b_{i+1}.

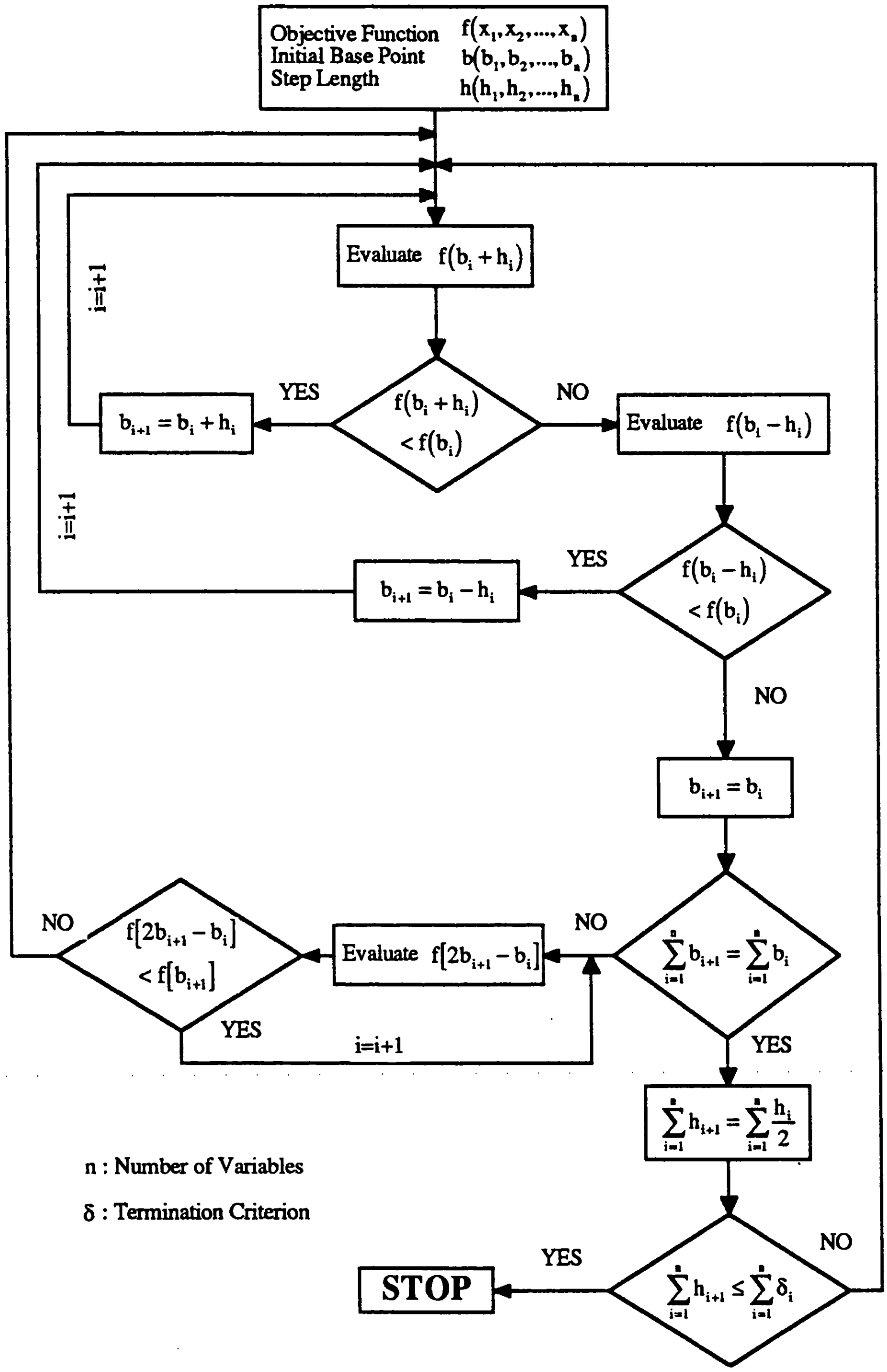


Figure 6.1 Hooke and Jeeves Direct Search Algorithm

(3) A pattern move attempts to speed up the search by using information already acquired about $f(x_1,x_2,x_3,\dots,x_n)$. It is invariably followed by a sequence of exploratory moves, with a view to finding an improved direction of search in which

to make another pattern move. The procedure for a pattern move from b_{i+1} is as follows.

- It seems sensible to move from b_{i+1} in the direction $(b_{i+1} - b_i)$, since a move in this direction has already led to a decrease in the value of $f(x_1, x_2, x_3, \ldots, x_n)$. Therefore , move from b_{i+1} to $(2b_{i+1} - b_i)$ and continue with a new sequence of exploratory moves about $(2b_{i+1} - b_i)$.
- If the lowest function value obtained during the pattern and exploratory moves of $(2b_{i+1} - b_i)$ is less than b_{i+1}, then a new base point b_{i+2} has been reached. In this case, return to $(2b_{i+1} - b_i)$ with all suffices increased by unity. Otherwise abandon the pattern move from b_{i+1} and continue with a new sequence of exploratory moves about b_{i+1}.

6.3 Application of the Optimisation Method

Having derived an analytical form of the response of a ship to an irregular seaway as a function of its underwater form, a formal optimisation problem can be formulated. In this study, the objective function f(x) is based on the estimator, R_S, of seakeeping index which is a function of selected ship form parameters as defined by (4.4). This objective function can be used for seeking of the optimal combination of involved design parameters.

6.3.1 Geometric Constraints

The proper selection of the constraints is the most essential part in the optimisation procedure. The optimisation maximises the estimator, R_S, as defined by (4.4) subject to any consistent combination of the constraints presented in Table 6.1. This table also presents the estimated values in the seakeeping index equation and the potential change in seakeeping index associated with each parameter. This data is obtained by multiplying the estimated constant for a parameter by its range. It is evident that the estimator, R_S, of seakeeping index can be used to define a hull which had parameters within the data base ranges thereof but better seakeeping characteristics than any hull in the data base. The form coefficients for such a hull can be obtained by inspection of Table 6.1.

Table 6.1 Coefficients and Characteristics of Parameters in the Seakeeping Index Equation

Parameter	Index Eq. Constants	Parameter min	Parameter max	Variable Range		Potential Change
Intercept	-57.72797	-	-	-	-	-
C_P	-21.18065	0.394	0.746	-8.336	-15.799	7.463
C_{WP}	76.31337	0.615	0.821	46.952	62.653	15.701
C_{VP}	13.20459	0.488	0.701	6.449	9.261	2.813
L/B	-6.58081	2.500	4.584	-16.452	-30.169	13.717
B/T	-3.25743	2.122	4.000	-6.911	-13.030	6.119
$L / \nabla^{1/3}$	10.43234	3.464	5.231	36.142	54.574	18.432
%LCB	0.87204	-4.150	0.009	-3.619	0.008	3.626
C_PxLCB	-1.46009	-2.423	0.005	3.538	-0.007	3.545
%LCF	0.40323	-7.853	-1.250	-3.166	-0.504	2.662

A guide-line the effect of different hull geometrical parameters on the three regression equations based on seakeeping, added and calm water resistance are presented in Table 6.2.

Table 6.2 Guide-line for Improvement of Hull Form

INDEX	C_P	C_{WP}	C_{VP}	L/B	B/T	$L / \nabla^{1/3}$	%LCB	C_PxLCB	%LCF
Seakeeping, R_S	-	+	+	-	-	+	+	-	+
Add. Res., R_{AR}	-	+	+	+	-	+	+	-	+
Calm Res., R_{CR}	-	-	-	+	+	-	-	+	+

The tendencies toward increasing seakeeping and added resistance index with increasing C_{WP}, LCB and LCF with decreasing C_P are discernible.

6.4 Optimisation Examples

Applying the above described optimisation procedure, two optimum hull forms were derived. To illustrate the process two different parent hull forms which were used in the seakeeping analysis were selected. The most intriguing question to be explored was whether or not the optimisation methodology can lead to appreciable seakeeping improvements within specified geometric limits.

The first example was carried out using parent hull form ITU/2-B (Hull 139) main dimensions and coefficients as the initial base points:

$$
\begin{aligned}
L &= 22.25\text{m} \\
C_P &= 0.599 \\
C_{WP} &= 0.789 \\
C_{VP} &= 0.677 \\
L/B &= 3.496 \\
B/T &= 2.503 \\
\%LCB &= -0.049 \\
\%LCF &= -3.037
\end{aligned}
$$

The redesign will take the displacement of the parent hull to be fixed and the beam and draught will have the maximum and minimum values allowed within given limits, respectively. The length and the coefficients will be allowed to vary over limited ranges encompassing their original values. The combination of these constraints as given in Table 6.1 can be written as follows:

$$
\begin{array}{cc}
B = 8.00 & 0.615 \leq C_{WP} \leq 0.821 \\
T = 2.00 & 0.488 \leq C_{VP} \leq 0.701 \\
20.00 \leq L \leq 30.20 & -4.15 \leq \%LCB \leq 0.009 \\
0.394 \leq C_P \leq 0.746 & -7.853 \leq \%LCF \leq -1.250
\end{array}
$$

Under these constraints, the nonlinear programming solution for the unspecified parameters were found to be as follows:

$$\begin{aligned} C_P &= 0.495 \\ C_{WP} &= 0.821 \\ C_{VP} &= 0.538 \\ L/B &= 3.406 \\ \%LCB &= -0.700 \\ \%LCF &= -1.500 \end{aligned}$$

It can be noted that waterplane area coefficient C_{WP} attained the "best" values within its specified ranges in the sense of maximising R_S in (4.4). On the other hand, C_P was driven to its poor value. Other coefficients were assigned an improved value intermediate to its range. These parameters were then used to produce a redesigned version of Hull 139 named OPTIMUM HULL 1 using the DEFORM module of the SFOLDS program as described in Chapter 4.

The second example was carried out using parent hull form ITU/4-K (Hull 74) main dimensions and coefficients as the initial base points:

$$\begin{aligned} B &= 6.51\mathrm{m} \\ T &= 2.60\mathrm{m} \\ C_P &= 0.558 \\ C_{WP} &= 0.748 \\ C_{VP} &= 0.666 \\ L/B &= 3.499 \\ B/T &= 2.501 \\ \%LCB &= 0.009 \\ \%LCF &= -1.840 \end{aligned}$$

In this example the beam, draught and coefficients of the parent form are allowed to vary under the constraints listed in Table 6.1, the displacement is kept constant and the length is fixed at 26 metres. The combination of these constraints as given in Table 6.1 can be written as follows:

$$L = 26.00 \qquad 0.615 \leq C_{WP} \leq 0.821$$
$$6.37 \leq B \leq 8.00 \qquad 0.488 \leq C_{VP} \leq 0.701$$
$$2.00 \leq T \leq 3.00 \qquad -4.15 \leq \%LCB \leq 0.009$$
$$0.394 \leq C_P \leq 0.746 \qquad -7.853 \leq \%LCF \leq -1.250$$

Hull form parameters of the final optimal form, named OPTIMUM HULL 2, were found to be as follows:

$$C_P = 0.483$$
$$C_{WP} = 0.821$$
$$C_{VP} = 0.526$$
$$L / B = 3.333$$
$$B / T = 3.545$$
$$\%LCB = -0.900$$
$$\%LCF = -1.700$$

It can be seen that OPTIMUM HULL 2 has the best combined values attained for all parameters to maximise R_S in (4.4) within the constraints applied. It can be noted that waterplane area coefficient C_{WP} attained the "best" values within its specified ranges.

As before, these parameters were then used to produce a redesigned version of a parent hull, Hull 74. The geometrical characteristics of these parent and optimum hull forms are shown in Table 6.3.

Table 6.3 Geometrical Characteristics and Seakeeping Responses of Optimisation Example

Particular	Parent Hull 1	Optimum Hull 1	Parent Hull 2	Optimum Hull 2
Length [m]	22.25	27.25	22.78	26.00
Beam [m]	6.37	8.00	6.51	7.80
Draught [m]	2.54	2.00	2.60	2.20
L/B	3.496	3.406	3.499	3.333
B/T	2.503	4.000	2.501	3.545
C_B	0.535	0.442	0.499	0.431
C_P	0.599	0.495	0.558	0.483
C_{VP}	0.677	0.538	0.666	0.526
C_{WP}	0.789	0.821	0.748	0.821
$L / \nabla^{1/3}$	3.853	4.720	3.945	4.503
%LCB	-0.049	-0.700	0.009	-0.900
%LCF	-3.037	-1.500	-1.840	-1.700
Heave [m]	0.421	0.324 (-23%)	0.446	0.316 (-29%)
Pitch [deg]	2.668	1.897 (-29%)	3.081	2.238 (-27%)
Vert. Mot. at FP [m]	0.649	0.581 (-10%)	0.689	0.585 (-15%)
Vert. Acc. at FP [g]	0.229	0.201 (-12%)	0.247	0.217 (-12%)
Rel. Mot. at FP [m]	0.685	0.628 (-8%)	0.729	0.634 (-13%)
Seakeeping Index	6.58	**14.56**	5.60	**14.29**
Added Res. Index	7.71	**7.87**	7.33	**8.29**
Calm Res. Index	1.54	**5.94**	2.82	**6.03**

The results presented in this table indicate that the optimisation process is sensitive to the perturbation in hull dimensions.

For the validation of the optimisation procedure, seakeeping responses for the optimum hull forms were calculated and compared with those predicted for the parent hulls. The SHIPMO-PC program was used to calculate the seakeeping characteristics of these optimum hull forms and the results were used to investigate to what degree each seakeeping characteristic of the derived hull is superior to the corresponding parent hull. The calculations were carried out for 10 knots and five ship headings from 0 degrees to 180 degrees at 45 degree increments. The responses were calculated for a significant wave height of 1.3m and modal period of 5.5 seconds.

The RMS values in head seas for heave, pitch and vertical motion, vertical acceleration and relative motion at fore perpendiculars of the optimum and parent hull forms are included in Table 6.3. The optimised hull forms have a considerable reduction in all RMS values considered. Optimum hull forms 1 and 2 give respectively a reduction of 23% and 29% over their parent hull forms in heave and 29% and 27% in pitch. The reduction for vertical motion at the FP are 10% and 15%. Vertical acceleration are reduced by 12% for both hull forms and the reduction for relative motions are 8% and 13% respectively.

The comparison of the RAO's of the parent and optimum hull forms are presented in Figure 6.2 through Figure 6.15. It can be seen from these figures that the optimum hull forms are superior to the parent hull forms with the exception of roll in quartering seas and relative motion at higher wave frequencies. Figure 6.16 and 6.17 illustrate the calm water resistance comparison of the parent and optimum hull forms. These figures indicate that the seakeeping optimised forms also have better resistance characteristics than the parent hulls due to increased length of the optimal forms.

The RMS values of the optimum and parent hull forms for heave, pitch and vertical motion, heave acceleration and relative motion at fore perpendiculars with different forward speeds at different heading angles were calculated. The results are presented in the form of polar diagrams and given in Figure 6.18 through Figure 6.23. It can be seen that the superior seakeeping performance of the optimised hull forms is preserved for all speeds and heading angles.

6.5 Conclusions

A seakeeping optimisation procedure was developed using the objective function based on the estimator, R_S, of seakeeping index which is a function of selected ship form parameters. The optimisation procedure developed was applied to different parent hull forms which were used in the seakeeping analysis. Two optimum hull forms were obtained and their seakeeping responses were compared with those predicted for the parent hulls. It was found that seakeeping optimised hulls were superior to the parent hull forms. The objective function based on the estimator, R_S, of seakeeping index can be used for seeking of the optimal combination of involved design parameters. It should provide a valuable tool to a designer at the initial design stage to investigate the effect of various form parameters on seakeeping performance.

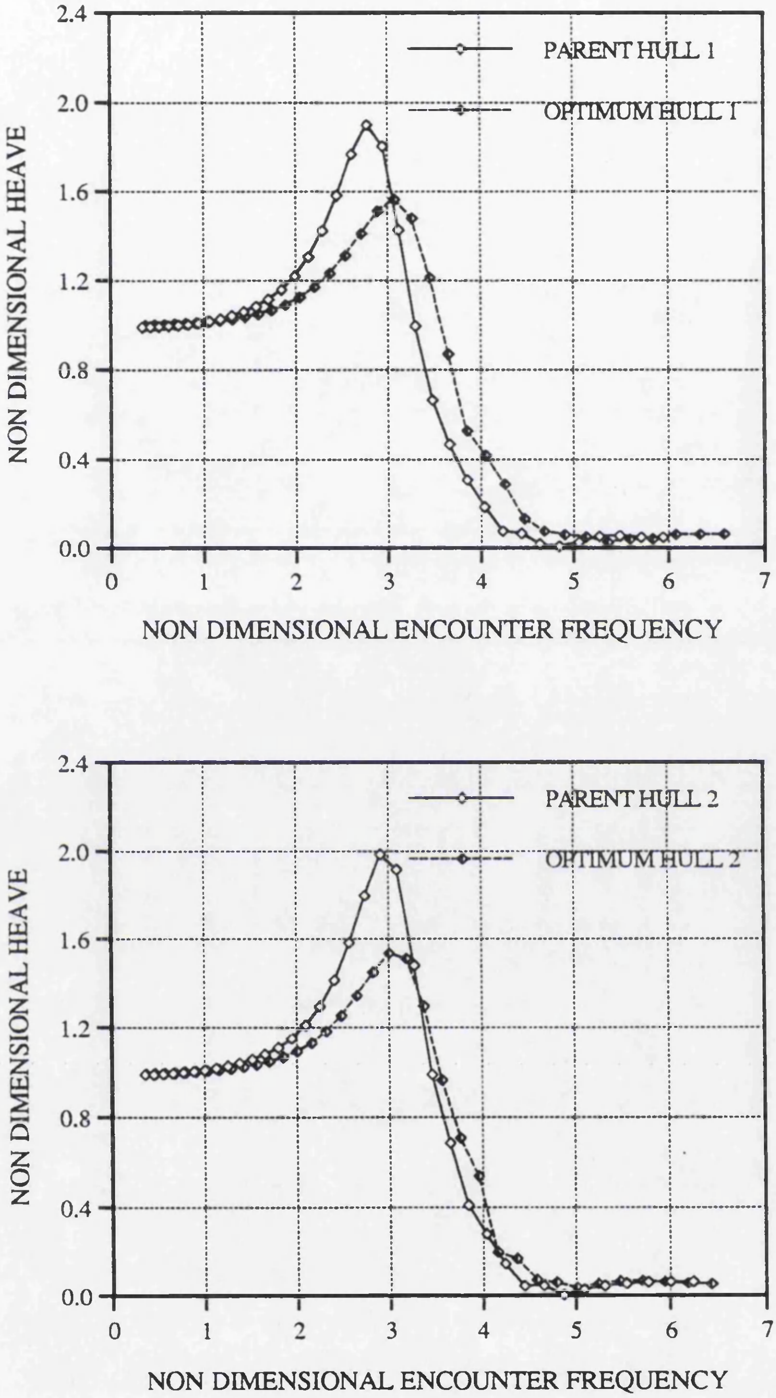
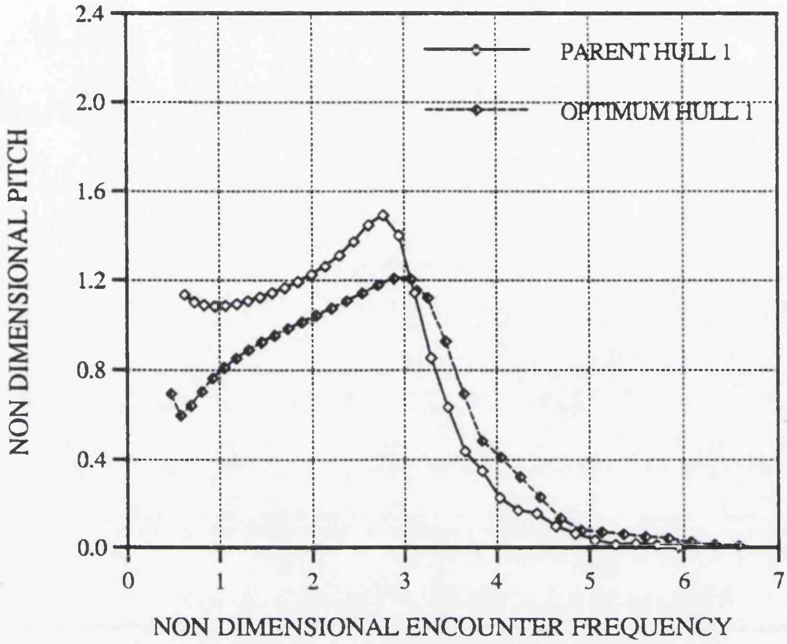


Figure 6.2 Comparison of Heave RAOs for Parent and Optimum Hull Forms in Head Seas, V=10 Knots



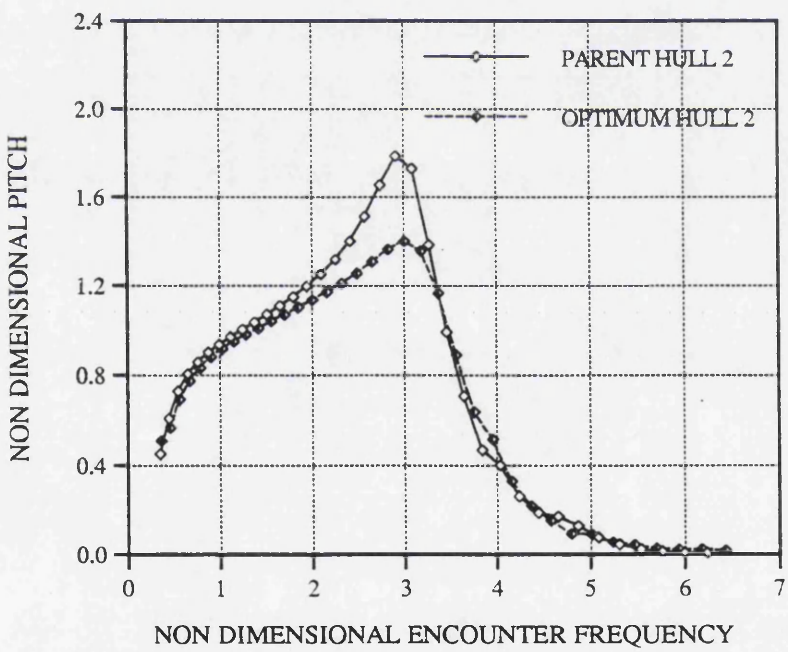
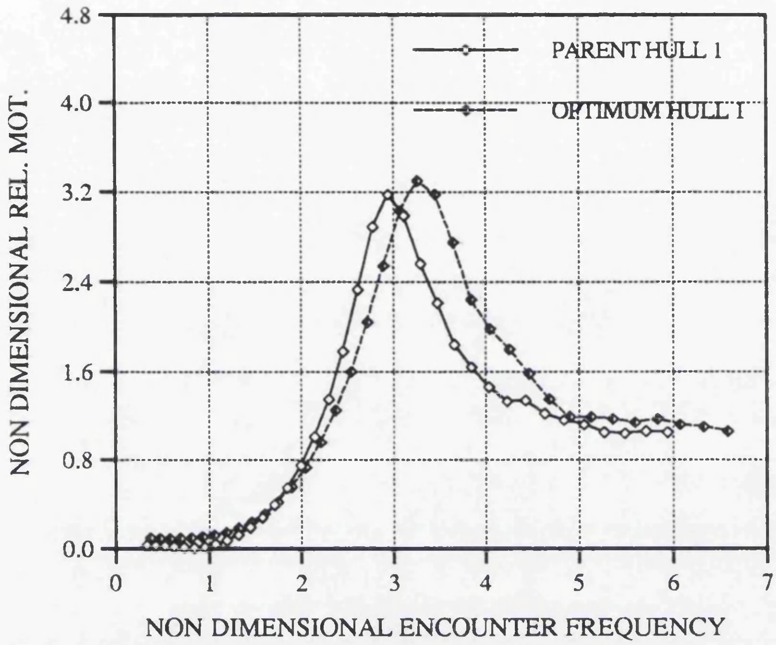


Figure 6.3 Comparison of Pitch RAOs for Parent and Optimum Hull Forms in Head Seas, V=10 Knots



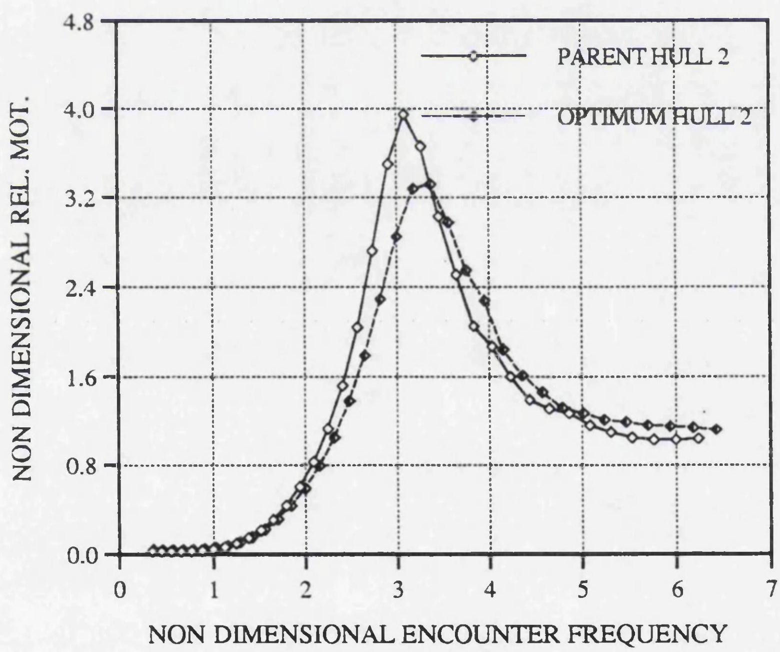


Figure 6.4 Comparison of Rel. Mot. RAOs at FP for Parent and Optimum Hull Forms in Head Seas, V=10 Knots

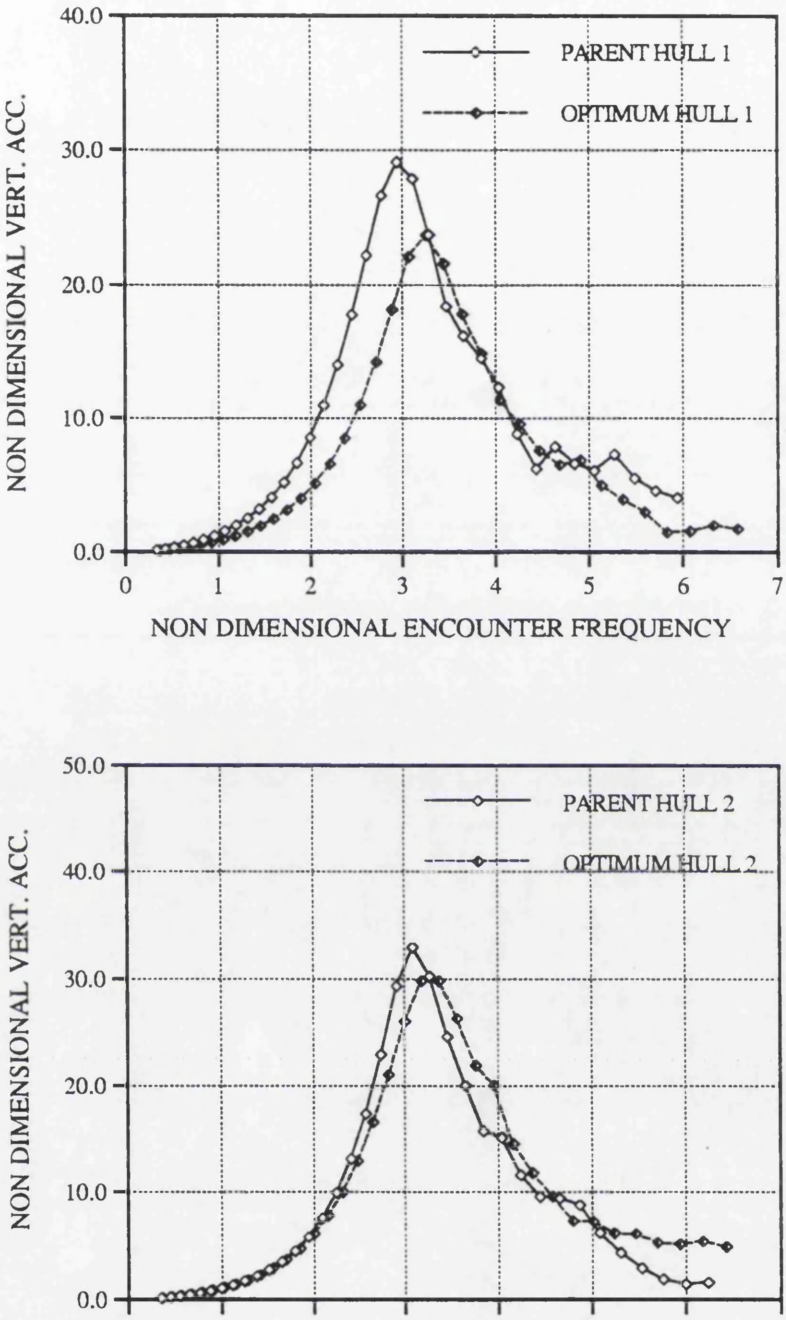


Figure 6.5 Comparison of Vert. Acc. RAOs at FP for Parent and Optimum Hull Forms in Head Seas, V=10 Knots

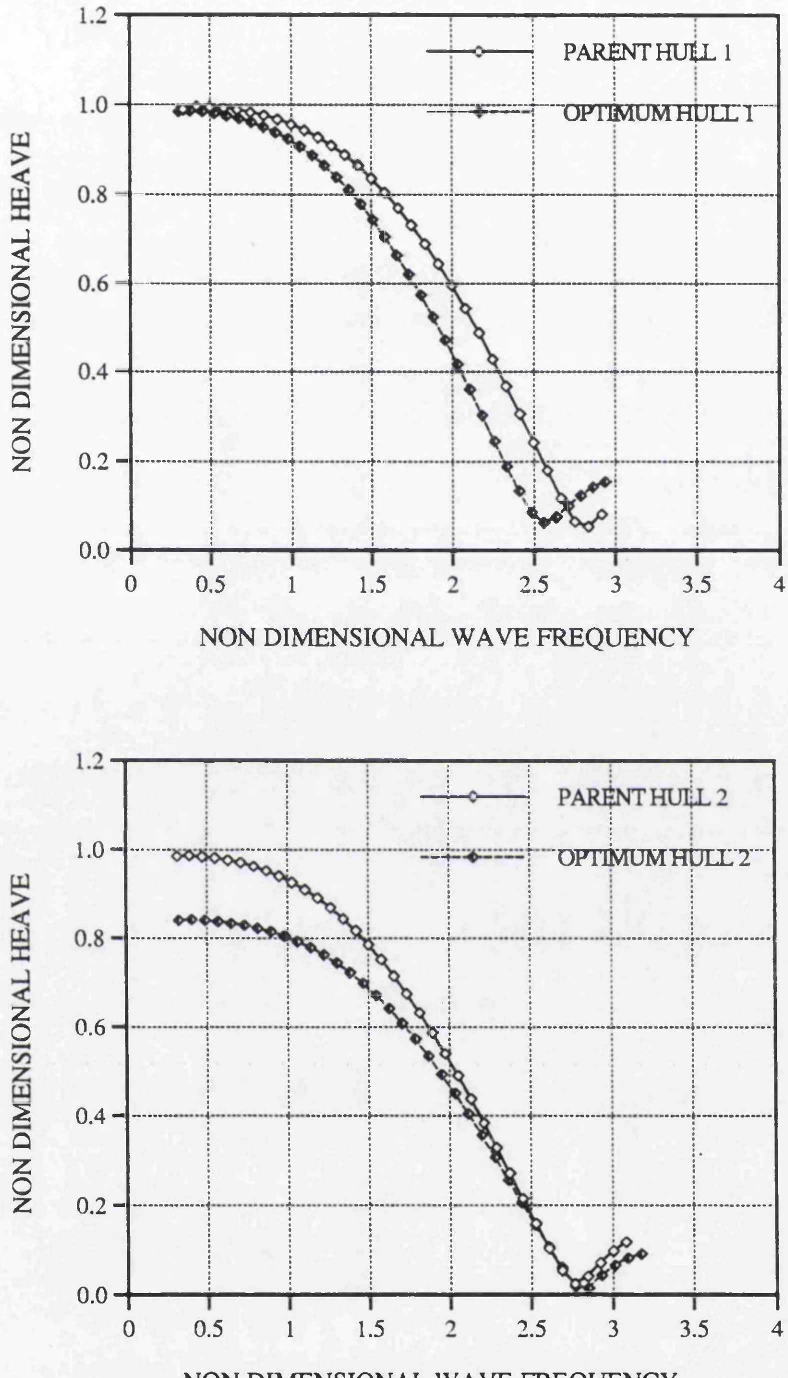
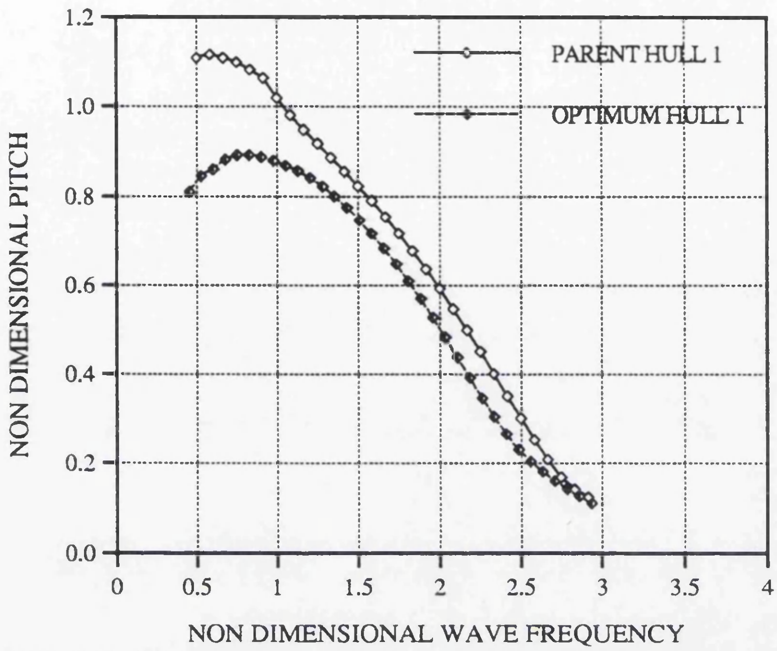


Figure 6.6 Comparison of Heave RAOs for Parent and Optimum Hull Forms in Following Seas, V=10 Knots



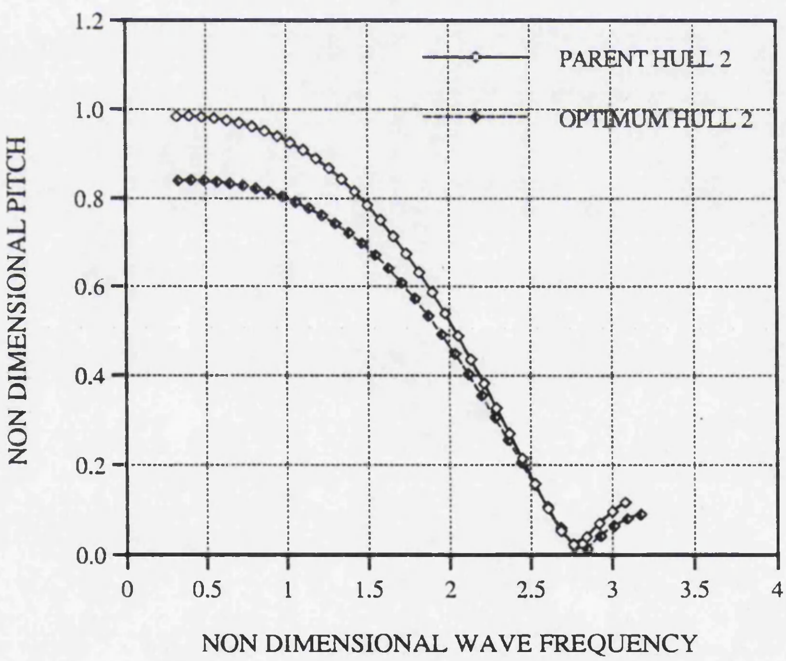
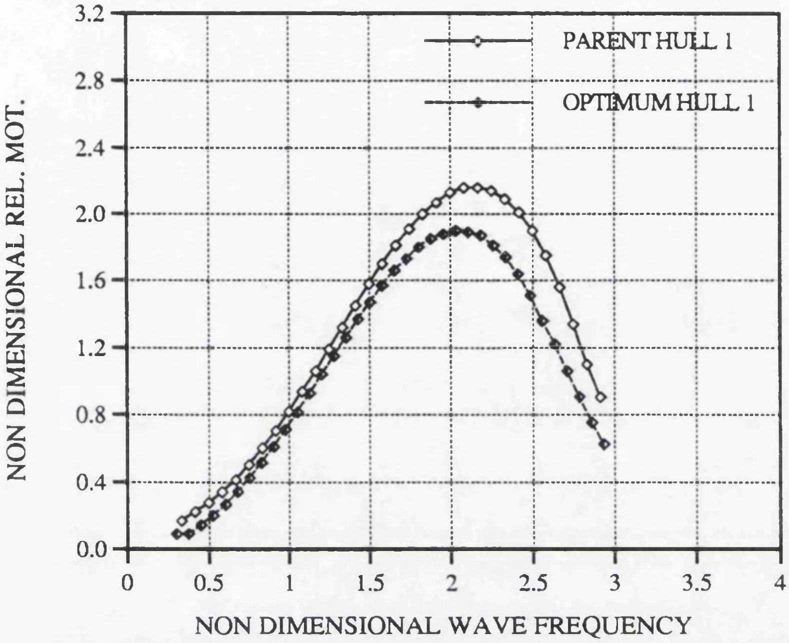


Figure 6.7 Comparison of Pitch RAOs for Parent and Optimum Hull Forms in Following Seas, V=10 Knots



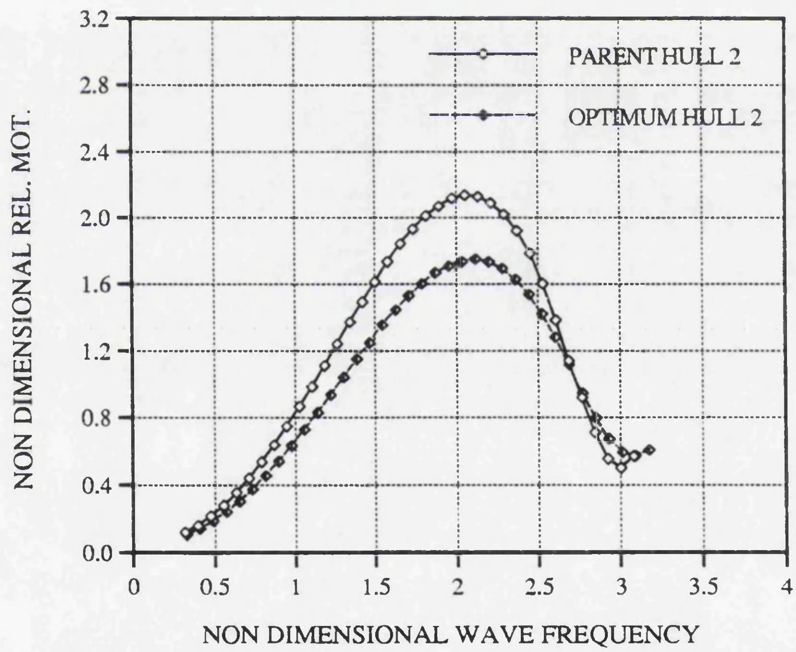
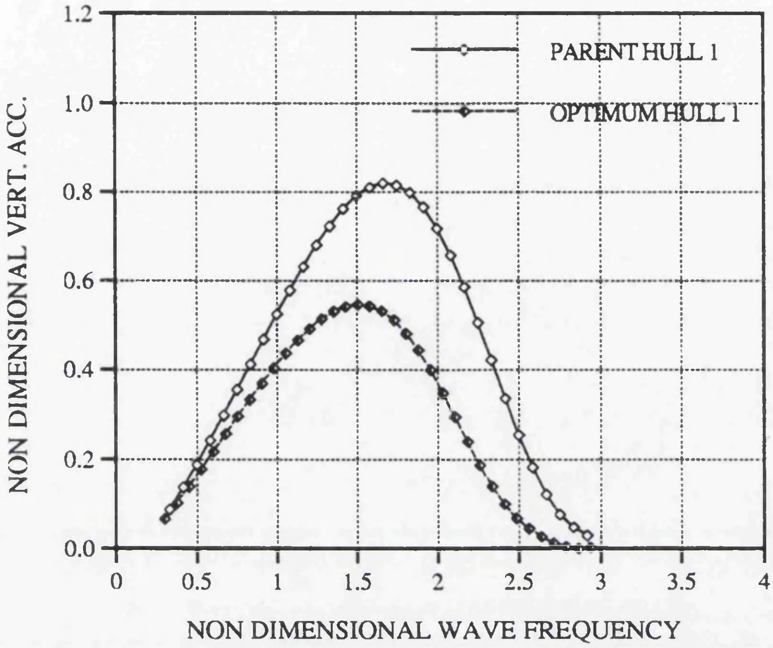


Figure 6.8 Comparison of Rel. Mot. RAOs at FP for Parent and Optimum Hull Forms in Following Seas, V=10 Knots



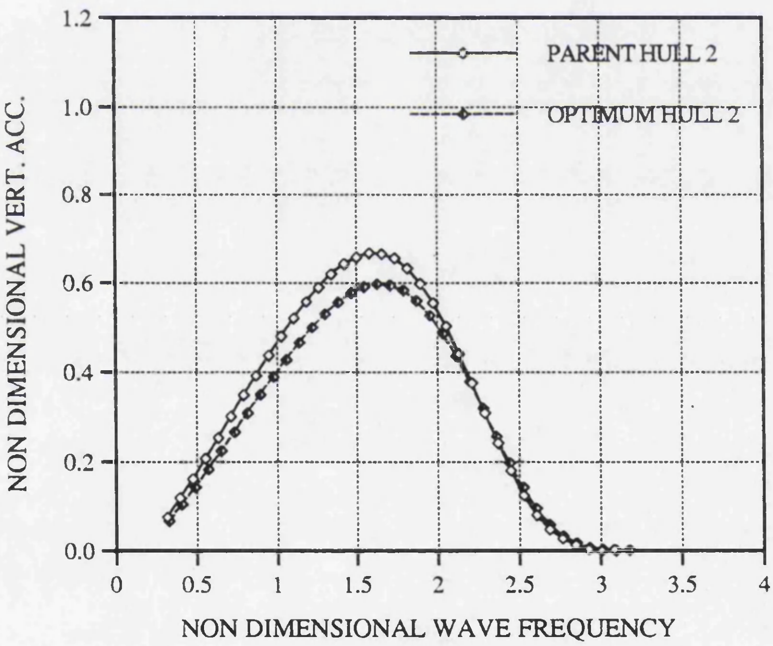
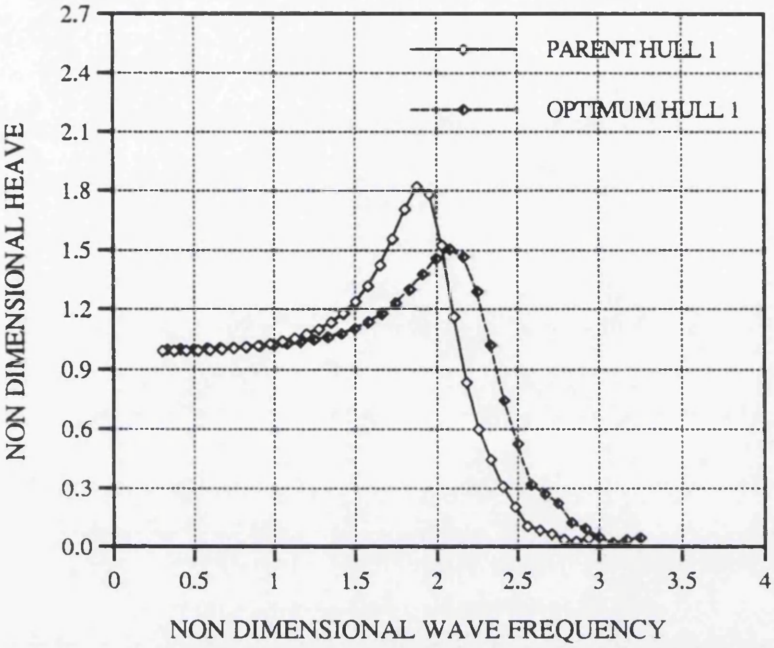


Figure 6.9 Comparison of Vert. Acc. RAOs at FP for Parent and Optimum Hull Forms in Following Seas, V=10 Knots



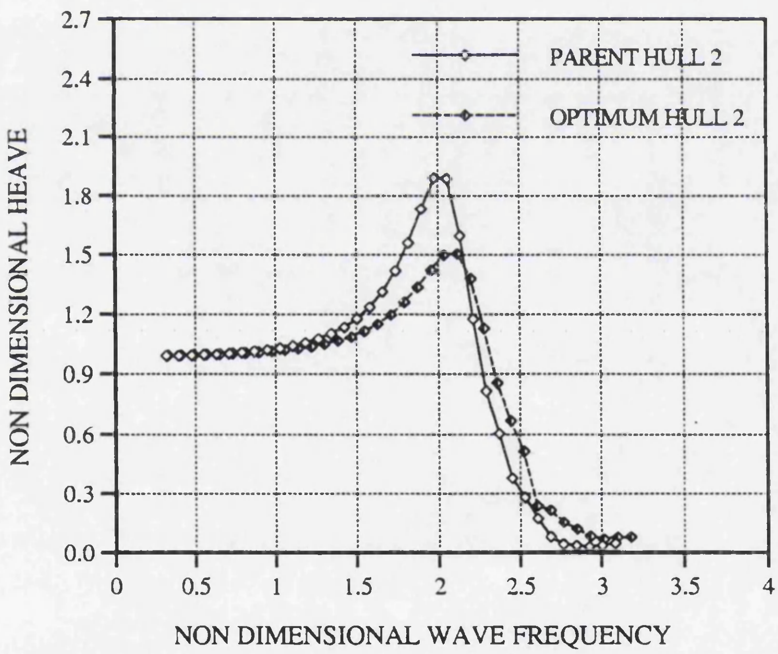


Figure 6.10 Comparison of Heave RAOs for Parent and Optimum Hull Forms in Quartering Seas, α=135 Deg., V=10 Knots

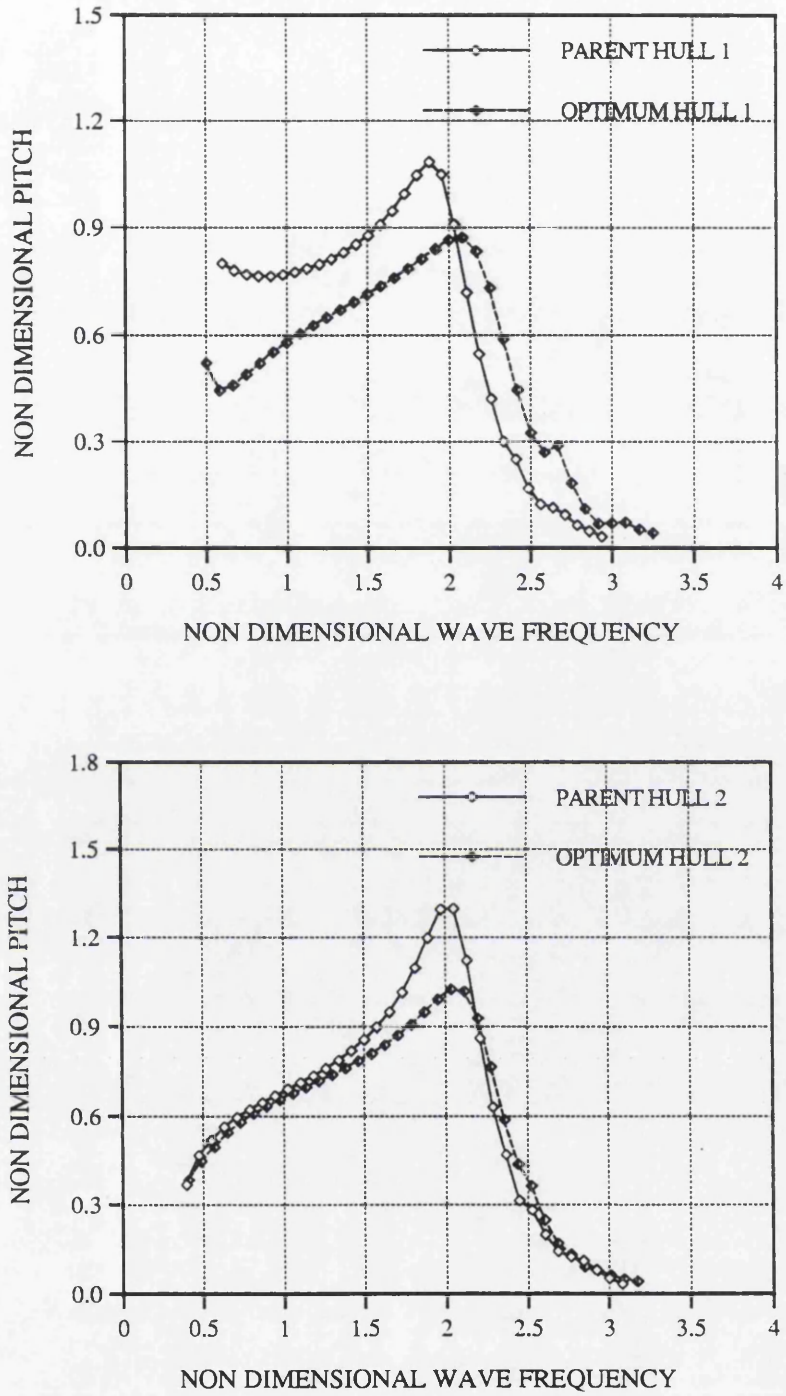
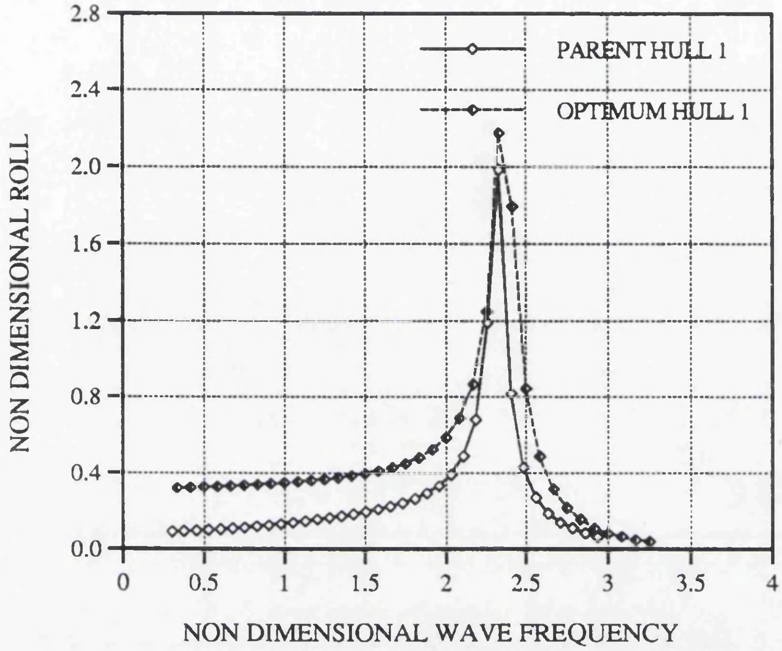


Figure 6.11 Comparison of Pitch RAOs for Parent and Optimum Hull Forms in Quartering Seas, α=135 Deg., V=10 Knots



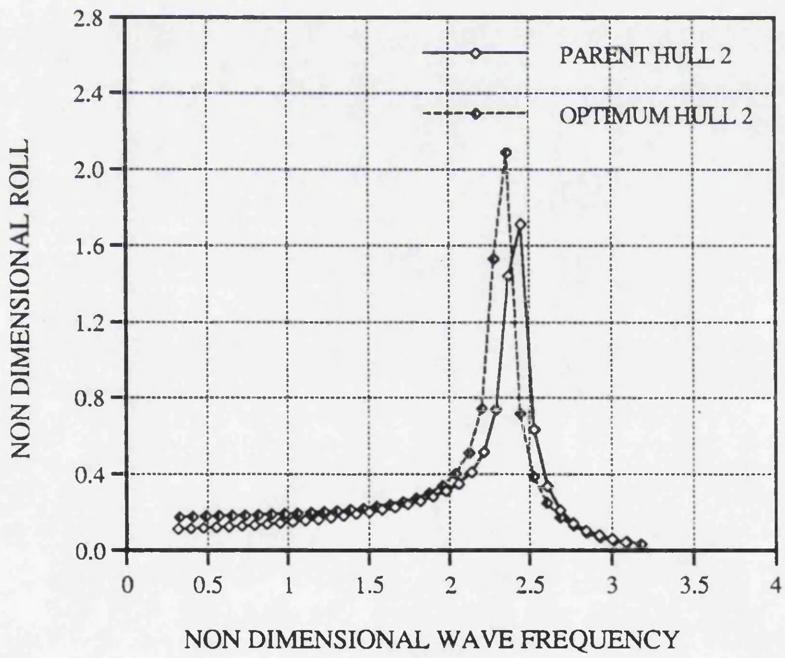


Figure 6.12 Comparison of Roll RAOs for Parent and Optimum Hull Forms in Quartering Seas, α=135 Deg., V=10 Knots

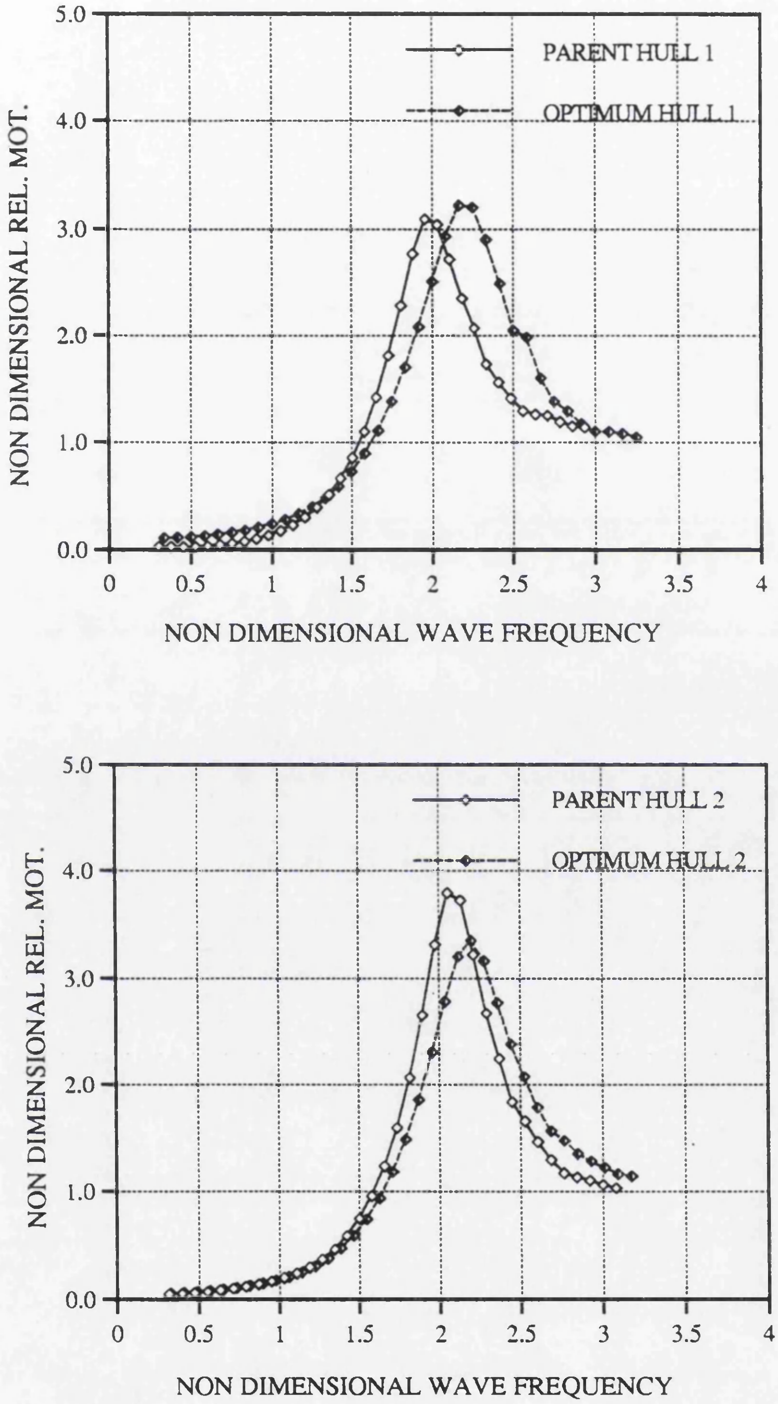
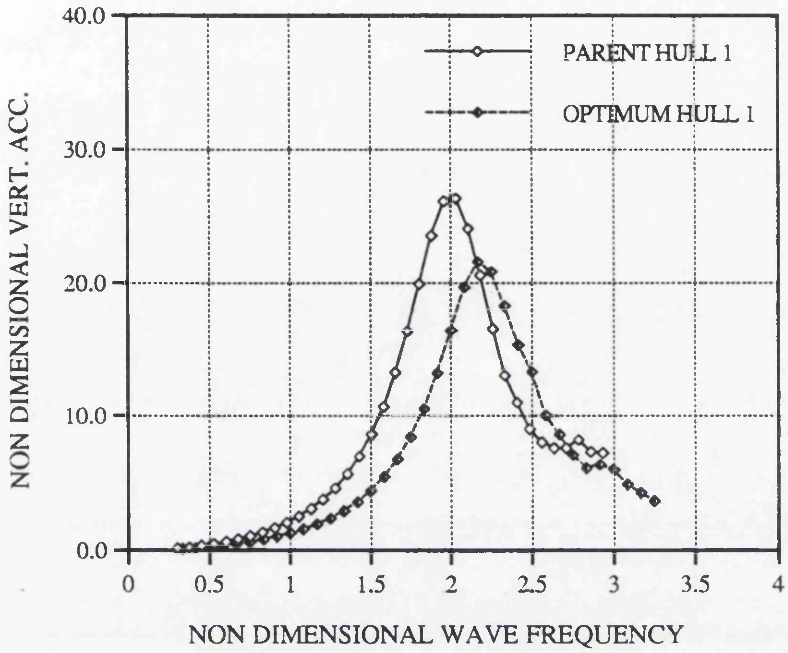


Figure 6.13 Comparison of Relative Motion RAOs at FP for Parent and Optimum Hull Forms in Quartering Seas, α=135 Deg., V=10 Knots



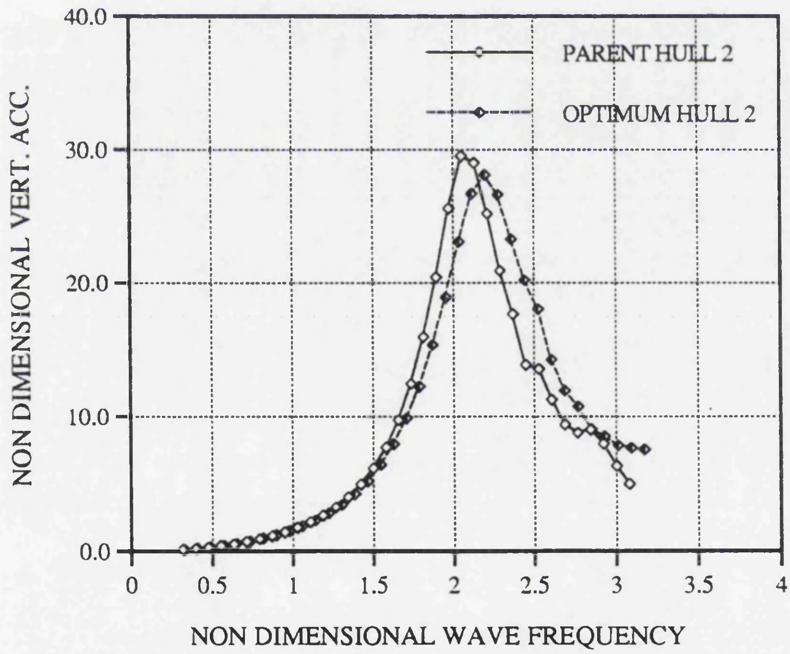
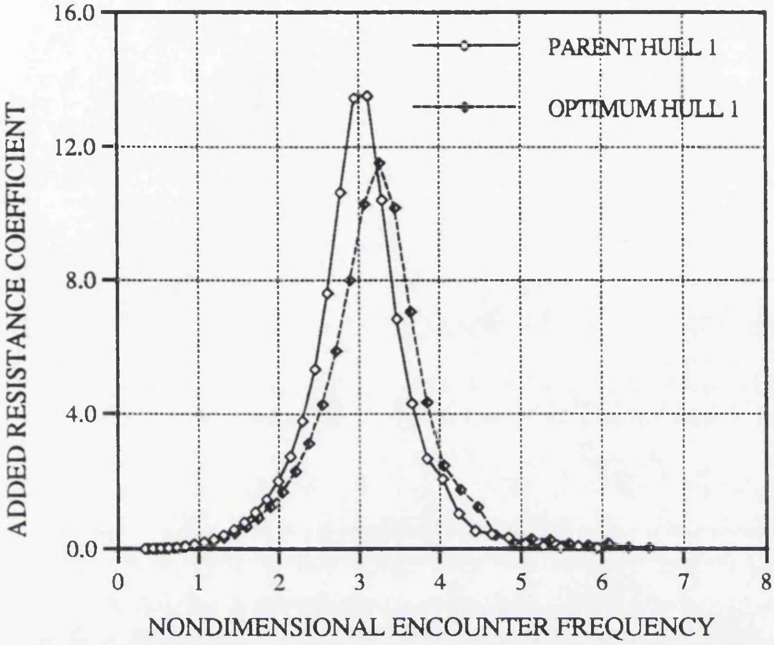


Figure 6.14 Comparison of Vertical Acceleration RAOs at FP for Parent and Optimum Hull Forms in Quartering Seas, α=135 Deg., V=10 Knots



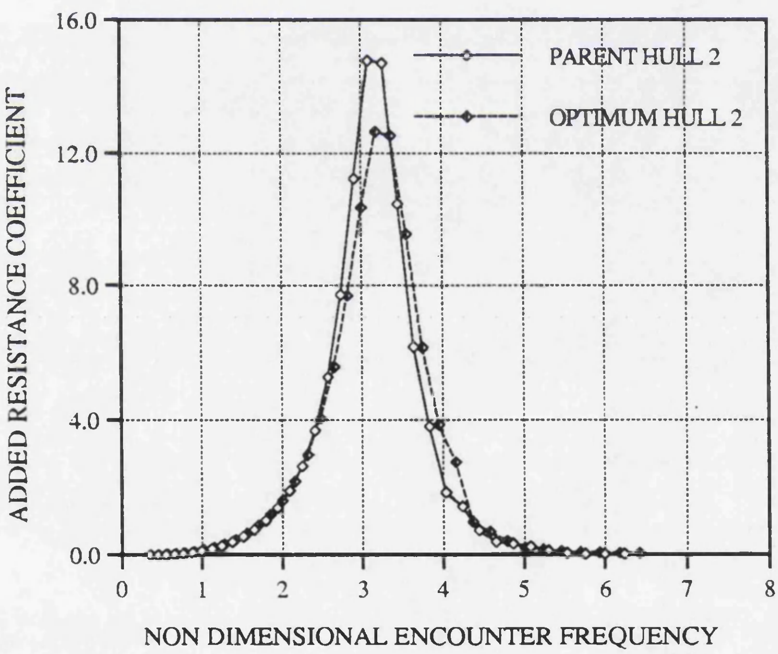


Figure 6.15 Comparison of Added Resistance RAOs for Parent and Optimum Hull Forms in Head Seas, V=10 Knots

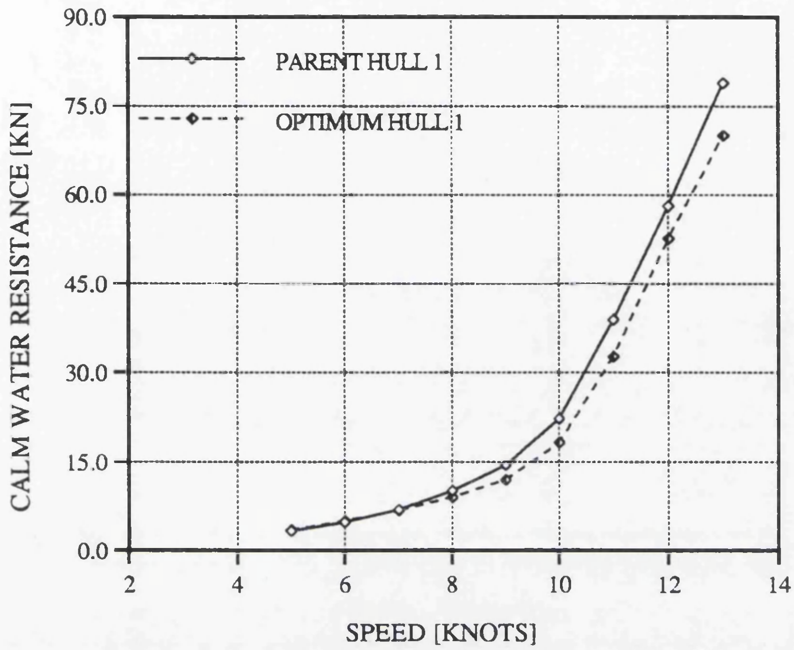


Figure 6.16 Resistance Comparisons for Parent and Optimum Hull Forms

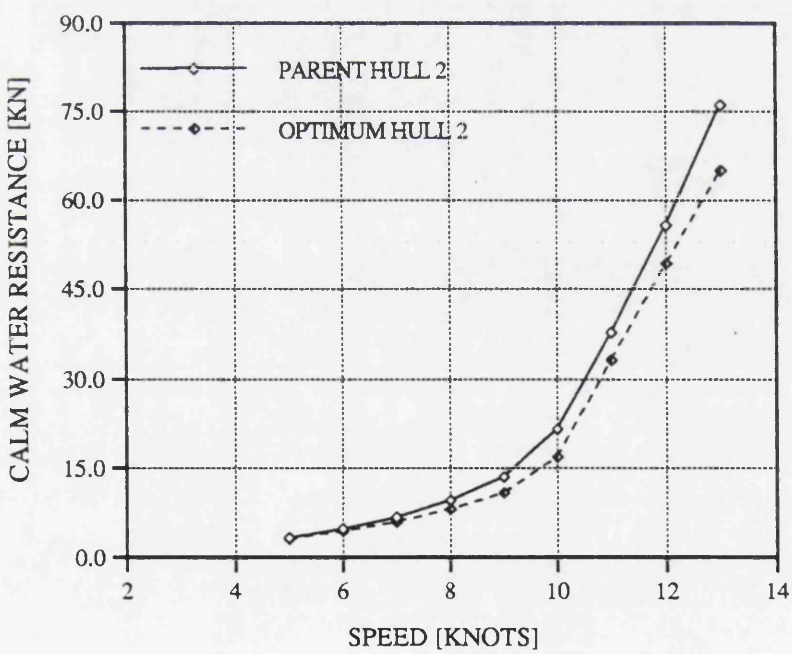


Figure 6.17 Resistance Comparisons for Parent and Optimum Hull Forms

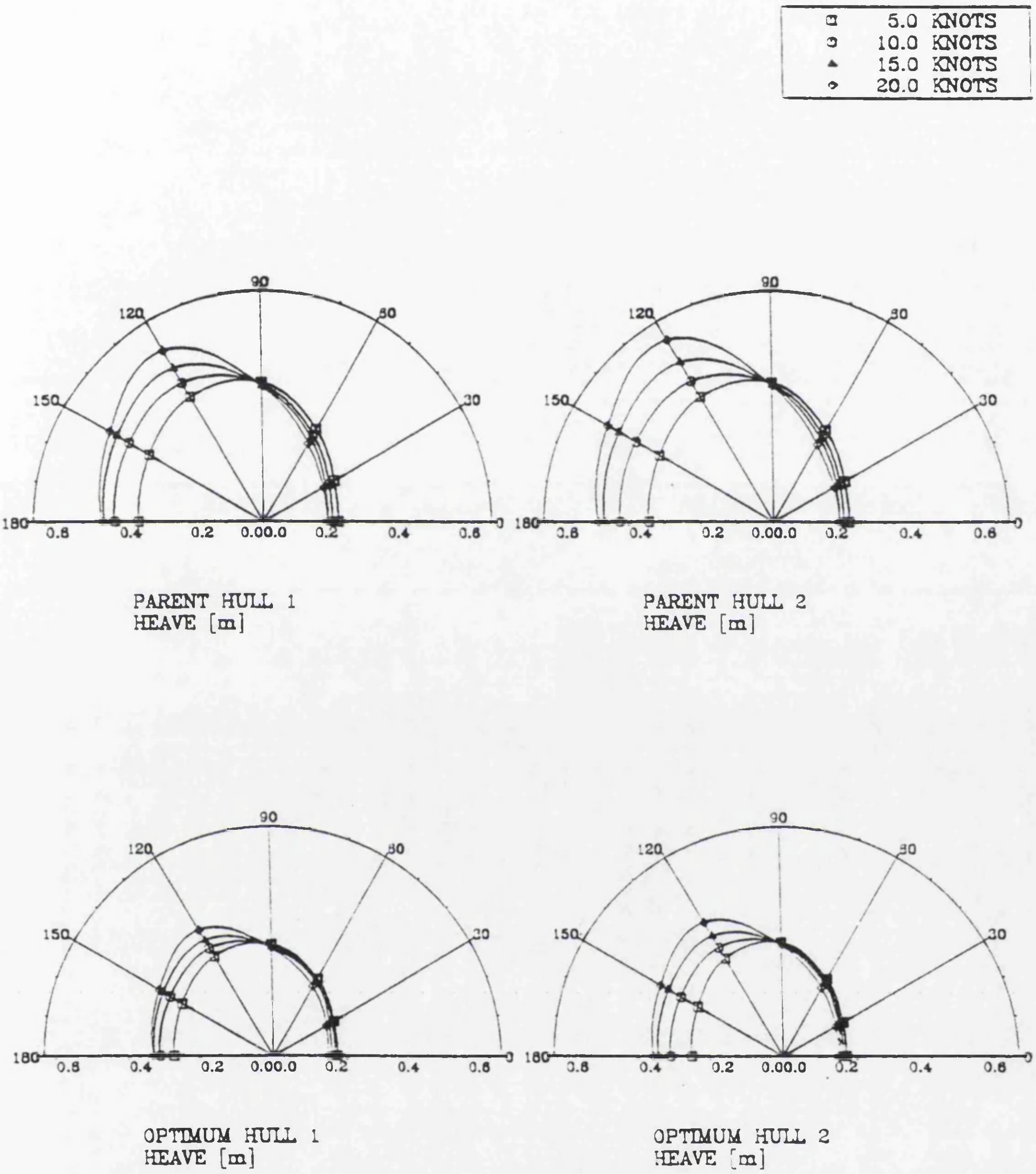


Figure 6.18 Heave Motion for Parent and Optimum Hull Forms for Various Speeds, To=5.5 Sec., H1/3=1.3 M.

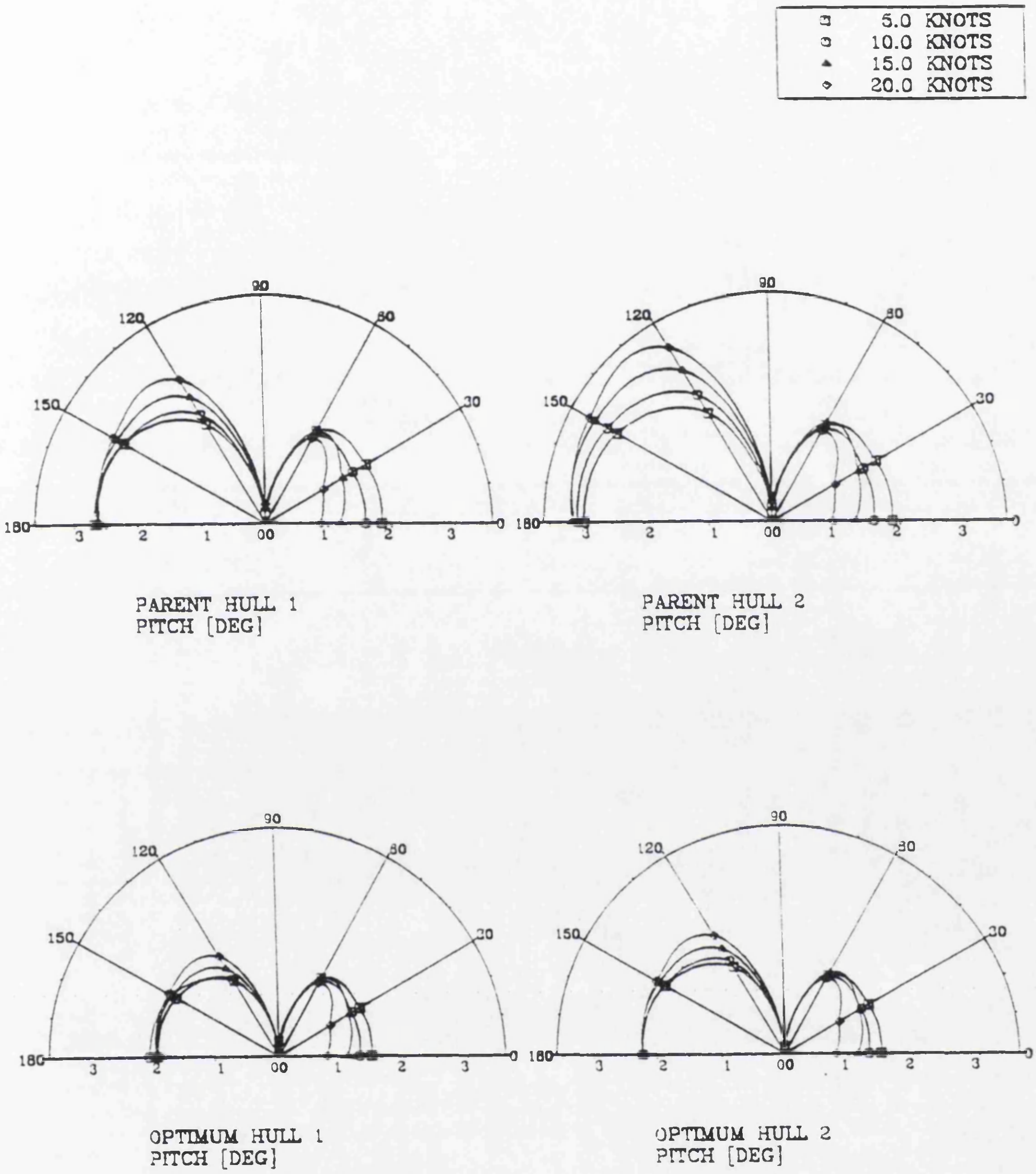


Figure 6.19 Pitch Motion for Parent and Optimum Hull Forms for Various Speeds. To=5.5 Sec., H1/3=1.3 M.

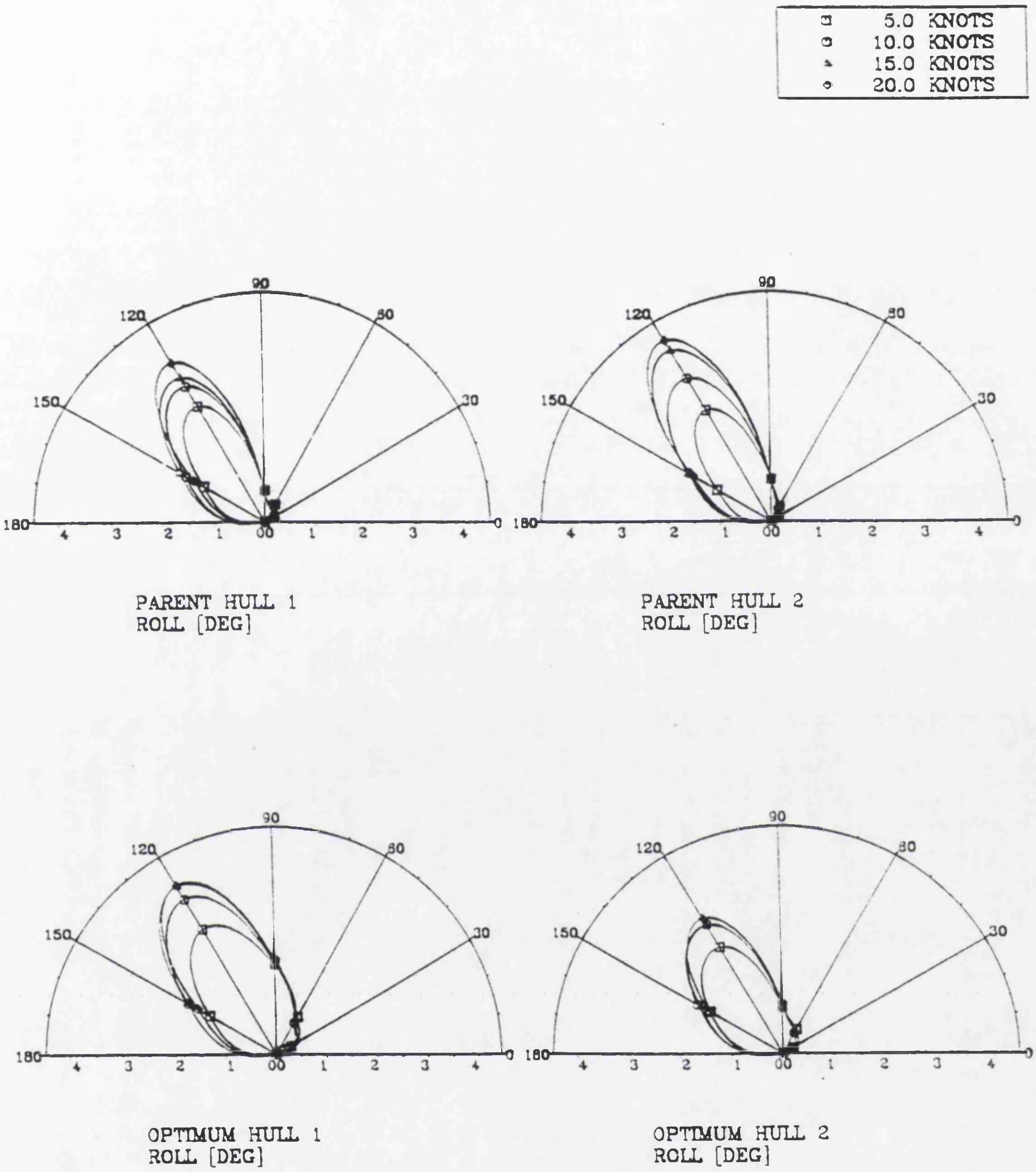


Figure 6.20 Roll Motion for Parent and Optimum Hull Forms for Various Speeds. To=5.5 Sec., H1/3=1.3 M.

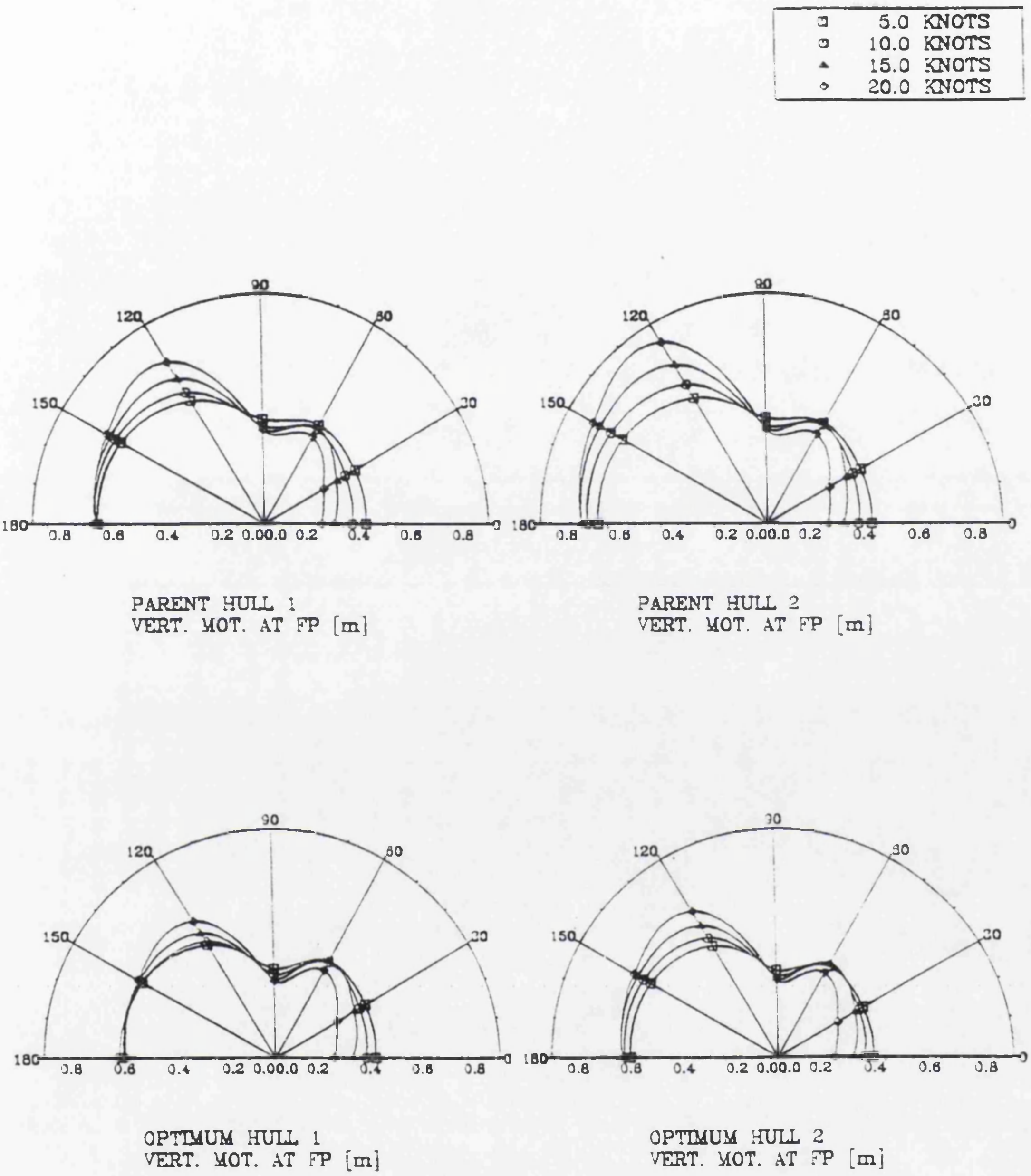


Figure 6.21 Vertical Motion at FP for Parent and Optimum Hull Forms for Various Speeds, To=5.5 Sec., H1/3=1.3 M.

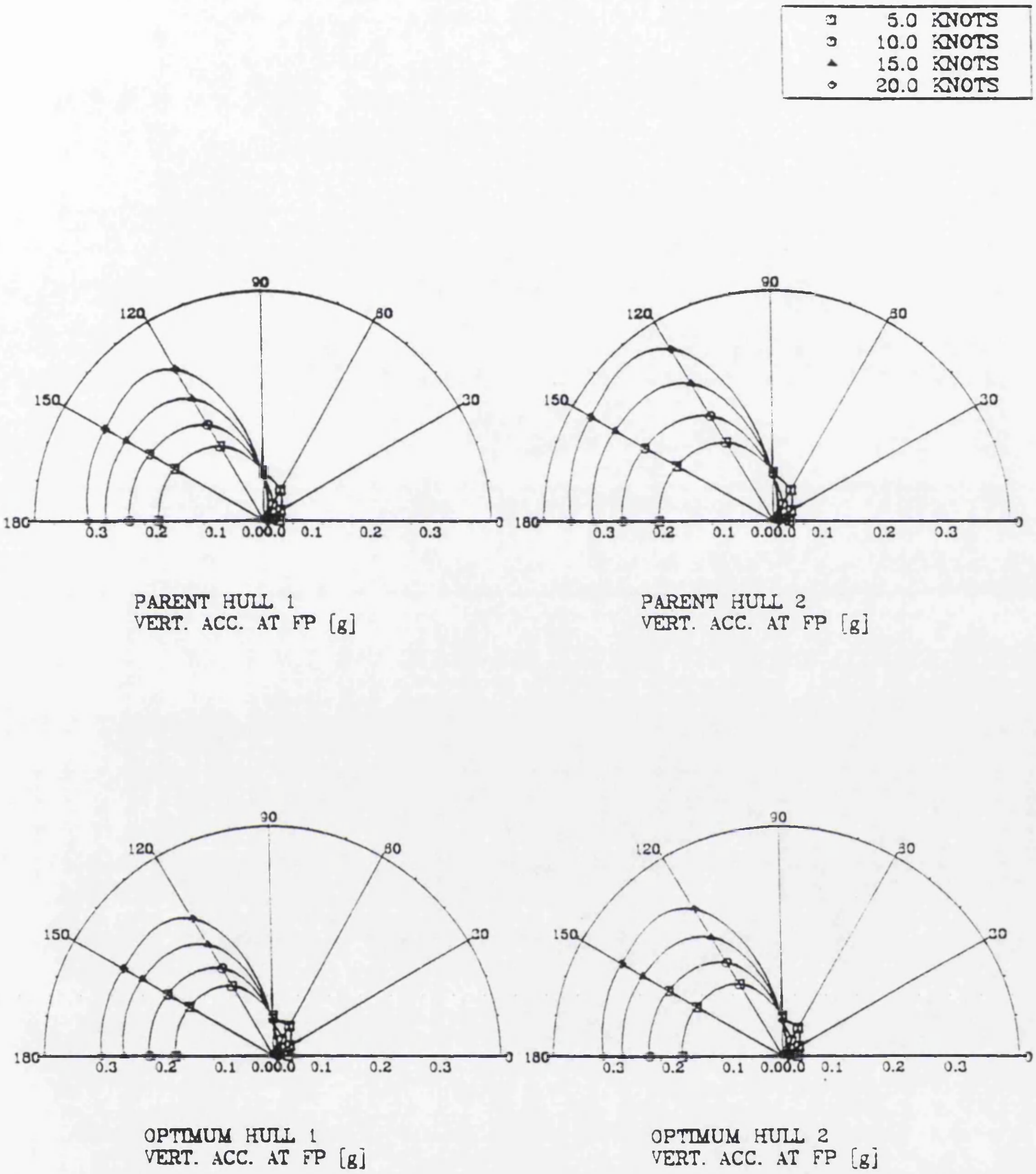


Figure 6.22 Vertical Acceleration at FP for Parent and Optimum Hull Forms for Various Speeds. To=5.5 Sec., H1/3=1.3 M.

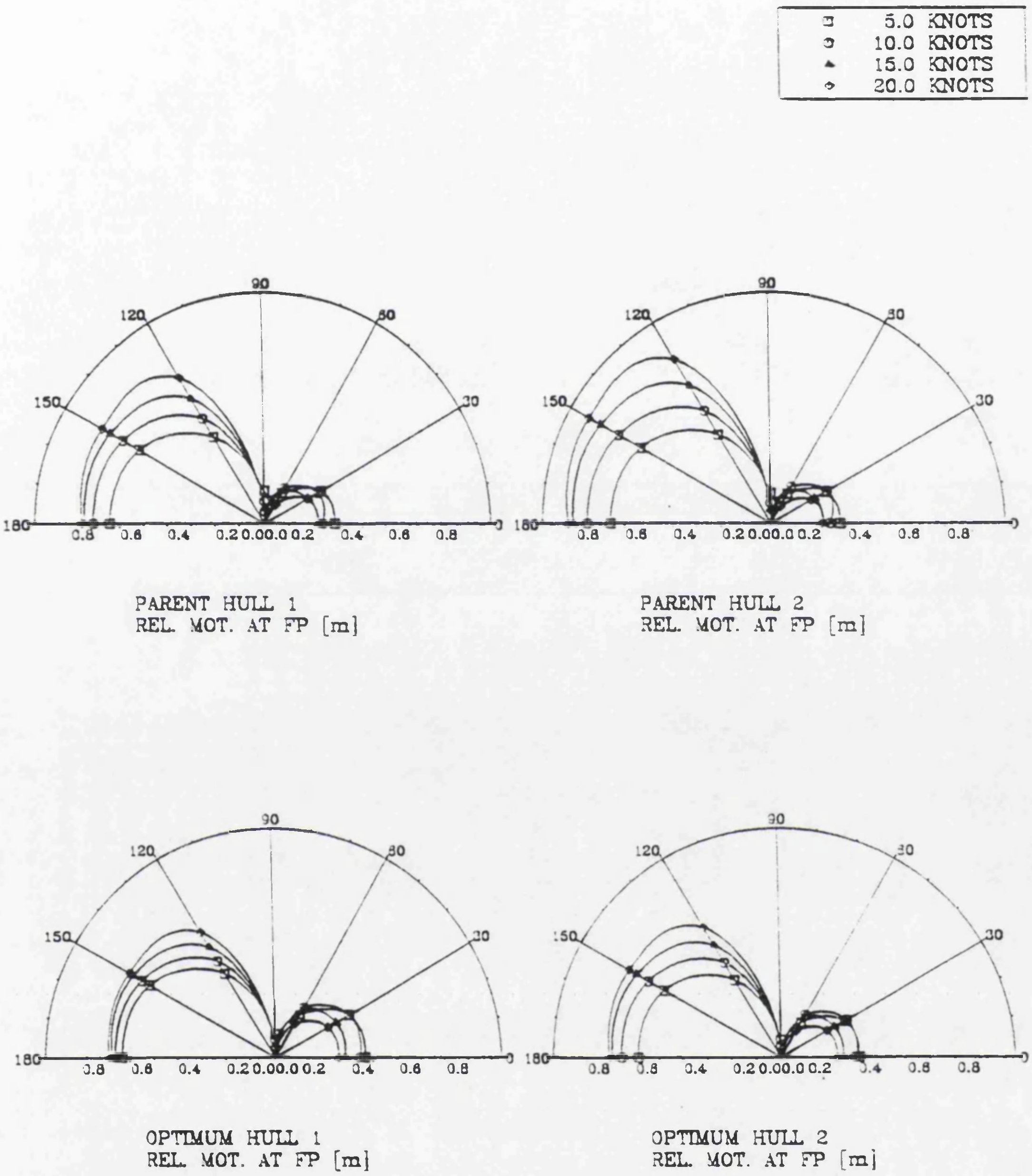


Figure 6.23 Relative Motion at FP for Parent and Optimum Hull Forms for Various Speeds. To=5.5 Sec., H1/3=1.3 M.

CHAPTER 7

CONCLUDING REMARKS AND RECOMMENDATIONS

One of the most significant advances in ship design has been the great increase in the use of computer-aided engineering analysis for hull form design and hydrodynamic performance evaluation. As the reliability of computational tool increases, a visible movement has been taking place in the last decade towards incorporating the seakeeping performance goals into the early stages of the ship design process. The efforts in the areas of hull form design and hydrodynamic performance prediction have provided naval architects with computer programs that can generate a preliminary body plan for the ship, predict its powering characteristics using standard series data or statistical methods, perform a strip theory based seakeeping analysis, and execute other design and analysis evaluations. There are various operational consequences of seakeeping performance characteristics which require the attention of the ship designer. In order to address these consequences the designer needs to be able to assess the seakeeping performance characteristics of a given ship design. The conventional methods of seakeeping performance assessment include full scale trials and model tests. However, these methods are not available in the early stage of design where the designer should decide on different form parameters. Several seakeeping design methodologies have attempted to establish the effect of size, main dimensions, and hull form on seakeeping. These methodologies are based on regression equations derived from experimental or computational data.

The main objective of the work reported in this thesis was to study the effect of main hull form parameters on the seakeeping performance of the series of fishing vessels. Numerical calculations have been first performed for different fishing vessel hull forms for various Froude numbers and wave headings using the computer programs based on the two-dimensional strip theory and the three-dimensional translating pulsating source distribution technique. It is observed that increasing ship length and B/T ratio increases the values of hydrodynamic coefficients in heave, roll and pitch modes of motion but decrease those values in sway and yaw modes of motion. Meanwhile a decrease in the C_M coefficient decreases the values of the surge hydrodynamic coefficient because the more slender the hull form the less the fluid forces acting in the longitudinal direction. Increasing C_{WP}, and the forward position of the LCB increases the hydrodynamic coefficients in heave and pitch modes of motion but decrease the roll mode of motion.

Experiments were carried out to determine the seakeeping and resistance characteristics of a typical Black Sea fishing vessel. These experiments yielded a useful set of data for the validation of theoretical methods. The strip theory results, in general, show good agreement with the experimental data as well as with the three-dimensional theory. It is concluded that the strip theory method is a reliable tool to predict the dynamic motion response values of a fishing vessel hull form. In comparison with the three-dimensional source distribution method, this procedure has an advantage in that less computer time is required.

The series of 159 fishing vessel hull forms were generated using the Lackenby linear distortion method from an existing Black Sea fishing vessel and the Istanbul Technical University series fishing vessels. Using the hull distortion program SFOLDS, the geometrical characteristics of the parent forms were modified by varying the main hull dimensions, prismatic coefficients and longitudinal centre of buoyancy while keeping the displacement constant for each vessel.

The numerical computations using the strip theory were carried out to determine the seakeeping performance of the series of fishing vessel hull forms. Six responses, heave, roll, pitch and vertical motion, heave acceleration and relative motion at fore perpendiculars were calculated using the sea conditions specified for the Black Sea. The relative magnitude of these responses were related to hull form parameters by Bales' method. The regression equation with respect to hull form parameters was evaluated. It was found that long vessels with a large waterplane area have the largest positive impact on the responses.

In order to compare the added resistance of the series of hull forms, calculations based on the Joosen method were carried out. To facilitate the comparison between the hull forms concerned, the added resistance index was calculated using a method similar to the seakeeping index. A regression equation with respect to the same hull form parameters was evaluated. It was found that the hull form parameters have the same effect on added resistance as they have on seakeeping with the exception of the L/B ratio.

Experimental resistance data for parent vessels were processed statistically and resistance prediction algorithms were developed. It was found that the algorithm based on the BSHC method agrees better than the Oortmerssen method with experiments for the loaded draft condition. The resistance algorithm will be useful for estimating the resistance of small size displacement vessels. It will provide a valuable tool applicable for parametric and optimisation studies at the initial stages of fishing vessel design. The calm water resistance index was also calculated to carry out a comparison between the seakeeping, added resistance and calm water resistance performance of the series of hull forms considered. It was found that as the L/B, B/T values become larger and the position of LCF gets closer to the midship the calm water resistance becomes smaller. On the other hand the seakeeping and added resistance performances improve as the C_{WP} and C_{VP} values increase and the position of the LCB and LCF gets closer to the midship.

The seakeeping optimisation procedure using the objective function based on the estimator of seakeeping index, R_S, which is a function of selected ship form parameters, was developed and applied to different parent hull forms used in the seakeeping analysis. The optimum hull forms which were the best form for the specified objective function within the defined geometric limits were generated and their seakeeping responses and resistance characteristics were compared with those predicted for the parent hulls. It was shown that the seakeeping optimised hulls were superior to the parent hull forms. The seakeeping optimised hulls also have better resistance characteristics than the parent hulls due to increased length of the optimal forms.

The discussions in this study have been concerned with the improvement of hull forms from the hydrodynamic point of view. This is understood to be a part of the total ship design process. In a real ship design problem, the designer must evolve a hull configuration which satisfies many requirements, one of which is seakeeping. Seakeeping is a consideration that can affect the final decision because it can affect the vessel's cost, and hence profitability, and feasibility to perform its mission.

A procedure for estimating the relative seakeeping performance of fishing vessels was developed. The full scope of the approach described in this study is most applicable in the early stage of the design when the designer will have the maximum freedom to manipulate the geometry of the vessel. The seakeeping estimator can be used for seeking the optimal combination of involved design parameters. It is anticipated that the method presented can be used as a useful tool by the designer at the initial design stage to determine a hull form with the best behaviour in waves under the geometrical constraints. The designer does not need to be a specialist in respect of seakeeping analysis to use the method effectively. It is interesting to note that the optimum hull form derived has a very similar geometrical character to the KTU/1-K hull form which was found with experience over years in the Black Sea area.

It was shown that for a given displacement and main dimensions seakeeping characteristics can be improved by a large waterplane coefficient. The suggestion of increasing length to improve seakeeping performance characteristics will undoubtedly lead to the objection that is too expensive as a solution. The answer is that, as in all other aspects of ship design, compromise is necessary. This compromise should be made on the basis of overall operating costs.

It has been shown that the requirements for other design considerations such as added resistance and calm water resistance may conflict with those for good seakeeping characteristics. Herein only the seakeeping characteristics were considered so it may happen that the best solution from this point of view may have not be an optimal calm water performance solution. The designer must decide on a suitable compromise taking into account all aspects of hull form design. The best overall solution might be chosen as a compromise giving to the seakeeping behaviour the weight the designer believes most appropriate.

Recommendation for Future Work

To evaluate the usefulness of the hull form design methodology developed, models of the parent fishing vessel hull forms and seakeeping optimised re-design of these forms should be built and tested for seakeeping and resistance.

The development of the present work would be to carry out an optimisation procedure with a general equation including seakeeping, resistance and stability characteristics as an objective function.

Further studies should also include the above waterline form and other dynamic effects such as slamming and deck wetness.

APPENDIX A

PARENT FISHING VESSEL HULL FORMS ADAPTED FOR CASE STUDIES

Table A.1 Main Particulars of KTU/1-K

L [m]	27.00	CP	0.704
B [m]	8.00	CM	0.634
T [m]	2.00	Cwp	0.798
L/B	3.38	Cvp	0.559
B/T	4.00	$L/\nabla^{1/3}$	4.676
CB	0.446	%LCB	-0.681

193

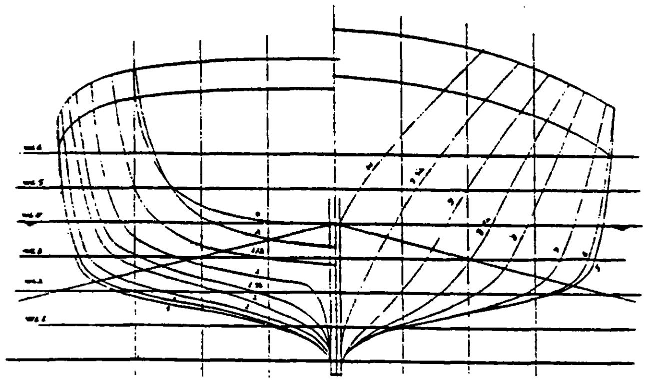


Figure A.1 Body Plan of KTU/1-K

Table A.2 Main Particulars of ITU/3-K

L [m]	20.00	CP	0.574
B [m]	5.71	CM	0.699
T [m]	2.29	Cwp	0.681
L/B	3.50	Cvp	0.589
B/T	2.50	$L/\nabla^{1/3}$	4.243
CB	0.401	%LCB	-3.306

105

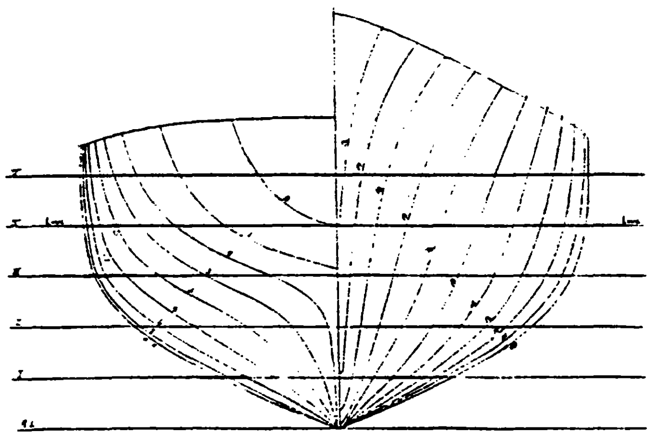


Figure A.2 Body Plan of ITU/3-K

Table A.3 Main Particulars of ITU/4-K

L [m]	20.00	CP	0.558
B [m]	5.71	CM	0.894
T [m]	2.29	Cwp	0.748
L/B	3.50	Cvp	0.667
B/T	2.50	$L/\nabla^{1/3}$	3.946
CB	0.499	%LCB	0.009

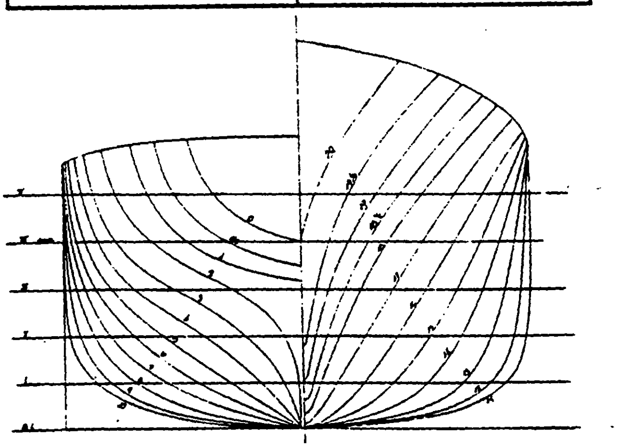


Figure A.3 Body Plan of ITU/4-K

130.5

Table A.4 Main Particulars of ITU/1-B

L [m]	20.00	CP	0.572
B [m]	5.71	CM	0.661
T [m]	2.29	Cwp	0.731
L/B	3.50	Cvp	0.517
B/T	2.50	$L/\nabla^{1/3}$	4.324
CB	0.378	%LCB	-4.150

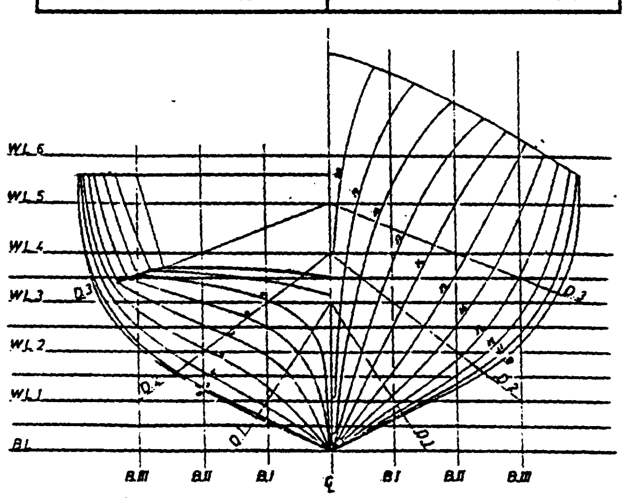


Figure A.4 Body Plan of ITU/1-B

98.9

Table A.5 Main Particulars of ITU/2-B

L [m]	20.00	CP	0.599
B [m]	5.71	CM	0.893
T [m]	2.29	Cwp	0.789
L/B	3.50	Cvp	0.678
B/T	2.50	$L/\nabla^{1/3}$	3.853
CB	0.535	%LCB	-0.049

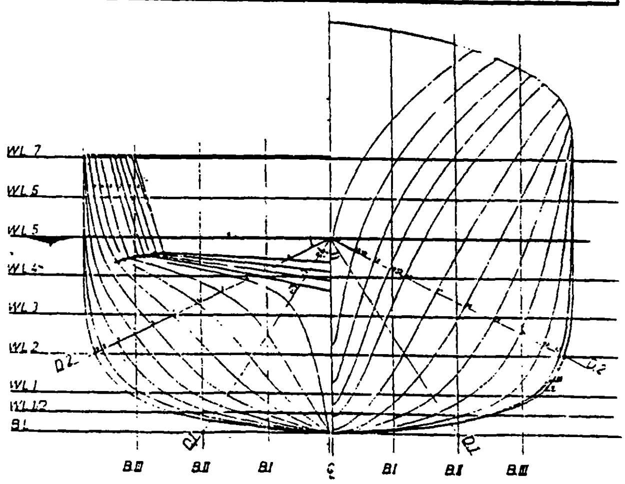


Figure A.5 Body Plan of ITU/2-B

Table A.6 Main Particulars of ITU/3-B

L [m]	20.00	CP	0.607
B [m]	5.71	CM	0.669
T [m]	2.29	Cwp	0.727
L/B	3.50	Cvp	0.558
B/T	2.50	$L/\nabla^{1/3}$	4.221
CB	0.406	%LCB	-3.999

139.9

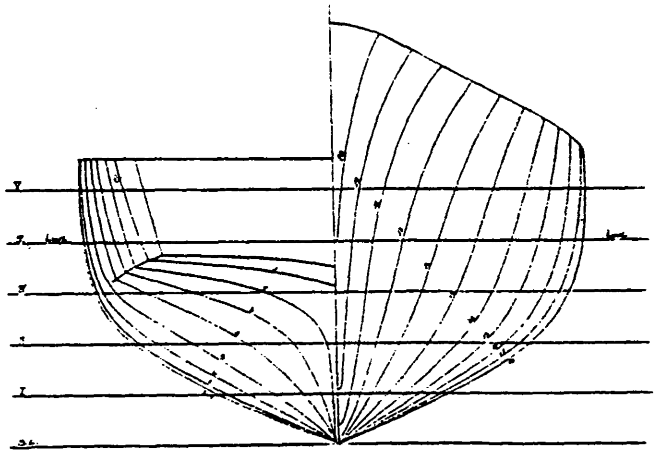


Figure A.6 Body Plan of ITU/3-B

Table A.7 Main Particulars of ITU/4-B

L [m]	20.00	CP	0.559
B [m]	5.71	CM	0.889
T [m]	2.29	Cwp	0.789
L/B	3.50	Cvp	0.630
B/T	2.50	$L/\nabla^{1/3}$	3.949
CB	0.497	%LCB	-0.096

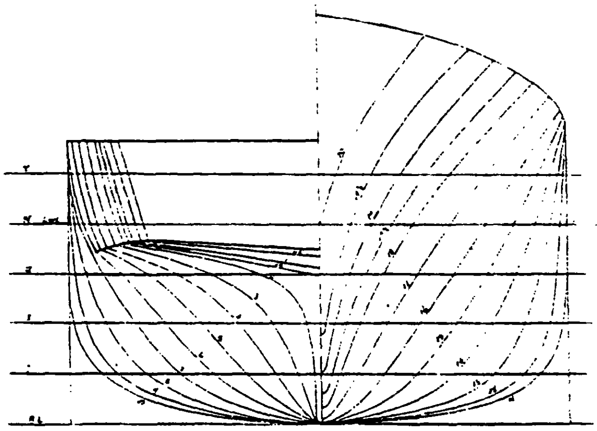


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Figure A.7 Body Plan of ITU/4-B

Table A.8 Main Particulars of ITU/5-B

L [m]	20.00	CP	0.616
B [m]	5.71	CM	0.721
T [m]	2.29	Cwp	0.745
L/B	3.50	Cvp	0.596
B/T	2.50	$L/\nabla^{1/3}$	4.101
CB	0.444	%LCB	-3.146

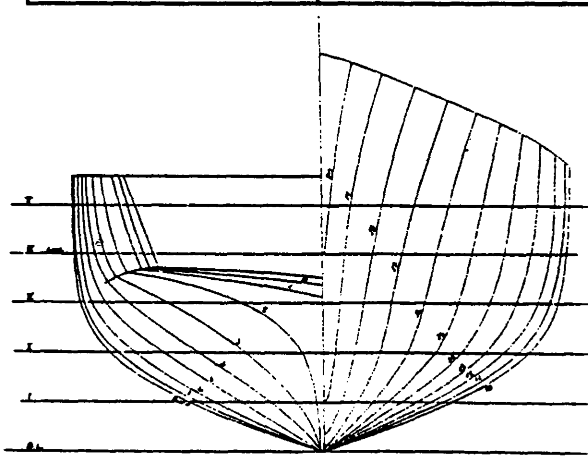

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Figure A.8 Body Plan of ITU/5-B

APPENDIX B

SIGNIFICANT RESPONSES AND SEAKEEPING INDEX FOR THE SERIES OF FISHING VESSEL HULL FORMS

Table B.1a. Main Particulars of the Series of Fishing Vessel Hull Forms

	HULL	L [m]	B [m]	T [m]	L/B	L/T	B/T	CB	CP	CM	Cvp	Cwp	$L/\nabla^{1/3}$	%LCB	%LCF
	01	27.00	7.55	2.00	3.576	13.500	3.775	0.472	0.746	0.633	0.575	0.821	4.676	-0.622	-2.367
	02	27.00	7.55	2.35	3.576	11.489	3.213	0.402	0.635	0.633	0.540	0.744	4.676	-1.493	-3.331
	03	27.00	7.70	2.00	3.506	13.500	3.850	0.463	0.731	0.633	0.574	0.806	4.676	-0.663	-2.956
	04	27.00	8.00	2.50	3.375	10.800	3.200	0.356	0.563	0.633	0.515	0.692	4.676	-3.119	-2.938
	05	27.00	7.55	2.50	3.576	10.800	3.020	0.378	0.597	0.633	0.522	0.724	4.676	-2.063	-3.709
	06	28.92	7.70	2.00	3.756	14.460	3.850	0.432	0.683	0.633	0.557	0.776	5.009	-2.151	-1.973
KTU/1-K	07	27.00	8.00	2.00	3.375	13.500	4.000	0.446	0.704	0.633	0.558	0.798	4.676	-0.681	-2.948
	08	27.00	7.70	2.50	3.506	10.800	3.080	0.370	0.585	0.633	0.525	0.705	4.676	-2.489	-3.597
	09	28.92	7.70	2.35	3.756	12.306	3.277	0.368	0.581	0.633	0.517	0.711	5.009	-0.719	-4.327
	10	27.00	8.00	2.35	3.375	11.489	3.404	0.379	0.599	0.633	0.529	0.717	4.676	-2.096	-3.564
	11	28.92	7.70	2.50	3.756	11.568	3.080	0.346	0.546	0.633	0.506	0.684	5.009	-0.806	-4.808
	12	28.92	8.00	2.35	3.615	12.306	3.404	0.354	0.559	0.633	0.518	0.683	5.009	-3.188	-3.790
	13	30.20	8.00	2.35	3.775	12.851	3.404	0.339	0.536	0.633	0.505	0.671	5.230	-1.990	-4.544
	14	30.20	7.70	2.35	3.922	12.851	3.277	0.352	0.556	0.633	0.515	0.684	5.230	-2.844	-3.852
	15	28.92	7.55	2.35	3.830	12.306	3.213	0.375	0.593	0.633	0.523	0.718	5.009	-0.771	-4.187
	16	30.20	7.70	2.50	3.922	12.080	3.080	0.331	0.523	0.633	0.502	0.659	5.230	-2.705	-4.476
	17	30.20	7.55	2.35	4.000	12.851	3.213	0.359	0.568	0.633	0.521	0.690	5.230	-3.089	-3.607
	18	30.20	7.70	2.00	3.922	15.100	3.850	0.414	0.654	0.633	0.544	0.761	5.230	-0.709	-3.408
	19	25.35	8.00	2.50	3.169	10.140	3.200	0.380	0.600	0.633	0.529	0.718	4.390	-2.071	-3.554
	20	23.20	7.70	2.35	3.013	9.872	3.277	0.459	0.724	0.633	0.570	0.804	4.018	-0.879	-2.537
	21	23.20	7.70	2.50	3.013	9.280	3.080	0.431	0.681	0.633	0.561	0.769	4.018	-2.164	-2.540
	22	25.35	7.70	2.35	3.292	10.787	3.277	0.420	0.663	0.633	0.547	0.767	4.390	-0.698	-3.295
	23	25.35	7.70	2.50	3.292	10.140	3.080	0.394	0.623	0.633	0.537	0.734	4.390	-1.905	-3.334
	24	23.20	8.00	2.50	2.900	9.280	3.200	0.415	0.655	0.633	0.555	0.747	4.018	-3.030	-2.530
	25	30.00	7.25	2.35	4.138	12.766	3.085	0.377	0.540	0.698	0.565	0.667	5.196	-2.020	-4.150
	26	30.00	7.40	2.28	4.054	13.158	3.246	0.380	0.545	0.698	0.564	0.674	5.196	-1.257	-3.583
	27	28.00	7.40	2.35	3.784	11.915	3.149	0.395	0.566	0.698	0.576	0.687	4.849	-1.829	-3.679
	28	26.50	7.25	2.35	3.655	11.277	3.085	0.426	0.611	0.698	0.597	0.715	4.590	-3.166	-4.137
	29	30.00	7.40	2.35	4.054	12.766	3.149	0.369	0.529	0.698	0.560	0.659	5.196	-1.707	-4.017
	30	28.00	7.40	2.28	3.784	12.281	3.246	0.407	0.584	0.698	0.581	0.702	4.849	-1.432	-3.214
	31	28.00	7.40	2.50	3.784	11.200	2.960	0.372	0.532	0.698	0.566	0.657	4.849	-3.025	-4.857
	32	26.50	7.40	2.28	3.581	11.623	3.246	0.431	0.617	0.698	0.590	0.730	4.590	-1.068	-2.590
	33	30.00	7.40	2.50	4.054	12.000	2.960	0.347	0.497	0.698	0.549	0.631	5.196	-2.583	-5.017
	34	26.50	7.40	2.35	3.581	11.277	3.149	0.418	0.598	0.698	0.586	0.713	4.590	-1.743	-3.307
	35	26.50	7.40	2.50	3.581	10.600	2.960	0.393	0.563	0.698	0.579	0.679	4.590	-3.396	-4.892
	36	28.00	7.25	2.35	3.862	11.915	3.085	0.404	0.578	0.698	0.581	0.694	4.849	-2.525	-4.107
	37	30.00	8.00	2.35	3.750	12.766	3.404	0.341	0.489	0.698	0.555	0.615	5.196	-1.733	-4.683
	38	26.50	8.00	2.35	3.313	11.277	3.404	0.386	0.554	0.698	0.568	0.680	4.590	-1.181	-3.420
	39	28.00	8.00	2.35	3.500	11.915	3.404	0.366	0.524	0.698	0.555	0.659	4.849	-0.893	-3.500
	40	27.56	7.70	2.00	3.579	13.780	3.850	0.454	0.650	0.698	0.608	0.747	4.773	-2.765	-3.257
	41	24.66	7.20	2.35	3.425	10.494	3.064	0.461	0.661	0.698	0.610	0.756	4.271	-2.368	-2.832
	42	24.66	7.04	2.50	3.503	9.864	2.816	0.444	0.635	0.698	0.600	0.739	4.271	-2.255	-3.076
	43	22.20	7.70	2.50	2.883	8.880	3.080	0.450	0.645	0.698	0.602	0.748	3.845	-1.721	-2.619
	44	22.20	7.04	2.80	3.153	7.929	2.514	0.440	0.630	0.698	0.597	0.737	3.845	-0.815	-2.169
	45	24.66	8.00	2.00	3.083	12.330	4.000	0.488	0.699	0.698	0.620	0.787	4.271	-1.496	-1.819
	46	21.80	7.04	3.00	3.097	7.267	2.347	0.418	0.599	0.698	0.589	0.710	3.776	-2.124	-3.433
ITU/3-K	47	24.50	7.00	2.80	3.500	8.750	2.500	0.401	0.574	0.698	0.589	0.681	4.243	-3.306	-4.740
	48	22.20	7.70	2.35	2.883	9.447	3.277	0.479	0.687	0.698	0.617	0.777	3.845	-1.712	-2.124
	49	30.00	7.20	2.35	4.167	12.766	3.064	0.379	0.543	0.698	0.574	0.661	5.196	-1.037	-2.917
	50	22.20	7.04	3.00	3.153	7.400	2.347	0.411	0.588	0.698	0.582	0.705	3.845	-0.775	-2.484
	51	30.00	7.20	2.00	4.167	15.000	3.600	0.446	0.638	0.698	0.602	0.740	5.196	-2.273	-3.083
	52	24.66	7.04	3.00	3.503	8.220	2.347	0.370	0.530	0.698	0.562	0.657	4.271	-1.399	-3.643
	53	30.00	8.00	2.00	3.750	15.000	4.000	0.401	0.575	0.698	0.583	0.688	5.196	-2.690	-4.150
	54	30.00	7.04	2.00	4.261	15.000	3.520	0.456	0.653	0.698	0.609	0.749	5.196	-2.597	-3.117
	55	20.00	7.65	2.35	2.614	8.511	3.255	0.535	0.600	0.893	0.693	0.772	3.464	-1.750	-1.300
	56	28.64	7.50	2.35	3.819	12.187	3.191	0.381	0.427	0.893	0.589	0.648	4.960	-0.594	-2.230
	57	28.64	7.65	2.28	3.744	12.561	3.355	0.385	0.432	0.893	0.584	0.660	4.960	-1.358	-2.510
	58	28.64	8.00	2.35	3.580	12.187	3.404	0.358	0.400	0.893	0.570	0.627	4.960	-0.503	-2.510
	59	25.30	8.00	2.35	3.163	10.766	3.404	0.405	0.453	0.893	0.610	0.664	4.382	-1.854	-2.835
	60	20.00	7.50	2.35	2.667	8.511	3.191	0.546	0.612	0.893	0.696	0.785	3.464	-0.360	-1.400
	61	20.00	7.65	2.28	2.614	8.772	3.355	0.552	0.618	0.893	0.701	0.787	3.464	-0.097	-1.250
	62	25.30	7.50	2.35	3.373	10.766	3.191	0.432	0.483	0.893	0.624	0.692	4.382	-0.470	-1.649
	63	25.30	7.65	2.35	3.307	10.766	3.255	0.423	0.474	0.893	0.622	0.681	4.382	-1.162	-2.282
	64	28.64	7.65	2.35	3.744	12.187	3.255	0.374	0.419	0.893	0.583	0.641	4.960	-0.649	-2.335
	65	20.00	7.65	2.50	2.614	8.000	3.060	0.503	0.564	0.893	0.671	0.750	3.464	-1.085	-1.350
	66	20.00	8.00	2.35	2.500	8.511	3.404	0.512	0.573	0.893	0.681	0.752	3.464	-2.445	-1.950
	67	25.30	7.65	2.28	3.307	11.096	3.355	0.436	0.488	0.893	0.635	0.687	4.382	-1.874	-2.321
	68	28.64	7.65	2.50	3.744	11.456	3.060	0.351	0.394	0.893	0.566	0.621	4.960	-0.370	-2.370
	69	25.30	7.65	2.50	3.307	10.120	3.060	0.398	0.446	0.893	0.603	0.660	4.382	-0.755	-2.203
	70	24.00	7.70	2.00	3.117	12.000	3.850	0.521	0.583	0.893	0.684	0.761	4.157	-0.058	-1.667
	71	21.35	7.20	2.35	2.965	9.085	3.064	0.533	0.597	0.893	0.694	0.768	3.698	-1.564	-1.646
	72	25.60	7.20	2.35	3.556	10.894	3.064	0.444	0.498	0.893	0.636	0.698	4.434	-0.727	-1.727
	73	21.35	6.51	3.00	3.280	7.117	2.170	0.462	0.517	0.893	0.651	0.709	3.698	-1.335	-2.020
ITU/4-K	74	22.78	6.51	2.60	3.499	8.751	2.501	0.499	0.558	0.893	0.666	0.748	3.945	0.009	-1.840
	75	21.35	7.20	2.60	2.965	8.202	2.766	0.481	0.539	0.893	0.662	0.726	3.698	-0.759	-1.458
	76	21.35	6.51	2.60	3.280	8.202	2.501	0.532	0.596	0.893	0.694	0.767	3.698	-1.560	-1.646
	77	22.78	8.00	2.00	2.848	11.390	4.000	0.528	0.591	0.893	0.693	0.763	3.945	-2.388	-2.201
	78	25.60	6.51	2.50	3.932	10.240	2.604	0.462	0.517	0.893	0.652	0.709	4.434	-1.836	-2.273
	79	26.35	8.00	2.00	3.294	13.175	4.000	0.457	0.511	0.893	0.646	0.707	4.564	-1.078	-1.874
	80	22.78	6.51	3.00	3.499	7.593	2.170	0.433	0.485	0.893	0.628	0.689	3.945	-0.478	-1.674
	81	24.00	7.20	2.60	3.333	9.220	2.766	0.428	0.479	0.893	0.624	0.685	4.157	-0.383	-1.667
	82	25.60	8.00	2.00	3.200	12.800	4.000	0.470	0.526	0.893	0.655	0.718	4.434	-1.141	-1.766
	83	22.78	7.70	2.50	2.958	9.112	3.080	0.439	0.492	0.893	0.633	0.694	3.945	-0.834	-1.850
	84	25.60	6.51	2.60	3.932	9.835	2.501	0.444	0.497	0.893	0.638	0.695	4.434	-1.203	-2.078

Table B.1b. Main Particulars of the Series of Fishing Vessel Hull Forms

	HULL	L [m]	B [m]	T [m]	L/B	L/T	B/T	CB	CP	CM	Cvp	Cwp	$L/\nabla^{1/3}$	%LCB	%LCF
	85	23.65	7.70	2.35	3.071	10.064	3.277	0.450	0.673	0.668	0.573	0.784	4.096	-2.372	-4.910
	86	24.38	7.20	2.50	3.386	9.752	2.880	0.439	0.657	0.668	0.564	0.778	4.222	-1.891	-4.977
	87	26.00	6.97	2.50	3.732	10.400	2.787	0.425	0.636	0.668	0.551	0.772	4.503	-0.900	-4.558
	88	24.38	6.97	2.50	3.499	9.752	2.787	0.453	0.679	0.668	0.578	0.784	4.222	-2.744	-5.059
	89	30.00	8.00	2.00	3.750	15.000	4.000	0.401	0.600	0.668	0.547	0.733	5.196	-3.033	-6.617
	90	24.38	7.20	2.80	3.386	8.707	2.571	0.392	0.586	0.668	0.541	0.724	4.222	-3.326	-6.905
ITU/3-B	91	24.38	6.97	2.80	3.499	8.707	2.488	0.405	0.606	0.668	0.557	0.727	4.222	-3.999	-7.069
	92	26.00	8.00	2.35	3.250	11.064	3.404	0.394	0.590	0.668	0.538	0.732	4.503	-2.388	-6.404
	93	26.00	7.20	2.50	3.611	10.400	2.880	0.411	0.616	0.668	0.550	0.748	4.503	-2.312	-5.865
	94	22.50	6.97	3.00	3.230	7.500	2.322	0.409	0.613	0.668	0.546	0.749	3.897	-1.769	-5.583
	95	28.20	7.70	2.00	3.662	14.100	3.850	0.443	0.664	0.668	0.572	0.775	4.884	-2.720	-5.342
	96	22.50	7.20	3.00	3.125	7.500	2.400	0.396	0.593	0.668	0.547	0.725	3.897	-3.591	-7.050
	97	28.20	7.20	2.35	3.917	12.000	3.064	0.403	0.604	0.668	0.544	0.741	4.884	-2.163	-5.980
	98	26.00	6.97	2.80	3.732	9.286	2.488	0.380	0.568	0.668	0.531	0.715	4.503	-3.154	-7.173
	99	28.20	6.97	2.50	4.048	11.280	2.787	0.392	0.587	0.668	0.539	0.727	4.884	-2.567	-6.548
	100	25.00	7.70	2.00	3.247	12.500	3.850	0.500	0.563	0.888	0.639	0.782	4.330	-2.436	-4.650
	101	22.80	7.20	2.35	3.167	9.702	3.064	0.499	0.562	0.888	0.634	0.786	3.949	-1.829	-4.303
	102	20.00	8.00	2.35	2.500	8.511	3.404	0.512	0.577	0.888	0.644	0.795	3.464	-1.565	-4.050
	103	27.00	7.20	2.35	3.750	11.489	3.064	0.421	0.475	0.888	0.586	0.719	4.676	-1.867	-6.769
	104	20.00	8.00	2.50	2.500	8.000	3.200	0.481	0.542	0.888	0.622	0.774	3.464	-2.160	-4.900
	105	27.00	7.70	2.00	3.506	13.500	3.850	0.463	0.521	0.888	0.619	0.748	4.676	-2.930	-6.250
	106	20.00	7.20	2.60	2.778	7.692	2.769	0.514	0.579	0.888	0.644	0.799	3.464	-1.040	-3.800
	107	22.80	7.20	2.60	3.167	8.769	2.769	0.451	0.508	0.888	0.597	0.756	3.949	-1.781	-5.268
	108	20.00	7.70	2.60	2.597	7.692	2.962	0.481	0.541	0.888	0.624	0.770	3.464	-2.395	-5.000
	109	27.85	8.00	2.00	3.481	13.925	4.000	0.432	0.486	0.888	0.593	0.728	4.823	-2.147	-6.598
	110	22.80	6.52	3.00	3.499	7.600	2.172	0.432	0.486	0.888	0.575	0.751	3.949	-0.798	-4.961
	111	23.65	7.20	2.60	3.285	9.096	2.769	0.435	0.490	0.888	0.595	0.730	4.096	-2.101	-6.474
	112	23.65	6.52	3.00	3.630	7.883	2.172	0.416	0.469	0.888	0.585	0.712	4.096	-2.118	-7.193
ITU/4-B	113	22.80	6.52	2.60	3.497	8.769	2.508	0.498	0.561	0.888	0.631	0.789	3.949	-0.096	-3.601
	114	27.00	6.52	2.50	4.144	10.800	2.606	0.438	0.493	0.888	0.595	0.736	4.676	-1.841	-6.213
	115	28.00	7.20	2.50	3.889	11.200	2.880	0.382	0.578	0.661	0.519	0.736	4.849	-3.504	-6.536
	116	30.20	7.50	2.50	4.027	12.080	3.000	0.340	0.514	0.661	0.488	0.696	5.230	-3.841	-7.853
	117	22.20	7.50	3.00	2.960	7.400	2.500	0.385	0.583	0.661	0.512	0.752	3.845	-1.671	-5.412
	118	27.97	7.50	2.50	3.729	11.186	3.000	0.367	0.555	0.661	0.508	0.723	4.843	-3.494	-7.029
	119	24.97	8.00	2.50	3.121	9.986	3.200	0.386	0.583	0.661	0.518	0.745	4.324	-2.724	-6.001
	120	30.20	7.50	2.35	4.027	12.851	3.191	0.362	0.547	0.661	0.502	0.720	5.230	-2.983	-6.793
	121	24.97	8.00	2.35	3.121	10.624	3.404	0.410	0.620	0.661	0.536	0.765	4.324	-3.064	-5.480
	122	20.00	7.20	3.00	2.778	6.667	2.400	0.446	0.674	0.661	0.552	0.808	3.464	-1.340	-3.600
	123	22.20	8.00	2.50	2.775	8.880	3.200	0.434	0.656	0.661	0.543	0.799	3.845	-1.162	-3.791
ITU/1-B	124	24.97	7.13	2.85	3.501	8.748	2.499	0.379	0.573	0.661	0.518	0.731	4.324	-4.150	-6.962
	125	30.20	8.00	2.00	3.775	15.100	4.000	0.398	0.603	0.661	0.526	0.757	5.230	-2.510	-5.469
	126	22.20	7.70	3.00	2.883	7.400	2.567	0.375	0.568	0.661	0.504	0.746	3.845	-1.356	-5.502
	127	30.20	7.13	2.50	4.234	12.080	2.853	0.357	0.541	0.661	0.492	0.726	5.230	-1.828	-6.230
	128	22.20	8.00	2.85	2.775	7.779	2.803	0.380	0.575	0.661	0.504	0.754	3.845	-0.793	-5.052
	129	22.20	7.13	2.85	3.113	7.779	2.499	0.426	0.644	0.661	0.537	0.794	3.845	-0.973	-3.881
	130	26.30	7.20	2.00	3.653	13.150	3.600	0.508	0.570	0.892	0.650	0.781	4.555	-1.426	-4.182
	131	29.18	7.50	2.00	3.891	14.590	3.750	0.440	0.493	0.892	0.596	0.738	5.054	-0.624	-4.967
	132	29.18	7.70	2.00	3.790	14.590	3.850	0.428	0.480	0.892	0.592	0.723	5.054	-1.008	-5.687
	133	20.00	7.20	3.00	2.778	6.667	2.400	0.446	0.500	0.892	0.606	0.736	3.464	-0.760	-2.550
	134	22.25	7.50	2.70	2.967	8.240	2.778	0.427	0.479	0.892	0.591	0.723	3.853	-0.849	-5.599
	135	29.18	6.37	2.00	4.584	14.590	3.183	0.518	0.581	0.892	0.661	0.784	5.054	-1.967	-4.282
	136	20.00	7.50	2.50	2.667	8.000	3.000	0.513	0.575	0.892	0.651	0.789	3.464	-0.570	-3.750
	137	24.80	7.20	2.50	3.444	9.920	2.880	0.431	0.483	0.892	0.592	0.728	4.295	-0.706	-5.347
	138	22.25	8.00	2.00	2.781	11.125	4.000	0.541	0.606	0.892	0.674	0.802	3.853	-1.362	-3.621
ITU/2-B	139	22.25	6.37	2.54	3.496	8.749	2.503	0.535	0.599	0.892	0.677	0.789	3.853	-0.049	-3.037
	140	22.25	6.37	3.00	3.496	7.416	2.122	0.453	0.508	0.892	0.608	0.745	3.853	-1.380	-5.104
	141	29.18	7.20	2.00	4.053	14.590	3.600	0.458	0.514	0.892	0.610	0.752	5.054	-1.073	-4.761
	142	24.80	7.70	2.00	3.221	12.400	3.850	0.504	0.565	0.892	0.648	0.778	4.295	-1.504	-4.298
	143	22.25	7.20	2.50	3.090	8.900	2.880	0.481	0.539	0.892	0.629	0.765	3.853	-1.209	-4.520
	144	24.80	6.37	2.54	3.893	9.752	2.505	0.479	0.537	0.892	0.625	0.766	4.295	-0.730	-4.218
	145	26.30	7.20	2.50	3.653	10.520	2.880	0.407	0.565	0.720	0.562	0.724	4.555	-2.376	-6.425
	146	29.18	7.50	2.50	3.891	11.672	3.000	0.352	0.489	0.720	0.514	0.684	5.054	-0.795	-6.886
	147	20.00	7.20	3.00	2.778	6.667	2.400	0.446	0.619	0.720	0.582	0.766	3.464	-0.970	-4.850
	148	23.68	7.50	3.00	3.157	7.893	2.500	0.361	0.502	0.720	0.524	0.689	4.101	-0.904	-6.949
	149	29.18	6.77	2.70	4.313	10.807	2.506	0.361	0.502	0.720	0.522	0.692	5.054	-0.411	-6.646
	150	20.00	7.50	2.70	2.667	7.407	2.778	0.475	0.660	0.720	0.601	0.791	3.464	-1.335	-4.150
	151	29.18	8.00	2.00	3.648	14.590	4.000	0.412	0.573	0.720	0.567	0.727	5.054	-2.152	-5.995
	152	26.30	7.70	2.50	3.416	10.520	3.080	0.380	0.528	0.720	0.537	0.708	4.555	-1.278	-6.501
	153	23.68	7.70	2.70	3.075	8.770	2.852	0.391	0.543	0.720	0.553	0.707	4.101	-2.660	-7.034
ITU/5-B	154	23.68	6.77	2.70	3.500	8.770	2.506	0.445	0.618	0.720	0.597	0.745	4.101	-3.146	-5.978
	155	24.80	7.70	2.70	3.221	9.185	2.852	0.373	0.519	0.720	0.542	0.689	4.295	-2.823	-7.565
	156	23.68	7.70	2.50	3.075	9.472	3.080	0.422	0.587	0.720	0.570	0.741	4.101	-1.774	-5.725
	157	29.18	7.20	2.35	4.053	12.417	3.064	0.390	0.542	0.720	0.547	0.713	5.054	-1.518	-6.441
	158	24.80	6.37	3.00	3.893	8.267	2.123	0.406	0.564	0.720	0.564	0.720	4.295	-2.496	-6.476
	159	24.80	6.77	2.70	3.666	9.185	2.506	0.425	0.590	0.720	0.570	0.745	4.295	-1.323	-5.387

Table B.2. Motions and Seakeeping Index for the Series of Hull Forms, V=0 Knots, Heading Angle 0 Deg.

HULL	Heave [m/m]	Pitch [deg/m]	Vert.Mot. at FP [m/m]	Vert.Acc. at FP [m/s^2/m]	Rel.Mot. at FP [m/m]	Sum	Index
01	0.17	1.92	0.42	0.747	0.373	4.126	8.49
02	0.18	2.08	0.46	0.836	0.407	3.788	6.73
03	0.17	1.94	0.42	0.756	0.372	4.090	8.30
04	0.19	2.20	0.50	0.936	0.465	3.492	5.19
05	0.18	2.14	0.48	0.892	0.436	3.625	5.88
06	0.16	1.75	0.41	0.718	0.413	4.244	9.10
07	0.17	1.91	0.42	0.743	0.375	4.145	8.58
08	0.18	2.15	0.48	0.898	0.444	3.598	5.74
09	0.17	1.89	0.45	0.797	0.436	3.957	7.61
10	0.18	2.07	0.46	0.851	0.432	3.726	6.41
11	0.17	2.00	0.47	0.860	0.461	3.747	6.51
12	0.17	1.96	0.47	0.864	0.483	3.727	6.41
13	0.17	1.87	0.47	0.835	0.489	3.848	7.04
14	0.16	1.86	0.47	0.841	0.495	3.845	7.03
15	0.17	1.88	0.44	0.795	0.432	3.972	7.69
16	0.17	1.97	0.50	0.903	0.522	3.641	5.97
17	0.16	1.85	0.46	0.831	0.491	3.869	7.15
18	0.15	1.66	0.40	0.704	0.420	4.378	9.80
19	0.19	2.29	0.49	0.917	0.404	3.534	5.41
20	0.20	2.45	0.47	0.917	0.311	3.624	5.87
21	0.21	2.51	0.49	0.965	0.329	3.485	5.15
22	0.19	2.17	0.45	0.839	0.361	3.789	6.73
23	0.19	2.27	0.48	0.906	0.393	3.575	5.62
24	0.21	2.54	0.50	0.985	0.347	3.408	4.75
25	0.17	2.16	0.53	0.981	0.534	3.437	4.90
26	0.17	2.12	0.52	0.951	0.514	3.523	5.35
27	0.18	2.31	0.53	1.001	0.488	3.360	4.50
28	0.19	2.37	0.53	1.010	0.456	3.340	4.40
29	0.17	2.18	0.53	0.994	0.536	3.409	4.76
30	0.18	2.25	0.51	0.964	0.471	3.462	5.03
31	0.19	2.46	0.57	1.107	0.529	3.142	3.37
32	0.18	2.31	0.50	0.946	0.417	3.501	5.23
33	0.18	2.31	0.57	1.087	0.579	3.207	3.70
34	0.19	2.37	0.52	0.995	0.438	3.377	4.59
35	0.19	2.56	0.57	1.120	0.488	3.109	3.20
36	0.18	2.28	0.53	1.001	0.490	3.370	4.55
37	0.17	2.17	0.52	0.976	0.527	3.448	4.96
38	0.19	2.49	0.54	1.044	0.460	3.248	3.92
39	0.18	2.38	0.54	1.029	0.496	3.286	4.12
40	0.17	2.01	0.45	0.820	0.420	3.846	7.03
41	0.20	2.42	0.50	0.970	0.363	3.478	5.12
42	0.20	2.57	0.53	1.033	0.382	3.321	4.30
43	0.21	2.83	0.53	1.087	0.305	3.281	4.09
44	0.22	3.06	0.57	1.205	0.312	3.085	3.07
45	0.19	2.26	0.46	0.874	0.348	3.723	6.39
46	0.23	3.33	0.62	1.312	0.325	2.901	2.11
47	0.21	2.96	0.62	1.278	0.441	2.870	1.96
48	0.21	2.70	0.51	1.024	0.295	3.422	4.82
49	0.17	2.20	0.52	0.966	0.506	3.461	5.03
50	0.23	3.34	0.62	1.321	0.335	2.880	2.00
51	0.16	1.82	0.44	0.773	0.441	4.069	8.19
52	0.22	3.20	0.66	1.365	0.448	2.740	1.28
53	0.17	1.94	0.47	0.850	0.494	3.777	6.67
54	0.16	1.79	0.43	0.757	0.432	4.126	8.49
55	0.23	3.06	0.52	1.103	0.201	3.329	5.38
56	0.18	2.22	0.50	0.931	0.420	3.557	5.53
57	0.18	2.25	0.50	0.931	0.434	3.525	5.36
58	0.18	2.22	0.50	0.926	0.427	3.552	5.50
59	0.20	2.59	0.53	1.020	0.369	3.334	4.37
60	0.23	3.07	0.52	1.088	0.192	3.593	5.71
61	0.23	3.05	0.51	1.073	0.191	3.620	5.86
62	0.20	2.56	0.52	1.010	0.341	3.404	4.73
63	0.20	2.59	0.53	1.020	0.358	3.355	4.48
64	0.18	2.22	0.50	0.923	0.418	3.569	5.59
65	0.23	3.23	0.54	1.151	0.212	3.394	4.68
66	0.23	3.08	0.53	1.113	0.209	3.473	5.09
67	0.20	2.53	0.52	0.999	0.355	3.408	4.75
68	0.18	2.29	0.52	0.961	0.431	3.468	5.07
69	0.20	2.69	0.54	1.067	0.362	3.263	4.00
70	0.20	2.48	0.48	0.932	0.291	3.646	5.99
71	0.22	2.97	0.54	1.116	0.246	3.368	4.54
72	0.20	2.56	0.52	1.012	0.354	3.387	4.64
73	0.24	3.62	0.65	1.405	0.305	2.809	1.64
74	0.22	3.02	0.56	1.145	0.273	3.253	3.94
75	0.23	3.24	0.57	1.190	0.251	3.209	3.72
76	0.22	3.12	0.56	1.170	0.247	3.268	4.02
77	0.20	2.59	0.49	0.970	0.288	3.550	5.49
78	0.20	2.60	0.54	1.068	0.355	3.293	4.15
79	0.19	2.30	0.48	0.896	0.366	3.635	5.93
80	0.23	3.41	0.63	1.331	0.320	2.887	2.04
81	0.21	2.94	0.57	1.141	0.325	3.160	3.46
82	0.19	2.36	0.48	0.906	0.349	3.615	5.83
83	0.22	3.03	0.56	1.141	0.297	3.192	3.63
84	0.20	2.71	0.56	1.107	0.365	3.205	3.70
85	0.20	2.35	0.49	0.921	0.372	3.540	5.44
86	0.19	2.32	0.49	0.931	0.388	3.519	5.33
87	0.18	2.16	0.48	0.888	0.415	3.633	5.92
88	0.19	2.31	0.49	0.927	0.389	3.528	5.38
89	0.16	1.67	0.43	0.739	0.471	4.182	8.78
90	0.21	2.63	0.58	1.128	0.462	3.064	2.96
91	0.21	2.57	0.57	1.113	0.456	3.101	3.15
92	0.19	2.13	0.49	0.898	0.447	3.574	5.62
93	0.19	2.22	0.50	0.931	0.444	3.503	5.25
94	0.22	2.91	0.58	1.181	0.382	3.006	2.66
95	0.16	1.79	0.43	0.752	0.432	4.114	8.42
96	0.22	2.98	0.61	1.234	0.412	2.898	2.10
97	0.17	1.97	0.48	0.855	0.470	3.748	6.52
98	0.20	2.43	0.56	1.073	0.497	3.170	3.51
99	0.17	1.97	0.49	0.878	0.478	3.681	6.17
100	0.18	2.12	0.46	0.836	0.352	3.826	6.92
101	0.20	2.48	0.50	0.955	0.302	3.550	5.49
102	0.22	2.87	0.51	1.020	0.243	3.492	5.19
103	0.19	2.35	0.56	1.035	0.456	3.274	4.05
104	0.22	2.95	0.53	1.063	0.256	3.367	4.54
105	0.17	2.07	0.48	0.868	0.431	3.706	6.30
106	0.23	3.01	0.54	1.083	0.246	3.360	4.50
107	0.21	2.58	0.52	1.005	0.323	3.397	4.69
108	0.23	3.03	0.55	1.107	0.259	3.290	4.14
109	0.18	2.05	0.50	0.893	0.453	3.638	5.95
110	0.22	2.80	0.56	1.111	0.336	3.170	3.51
111	0.21	2.81	0.59	1.139	0.391	3.057	2.92
112	0.23	3.25	0.69	1.352	0.436	2.687	1.00
113	0.21	2.59	0.51	0.995	0.299	3.460	5.02
114	0.19	2.28	0.54	1.004	0.435	3.375	4.58
115	0.17	1.99	0.49	0.880	0.482	3.687	6.20
116	0.16	1.80	0.48	0.835	0.519	3.854	7.07
117	0.22	2.79	0.55	1.098	0.355	3.170	3.51
118	0.17	2.01	0.50	0.885	0.490	3.647	6.00
119	0.19	2.28	0.50	0.936	0.428	3.476	5.11
120	0.16	1.76	0.46	0.803	0.494	3.985	7.75
121	0.19	2.18	0.48	0.873	0.408	3.648	6.00
122	0.23	2.91	0.53	1.084	0.252	3.359	4.50
123	0.20	2.52	0.49	0.942	0.318	3.533	5.40
124	0.20	2.47	0.55	1.054	0.459	3.218	3.76
125	0.15	1.59	0.41	0.691	0.441	4.417	10.00
126	0.22	2.81	0.56	1.107	0.362	3.142	3.37
127	0.16	1.74	0.46	0.792	0.472	4.021	7.94
128	0.21	2.71	0.53	1.048	0.350	3.255	3.95
129	0.21	2.66	0.52	1.038	0.326	3.337	4.38
130	0.18	1.99	0.45	0.820	0.364	3.907	7.35
131	0.17	1.78	0.44	0.788	0.425	4.047	8.07
132	0.17	1.84	0.47	0.817	0.459	3.893	7.27
133	0.24	3.17	0.56	1.149	0.245	3.241	3.88
134	0.22	3.03	0.59	1.168	0.357	3.016	2.71
135	0.16	1.75	0.44	0.787	0.386	4.134	8.53
136	0.23	3.06	0.54	1.092	0.253	3.317	4.28
137	0.20	2.53	0.55	1.033	0.404	3.256	3.96
138	0.20	2.47	0.48	0.912	0.298	3.640	5.96
139	0.21	2.72	0.53	1.043	0.293	3.368	4.54
140	0.23	3.07	0.61	1.211	0.348	2.970	2.47
141	0.16	1.76	0.44	0.778	0.413	4.103	8.37
142	0.19	2.18	0.46	0.855	0.361	3.747	6.52
143	0.21	2.70	0.53	1.037	0.314	3.325	4.32
144	0.20	2.41	0.52	0.989	0.362	3.423	4.83
145	0.19	2.12	0.50	0.908	0.446	3.554	5.51
146	0.18	2.00	0.51	0.923	0.533	3.534	5.41
147	0.24	3.32	0.60	1.263	0.306	2.941	2.32
148	0.22	2.90	0.62	1.236	0.459	2.844	1.82
149	0.18	2.03	0.52	0.945	0.528	3.480	5.13
150	0.23	3.00	0.54	1.117	0.279	3.228	3.82
151	0.16	1.77	0.44	0.772	0.468	4.046	8.07
152	0.19	2.24	0.52	0.955	0.473	3.415	4.79
153	0.21	2.59	0.55	1.067	0.419	3.167	3.50
154	0.21	2.62	0.55	1.082	0.413	3.168	3.50
155	0.21	2.60	0.58	1.120	0.487	3.053	2.90
156	0.20	2.51	0.53	1.014	0.402	3.297	4.17
157	0.17	1.89	0.48	0.845	0.494	3.790	6.74
158	0.21	2.59	0.58	1.130	0.449	3.067	2.98
159	0.20	2.46	0.54	1.024	0.423	3.285	4.11

Table B.3. Motions and Seakeeping Index for the Series of Hull Forms, V=5 Knots, Heading Angle 0 Deg.

HULL	Heave [m/m]	Pitch [deg/m]	Vert.Mot. at FP [m/m]	Vert.Acc. at FP [m/s^2/m]	Rel.Mot. at FP [m/m]	Sum	Index
01	0.16	1.60	0.38	0.272	0.455	4.354	7.35
02	0.16	1.62	0.39	0.277	0.474	4.264	6.69
03	0.16	1.61	0.38	0.272	0.456	4.335	7.21
04	0.17	1.68	0.41	0.299	0.521	4.000	4.75
05	0.17	1.63	0.39	0.284	0.488	4.188	6.13
06	0.15	1.44	0.36	0.259	0.471	4.578	9.00
07	0.16	1.58	0.38	0.272	0.461	4.353	7.34
08	0.17	1.64	0.40	0.287	0.497	4.144	5.80
09	0.16	1.49	0.38	0.267	0.488	4.419	7.83
10	0.17	1.62	0.39	0.284	0.492	4.183	6.09
11	0.16	1.53	0.39	0.274	0.499	4.310	7.03
12	0.16	1.53	0.40	0.282	0.521	4.224	6.39
13	0.15	1.46	0.39	0.277	0.520	4.330	7.17
14	0.15	1.45	0.39	0.274	0.520	4.363	7.42
15	0.16	1.48	0.38	0.267	0.483	4.440	7.98
16	0.16	1.50	0.41	0.284	0.537	4.220	6.37
17	0.15	1.44	0.39	0.269	0.516	4.416	7.81
18	0.15	1.36	0.36	0.249	0.471	4.714	10.00
19	0.18	1.76	0.41	0.297	0.485	4.014	4.85
20	0.19	1.94	0.41	0.307	0.439	3.923	4.17
21	0.19	1.93	0.41	0.307	0.450	3.912	4.09
22	0.17	1.71	0.39	0.282	0.450	4.207	6.26
23	0.17	1.74	0.40	0.287	0.473	4.091	5.42
24	0.19	1.95	0.42	0.307	0.467	3.855	3.68
25	0.16	1.62	0.43	0.312	0.551	3.989	4.66
26	0.16	1.61	0.42	0.303	0.543	4.034	4.99
27	0.17	1.75	0.43	0.317	0.536	3.874	3.82
28	0.17	1.78	0.43	0.312	0.517	3.890	3.94
29	0.16	1.64	0.43	0.312	0.553	3.962	4.46
30	0.17	1.72	0.43	0.307	0.524	3.952	4.39
31	0.17	1.79	0.45	0.322	0.556	3.783	3.15
32	0.17	1.78	0.42	0.307	0.496	3.954	4.40
33	0.16	1.67	0.44	0.322	0.572	3.863	3.73
34	0.17	1.80	0.43	0.312	0.509	3.894	3.96
35	0.18	1.86	0.45	0.327	0.544	3.723	2.70
36	0.17	1.72	0.43	0.307	0.534	3.938	4.29
37	0.16	1.60	0.41	0.297	0.534	4.106	5.53
38	0.18	1.89	0.45	0.327	0.537	3.708	2.59
39	0.18	1.80	0.44	0.322	0.547	3.783	3.15
40	0.16	1.62	0.40	0.282	0.489	4.221	6.37
41	0.18	1.83	0.41	0.297	0.453	4.035	5.00
42	0.18	1.90	0.42	0.310	0.467	3.910	4.08
43	0.20	2.12	0.44	0.327	0.446	3.720	2.68
44	0.19	2.10	0.42	0.312	0.414	3.873	3.81
45	0.18	1.85	0.42	0.307	0.463	3.949	4.37
46	0.20	2.20	0.44	0.327	0.443	3.682	2.40
47	0.18	1.99	0.45	0.337	0.508	3.671	2.32
48	0.20	2.09	0.43	0.325	0.437	3.764	3.01
49	0.16	1.64	0.42	0.297	0.527	4.077	5.31
50	0.20	2.20	0.44	0.327	0.436	3.707	2.58
51	0.15	1.46	0.38	0.269	0.491	4.475	8.24
52	0.19	2.07	0.46	0.337	0.505	3.621	1.95
53	0.16	1.54	0.41	0.294	0.536	4.160	5.92
54	0.15	1.43	0.37	0.262	0.482	4.559	8.86
55	0.20	2.25	0.42	0.316	0.360	3.917	4.13
56	0.16	1.63	0.39	0.282	0.473	4.265	6.69
57	0.16	1.69	0.41	0.294	0.495	4.115	5.59
58	0.16	1.64	0.40	0.282	0.479	4.239	6.50
59	0.18	1.91	0.42	0.312	0.472	3.908	4.06
60	0.20	2.24	0.41	0.310	0.345	3.990	4.67
61	0.20	2.27	0.42	0.316	0.352	3.928	4.21
62	0.17	1.87	0.41	0.297	0.442	4.050	5.11
63	0.18	1.90	0.42	0.301	0.462	3.966	4.49
64	0.16	1.65	0.40	0.282	0.480	4.228	6.43
65	0.20	2.31	0.43	0.322	0.366	3.849	3.63
66	0.20	2.28	0.43	0.322	0.376	3.833	3.52
67	0.17	1.87	0.41	0.297	0.455	4.023	4.91
68	0.16	1.67	0.40	0.287	0.484	4.178	6.05
69	0.18	1.92	0.42	0.310	0.460	3.924	4.18
70	0.18	1.90	0.40	0.295	0.416	4.081	5.34
71	0.19	2.13	0.42	0.310	0.382	3.953	4.40
72	0.17	1.86	0.41	0.297	0.449	4.047	5.09
73	0.19	2.21	0.42	0.312	0.372	3.946	4.35
74	0.18	2.06	0.41	0.301	0.389	4.029	4.96
75	0.20	2.23	0.43	0.322	0.388	3.843	3.59
76	0.19	2.12	0.41	0.306	0.371	4.017	4.87
77	0.19	2.01	0.42	0.312	0.432	3.892	3.95
78	0.17	1.81	0.40	0.292	0.436	4.144	5.80
79	0.17	1.79	0.41	0.297	0.471	4.046	5.08
80	0.18	2.15	0.42	0.312	0.403	3.910	4.08
81	0.18	2.04	0.42	0.310	0.436	3.893	3.95
82	0.17	1.83	0.41	0.297	0.460	4.039	5.03
83	0.19	2.14	0.43	0.320	0.426	3.809	3.33
84	0.17	1.86	0.41	0.297	0.441	4.072	5.28
85	0.18	1.88	0.42	0.310	0.472	3.899	4.00
86	0.18	1.81	0.41	0.297	0.470	4.008	4.80
87	0.17	1.69	0.40	0.287	0.473	4.155	5.88
88	0.17	1.79	0.41	0.297	0.464	4.051	5.12
89	0.15	1.41	0.39	0.274	0.528	4.398	7.68
90	0.18	1.93	0.44	0.327	0.513	3.732	2.77
91	0.18	1.88	0.44	0.320	0.507	3.792	3.21
92	0.17	1.73	0.42	0.307	0.519	3.932	4.24
93	0.17	1.73	0.42	0.297	0.501	4.020	4.89
94	0.19	2.07	0.44	0.322	0.465	3.742	2.85
95	0.15	1.49	0.38	0.269	0.494	4.402	7.70
96	0.19	2.10	0.45	0.337	0.495	3.608	1.86
97	0.16	1.57	0.40	0.284	0.513	4.206	6.26
98	0.17	1.79	0.44	0.322	0.526	3.838	3.55
99	0.16	1.54	0.40	0.284	0.513	4.230	6.44
100	0.17	1.72	0.39	0.287	0.452	4.187	6.12
101	0.18	1.91	0.40	0.297	0.418	4.073	5.28
102	0.20	2.22	0.42	0.317	0.396	3.826	3.46
103	0.17	1.77	0.45	0.322	0.534	3.820	3.42
104	0.20	2.22	0.42	0.317	0.401	3.819	3.41
105	0.16	1.67	0.42	0.297	0.515	4.045	5.07
106	0.20	2.20	0.42	0.310	0.375	3.931	4.23
107	0.18	1.93	0.41	0.297	0.429	4.019	4.88
108	0.20	2.23	0.43	0.320	0.398	3.818	3.40
109	0.17	1.66	0.43	0.307	0.539	3.958	4.43
110	0.18	1.94	0.40	0.297	0.411	4.076	5.31
111	0.19	2.03	0.45	0.332	0.490	3.696	2.50
112	0.19	2.16	0.48	0.360	0.511	3.492	1.00
113	0.18	1.90	0.39	0.282	0.399	4.176	6.04
114	0.16	1.70	0.42	0.297	0.497	4.071	5.27
115	0.16	1.57	0.41	0.291	0.516	4.172	6.01
116	0.15	1.44	0.40	0.287	0.545	4.278	6.79
117	0.19	2.09	0.44	0.322	0.464	3.720	2.68
118	0.16	1.60	0.42	0.297	0.532	4.077	5.31
119	0.18	1.83	0.43	0.315	0.511	3.832	3.51
120	0.15	1.44	0.40	0.278	0.531	4.359	7.39
121	0.17	1.80	0.42	0.307	0.496	3.936	4.27
122	0.20	2.21	0.42	0.322	0.387	3.830	3.49
123	0.19	2.05	0.43	0.322	0.447	3.779	3.12
124	0.18	1.86	0.44	0.322	0.515	3.804	3.30
125	0.14	1.37	0.37	0.259	0.506	4.583	9.04
126	0.20	2.10	0.44	0.325	0.468	3.692	2.48
127	0.15	1.40	0.39	0.267	0.512	4.477	8.26
128	0.20	2.08	0.44	0.322	0.464	3.719	2.67
129	0.19	2.03	0.42	0.310	0.427	3.882	3.87
130	0.16	1.61	0.38	0.274	0.456	4.324	7.13
131	0.15	1.45	0.38	0.269	0.498	4.437	7.96
132	0.16	1.51	0.41	0.287	0.531	4.189	6.13
133	0.20	2.14	0.40	0.295	0.347	4.104	5.51
134	0.20	2.16	0.45	0.335	0.475	3.615	1.91
135	0.14	1.40	0.36	0.254	0.458	4.699	9.89
136	0.20	2.25	0.43	0.322	0.391	3.807	3.32
137	0.18	1.88	0.43	0.312	0.491	3.856	3.69
138	0.19	2.00	0.42	0.307	0.434	3.899	4.00
139	0.18	1.99	0.40	0.295	0.394	4.079	5.33
140	0.19	2.06	0.42	0.310	0.430	3.888	3.92
141	0.15	1.43	0.37	0.257	0.487	4.557	8.85
142	0.17	1.76	0.40	0.292	0.459	4.105	5.52
143	0.19	2.01	0.42	0.307	0.426	3.922	4.17
144	0.17	1.77	0.39	0.287	0.434	4.190	6.14
145	0.17	1.66	0.41	0.294	0.500	4.088	5.39
146	0.16	1.53	0.41	0.291	0.539	4.124	5.66
147	0.21	2.28	0.44	0.325	0.418	3.698	2.52
148	0.19	2.00	0.45	0.332	0.512	3.635	2.05
149	0.16	1.52	0.40	0.284	0.524	4.207	6.27
150	0.20	2.21	0.42	0.318	0.402	3.806	3.32
151	0.15	1.47	0.39	0.272	0.519	4.349	7.31
152	0.17	1.73	0.42	0.307	0.521	3.930	4.23
153	0.19	1.93	0.43	0.317	0.501	3.767	3.02
154	0.18	1.91	0.42	0.312	0.478	3.873	3.81
155	0.19	1.91	0.45	0.332	0.537	3.671	2.32
156	0.19	1.93	0.43	0.317	0.491	3.792	3.21
157	0.15	1.48	0.39	0.272	0.514	4.352	7.34
158	0.17	1.82	0.42	0.307	0.484	3.953	4.40
159	0.18	1.82	0.41	0.300	0.480	3.974	4.55

Table B.4. Motions and Seakeeping Index for the Series of Hull Forms, V=10 Knots, Heading Angle 0 Deg.

HULL	Heave [m/m]	Pitch [deg/m]	Vert.Mot. at FP [m/m]	Vert.Acc. at FP [m/s^2/m]	Rel.Mot. at FP [m/m]	Sum	Index
01	0.16	1.54	0.37	0.057	0.437	3.987	5.31
02	0.16	1.36	0.34	0.057	0.452	4.141	6.71
03	0.16	1.52	0.37	0.057	0.436	3.998	5.41
04	0.16	1.38	0.36	0.057	0.507	3.989	5.33
05	0.16	1.32	0.34	0.057	0.463	4.172	6.98
06	0.14	1.24	0.33	0.057	0.464	4.321	8.33
07	0.16	1.47	0.36	0.057	0.436	4.043	5.82
08	0.16	1.33	0.34	0.057	0.481	4.116	6.48
09	0.15	1.26	0.33	0.057	0.483	4.239	7.59
10	0.16	1.34	0.35	0.057	0.475	4.111	6.43
11	0.15	1.26	0.34	0.057	0.494	4.207	7.30
12	0.15	1.25	0.34	0.057	0.517	4.168	6.95
13	0.15	1.22	0.34	0.057	0.523	4.218	7.40
14	0.15	1.20	0.34	0.057	0.519	4.263	7.81
15	0.15	1.26	0.33	0.057	0.478	4.253	7.71
16	0.15	1.24	0.35	0.058	0.536	4.131	6.61
17	0.14	1.18	0.33	0.057	0.512	4.317	8.30
18	0.14	1.22	0.33	0.057	0.471	4.356	8.65
19	0.17	1.45	0.36	0.057	0.462	3.982	5.27
20	0.18	1.76	0.38	0.062	0.372	3.797	3.59
21	0.18	1.64	0.37	0.062	0.400	3.836	3.95
22	0.16	1.45	0.35	0.057	0.421	4.083	6.17
23	0.17	1.43	0.35	0.057	0.443	4.052	5.89
24	0.18	1.64	0.37	0.062	0.431	3.760	3.25
25	0.15	1.39	0.38	0.067	0.544	3.820	3.79
26	0.15	1.39	0.38	0.067	0.537	3.828	3.87
27	0.16	1.49	0.38	0.067	0.517	3.730	2.98
28	0.16	1.51	0.38	0.062	0.488	3.818	3.77
29	0.15	1.39	0.38	0.067	0.544	3.812	3.72
30	0.16	1.49	0.38	0.064	0.506	3.790	3.52
31	0.16	1.47	0.38	0.067	0.533	3.724	2.92
32	0.16	1.56	0.38	0.062	0.462	3.810	3.70
33	0.16	1.37	0.38	0.067	0.556	3.802	3.64
34	0.16	1.54	0.38	0.062	0.479	3.803	3.64
35	0.17	1.53	0.39	0.067	0.510	3.679	2.52
36	0.16	1.46	0.38	0.064	0.514	3.816	3.76
37	0.15	1.20	0.33	0.057	0.497	4.277	7.93
38	0.17	1.65	0.40	0.072	0.513	3.511	1.00
39	0.17	1.54	0.39	0.072	0.536	3.584	1.66
40	0.15	1.40	0.36	0.057	0.466	4.074	6.09
41	0.16	1.49	0.35	0.057	0.398	4.087	6.21
42	0.17	1.62	0.37	0.062	0.427	3.840	3.98
43	0.18	1.78	0.38	0.062	0.377	3.765	3.30
44	0.18	1.58	0.34	0.057	0.360	4.097	6.30
45	0.17	1.70	0.39	0.062	0.395	3.790	3.53
46	0.18	1.73	0.36	0.062	0.388	3.806	3.67
47	0.17	1.50	0.36	0.062	0.451	3.882	4.36
48	0.18	1.82	0.38	0.062	0.359	3.780	3.44
49	0.15	1.35	0.36	0.057	0.510	4.087	6.22
50	0.18	1.66	0.35	0.057	0.368	4.013	5.54
51	0.14	1.26	0.34	0.057	0.480	4.268	7.86
52	0.17	1.56	0.36	0.062	0.446	3.849	4.06
53	0.15	1.31	0.36	0.062	0.533	3.989	5.33
54	0.14	1.23	0.34	0.057	0.472	4.336	8.47
55	0.19	1.82	0.35	0.062	0.301	3.993	5.36
56	0.15	1.28	0.32	0.057	0.433	4.338	8.49
57	0.15	1.37	0.35	0.057	0.472	4.133	6.63
58	0.15	1.27	0.32	0.057	0.445	4.307	8.21
59	0.17	1.50	0.35	0.057	0.420	4.044	5.83
60	0.18	1.83	0.35	0.057	0.278	4.164	6.91
61	0.19	1.88	0.35	0.057	0.275	4.133	6.63
62	0.16	1.51	0.34	0.057	0.384	4.142	6.71
63	0.16	1.53	0.35	0.057	0.410	4.048	5.86
64	0.15	1.33	0.33	0.057	0.453	4.233	7.54
65	0.19	1.86	0.35	0.062	0.298	3.979	5.24
66	0.19	1.85	0.36	0.062	0.329	3.876	4.30
67	0.16	1.49	0.35	0.057	0.394	4.121	6.52
68	0.15	1.34	0.34	0.057	0.456	4.209	7.32
69	0.16	1.53	0.35	0.057	0.405	4.062	5.98
70	0.17	1.62	0.36	0.057	0.344	4.098	6.31
71	0.18	1.71	0.35	0.057	0.299	4.172	6.98
72	0.16	1.51	0.35	0.057	0.393	4.118	6.49
73	0.17	1.57	0.31	0.051	0.304	4.435	9.36
74	0.17	1.70	0.35	0.057	0.312	4.182	7.07
75	0.18	1.77	0.35	0.057	0.304	4.118	6.49
76	0.17	1.70	0.34	0.057	0.292	4.235	7.55
77	0.18	1.71	0.37	0.062	0.352	3.889	4.42
78	0.15	1.44	0.33	0.057	0.380	4.253	7.72
79	0.16	1.54	0.37	0.062	0.430	3.906	4.57
80	0.17	1.60	0.33	0.051	0.326	4.341	8.52
81	0.17	1.61	0.35	0.057	0.364	4.088	6.22
82	0.16	1.56	0.36	0.062	0.414	3.914	4.65
83	0.18	1.71	0.36	0.062	0.353	3.929	4.78
84	0.16	1.50	0.34	0.057	0.382	4.193	7.17
85	0.17	1.62	0.37	0.062	0.412	3.854	4.11
86	0.16	1.55	0.36	0.057	0.419	4.005	5.47
87	0.16	1.47	0.35	0.057	0.439	4.083	6.18
88	0.16	1.52	0.35	0.057	0.419	4.056	5.93
89	0.14	1.26	0.36	0.058	0.539	4.132	6.62
90	0.16	1.53	0.36	0.057	0.444	3.980	5.24
91	0.16	1.49	0.36	0.057	0.437	4.029	5.68
92	0.16	1.46	0.37	0.062	0.488	3.858	4.14
93	0.16	1.47	0.36	0.057	0.474	3.996	5.39
94	0.17	1.60	0.35	0.057	0.375	4.063	5.99
95	0.15	1.32	0.35	0.057	0.492	4.166	6.93
96	0.17	1.61	0.36	0.057	0.401	3.978	5.23
97	0.15	1.36	0.36	0.057	0.504	4.084	6.18
98	0.16	1.47	0.36	0.057	0.485	3.978	5.22
99	0.15	1.30	0.35	0.057	0.500	4.174	7.00
100	0.16	1.48	0.35	0.057	0.400	4.129	6.60
101	0.16	1.59	0.35	0.057	0.329	4.203	7.27
102	0.18	1.75	0.34	0.057	0.300	4.133	6.63
103	0.16	1.53	0.39	0.062	0.497	3.784	3.47
104	0.18	1.67	0.33	0.055	0.320	4.173	6.99
105	0.16	1.48	0.38	0.062	0.491	3.856	4.12
106	0.18	1.69	0.33	0.051	0.273	4.410	9.14
107	0.16	1.51	0.33	0.057	0.333	4.265	7.83
108	0.18	1.64	0.33	0.055	0.311	4.233	7.54
109	0.16	1.48	0.39	0.067	0.520	3.715	2.85
110	0.16	1.48	0.31	0.051	0.316	4.505	10.00
111	0.17	1.59	0.36	0.057	0.390	4.013	5.54
112	0.17	1.69	0.37	0.057	0.390	3.947	4.95
113	0.16	1.60	0.34	0.051	0.313	4.365	8.73
114	0.15	1.46	0.36	0.057	0.468	4.044	5.82
115	0.15	1.33	0.35	0.057	0.494	4.138	6.68
116	0.14	1.21	0.35	0.057	0.538	4.233	7.54
117	0.18	1.66	0.36	0.057	0.371	3.998	5.41
118	0.15	1.38	0.37	0.057	0.521	4.013	5.54
119	0.17	1.58	0.38	0.062	0.459	3.790	3.52
120	0.14	1.25	0.35	0.057	0.531	4.203	7.26
121	0.17	1.57	0.38	0.062	0.457	3.816	3.76
122	0.18	1.75	0.34	0.055	0.284	4.233	7.53
123	0.18	1.79	0.38	0.062	0.352	3.831	3.89
124	0.16	1.51	0.36	0.057	0.462	3.969	5.15
125	0.14	1.23	0.35	0.057	0.514	4.257	7.75
126	0.18	1.63	0.35	0.057	0.373	4.013	5.54
127	0.14	1.23	0.34	0.057	0.512	4.273	7.90
128	0.18	1.65	0.36	0.057	0.371	3.992	5.36
129	0.17	1.70	0.36	0.057	0.324	4.094	6.28
130	0.15	1.45	0.35	0.057	0.433	4.107	6.40
131	0.15	1.33	0.36	0.057	0.512	4.128	6.59
132	0.15	1.42	0.39	0.064	0.547	3.811	3.71
133	0.18	1.58	0.31	0.051	0.291	4.444	9.44
134	0.18	1.74	0.37	0.062	0.374	3.850	4.07
135	0.13	1.24	0.33	0.057	0.454	4.408	9.12
136	0.18	1.76	0.34	0.055	0.294	4.202	7.25
137	0.17	1.62	0.37	0.062	0.440	3.828	3.87
138	0.18	1.74	0.37	0.062	0.347	3.896	4.48
139	0.17	1.72	0.35	0.055	0.309	4.212	7.34
140	0.16	1.61	0.33	0.051	0.339	4.304	8.18
141	0.14	1.30	0.34	0.057	0.495	4.222	7.43
142	0.16	1.55	0.36	0.057	0.415	4.012	5.53
143	0.17	1.64	0.35	0.057	0.325	4.165	6.92
144	0.15	1.55	0.35	0.057	0.395	4.134	6.64
145	0.16	1.40	0.35	0.057	0.478	4.071	6.07
146	0.15	1.32	0.36	0.057	0.535	4.071	6.07
147	0.18	1.71	0.34	0.051	0.324	4.200	7.24
148	0.17	1.53	0.35	0.057	0.423	4.011	5.53
149	0.15	1.31	0.35	0.057	0.518	4.146	6.75
150	0.18	1.79	0.35	0.055	0.319	4.082	6.16
151	0.15	1.29	0.35	0.057	0.523	4.141	6.71
152	0.16	1.46	0.36	0.057	0.501	3.955	5.01
153	0.17	1.51	0.35	0.057	0.441	3.988	5.31
154	0.16	1.54	0.35	0.057	0.421	4.036	5.75
155	0.17	1.54	0.37	0.062	0.495	3.780	3.43
156	0.17	1.63	0.37	0.062	0.434	3.810	3.70
157	0.14	1.24	0.33	0.057	0.505	4.275	7.91
158	0.15	1.42	0.33	0.057	0.426	4.185	7.10
159	0.16	1.52	0.35	0.057	0.436	4.036	5.75

Table B.5. Motions and Seakeeping Index for the Series of Hull Forms, V=15 Knots, Heading Angle 0 Deg.

HULL	Heave [m/m]	Pitch [deg/m]	Vert.Mot. at FP [m/m]	Vert.Acc. at FP [m/s^2/m]	Rel.Mot. at FP [m/m]	Sum	Index
01	0.15	1.26	0.30	0.040	0.347	3.923	5.25
02	0.15	1.21	0.30	0.030	0.403	4.076	6.35
03	0.15	1.25	0.30	0.036	0.348	4.020	5.95
04	0.16	1.28	0.33	0.040	0.459	3.602	2.91
05	0.15	1.19	0.31	0.030	0.424	4.045	6.13
06	0.14	1.09	0.29	0.030	0.404	4.262	7.71
07	0.15	1.22	0.30	0.030	0.359	4.186	7.16
08	0.15	1.23	0.32	0.040	0.441	3.710	3.69
09	0.14	1.14	0.30	0.030	0.426	4.127	6.73
10	0.15	1.22	0.31	0.036	0.432	3.827	4.55
11	0.15	1.17	0.31	0.036	0.446	3.886	4.97
12	0.15	1.17	0.32	0.036	0.473	3.813	4.44
13	0.14	1.15	0.32	0.040	0.478	3.756	4.03
14	0.14	1.12	0.32	0.036	0.474	3.895	5.04
15	0.14	1.12	0.30	0.030	0.415	4.184	7.14
16	0.15	1.15	0.33	0.040	0.490	3.715	3.73
17	0.14	1.10	0.31	0.036	0.469	3.947	5.42
18	0.13	1.05	0.29	0.030	0.387	4.374	8.52
19	0.16	1.32	0.32	0.040	0.419	3.643	3.21
20	0.17	1.39	0.30	0.051	0.331	3.636	3.15
21	0.17	1.38	0.31	0.049	0.361	3.581	2.76
22	0.16	1.27	0.30	0.036	0.379	3.898	5.07
23	0.16	1.28	0.31	0.040	0.404	3.725	3.80
24	0.17	1.41	0.32	0.051	0.386	3.453	1.83
25	0.14	1.23	0.33	0.045	0.467	3.399	2.89
26	0.15	1.23	0.33	0.040	0.457	3.703	3.64
27	0.15	1.28	0.33	0.045	0.439	3.573	2.70
28	0.16	1.29	0.32	0.051	0.422	3.519	2.30
29	0.15	1.24	0.34	0.045	0.472	3.564	2.63
30	0.15	1.28	0.32	0.040	0.425	3.705	3.66
31	0.15	1.29	0.34	0.055	0.469	3.377	1.27
32	0.15	1.29	0.31	0.040	0.389	3.763	4.08
33	0.15	1.25	0.35	0.055	0.499	3.377	1.28
34	0.16	1.30	0.32	0.045	0.411	3.611	2.98
35	0.16	1.32	0.33	0.055	0.447	3.378	1.28
36	0.15	1.25	0.32	0.045	0.439	3.613	2.99
37	0.15	1.16	0.32	0.045	0.492	3.626	3.08
38	0.16	1.39	0.34	0.055	0.432	3.340	1.00
39	0.16	1.35	0.34	0.051	0.458	3.382	1.31
40	0.15	1.20	0.31	0.030	0.405	4.088	6.44
41	0.16	1.25	0.30	0.040	0.370	3.844	4.67
42	0.16	1.35	0.31	0.055	0.368	3.550	2.53
43	0.17	1.43	0.31	0.055	0.342	3.509	2.24
44	0.17	1.34	0.29	0.055	0.343	3.603	2.92
45	0.16	1.32	0.30	0.040	0.346	3.822	4.51
46	0.17	1.42	0.30	0.061	0.349	3.455	1.84
47	0.16	1.31	0.32	0.055	0.418	3.441	1.73
48	0.17	1.42	0.31	0.055	0.327	3.556	2.58
49	0.14	1.22	0.32	0.040	0.456	3.737	3.89
50	0.17	1.37	0.30	0.061	0.345	3.523	2.33
51	0.13	1.09	0.29	0.030	0.403	4.287	7.89
52	0.16	1.34	0.31	0.061	0.408	3.399	1.43
53	0.14	1.19	0.33	0.036	0.469	3.814	4.45
54	0.13	1.06	0.29	0.030	0.399	4.339	8.27
55	0.18	1.43	0.29	0.055	0.287	3.707	3.68
56	0.14	1.10	0.28	0.030	0.400	4.273	7.79
57	0.15	1.22	0.31	0.040	0.427	3.798	4.33
58	0.14	1.13	0.29	0.030	0.416	4.179	7.11
59	0.16	1.29	0.30	0.040	0.387	3.784	4.24
60	0.17	1.42	0.28	0.055	0.275	3.784	4.23
61	0.18	1.43	0.28	0.055	0.273	3.772	4.15
62	0.15	1.23	0.28	0.036	0.353	4.044	6.12
63	0.16	1.28	0.30	0.040	0.372	3.838	4.63
64	0.14	1.17	0.30	0.036	0.408	4.009	5.87
65	0.17	1.45	0.28	0.061	0.285	3.663	3.36
66	0.18	1.46	0.29	0.055	0.302	3.613	2.99
67	0.15	1.24	0.29	0.036	0.366	3.989	5.72
68	0.14	1.17	0.29	0.036	0.407	4.009	5.87
69	0.16	1.27	0.29	0.040	0.367	3.860	4.78
70	0.16	1.28	0.28	0.040	0.323	3.962	5.53
71	0.17	1.34	0.28	0.051	0.298	3.816	4.47
72	0.15	1.24	0.29	0.040	0.355	3.949	5.43
73	0.16	1.28	0.27	0.055	0.309	3.826	4.54
74	0.16	1.31	0.27	0.051	0.295	3.909	5.14
75	0.17	1.37	0.28	0.055	0.297	3.751	3.99
76	0.16	1.32	0.27	0.055	0.291	3.846	4.69
77	0.17	1.36	0.30	0.040	0.331	3.835	4.60
78	0.15	1.17	0.27	0.036	0.350	4.161	6.98
79	0.15	1.28	0.30	0.036	0.372	3.930	5.29
80	0.16	1.28	0.27	0.049	0.319	3.893	5.02
81	0.16	1.30	0.28	0.043	0.339	3.863	4.81
82	0.16	1.30	0.30	0.040	0.365	3.829	4.56
83	0.17	1.37	0.29	0.051	0.329	3.691	3.56
84	0.15	1.19	0.27	0.040	0.343	4.067	6.29
85	0.16	1.24	0.29	0.040	0.366	3.877	4.91
86	0.15	1.17	0.28	0.040	0.366	3.992	5.74
87	0.14	1.10	0.27	0.030	0.363	4.370	8.50
88	0.15	1.17	0.28	0.040	0.369	3.990	5.73
89	0.13	1.02	0.29	0.030	0.448	4.289	7.90
90	0.16	1.16	0.29	0.040	0.403	3.887	4.98
91	0.15	1.12	0.28	0.040	0.400	3.946	5.41
92	0.15	1.14	0.29	0.030	0.419	4.113	6.62
93	0.15	1.14	0.29	0.036	0.401	4.041	6.10
94	0.16	1.21	0.28	0.049	0.361	3.800	4.35
95	0.14	1.06	0.28	0.030	0.406	4.318	8.12
96	0.16	1.23	0.29	0.049	0.384	3.690	3.55
97	0.14	1.09	0.29	0.030	0.413	4.275	7.80
98	0.15	1.10	0.28	0.040	0.415	3.973	5.61
99	0.14	0.99	0.27	0.030	0.420	4.392	8.66
100	0.15	1.11	0.27	0.030	0.355	4.362	8.44
101	0.15	1.14	0.26	0.036	0.327	4.251	7.63
102	0.17	1.33	0.28	0.040	0.312	3.937	5.35
103	0.14	1.08	0.28	0.030	0.390	4.311	8.07
104	0.17	1.31	0.28	0.040	0.328	3.897	5.06
105	0.14	1.09	0.28	0.030	0.393	4.278	7.83
106	0.17	1.26	0.26	0.040	0.301	4.083	6.41
107	0.15	1.10	0.26	0.030	0.345	4.395	8.68
108	0.17	1.29	0.27	0.040	0.324	3.944	5.40
109	0.14	1.08	0.29	0.030	0.404	4.263	7.72
110	0.15	1.03	0.24	0.030	0.336	4.577	10.00
111	0.15	1.14	0.27	0.036	0.369	4.104	6.56
112	0.15	1.11	0.26	0.040	0.358	4.105	6.57
113	0.15	1.11	0.25	0.040	0.309	4.303	8.01
114	0.14	1.05	0.26	0.030	0.368	4.471	9.23
115	0.14	1.00	0.27	0.030	0.409	4.406	8.75
116	0.13	0.95	0.28	0.030	0.458	4.392	8.65
117	0.16	1.26	0.28	0.049	0.358	3.738	3.90
118	0.14	1.06	0.29	0.030	0.428	4.246	7.59
119	0.15	1.19	0.29	0.040	0.395	3.858	4.77
120	0.13	1.01	0.29	0.030	0.440	4.338	8.26
121	0.15	1.22	0.30	0.040	0.391	3.843	4.66
122	0.17	1.30	0.27	0.055	0.301	3.799	4.34
123	0.16	1.31	0.29	0.049	0.329	3.760	4.06
124	0.15	1.16	0.29	0.040	0.408	3.884	4.96
125	0.13	1.00	0.28	0.030	0.415	4.405	8.75
126	0.17	1.25	0.28	0.040	0.364	3.851	4.72
127	0.13	0.97	0.27	0.030	0.412	4.507	9.49
128	0.17	1.27	0.29	0.040	0.359	3.846	4.68
129	0.16	1.21	0.27	0.049	0.319	3.936	5.34
130	0.14	1.09	0.27	0.030	0.348	4.434	8.96
131	0.13	1.08	0.29	0.030	0.402	4.327	8.18
132	0.14	1.09	0.30	0.030	0.413	4.238	7.54
133	0.17	1.28	0.26	0.040	0.302	4.051	6.18
134	0.16	1.27	0.28	0.049	0.352	3.765	4.10
135	0.12	1.05	0.27	0.036	0.354	4.400	8.72
136	0.17	1.32	0.27	0.049	0.307	3.843	4.66
137	0.15	1.17	0.28	0.040	0.370	3.998	5.79
138	0.16	1.29	0.28	0.040	0.328	3.932	5.31
139	0.15	1.20	0.25	0.040	0.293	4.242	7.57
140	0.15	1.15	0.25	0.040	0.334	4.151	6.90
141	0.13	1.06	0.28	0.030	0.389	4.405	8.75
142	0.15	1.17	0.28	0.030	0.357	4.265	7.73
143	0.16	1.16	0.26	0.040	0.329	4.107	6.59
144	0.14	1.12	0.26	0.036	0.326	4.354	8.38
145	0.14	1.05	0.27	0.030	0.408	4.303	8.01
146	0.14	1.01	0.28	0.030	0.441	4.312	8.08
147	0.17	1.32	0.28	0.055	0.329	3.674	3.43
148	0.16	1.14	0.28	0.040	0.399	3.910	5.15
149	0.13	0.99	0.27	0.030	0.420	4.453	9.10
150	0.17	1.37	0.28	0.055	0.315	3.678	3.46
151	0.14	1.07	0.30	0.030	0.439	4.223	7.43
152	0.15	1.15	0.29	0.040	0.427	3.864	4.81
153	0.16	1.20	0.29	0.040	0.410	3.801	4.36
154	0.15	1.19	0.28	0.040	0.382	3.921	5.23
155	0.16	1.22	0.31	0.049	0.436	3.587	2.80
156	0.16	1.24	0.29	0.040	0.383	3.827	4.55
157	0.13	0.99	0.28	0.030	0.435	4.391	8.65
158	0.15	1.02	0.26	0.040	0.389	4.165	7.01
159	0.15	1.15	0.27	0.040	0.378	4.015	5.91

Table B.6. Motions and Seakeeping Index for the Series of Hull Forms, V=0 Knots, Heading Angle 45 Deg.

HULL	Heave [m/m]	Roll [deg/m]	Pitch [deg/m]	Vert.Mot. at FP [m/m]	Vert.Acc. at FP [m/s^2/m]	Rel.Mot. at FP [m/m]	Sum	Index
01	0.23	1.43	2.07	0.48	1.017	0.287	4.465	7.76
02	0.24	1.29	2.26	0.52	1.129	0.304	4.188	6.14
03	0.23	1.51	2.09	0.48	1.031	0.285	4.428	7.55
04	0.25	1.60	2.34	0.56	1.201	0.337	3.932	4.64
05	0.24	1.20	2.32	0.55	1.192	0.322	4.070	5.45
06	0.22	1.55	1.94	0.48	0.987	0.340	4.490	7.91
07	0.23	1.64	2.07	0.48	1.017	0.292	4.428	7.54
08	0.24	1.31	2.32	0.55	1.182	0.328	4.041	5.28
09	0.23	1.39	2.10	0.52	1.088	0.350	4.254	6.52
10	0.24	1.60	2.23	0.52	1.118	0.321	4.117	5.73
11	0.23	1.36	2.23	0.55	1.158	0.362	4.080	5.51
12	0.23	1.67	2.14	0.54	1.133	0.382	4.065	5.42
13	0.23	1.70	2.08	0.54	1.118	0.404	4.107	5.67
14	0.23	1.46	2.08	0.54	1.128	0.410	4.131	5.81
15	0.23	1.28	2.10	0.52	1.088	0.348	4.285	6.71
16	0.23	1.46	2.20	0.57	1.205	0.424	3.954	4.77
17	0.23	1.36	2.07	0.54	1.123	0.409	4.167	6.02
18	0.22	1.45	1.87	0.48	0.966	0.362	4.581	8.44
19	0.25	1.51	2.41	0.54	1.177	0.280	4.028	5.20
20	0.26	1.35	2.48	0.51	1.144	0.204	4.255	6.53
21	0.27	1.30	2.54	0.53	1.188	0.215	4.140	5.86
22	0.25	1.30	2.30	0.51	1.104	0.259	4.270	6.62
23	0.25	1.27	2.40	0.54	1.180	0.276	4.091	5.57
24	0.27	1.58	2.56	0.54	1.197	0.223	4.040	5.28
25	0.23	1.22	2.41	0.60	1.310	0.415	3.831	4.05
26	0.23	1.32	2.36	0.59	1.269	0.402	3.886	4.37
27	0.24	1.36	2.50	0.59	1.298	0.355	3.816	3.96
28	0.25	1.22	2.51	0.58	1.279	0.322	3.885	4.36
29	0.23	1.34	2.43	0.61	1.317	0.413	3.787	3.79
30	0.24	1.30	2.44	0.57	1.255	0.346	3.915	4.54
31	0.25	1.26	2.64	0.63	1.386	0.372	3.674	3.13
32	0.25	1.34	2.46	0.55	1.222	0.294	3.994	5.01
33	0.24	1.34	2.56	0.64	1.414	0.435	3.623	2.83
34	0.25	1.34	2.52	0.57	1.265	0.307	3.892	4.41
35	0.25	1.39	2.68	0.61	1.372	0.330	3.673	3.12
36	0.24	1.36	2.47	0.59	1.298	0.358	3.816	3.96
37	0.23	1.67	2.42	0.60	1.308	0.407	3.759	3.63
38	0.25	1.70	2.61	0.58	1.285	0.310	3.771	3.70
39	0.24	1.77	2.55	0.59	1.310	0.354	3.718	3.39
40	0.23	1.52	2.17	0.51	1.095	0.323	4.217	6.31
41	0.26	0.96	2.51	0.54	1.220	0.251	4.154	5.94
42	0.26	0.80	2.67	0.57	1.299	0.261	4.083	5.52
43	0.27	1.17	2.78	0.55	1.251	0.192	4.093	5.58
44	0.28	0.51	3.04	0.59	1.393	0.212	4.251	6.51
45	0.25	1.72	2.32	0.50	1.099	0.241	4.238	6.44
46	0.29	0.52	3.25	0.62	1.446	0.231	4.076	5.48
47	0.27	0.83	3.02	0.65	1.485	0.290	3.710	3.34
48	0.27	1.24	2.65	0.53	1.198	0.186	4.208	6.26
49	0.24	1.15	2.47	0.60	1.308	0.387	3.853	4.18
50	0.29	0.44	3.30	0.63	1.476	0.234	4.195	6.18
51	0.22	1.21	2.04	0.52	1.080	0.370	4.349	7.08
52	0.27	0.61	3.28	0.68	1.576	0.303	3.746	3.55
53	0.23	1.93	2.13	0.54	1.133	0.395	4.053	5.35
54	0.22	1.11	2.01	0.51	1.060	0.365	4.430	7.56
55	0.29	0.54	2.88	0.54	1.245	0.141	4.708	9.19
56	0.24	0.69	2.49	0.58	1.268	0.318	4.204	6.23
57	0.24	1.14	2.49	0.57	1.245	0.320	3.986	4.96
58	0.24	0.98	2.48	0.57	1.249	0.318	4.053	5.35
59	0.26	0.97	2.71	0.57	1.275	0.248	4.029	5.21
60	0.29	0.49	2.92	0.53	1.245	0.139	4.795	9.69
61	0.29	0.60	2.89	0.53	1.225	0.134	4.716	9.23
62	0.26	0.66	2.72	0.57	1.283	0.236	4.258	6.55
63	0.26	0.72	2.73	0.57	1.288	0.243	4.175	6.06
64	0.24	0.79	2.48	0.57	1.239	0.314	4.171	6.04
65	0.29	0.52	3.07	0.56	1.294	0.161	4.521	8.09
66	0.29	0.76	2.88	0.54	1.235	0.143	4.485	7.88
67	0.26	0.69	2.66	0.56	1.266	0.242	4.247	6.49
68	0.24	0.72	2.58	0.59	1.292	0.320	4.119	5.74
69	0.26	0.70	2.84	0.59	1.342	0.247	4.094	5.59
70	0.26	0.92	2.56	0.53	1.182	0.200	4.350	7.09
71	0.28	0.53	2.94	0.57	1.328	0.180	4.429	7.55
72	0.26	0.59	2.74	0.58	1.313	0.250	4.263	6.58
73	0.30	0.85	3.61	0.67	1.611	0.289	3.445	1.79
74	0.28	0.55	3.13	0.60	1.415	0.216	4.161	5.98
75	0.29	0.47	3.19	0.59	1.375	0.200	4.333	6.99
76	0.29	0.64	3.13	0.60	1.411	0.205	4.071	5.46
77	0.27	1.12	2.58	0.53	1.186	0.191	4.268	6.61
78	0.26	0.41	2.82	0.61	1.387	0.260	4.439	7.61
79	0.24	1.18	2.44	0.53	1.167	0.260	4.174	6.06
80	0.29	0.91	3.52	0.67	1.577	0.281	3.492	2.07
81	0.27	0.59	3.06	0.61	1.400	0.232	4.112	5.70
82	0.25	1.15	2.48	0.53	1.167	0.243	4.199	6.20
83	0.28	0.71	3.04	0.59	1.352	0.205	4.105	5.66
84	0.26	0.55	2.95	0.62	1.440	0.269	4.094	5.59
85	0.26	1.34	2.46	0.53	1.177	0.257	4.082	5.52
86	0.26	0.90	2.49	0.55	1.220	0.277	4.136	5.83
87	0.25	0.74	2.40	0.56	1.225	0.316	4.213	6.29
88	0.26	0.73	2.48	0.55	1.230	0.283	4.214	6.29
89	0.22	1.73	1.87	0.50	1.006	0.413	4.381	7.27
90	0.27	0.79	2.79	0.62	1.412	0.317	3.823	4.00
91	0.27	0.73	2.73	0.62	1.412	0.322	3.860	4.22
92	0.25	1.64	2.28	0.54	1.161	0.336	3.993	5.00
93	0.25	0.89	2.42	0.57	1.239	0.334	4.060	5.39
94	0.28	0.59	3.02	0.62	1.440	0.262	3.989	4.97
95	0.23	1.51	1.99	0.50	1.025	0.365	4.362	7.16
96	0.28	0.70	3.03	0.63	1.450	0.273	3.843	4.12
97	0.23	1.00	2.23	0.56	1.186	0.385	4.129	5.80
98	0.26	0.72	2.65	0.63	1.406	0.364	3.871	4.28
99	0.24	0.86	2.22	0.57	1.206	0.396	4.142	5.87
100	0.24	1.08	2.28	0.51	1.114	0.271	4.309	6.85
101	0.26	0.75	2.61	0.55	1.226	0.214	4.313	6.87
102	0.28	1.12	2.83	0.54	1.220	0.160	4.260	6.56
103	0.24	1.00	2.57	0.62	1.331	0.351	3.834	4.07
104	0.28	1.12	2.90	0.56	1.260	0.175	4.110	5.69
105	0.24	1.17	2.26	0.55	1.166	0.347	4.112	5.70
106	0.29	0.84	3.03	0.57	1.319	0.185	4.094	5.59
107	0.27	0.79	2.72	0.57	1.298	0.232	4.108	5.67
108	0.29	0.95	2.99	0.57	1.309	0.186	4.055	5.36
109	0.23	1.42	2.25	0.56	1.177	0.365	4.022	5.17
110	0.28	1.08	3.02	0.63	1.440	0.259	3.674	3.13
111	0.27	1.07	2.95	0.63	1.399	0.282	3.699	3.27
112	0.27	1.19	3.38	0.72	1.589	0.348	3.310	1.00
113	0.27	0.78	2.79	0.58	1.311	0.221	4.114	5.71
114	0.25	0.84	2.57	0.62	1.335	0.344	3.927	4.61
115	0.24	1.10	2.22	0.56	1.196	0.391	4.074	5.48
116	0.22	1.26	2.02	0.55	1.137	0.451	4.156	5.96
117	0.27	0.82	2.83	0.58	1.304	0.227	4.061	5.40
118	0.24	1.25	2.23	0.56	1.186	0.391	4.033	5.23
119	0.25	1.68	2.40	0.54	1.177	0.303	3.967	4.85
120	0.22	1.26	1.99	0.53	1.097	0.438	4.260	6.56
121	0.25	1.65	2.29	0.52	1.122	0.296	4.108	5.67
122	0.29	0.46	2.86	0.55	1.256	0.166	4.695	9.11
123	0.26	1.47	2.55	0.52	1.148	0.205	4.196	6.19
124	0.26	0.89	2.62	0.60	1.328	0.323	3.900	4.45
125	0.21	1.74	1.80	0.48	0.948	0.391	4.577	8.42
126	0.27	0.93	2.83	0.58	1.304	0.229	3.995	5.01
127	0.22	0.99	2.00	0.54	1.092	0.418	4.357	7.13
128	0.27	1.24	2.73	0.55	1.245	0.219	4.014	5.12
129	0.27	0.60	2.74	0.56	1.279	0.217	4.337	7.01
130	0.24	0.87	2.20	0.52	1.093	0.292	4.428	7.54
131	0.23	0.96	2.01	0.51	1.044	0.369	4.465	7.76
132	0.23	1.06	2.08	0.54	1.112	0.394	4.254	6.52
133	0.29	1.03	3.15	0.59	1.342	0.216	3.825	4.02
134	0.27	0.93	3.11	0.62	1.386	0.253	3.771	3.70
135	0.22	0.52	2.03	0.51	1.059	0.347	4.847	10.00
136	0.29	0.79	3.06	0.57	1.309	0.186	4.125	5.77
137	0.26	0.91	2.74	0.61	1.327	0.287	3.893	4.41
138	0.26	1.22	2.53	0.52	1.147	0.199	4.276	6.65
139	0.28	0.79	2.93	0.59	1.370	0.222	3.996	5.01
140	0.29	1.11	3.25	0.66	1.512	0.285	3.482	2.00
141	0.22	0.86	2.00	0.51	1.039	0.361	4.548	8.25
142	0.25	1.12	2.35	0.52	1.128	0.270	4.239	6.44
143	0.28	0.90	2.82	0.58	1.313	0.221	4.011	5.10
144	0.26	0.86	2.70	0.60	1.338	0.276	3.951	4.75
145	0.25	0.89	2.33	0.57	1.214	0.342	4.097	5.61
146	0.24	1.15	2.28	0.59	1.264	0.436	3.890	4.39
147	0.30	0.61	3.29	0.62	1.440	0.230	3.942	4.70
148	0.27	1.00	3.03	0.65	1.469	0.304	3.594	2.66
149	0.24	0.80	2.36	0.62	1.321	0.434	3.944	4.71
150	0.29	0.79	2.97	0.57	1.315	0.184	4.146	5.90
151	0.22	1.60	1.99	0.51	1.054	0.401	4.270	6.62
152	0.25	1.21	2.45	0.58	1.254	0.348	3.889	4.39
153	0.27	1.10	2.70	0.59	1.311	0.280	3.838	4.09
154	0.27	0.54	2.80	0.61	1.402	0.290	4.102	5.63
155	0.26	1.17	2.74	0.62	1.376	0.330	3.675	3.13
156	0.26	1.11	2.64	0.57	1.275	0.271	3.929	4.62
157	0.23	0.97	2.16	0.56	1.186	0.422	4.133	5.82
158	0.27	0.58	2.85	0.65	1.482	0.327	3.909	4.50
159	0.26	0.54	2.70	0.60	1.366	0.305	4.162	5.99

Table B.7. Motions and Seakeeping Index for the Series of Hull Forms, V=5 Knots, Heading Angle 45 Deg.

HULL	Heave [m/m]	Roll [deg/m]	Pitch [deg/m]	Vert.Mot. at FP [m/m]	Vert.Acc. at FP [m/s^2/m]	Rel.Mot. at FP [m/m]	Sum	Index
01	0.22	0.87	1.84	0.46	0.507	0.421	4.668	6.30
02	0.23	0.79	1.89	0.48	0.522	0.443	4.570	5.66
03	0.22	0.91	1.85	0.47	0.512	0.420	4.634	6.08
04	0.23	0.92	1.95	0.51	0.562	0.491	4.292	3.84
05	0.23	0.75	1.90	0.49	0.535	0.459	4.511	5.27
06	0.21	0.95	1.70	0.46	0.489	0.458	4.768	6.95
07	0.22	1.00	1.84	0.47	0.517	0.432	4.578	5.71
08	0.23	0.80	1.91	0.49	0.537	0.469	4.464	4.96
09	0.22	0.85	1.77	0.47	0.517	0.475	4.611	5.93
10	0.23	0.93	1.88	0.48	0.532	0.462	4.463	4.96
11	0.22	0.81	1.82	0.49	0.532	0.487	4.523	5.35
12	0.22	0.98	1.80	0.49	0.532	0.509	4.438	4.79
13	0.22	0.99	1.74	0.49	0.527	0.519	4.496	5.17
14	0.22	0.90	1.73	0.49	0.527	0.521	4.535	5.43
15	0.22	0.80	1.76	0.47	0.507	0.469	4.665	6.28
16	0.22	0.87	1.79	0.51	0.547	0.538	4.412	4.62
17	0.21	0.86	1.72	0.48	0.522	0.516	4.583	5.74
18	0.21	0.94	1.63	0.45	0.479	0.461	4.858	7.54
19	0.24	0.86	2.01	0.49	0.547	0.440	4.380	4.42
20	0.25	0.75	2.15	0.49	0.556	0.377	4.428	4.73
21	0.25	0.73	2.15	0.49	0.561	0.388	4.411	4.62
22	0.23	0.78	1.95	0.47	0.517	0.406	4.602	5.87
23	0.24	0.76	2.00	0.49	0.541	0.430	4.465	4.97
24	0.25	0.82	2.17	0.50	0.563	0.402	4.318	4.01
25	0.23	0.75	1.94	0.53	0.585	0.543	4.265	3.67
26	0.22	0.80	1.93	0.53	0.585	0.536	4.264	3.66
27	0.23	0.79	2.04	0.53	0.591	0.509	4.198	3.23
28	0.24	0.72	2.05	0.52	0.581	0.478	4.288	3.82
29	0.23	0.80	1.96	0.54	0.597	0.548	4.202	3.25
30	0.23	0.77	2.02	0.52	0.582	0.496	4.266	3.67
31	0.24	0.71	2.10	0.55	0.615	0.532	4.126	2.76
32	0.24	0.77	2.05	0.51	0.572	0.455	4.322	4.04
33	0.23	0.79	2.00	0.55	0.621	0.570	4.103	2.61
34	0.24	0.77	2.07	0.52	0.581	0.469	4.268	3.69
35	0.24	0.78	2.15	0.54	0.615	0.505	4.087	2.50
36	0.23	0.79	2.01	0.53	0.591	0.509	4.225	3.41
37	0.22	0.90	1.93	0.52	0.575	0.537	4.272	3.71
38	0.24	0.90	2.17	0.54	0.606	0.488	4.068	2.38
39	0.24	0.94	2.10	0.54	0.604	0.515	4.077	2.44
40	0.22	0.89	1.88	0.49	0.537	0.461	4.491	5.14
41	0.24	0.58	2.08	0.49	0.551	0.404	4.556	5.57
42	0.24	0.51	2.14	0.50	0.566	0.412	4.528	5.38
43	0.26	0.61	2.33	0.51	0.585	0.374	4.344	4.18
44	0.25	0.37	2.32	0.50	0.566	0.345	4.750	6.84
45	0.24	0.93	2.08	0.50	0.557	0.410	4.354	4.25
46	0.26	0.40	2.44	0.52	0.606	0.369	4.494	5.16
47	0.25	0.53	2.29	0.54	0.619	0.452	4.237	3.48
48	0.26	0.64	2.29	0.51	0.581	0.368	4.375	4.39
49	0.22	0.71	1.97	0.52	0.577	0.519	4.329	4.08
50	0.26	0.36	2.45	0.52	0.594	0.358	4.623	6.00
51	0.21	0.77	1.74	0.48	0.517	0.483	4.687	6.42
52	0.25	0.43	2.39	0.55	0.629	0.444	4.292	3.84
53	0.22	1.09	1.83	0.51	0.557	0.527	4.334	4.12
54	0.21	0.72	1.71	0.47	0.504	0.473	4.792	7.11
55	0.26	0.30	2.45	0.49	0.563	0.291	5.026	8.64
56	0.22	0.43	1.98	0.49	0.542	0.451	4.762	6.91
57	0.22	0.59	2.04	0.51	0.567	0.475	4.453	4.89
58	0.22	0.53	1.98	0.50	0.545	0.458	4.618	5.97
59	0.24	0.52	2.22	0.51	0.581	0.421	4.439	4.80
60	0.26	0.26	2.43	0.48	0.551	0.278	5.220	9.91
61	0.27	0.32	2.45	0.48	0.556	0.283	5.007	8.51
62	0.24	0.39	2.18	0.50	0.563	0.393	4.730	6.71
63	0.24	0.45	2.21	0.51	0.576	0.413	4.550	5.53
64	0.22	0.47	2.00	0.50	0.551	0.461	4.655	6.22
65	0.27	0.28	2.52	0.50	0.576	0.292	5.012	8.55
66	0.26	0.40	2.48	0.50	0.571	0.300	4.749	6.83
67	0.24	0.43	2.18	0.50	0.566	0.405	4.635	6.08
68	0.22	0.44	2.02	0.51	0.562	0.464	4.638	6.10
69	0.24	0.40	2.25	0.51	0.581	0.409	4.593	5.81
70	0.24	0.52	2.16	0.48	0.547	0.362	4.661	6.26
71	0.26	0.29	2.36	0.49	0.566	0.317	5.006	8.51
72	0.24	0.35	2.18	0.50	0.566	0.404	4.780	7.03
73	0.26	0.43	2.52	0.50	0.579	0.308	4.667	6.29
74	0.25	0.29	2.36	0.50	0.566	0.332	4.978	8.33
75	0.26	0.25	2.49	0.51	0.587	0.319	5.013	8.55
76	0.25	0.31	2.39	0.49	0.566	0.314	4.947	8.12
77	0.25	0.60	2.25	0.50	0.568	0.370	4.464	4.96
78	0.23	0.26	2.13	0.49	0.553	0.395	5.098	9.11
79	0.23	0.66	2.08	0.50	0.560	0.429	4.449	4.87
80	0.25	0.45	2.49	0.51	0.594	0.342	4.523	5.35
81	0.25	0.33	2.36	0.52	0.589	0.377	4.707	6.56
82	0.24	0.63	2.11	0.50	0.557	0.413	4.488	5.12
83	0.25	0.37	2.41	0.51	0.585	0.354	4.651	6.19
84	0.23	0.32	2.20	0.51	0.570	0.398	4.855	7.52
85	0.24	0.77	2.14	0.50	0.566	0.419	4.334	4.11
86	0.24	0.60	2.09	0.50	0.557	0.427	4.465	4.97
87	0.23	0.56	2.00	0.49	0.547	0.444	4.567	5.64
88	0.24	0.52	2.07	0.49	0.551	0.422	4.584	5.75
89	0.21	1.10	1.70	0.49	0.527	0.528	4.504	5.23
90	0.25	0.58	2.22	0.53	0.606	0.465	4.234	3.46
91	0.25	0.52	2.18	0.53	0.600	0.463	4.318	4.01
92	0.24	1.00	2.02	0.51	0.575	0.491	4.190	3.17
93	0.24	0.64	2.03	0.51	0.562	0.471	4.398	4.53
94	0.26	0.47	2.35	0.52	0.601	0.404	4.384	4.44
95	0.22	0.94	1.78	0.48	0.517	0.484	4.577	5.71
96	0.26	0.53	2.38	0.54	0.621	0.428	4.218	3.36
97	0.22	0.70	1.88	0.50	0.557	0.505	4.450	4.88
98	0.24	0.56	2.11	0.53	0.600	0.499	4.279	3.76
99	0.22	0.63	1.86	0.50	0.547	0.509	4.513	5.29
100	0.23	0.67	2.01	0.48	0.532	0.419	4.370	5.66
101	0.24	0.44	2.20	0.49	0.551	0.370	4.713	6.60
102	0.27	0.56	2.44	0.50	0.576	0.322	4.492	5.15
103	0.24	0.63	2.13	0.55	0.625	0.522	4.135	2.81
104	0.26	0.55	2.45	0.50	0.576	0.328	4.484	5.09
105	0.23	0.74	1.99	0.52	0.575	0.502	4.302	3.91
106	0.26	0.42	2.46	0.49	0.571	0.311	4.693	6.46
107	0.25	0.46	2.23	0.50	0.563	0.383	4.585	5.76
108	0.26	0.48	2.48	0.50	0.585	0.326	4.527	5.38
109	0.23	0.87	1.98	0.53	0.590	0.528	4.175	3.08
110	0.24	0.56	2.27	0.49	0.561	0.368	4.528	5.38
111	0.25	0.59	2.37	0.55	0.629	0.445	4.136	2.82
112	0.26	0.63	2.57	0.59	0.693	0.472	3.857	1.00
113	0.24	0.43	2.22	0.48	0.547	0.357	4.752	6.85
114	0.23	0.53	2.05	0.52	0.585	0.486	4.415	4.64
115	0.22	0.72	1.88	0.50	0.557	0.502	4.433	4.90
116	0.22	0.84	1.76	0.51	0.555	0.554	4.431	4.75
117	0.26	0.58	2.34	0.52	0.594	0.395	4.311	3.97
118	0.22	0.78	1.91	0.52	0.570	0.520	4.335	4.13
119	0.24	0.94	2.11	0.52	0.585	0.465	4.177	3.09
120	0.21	0.85	1.75	0.50	0.542	0.537	4.504	5.23
121	0.24	0.94	2.05	0.50	0.560	0.451	4.296	3.87
122	0.26	0.37	2.41	0.49	0.566	0.314	4.798	7.15
123	0.25	0.80	2.27	0.50	0.576	0.378	4.302	3.91
124	0.24	0.63	2.16	0.53	0.598	0.474	4.255	3.60
125	0.21	1.10	1.66	0.47	0.502	0.504	4.668	6.30
126	0.26	0.65	2.35	0.52	0.594	0.396	4.260	3.63
127	0.21	0.71	1.72	0.49	0.517	0.514	4.670	6.31
128	0.26	0.76	2.32	0.51	0.585	0.390	4.245	3.53
129	0.25	0.45	2.27	0.50	0.566	0.365	4.605	5.89
130	0.23	0.57	1.91	0.48	0.522	0.433	4.707	6.56
131	0.22	0.65	1.75	0.48	0.511	0.493	4.697	6.49
132	0.23	0.72	1.83	0.51	0.560	0.531	4.401	4.56
133	0.26	0.47	2.43	0.48	0.556	0.288	4.752	6.85
134	0.27	0.50	2.46	0.54	0.621	0.409	4.228	3.43
135	0.20	0.36	1.71	0.46	0.487	0.454	5.234	10.00
136	0.27	0.43	2.49	0.50	0.581	0.318	4.605	5.89
137	0.25	0.55	2.21	0.52	0.591	0.453	4.304	3.92
138	0.25	0.70	2.25	0.50	0.561	0.372	4.407	4.59
139	0.25	0.44	2.28	0.49	0.556	0.343	4.711	6.58
140	0.26	0.55	2.40	0.51	0.594	0.377	4.360	4.29
141	0.21	0.59	1.73	0.47	0.507	0.481	4.808	7.21
142	0.24	0.68	2.05	0.49	0.545	0.422	4.489	5.13
143	0.25	0.51	2.29	0.50	0.576	0.368	4.497	5.18
144	0.23	0.50	2.08	0.49	0.545	0.397	4.671	6.32
145	0.23	0.64	1.96	0.50	0.555	0.478	4.443	4.83
146	0.23	0.76	1.86	0.52	0.567	0.540	4.333	4.11
147	0.27	0.43	2.51	0.51	0.591	0.339	4.510	5.27
148	0.26	0.68	2.32	0.54	0.624	0.458	4.074	2.42
149	0.23	0.61	1.86	0.51	0.560	0.529	4.446	4.85
150	0.27	0.50	2.39	0.49	0.561	0.323	4.595	5.82
151	0.22	1.02	1.77	0.49	0.532	0.517	4.464	4.97
152	0.24	0.79	2.04	0.52	0.575	0.496	4.235	3.47
153	0.25	0.71	2.22	0.52	0.591	0.449	4.199	3.23
154	0.25	0.44	2.20	0.51	0.576	0.431	4.510	5.27
155	0.25	0.75	2.20	0.54	0.614	0.494	4.072	2.41
156	0.25	0.71	2.20	0.51	0.591	0.436	4.237	3.48
157	0.22	0.69	1.79	0.49	0.532	0.515	4.564	5.62
158	0.24	0.41	2.14	0.51	0.581	0.448	4.558	5.58
159	0.24	0.44	2.13	0.51	0.570	0.443	4.545	5.49

Table B.8. Motions and Seakeeping Index for the Series of Hull Forms, V=10 Knots, Heading Angle 45 Deg.

HULL	Heave [m/m]	Roll [deg/m]	Pitch [deg/m]	Vert.Mot. at FP [m/m]	Vert.Acc. at FP [m/s^2/m]	Rel.Mot. at FP [m/m]	Sum	Index
01	0.22	0.68	1.76	0.46	0.193	0.453	4.620	4.73
02	0.22	0.64	1.75	0.46	0.195	0.483	4.577	4.43
03	0.22	0.71	1.76	0.46	0.193	0.453	4.600	4.59
04	0.23	0.74	1.83	0.50	0.208	0.539	4.270	2.28
05	0.22	0.62	1.73	0.47	0.195	0.497	4.573	4.40
06	0.21	0.76	1.57	0.44	0.184	0.489	4.766	5.76
07	0.23	0.80	1.78	0.47	0.195	0.466	4.503	3.91
08	0.23	0.66	1.76	0.48	0.199	0.514	4.469	3.67
09	0.22	0.69	1.62	0.46	0.195	0.506	4.637	4.85
10	0.23	0.75	1.76	0.48	0.199	0.507	4.431	3.41
11	0.22	0.66	1.64	0.46	0.195	0.518	4.605	4.62
12	0.22	0.79	1.65	0.48	0.199	0.546	4.456	3.58
13	0.22	0.78	1.58	0.47	0.195	0.550	4.542	4.18
14	0.21	0.73	1.56	0.47	0.195	0.548	4.597	4.57
15	0.22	0.65	1.60	0.45	0.193	0.497	4.708	5.35
16	0.22	0.69	1.60	0.48	0.199	0.563	4.519	4.02
17	0.21	0.71	1.54	0.46	0.195	0.542	4.654	4.97
18	0.20	0.75	1.47	0.43	0.180	0.480	4.921	6.84
19	0.24	0.70	1.92	0.49	0.204	0.495	4.309	2.55
20	0.25	0.60	2.14	0.50	0.204	0.421	4.359	2.90
21	0.25	0.59	2.12	0.50	0.204	0.442	4.344	2.80
22	0.23	0.64	1.85	0.47	0.193	0.455	4.551	4.25
23	0.23	0.64	1.89	0.48	0.204	0.481	4.408	3.25
24	0.25	0.66	2.15	0.51	0.213	0.463	4.191	1.72
25	0.22	0.59	1.73	0.50	0.208	0.561	4.434	3.43
26	0.22	0.62	1.74	0.50	0.208	0.556	4.404	3.22
27	0.23	0.61	1.87	0.51	0.208	0.539	4.320	2.63
28	0.23	0.55	1.90	0.50	0.208	0.518	4.374	3.00
29	0.22	0.62	1.75	0.50	0.208	0.568	4.371	2.99
30	0.23	0.60	1.85	0.50	0.208	0.527	4.362	2.92
31	0.23	0.56	1.89	0.52	0.214	0.562	4.282	2.36
32	0.23	0.59	1.92	0.49	0.204	0.491	4.396	3.16
33	0.22	0.61	1.76	0.51	0.214	0.588	4.308	2.54
34	0.23	0.58	1.93	0.50	0.208	0.507	4.351	2.84
35	0.24	0.59	1.98	0.52	0.220	0.544	4.192	1.73
36	0.23	0.60	1.83	0.50	0.208	0.539	4.365	2.94
37	0.22	0.73	1.68	0.48	0.199	0.559	4.466	3.65
38	0.24	0.70	2.05	0.53	0.220	0.530	4.088	1.00
39	0.24	0.72	1.94	0.52	0.220	0.551	4.134	1.32
40	0.22	0.70	1.76	0.48	0.199	0.499	4.488	3.81
41	0.23	0.46	1.93	0.48	0.200	0.451	4.614	4.69
42	0.23	0.41	1.99	0.49	0.204	0.457	4.603	4.61
43	0.25	0.49	2.30	0.51	0.210	0.422	4.336	2.74
44	0.24	0.32	2.13	0.47	0.195	0.400	4.865	6.45
45	0.24	0.72	2.05	0.50	0.208	0.450	4.277	2.32
46	0.25	0.33	2.28	0.50	0.208	0.422	4.607	4.64
47	0.24	0.41	2.04	0.51	0.204	0.497	4.483	3.77
48	0.25	0.51	2.28	0.51	0.210	0.412	4.344	2.80
49	0.22	0.56	1.74	0.48	0.204	0.540	4.515	4.00
50	0.25	0.35	2.19	0.48	0.195	0.404	4.739	5.57
51	0.21	0.60	1.57	0.45	0.195	0.504	4.774	5.81
52	0.24	0.38	2.06	0.50	0.204	0.478	4.554	4.27
53	0.22	0.85	1.69	0.49	0.208	0.561	4.334	2.73
54	0.20	0.56	1.53	0.44	0.187	0.494	4.909	6.76
55	0.25	0.27	2.44	0.49	0.202	0.336	4.956	7.09
56	0.21	0.38	1.70	0.45	0.189	0.473	4.990	7.32
57	0.22	0.50	1.82	0.48	0.204	0.509	4.567	4.36
58	0.21	0.45	1.72	0.46	0.193	0.484	4.821	6.14
59	0.23	0.45	2.04	0.49	0.204	0.466	4.512	3.97
60	0.25	0.24	2.40	0.48	0.195	0.320	5.193	8.75
61	0.25	0.28	2.44	0.48	0.195	0.319	5.013	7.49
62	0.23	0.36	1.95	0.47	0.189	0.429	4.882	6.57
63	0.23	0.41	2.02	0.49	0.202	0.454	4.621	4.74
64	0.21	0.41	1.76	0.46	0.193	0.489	4.826	6.18
65	0.25	0.26	2.48	0.49	0.202	0.332	4.975	7.22
66	0.25	0.35	2.48	0.50	0.208	0.347	4.671	5.09
67	0.23	0.39	1.98	0.48	0.198	0.446	4.723	5.46
68	0.22	0.39	1.76	0.46	0.193	0.487	4.862	6.43
69	0.23	0.36	2.01	0.48	0.202	0.446	4.722	5.45
70	0.24	0.44	2.04	0.47	0.198	0.402	4.689	5.22
71	0.24	0.26	2.23	0.48	0.195	0.361	5.082	7.97
72	0.23	0.32	1.95	0.47	0.193	0.438	4.924	6.86
73	0.23	0.38	2.18	0.46	0.187	0.356	4.909	6.76
74	0.23	0.28	2.12	0.46	0.189	0.371	5.115	8.21
75	0.25	0.25	2.33	0.49	0.195	0.359	5.063	7.84
76	0.24	0.29	2.22	0.47	0.195	0.360	5.004	7.42
77	0.24	0.52	2.21	0.50	0.204	0.412	4.424	3.36
78	0.22	0.26	1.83	0.45	0.189	0.426	5.265	9.26
79	0.23	0.55	1.96	0.49	0.204	0.468	4.467	3.66
80	0.23	0.42	2.13	0.46	0.187	0.379	4.828	6.19
81	0.24	0.32	2.11	0.48	0.198	0.414	4.842	6.29
82	0.23	0.52	2.00	0.49	0.204	0.455	4.484	3.78
83	0.24	0.34	2.23	0.49	0.202	0.396	4.734	5.53
84	0.22	0.31	1.87	0.45	0.189	0.421	5.092	8.04
85	0.24	0.64	2.03	0.49	0.202	0.455	4.367	2.96
86	0.23	0.52	1.92	0.47	0.198	0.456	4.568	4.36
87	0.22	0.52	1.77	0.45	0.189	0.459	4.739	5.57
88	0.23	0.46	1.89	0.47	0.189	0.454	4.715	5.40
89	0.21	0.90	1.57	0.47	0.199	0.553	4.504	3.92
90	0.23	0.55	1.94	0.48	0.202	0.483	4.448	3.53
91	0.23	0.47	1.91	0.48	0.202	0.482	4.556	4.28
92	0.23	0.84	1.87	0.49	0.204	0.519	4.257	2.19
93	0.23	0.58	1.83	0.47	0.198	0.495	4.522	4.04
94	0.24	0.49	2.08	0.47	0.195	0.428	4.565	4.34
95	0.21	0.76	1.64	0.46	0.195	0.509	4.596	4.56
96	0.24	0.53	2.10	0.49	0.202	0.455	4.407	3.24
97	0.22	0.62	1.69	0.47	0.195	0.519	4.605	4.62
98	0.23	0.55	1.82	0.48	0.202	0.506	4.513	3.98
99	0.21	0.57	1.63	0.46	0.193	0.519	4.710	5.36
100	0.22	0.60	1.86	0.46	0.193	0.447	4.623	4.75
101	0.23	0.42	2.00	0.46	0.189	0.400	4.819	6.13
102	0.25	0.51	2.35	0.48	0.195	0.349	4.574	4.41
103	0.23	0.58	1.86	0.50	0.208	0.520	4.385	3.08
104	0.25	0.51	2.33	0.48	0.195	0.361	4.564	4.34
105	0.22	0.65	1.82	0.49	0.204	0.517	4.404	3.21
106	0.25	0.40	2.28	0.46	0.193	0.339	4.809	6.06
107	0.23	0.46	1.98	0.46	0.189	0.410	4.755	5.68
108	0.25	0.46	2.32	0.48	0.195	0.359	4.637	4.85
109	0.23	0.76	1.80	0.50	0.208	0.537	4.294	2.45
110	0.23	0.55	1.90	0.43	0.180	0.387	4.885	6.59
111	0.24	0.55	2.06	0.49	0.202	0.457	4.412	3.27
112	0.24	0.60	2.09	0.49	0.202	0.455	4.371	2.98
113	0.23	0.42	1.95	0.44	0.180	0.379	4.985	7.29
114	0.22	0.53	1.76	0.46	0.193	0.485	4.702	5.31
115	0.21	0.60	1.64	0.46	0.193	0.508	4.699	5.29
116	0.21	0.72	1.55	0.47	0.195	0.561	4.617	4.71
117	0.25	0.53	2.15	0.49	0.202	0.427	4.428	3.38
118	0.22	0.65	1.71	0.48	0.199	0.535	4.503	3.91
119	0.24	0.76	1.96	0.50	0.204	0.493	4.270	2.28
120	0.21	0.71	1.56	0.46	0.195	0.548	4.637	4.85
121	0.23	0.76	1.95	0.49	0.204	0.487	4.299	2.48
122	0.25	0.34	2.27	0.47	0.193	0.347	4.872	6.50
123	0.25	0.66	2.20	0.49	0.202	0.408	4.342	2.78
124	0.23	0.55	1.92	0.49	0.202	0.499	4.440	3.47
125	0.20	0.89	1.53	0.45	0.195	0.526	4.644	4.90
126	0.25	0.60	2.14	0.49	0.202	0.427	4.382	3.06
127	0.20	0.63	1.50	0.44	0.187	0.517	4.850	6.34
128	0.25	0.67	2.15	0.49	0.202	0.422	4.339	2.76
129	0.24	0.42	2.06	0.46	0.195	0.388	4.759	5.70
130	0.22	0.50	1.75	0.43	0.189	0.454	4.804	6.02
131	0.21	0.57	1.61	0.45	0.193	0.512	4.747	5.62
132	0.22	0.62	1.68	0.48	0.199	0.542	4.512	3.98
133	0.24	0.43	2.27	0.46	0.187	0.333	4.838	6.26
134	0.25	0.48	2.21	0.49	0.202	0.425	4.444	3.50
135	0.20	0.34	1.51	0.42	0.180	0.463	5.371	10.00
136	0.25	0.41	2.34	0.47	0.193	0.344	4.733	5.53
137	0.23	0.52	1.96	0.48	0.198	0.466	4.519	4.03
138	0.25	0.61	2.17	0.49	0.202	0.403	4.412	3.27
139	0.23	0.40	2.02	0.44	0.180	0.363	4.998	7.38
140	0.23	0.53	2.04	0.45	0.187	0.396	4.715	5.40
141	0.21	0.52	1.57	0.44	0.184	0.498	4.912	6.78
142	0.23	0.59	1.92	0.47	0.198	0.452	4.530	4.10
143	0.24	0.48	2.06	0.46	0.187	0.392	4.729	5.50
144	0.22	0.45	1.79	0.43	0.180	0.409	5.004	7.42
145	0.22	0.58	1.74	0.46	0.193	0.498	4.614	4.69
146	0.22	0.66	1.61	0.46	0.193	0.537	4.616	4.70
147	0.25	0.43	2.30	0.47	0.193	0.369	4.649	4.93
148	0.24	0.63	1.96	0.47	0.195	0.466	4.439	3.46
149	0.21	0.58	1.57	0.44	0.189	0.516	4.791	5.93
150	0.25	0.45	2.28	0.47	0.193	0.361	4.661	5.02
151	0.22	0.85	1.63	0.47	0.199	0.541	4.481	3.76
152	0.23	0.70	1.84	0.48	0.202	0.518	4.362	2.92
153	0.24	0.64	2.01	0.49	0.202	0.483	4.326	2.67
154	0.23	0.42	1.97	0.47	0.195	0.461	4.662	5.03
155	0.24	0.67	1.98	0.50	0.204	0.520	4.250	2.13
156	0.24	0.63	2.04	0.49	0.202	0.467	4.339	2.76
157	0.21	0.62	1.56	0.45	0.189	0.523	4.761	5.72
158	0.22	0.45	1.78	0.44	0.183	0.457	4.873	6.50
159	0.23	0.46	1.87	0.46	0.189	0.462	4.716	5.40

Table B.9. Motions and Seakeeping Index for the Series of Hull Forms, V=15 Knots, Heading Angle 45 Deg.

HULL	Heave [m/m]	Roll [deg/m]	Pitch [deg/m]	Vert.Mot. at FP [m/m]	Vert.Acc. at FP [m/s^2/m]	Rel.Mot. at FP [m/m]	Sum	Index
01	0.21	0.77	1.84	0.46	0.057	0.357	4.271	3.64
02	0.22	0.68	1.89	0.49	0.057	0.434	4.130	2.81
03	0.21	0.80	1.83	0.46	0.057	0.359	4.260	3.58
04	0.22	0.76	1.99	0.52	0.062	0.496	3.829	1.01
05	0.22	0.64	1.89	0.50	0.057	0.465	4.093	2.58
06	0.21	0.83	1.68	0.47	0.057	0.450	4.220	3.34
07	0.21	0.90	1.84	0.46	0.057	0.370	4.195	3.19
08	0.22	0.68	1.94	0.51	0.057	0.482	4.003	2.05
09	0.21	0.71	1.77	0.49	0.057	0.476	4.135	2.83
10	0.22	0.81	1.91	0.50	0.057	0.464	3.989	1.97
11	0.22	0.65	1.82	0.50	0.057	0.503	4.085	2.54
12	0.22	0.82	1.83	0.52	0.062	0.537	3.875	1.28
13	0.21	0.80	1.77	0.51	0.062	0.550	3.920	1.55
14	0.21	0.74	1.74	0.51	0.062	0.551	3.966	1.82
15	0.21	0.67	1.73	0.48	0.057	0.466	4.207	3.27
16	0.22	0.67	1.80	0.53	0.062	0.571	3.925	1.58
17	0.21	0.72	1.71	0.51	0.057	0.549	4.083	2.53
18	0.20	0.81	1.53	0.44	0.057	0.430	4.402	4.43
19	0.23	0.75	2.05	0.50	0.057	0.429	3.980	1.91
20	0.23	0.68	2.10	0.46	0.051	0.301	4.352	4.13
21	0.23	0.62	2.12	0.48	0.051	0.340	4.268	3.63
22	0.22	0.71	1.97	0.48	0.055	0.389	4.160	2.98
23	0.22	0.67	2.02	0.49	0.057	0.418	4.059	2.38
24	0.23	0.71	2.16	0.49	0.051	0.362	4.145	2.89
25	0.21	0.58	1.86	0.52	0.062	0.530	3.992	1.98
26	0.21	0.63	1.86	0.52	0.062	0.513	3.976	1.89
27	0.22	0.61	1.97	0.52	0.057	0.473	4.039	2.26
28	0.22	0.55	2.01	0.51	0.057	0.450	4.093	2.58
29	0.22	0.62	1.89	0.53	0.062	0.534	3.938	1.66
30	0.22	0.63	1.94	0.51	0.057	0.456	4.072	2.46
31	0.22	0.54	2.01	0.54	0.062	0.516	3.929	1.60
32	0.22	0.60	1.97	0.49	0.057	0.401	4.160	2.98
33	0.22	0.58	1.93	0.55	0.062	0.575	3.883	1.33
34	0.22	0.58	2.00	0.50	0.057	0.428	4.106	2.66
35	0.22	0.54	2.06	0.53	0.062	0.473	3.955	1.76
36	0.22	0.57	1.94	0.52	0.057	0.481	4.081	2.51
37	0.22	0.75	1.86	0.53	0.062	0.575	3.857	1.17
38	0.23	0.75	2.08	0.51	0.057	0.432	3.944	1.69
39	0.22	0.75	2.03	0.53	0.062	0.482	3.828	1.00
40	0.21	0.80	1.86	0.49	0.057	0.439	4.092	2.58
41	0.22	0.49	2.01	0.48	0.055	0.384	4.312	3.89
42	0.22	0.39	2.09	0.49	0.055	0.374	4.398	4.40
43	0.23	0.52	2.19	0.47	0.051	0.302	4.410	4.48
44	0.23	0.25	2.18	0.47	0.047	0.326	4.961	7.76
45	0.22	0.87	2.00	0.47	0.055	0.330	4.201	3.23
46	0.23	0.24	2.26	0.47	0.051	0.317	4.887	7.32
47	0.22	0.31	2.13	0.51	0.055	0.438	4.419	4.52
48	0.23	0.59	2.16	0.46	0.051	0.287	4.409	4.47
49	0.21	0.55	1.87	0.52	0.057	0.520	4.109	2.68
50	0.23	0.31	2.20	0.46	0.047	0.320	4.779	6.68
51	0.20	0.65	1.64	0.47	0.057	0.461	4.327	3.98
52	0.23	0.31	2.15	0.50	0.051	0.417	4.494	4.98
53	0.21	0.92	1.82	0.52	0.062	0.525	3.873	1.27
54	0.20	0.60	1.60	0.46	0.057	0.462	4.407	4.46
55	0.23	0.30	2.24	0.43	0.047	0.223	5.134	8.79
56	0.21	0.38	1.78	0.47	0.055	0.455	4.523	5.15
57	0.21	0.53	1.93	0.50	0.057	0.469	4.184	3.12
58	0.21	0.47	1.82	0.48	0.057	0.468	4.321	3.94
59	0.22	0.48	2.05	0.48	0.051	0.387	4.357	4.16
60	0.23	0.26	2.21	0.42	0.047	0.210	5.336	10.00
61	0.23	0.33	2.21	0.42	0.047	0.203	5.185	9.09
62	0.21	0.37	1.98	0.46	0.051	0.358	4.625	5.75
63	0.22	0.42	2.04	0.47	0.051	0.370	4.470	4.83
64	0.21	0.42	1.86	0.48	0.057	0.456	4.373	4.26
65	0.23	0.26	2.25	0.43	0.047	0.216	5.305	9.81
66	0.23	0.40	2.26	0.44	0.047	0.234	4.879	7.27
67	0.21	0.42	1.99	0.47	0.051	0.372	4.510	5.07
68	0.21	0.37	1.86	0.48	0.057	0.456	4.448	4.70
69	0.22	0.35	2.03	0.47	0.051	0.368	4.591	5.55
70	0.22	0.53	2.01	0.45	0.051	0.305	4.535	5.22
71	0.22	0.26	2.15	0.44	0.047	0.261	5.164	8.97
72	0.21	0.33	1.98	0.46	0.051	0.364	4.693	6.16
73	0.22	0.54	2.18	0.44	0.047	0.283	4.617	5.71
74	0.22	0.33	2.11	0.44	0.047	0.273	4.961	7.76
75	0.22	0.24	2.19	0.44	0.047	0.247	5.251	9.49
76	0.22	0.35	2.17	0.44	0.047	0.257	4.929	7.57
77	0.22	0.63	2.10	0.45	0.051	0.297	4.413	4.49
78	0.21	0.28	1.92	0.46	0.051	0.383	4.853	7.11
79	0.22	0.64	1.97	0.48	0.055	0.373	4.249	3.51
80	0.22	0.55	2.13	0.45	0.047	0.303	4.576	5.46
81	0.22	0.31	2.08	0.46	0.051	0.324	4.760	6.56
82	0.22	0.62	2.00	0.47	0.051	0.359	4.324	3.96
83	0.22	0.33	2.14	0.45	0.047	0.293	4.834	7.00
84	0.21	0.36	1.92	0.46	0.051	0.369	4.690	6.14
85	0.22	0.70	1.94	0.45	0.051	0.348	4.340	4.06
86	0.22	0.52	1.87	0.45	0.051	0.365	4.483	4.91
87	0.21	0.54	1.72	0.44	0.051	0.380	4.565	5.40
88	0.22	0.46	1.88	0.45	0.051	0.376	4.529	5.18
89	0.20	0.99	1.58	0.47	0.057	0.500	4.185	3.13
90	0.22	0.53	1.89	0.47	0.051	0.413	4.356	4.15
91	0.22	0.42	1.86	0.46	0.051	0.418	4.497	4.99
92	0.22	0.89	1.82	0.47	0.055	0.434	4.123	2.76
93	0.21	0.60	1.81	0.46	0.051	0.423	4.349	4.11
94	0.22	0.47	1.98	0.44	0.047	0.342	4.609	5.66
95	0.21	0.85	1.65	0.46	0.057	0.444	4.260	3.58
96	0.22	0.50	2.01	0.46	0.047	0.368	4.482	4.90
97	0.21	0.65	1.68	0.46	0.055	0.458	4.322	3.95
98	0.21	0.54	1.78	0.47	0.051	0.445	4.385	4.32
99	0.21	0.57	1.62	0.46	0.055	0.478	4.407	4.46
100	0.21	0.67	1.78	0.44	0.051	0.360	4.478	4.88
101	0.21	0.43	1.88	0.42	0.047	0.310	4.834	7.00
102	0.23	0.55	2.08	0.41	0.047	0.244	4.784	6.70
103	0.21	0.59	1.73	0.46	0.051	0.416	4.435	4.63
104	0.23	0.52	2.08	0.42	0.047	0.265	4.731	6.39
105	0.21	0.71	1.73	0.46	0.055	0.415	4.313	3.90
106	0.22	0.40	2.06	0.41	0.047	0.242	5.000	7.99
107	0.22	0.45	1.87	0.43	0.047	0.334	4.745	6.47
108	0.23	0.44	2.08	0.42	0.047	0.265	4.813	6.88
109	0.21	0.83	1.69	0.46	0.057	0.429	4.227	3.38
110	0.21	0.64	1.82	0.41	0.047	0.334	4.667	6.00
111	0.22	0.55	1.89	0.44	0.047	0.359	4.556	5.34
112	0.21	0.69	1.87	0.44	0.047	0.353	4.516	5.11
113	0.21	0.46	1.84	0.41	0.047	0.295	4.897	7.38
114	0.20	0.56	1.67	0.44	0.051	0.404	4.570	5.43
115	0.20	0.58	1.59	0.45	0.055	0.458	4.463	4.79
116	0.20	0.73	1.54	0.47	0.057	0.534	4.280	3.70
117	0.22	0.48	2.01	0.44	0.047	0.326	4.600	5.61
118	0.21	0.66	1.69	0.47	0.057	0.472	4.257	3.56
119	0.22	0.78	1.86	0.46	0.051	0.393	4.255	3.55
120	0.20	0.74	1.56	0.46	0.057	0.506	4.303	3.84
121	0.22	0.84	1.89	0.47	0.051	0.387	4.239	3.45
122	0.23	0.28	2.08	0.42	0.047	0.249	5.181	9.07
123	0.22	0.72	2.00	0.43	0.047	0.284	4.554	5.33
124	0.22	0.48	1.89	0.47	0.051	0.427	4.388	4.34
125	0.20	0.96	1.53	0.45	0.057	0.462	4.324	3.96
126	0.23	0.56	2.00	0.44	0.047	0.333	4.514	5.09
127	0.20	0.63	1.46	0.43	0.055	0.472	4.563	5.38
128	0.23	0.66	2.00	0.44	0.047	0.323	4.473	4.85
129	0.22	0.37	1.93	0.42	0.047	0.295	4.908	7.44
130	0.21	0.54	1.70	0.43	0.051	0.364	4.627	5.77
131	0.20	0.61	1.62	0.45	0.055	0.441	4.441	4.66
132	0.21	0.65	1.66	0.46	0.057	0.445	4.312	3.89
133	0.22	0.48	2.15	0.42	0.047	0.243	4.830	6.98
134	0.22	0.46	2.01	0.43	0.047	0.307	4.686	6.12
135	0.19	0.37	1.48	0.42	0.051	0.404	5.029	8.17
136	0.23	0.40	2.09	0.41	0.047	0.240	4.970	7.82
137	0.22	0.51	1.86	0.44	0.051	0.361	4.524	5.15
138	0.22	0.71	1.98	0.43	0.047	0.283	4.585	5.52
139	0.21	0.44	1.91	0.41	0.047	0.267	4.960	7.75
140	0.21	0.66	1.94	0.42	0.047	0.313	4.608	5.66
141	0.20	0.56	1.58	0.44	0.051	0.430	4.606	5.64
142	0.21	0.67	1.84	0.44	0.051	0.350	4.444	4.67
143	0.22	0.47	1.91	0.42	0.047	0.301	4.783	6.70
144	0.21	0.49	1.73	0.41	0.047	0.335	4.836	7.01
145	0.21	0.58	1.73	0.46	0.051	0.440	4.401	4.42
146	0.21	0.66	1.57	0.45	0.051	0.492	4.413	4.49
147	0.23	0.41	2.12	0.43	0.047	0.271	4.803	6.82
148	0.23	0.58	1.88	0.45	0.047	0.395	4.437	4.64
149	0.20	0.57	1.50	0.43	0.051	0.475	4.598	5.59
150	0.23	0.43	2.12	0.43	0.047	0.257	4.811	6.86
151	0.21	0.94	1.66	0.47	0.057	0.485	4.153	2.94
152	0.22	0.72	1.82	0.47	0.051	0.447	4.222	3.35
153	0.23	0.63	1.95	0.47	0.051	0.403	4.252	3.53
154	0.22	0.39	1.95	0.46	0.051	0.385	4.552	5.32
155	0.22	0.65	1.94	0.48	0.051	0.441	4.173	3.06
156	0.22	0.66	1.96	0.46	0.051	0.365	4.313	3.90
157	0.21	0.65	1.57	0.45	0.051	0.501	4.438	4.64
158	0.21	0.49	1.75	0.44	0.047	0.421	4.615	5.70
159	0.22	0.46	1.85	0.45	0.051	0.388	4.527	5.17

Table B.10. Motions and Seakeeping Index for the Series of Hull Forms, V=0 Knots, Heading Angle 90 Deg.

HULL	Heave [m/m]	Roll [deg/m]	Pitch [deg/m]	Vert.Mot. at FP [m/m]	Vert.Acc. at FP [m/s^2/m]	Rel.Mot. at FP [m/m]	Sum	Index
01	0.39	3.73	0.20	0.41	0.948	0.084	4.523	8.13
02	0.40	2.15	0.32	0.45	1.047	0.120	3.851	5.63
03	0.39	3.88	0.21	0.41	0.943	0.083	4.515	8.11
04	0.40	2.33	0.45	0.46	1.076	0.157	3.533	4.44
05	0.41	1.65	0.40	0.46	1.094	0.145	3.602	4.70
06	0.39	3.70	0.24	0.43	0.998	0.086	4.301	7.31
07	0.39	4.51	0.22	0.42	0.960	0.083	4.463	7.91
08	0.40	1.86	0.43	0.46	1.096	0.152	3.543	4.48
09	0.40	2.37	0.36	0.45	1.056	0.131	3.730	5.18
10	0.40	2.85	0.38	0.45	1.043	0.128	3.746	5.24
11	0.41	1.80	0.42	0.46	1.094	0.153	3.552	4.51
12	0.40	2.85	0.39	0.45	1.066	0.139	3.652	4.88
13	0.40	2.83	0.38	0.45	1.056	0.139	3.675	4.97
14	0.40	2.38	0.38	0.46	1.087	0.140	3.634	4.82
15	0.40	2.16	0.35	0.45	1.066	0.129	3.736	5.20
16	0.41	1.88	0.44	0.47	1.109	0.167	3.470	4.21
17	0.40	2.17	0.37	0.46	1.100	0.139	3.630	4.80
18	0.39	3.90	0.23	0.42	0.985	0.083	4.385	7.62
19	0.40	2.34	0.43	0.45	1.061	0.145	3.611	4.73
20	0.39	2.46	0.31	0.43	0.983	0.118	3.977	6.10
21	0.40	1.81	0.38	0.45	1.041	0.134	3.736	5.20
22	0.40	2.51	0.32	0.44	1.026	0.113	3.923	5.90
23	0.40	1.90	0.40	0.46	1.071	0.141	3.639	4.84
24	0.40	2.20	0.42	0.45	1.043	0.140	3.671	4.96
25	0.41	1.50	0.38	0.46	1.071	0.151	3.629	4.80
26	0.40	1.93	0.35	0.45	1.038	0.140	3.732	5.18
27	0.40	1.72	0.38	0.45	1.051	0.147	3.672	4.96
28	0.41	1.46	0.39	0.46	1.071	0.144	3.655	4.90
29	0.41	1.68	0.39	0.46	1.056	0.152	3.635	4.82
30	0.40	1.95	0.35	0.45	1.036	0.134	3.768	5.32
31	0.41	1.17	0.44	0.46	1.081	0.172	3.529	4.43
32	0.40	1.92	0.35	0.44	1.023	0.129	3.818	5.50
33	0.41	1.20	0.46	0.47	1.091	0.180	3.478	4.24
34	0.40	1.68	0.39	0.45	1.051	0.143	3.679	4.99
35	0.41	1.23	0.46	0.46	1.081	0.172	3.510	4.36
36	0.41	1.50	0.39	0.46	1.066	0.149	3.638	4.83
37	0.40	2.08	0.40	0.45	1.076	0.151	3.608	4.72
38	0.40	2.62	0.40	0.44	0.992	0.144	3.737	5.20
39	0.40	2.60	0.38	0.44	0.998	0.144	3.740	5.22
40	0.39	3.32	0.27	0.43	0.994	0.092	4.189	6.89
41	0.41	1.33	0.32	0.45	1.053	0.118	3.886	5.76
42	0.41	0.67	0.42	0.47	1.106	0.151	3.666	4.94
43	0.40	1.50	0.42	0.44	1.017	0.144	3.713	5.12
44	0.42	0.36	0.47	0.47	1.125	0.172	3.725	5.16
45	0.38	3.97	0.25	0.41	0.930	0.090	4.387	7.63
46	0.43	0.83	0.67	0.49	1.154	0.229	3.230	3.31
47	0.42	0.60	0.56	0.49	1.159	0.207	3.385	3.89
48	0.40	2.06	0.34	0.43	0.985	0.121	3.931	5.93
49	0.41	1.25	0.32	0.45	1.066	0.139	3.773	5.34
50	0.43	0.72	0.56	0.48	1.119	0.202	3.391	3.91
51	0.40	2.55	0.26	0.44	1.028	0.097	4.113	6.60
52	0.43	0.84	0.63	0.49	1.144	0.227	3.255	3.41
53	0.39	3.72	0.29	0.43	0.994	0.108	4.035	6.31
54	0.40	2.33	0.25	0.44	1.038	0.093	4.165	6.80
55	0.42	0.64	0.32	0.45	1.061	0.160	3.808	5.47
56	0.43	0.61	0.36	0.48	1.150	0.169	3.617	4.76
57	0.42	1.60	0.33	0.46	1.104	0.155	3.616	4.75
58	0.42	1.25	0.38	0.47	1.119	0.166	3.532	4.44
59	0.42	1.19	0.40	0.47	1.109	0.174	3.510	4.36
60	0.42	0.51	0.33	0.45	1.061	0.166	3.834	5.56
61	0.41	0.87	0.30	0.44	1.023	0.158	3.851	5.63
62	0.43	0.59	0.37	0.47	1.125	0.171	3.641	4.84
63	0.42	0.75	0.41	0.47	1.119	0.184	3.532	4.44
64	0.42	0.77	0.37	0.47	1.134	0.171	3.577	4.61
65	0.42	0.18	0.47	0.47	1.091	0.202	4.135	6.69
66	0.41	1.05	0.37	0.46	1.061	0.159	3.665	4.93
67	0.42	0.88	0.32	0.46	1.106	0.158	3.692	5.04
68	0.43	0.34	0.43	0.48	1.155	0.189	3.700	5.06
69	0.43	0.31	0.46	0.48	1.142	0.198	3.719	5.14
70	0.41	1.97	0.32	0.45	1.053	0.141	3.746	5.24
71	0.43	0.15	0.47	0.48	1.150	0.206	4.181	6.86
72	0.43	0.26	0.42	0.48	1.168	0.195	3.805	5.46
73	0.47	2.07	0.84	0.56	1.379	0.344	2.649	1.15
74	0.46	1.23	0.60	0.52	1.246	0.269	2.994	2.43
75	0.44	0.65	0.60	0.50	1.172	0.251	3.231	3.32
76	0.46	1.23	0.57	0.52	1.250	0.269	3.003	2.47
77	0.40	2.39	0.36	0.45	1.048	0.147	3.682	5.00
78	0.45	0.94	0.49	0.52	1.290	0.239	3.091	2.79
79	0.41	2.45	0.33	0.45	1.048	0.141	3.730	5.18
80	0.47	1.98	0.78	0.55	1.334	0.326	2.724	1.43
81	0.44	0.51	0.55	0.50	1.184	0.239	3.323	3.66
82	0.41	2.41	0.34	0.45	1.053	0.143	3.706	5.09
83	0.43	0.32	0.53	0.48	1.144	0.216	3.623	4.78
84	0.46	1.10	0.52	0.52	1.286	0.248	3.035	2.59
85	0.40	2.50	0.28	0.43	1.013	0.121	3.959	6.03
86	0.42	1.24	0.33	0.45	1.072	0.144	3.723	5.15
87	0.42	1.08	0.30	0.45	1.095	0.141	3.761	5.29
88	0.42	0.88	0.31	0.46	1.102	0.143	3.761	5.29
89	0.39	4.64	0.21	0.42	0.973	0.095	4.356	7.51
90	0.42	0.54	0.43	0.47	1.119	0.184	3.599	4.69
91	0.43	0.38	0.49	0.49	1.190	0.204	3.528	4.42
92	0.40	3.33	0.31	0.43	1.008	0.131	3.854	5.64
93	0.42	1.37	0.34	0.45	1.085	0.149	3.674	4.97
94	0.44	0.44	0.57	0.49	1.174	0.227	3.401	3.95
95	0.40	3.95	0.19	0.42	0.983	0.086	4.493	8.02
96	0.43	0.43	0.59	0.48	1.150	0.225	3.452	4.14
97	0.41	1.86	0.28	0.45	1.070	0.130	3.841	5.59
98	0.43	0.41	0.49	0.48	1.178	0.205	3.521	4.40
99	0.42	1.07	0.36	0.47	1.130	0.160	3.579	4.62
100	0.41	2.47	0.29	0.45	1.072	0.130	3.792	5.41
101	0.43	0.50	0.43	0.48	1.157	0.197	3.533	4.44
102	0.41	1.44	0.51	0.46	1.070	0.201	3.414	4.00
103	0.43	0.82	0.62	0.50	1.177	0.263	3.178	3.12
104	0.42	1.02	0.60	0.47	1.119	0.224	3.299	3.57
105	0.41	2.63	0.38	0.46	1.091	0.164	3.527	4.42
106	0.44	0.25	0.66	0.49	1.177	0.260	3.589	4.65
107	0.44	0.17	0.59	0.50	1.231	0.236	3.860	5.66
108	0.43	0.37	0.65	0.49	1.157	0.245	3.451	4.14
109	0.41	3.40	0.41	0.45	1.061	0.178	3.501	4.32
110	0.47	1.40	0.85	0.55	1.379	0.331	2.713	1.38
111	0.44	0.15	0.80	0.52	1.222	0.307	3.818	5.50
112	0.46	1.54	1.14	0.56	1.302	0.400	2.673	1.24
113	0.45	0.76	0.64	0.52	1.271	0.267	3.044	2.62
114	0.45	0.40	0.66	0.53	1.299	0.286	3.177	3.12
115	0.41	1.65	0.24	0.44	1.041	0.107	4.102	6.56
116	0.40	2.25	0.27	0.44	1.043	0.119	3.955	6.02
117	0.41	0.70	0.41	0.45	1.046	0.164	3.713	5.11
118	0.40	2.07	0.27	0.44	1.023	0.117	3.999	6.18
119	0.39	3.00	0.26	0.42	0.968	0.110	4.135	6.69
120	0.40	2.87	0.22	0.43	1.011	0.100	4.235	7.06
121	0.39	3.43	0.22	0.42	0.958	0.093	4.386	7.62
122	0.42	0.24	0.35	0.44	1.036	0.150	4.249	7.11
123	0.39	2.92	0.22	0.41	0.934	0.102	4.351	7.49
124	0.42	0.63	0.36	0.46	1.097	0.156	3.741	5.22
125	0.39	4.91	0.14	0.40	0.930	0.070	5.024	10.00
126	0.41	1.02	0.40	0.44	1.023	0.156	3.718	5.13
127	0.41	1.81	0.25	0.44	1.057	0.112	4.025	6.28
128	0.40	1.90	0.34	0.43	0.983	0.133	3.882	5.74
129	0.41	0.51	0.30	0.44	1.038	0.131	4.048	6.36
130	0.42	1.67	0.36	0.46	1.119	0.165	3.527	4.42
131	0.42	2.22	0.36	0.45	1.095	0.170	3.537	4.46
132	0.41	2.67	0.38	0.45	1.066	0.173	3.545	4.49
133	0.44	1.33	1.06	0.54	1.290	0.341	2.790	1.67
134	0.43	0.35	0.86	0.50	1.146	0.309	3.340	3.72
135	0.44	0.55	0.32	0.48	1.199	0.170	3.632	4.81
136	0.43	0.27	0.66	0.48	1.129	0.251	3.616	4.75
137	0.44	0.24	0.69	0.50	1.182	0.280	3.567	4.57
138	0.41	2.70	0.36	0.44	1.021	0.155	3.691	5.03
139	0.46	0.93	0.67	0.52	1.266	0.281	2.978	2.37
140	0.47	2.01	1.03	0.56	1.368	0.383	2.610	1.00
141	0.42	1.79	0.34	0.46	1.115	0.165	3.561	4.55
142	0.41	2.40	0.36	0.45	1.076	0.156	3.600	4.69
143	0.44	0.19	0.64	0.50	1.195	0.254	3.775	5.34
144	0.46	0.87	0.64	0.53	1.317	0.279	2.953	2.28
145	0.42	0.98	0.45	0.47	1.150	0.186	3.417	4.01
146	0.42	1.56	0.44	0.46	1.104	0.186	3.436	4.08
147	0.43	0.55	0.77	0.49	1.154	0.263	3.241	3.35
148	0.42	0.55	0.76	0.48	1.133	0.260	3.295	3.56
149	0.43	0.40	0.55	0.49	1.206	0.227	3.422	4.03
150	0.42	0.63	0.52	0.46	1.094	0.187	3.537	4.46
151	0.40	4.04	0.24	0.43	0.998	0.106	4.140	6.70
152	0.41	1.75	0.45	0.46	1.086	0.182	3.455	4.15
153	0.42	1.03	0.58	0.48	1.129	0.219	3.301	3.58
154	0.44	0.42	0.52	0.49	1.203	0.220	3.426	4.04
155	0.42	1.14	0.58	0.47	1.119	0.225	3.295	3.55
156	0.41	1.61	0.45	0.46	1.074	0.175	3.497	4.31
157	0.42	1.53	0.37	0.46	1.130	0.159	3.538	4.46
158	0.46	1.31	0.70	0.53	1.314	0.284	2.877	2.00
159	0.44	0.30	0.52	0.49	1.193	0.217	3.585	4.64

Table B.11. Motions and Seakeeping Index for the Series of Hull Forms, V=5 Knots, Heading Angle 90 Deg.

HULL	Heave [m/m]	Roll [deg/m]	Pitch [deg/m]	Vert.Mot. at FP [m/m]	Vert.Acc. at FP [m/s^2/m]	Rel.Mot. at FP [m/m]	Sum	Index
01	0.39	3.77	0.13	0.41	0.932	0.070	4.639	8.36
02	0.40	2.23	0.20	0.43	1.018	0.094	3.973	5.56
03	0.39	3.93	0.14	0.41	0.924	0.070	4.584	8.13
04	0.40	2.45	0.30	0.44	1.041	0.126	3.601	4.00
05	0.41	1.75	0.26	0.45	1.058	0.116	3.686	4.35
06	0.39	3.76	0.17	0.42	0.973	0.071	4.332	7.07
07	0.39	4.58	0.14	0.41	0.930	0.071	4.539	7.94
08	0.41	1.96	0.28	0.45	1.058	0.122	3.621	4.08
09	0.40	2.46	0.25	0.44	1.028	0.109	3.768	4.70
10	0.40	2.96	0.26	0.44	1.018	0.104	3.796	4.82
11	0.41	1.90	0.28	0.45	1.053	0.126	3.619	4.07
12	0.40	2.97	0.28	0.44	1.034	0.115	3.684	4.34
13	0.40	2.94	0.27	0.44	1.028	0.116	3.701	4.42
14	0.40	2.48	0.26	0.45	1.047	0.116	3.678	4.32
15	0.40	2.25	0.24	0.44	1.034	0.107	3.776	4.73
16	0.41	1.98	0.30	0.45	1.066	0.138	3.522	3.66
17	0.41	2.27	0.26	0.45	1.058	0.114	3.678	4.32
18	0.39	3.96	0.17	0.42	0.960	0.071	4.352	7.15
19	0.40	2.46	0.28	0.44	1.034	0.115	3.691	4.37
20	0.40	2.53	0.18	0.42	0.960	0.090	4.142	6.27
21	0.40	1.90	0.24	0.43	1.018	0.102	3.848	5.03
22	0.40	2.60	0.20	0.43	0.998	0.089	4.030	5.80
23	0.40	2.00	0.26	0.44	1.043	0.111	3.732	4.55
24	0.40	2.31	0.28	0.44	1.018	0.106	3.766	4.69
25	0.41	1.39	0.25	0.44	1.034	0.123	3.715	4.48
26	0.40	2.03	0.22	0.44	1.008	0.113	3.821	4.92
27	0.41	1.81	0.23	0.44	1.013	0.116	3.794	4.81
28	0.41	1.54	0.24	0.44	1.038	0.113	3.777	4.74
29	0.41	1.78	0.24	0.44	1.023	0.123	3.729	4.53
30	0.40	2.04	0.21	0.43	1.003	0.107	3.889	5.21
31	0.41	1.26	0.27	0.45	1.049	0.134	3.647	4.19
32	0.40	1.99	0.21	0.43	0.998	0.103	3.936	5.41
33	0.41	1.31	0.29	0.45	1.056	0.144	3.566	3.85
34	0.41	1.76	0.24	0.44	1.013	0.113	3.805	4.86
35	0.41	1.31	0.28	0.45	1.049	0.135	3.622	4.08
36	0.41	1.57	0.24	0.44	1.034	0.118	3.748	4.61
37	0.40	2.20	0.26	0.44	1.043	0.123	3.675	4.31
38	0.40	2.75	0.24	0.42	0.970	0.114	3.857	5.07
39	0.40	2.72	0.24	0.42	0.970	0.115	3.851	5.05
40	0.39	3.40	0.19	0.42	0.973	0.076	4.222	6.61
41	0.41	1.40	0.20	0.44	1.032	0.090	4.014	5.73
42	0.42	0.74	0.25	0.45	1.072	0.118	3.787	4.78
43	0.40	1.59	0.25	0.43	1.000	0.109	3.848	5.03
44	0.43	0.34	0.27	0.46	1.102	0.129	3.925	5.36
45	0.38	4.04	0.16	0.40	0.914	0.074	4.467	7.64
46	0.43	0.78	0.37	0.47	1.127	0.177	3.372	3.03
47	0.43	0.59	0.32	0.47	1.125	0.160	3.533	3.71
48	0.40	2.14	0.20	0.42	0.973	0.092	4.076	5.99
49	0.41	1.33	0.17	0.44	1.034	0.106	3.988	5.62
50	0.43	0.67	0.29	0.46	1.105	0.153	3.574	3.88
51	0.40	2.61	0.18	0.43	1.005	0.081	4.136	6.25
52	0.43	0.79	0.33	0.47	1.106	0.175	3.426	3.26
53	0.39	3.80	0.20	0.42	0.968	0.090	4.065	5.95
54	0.40	2.40	0.17	0.43	1.018	0.076	4.197	6.50
55	0.42	0.69	0.32	0.43	1.028	0.108	3.835	4.98
56	0.43	0.66	0.18	0.45	1.081	0.128	3.904	5.27
57	0.42	1.70	0.16	0.44	1.043	0.114	3.953	5.48
58	0.42	1.31	0.20	0.45	1.057	0.126	3.774	4.72
59	0.42	1.27	0.21	0.44	1.057	0.126	3.776	4.73
60	0.42	0.56	0.25	0.43	1.017	0.114	3.955	5.48
61	0.41	0.93	0.24	0.42	0.988	0.107	3.951	5.47
62	0.43	0.66	0.17	0.44	1.062	0.125	3.974	5.57
63	0.42	0.83	0.19	0.44	1.057	0.134	3.855	5.06
64	0.42	0.83	0.19	0.45	1.072	0.129	3.858	5.08
65	0.42	0.22	0.27	0.44	1.041	0.141	4.260	6.77
66	0.41	1.13	0.33	0.43	1.034	0.110	3.724	4.51
67	0.42	0.96	0.17	0.44	1.049	0.111	3.986	5.62
68	0.43	0.38	0.23	0.46	1.087	0.145	3.908	5.29
69	0.43	0.37	0.21	0.45	1.072	0.146	3.985	5.61
70	0.41	2.03	0.15	0.42	0.998	0.104	4.112	6.14
71	0.43	0.19	0.24	0.45	1.077	0.147	4.328	7.05
72	0.43	0.31	0.18	0.45	1.090	0.144	4.118	6.17
73	0.47	2.05	0.35	0.51	1.248	0.251	2.936	1.20
74	0.46	1.22	0.21	0.47	1.140	0.196	3.415	3.21
75	0.44	0.63	0.24	0.46	1.097	0.180	3.594	3.96
76	0.46	1.21	0.27	0.47	1.155	0.193	3.297	2.72
77	0.40	2.46	0.20	0.42	0.994	0.107	3.921	5.34
78	0.45	0.92	0.22	0.48	1.185	0.177	3.422	3.24
79	0.41	2.52	0.17	0.43	0.994	0.107	4.028	5.79
80	0.47	1.94	0.28	0.50	1.214	0.241	3.061	1.72
81	0.44	0.47	0.22	0.46	1.100	0.174	3.733	4.55
82	0.41	2.48	0.17	0.43	0.998	0.107	4.013	5.73
83	0.43	0.38	0.24	0.45	1.072	0.157	3.883	5.18
84	0.46	1.07	0.21	0.48	1.189	0.184	3.389	3.10
85	0.40	2.61	0.16	0.42	0.988	0.090	4.186	6.46
86	0.42	1.32	0.18	0.43	1.034	0.109	3.960	5.51
87	0.42	1.17	0.16	0.44	1.047	0.107	4.032	5.81
88	0.42	0.95	0.17	0.44	1.059	0.106	4.009	5.71
89	0.39	4.73	0.14	0.41	0.955	0.078	4.432	7.49
90	0.42	0.65	0.23	0.45	1.075	0.139	3.774	4.72
91	0.43	0.43	0.27	0.46	1.136	0.157	3.695	4.39
92	0.40	3.46	0.20	0.42	0.988	0.105	3.945	5.44
93	0.42	1.48	0.19	0.44	1.047	0.114	3.884	5.18
94	0.44	0.42	0.29	0.46	1.119	0.174	3.649	4.20
95	0.40	4.03	0.11	0.41	0.960	0.068	4.696	8.60
96	0.43	0.46	0.33	0.46	1.115	0.175	3.596	3.98
97	0.41	1.96	0.15	0.43	1.026	0.100	4.097	6.08
98	0.43	0.51	0.28	0.46	1.125	0.161	3.635	4.14
99	0.42	1.15	0.22	0.45	1.092	0.128	3.695	4.39
100	0.41	2.54	0.17	0.43	1.032	0.099	4.008	5.71
101	0.43	0.55	0.21	0.45	1.087	0.146	3.803	4.84
102	0.41	1.53	0.26	0.43	1.017	0.149	3.646	4.19
103	0.43	0.88	0.35	0.46	1.086	0.209	3.372	3.03
104	0.42	1.11	0.32	0.44	1.057	0.167	3.504	3.59
105	0.41	2.70	0.22	0.44	1.041	0.130	3.696	4.40
106	0.44	0.21	0.29	0.45	1.095	0.193	4.072	5.98
107	0.44	0.17	0.32	0.47	1.161	0.184	4.139	6.26
108	0.43	0.44	0.33	0.45	1.087	0.182	3.635	4.14
109	0.40	3.48	0.24	0.43	1.008	0.144	3.659	4.24
110	0.46	1.36	0.44	0.51	1.261	0.260	2.921	1.14
111	0.43	0.18	0.41	0.47	1.114	0.237	3.989	5.63
112	0.45	1.50	0.64	0.49	1.148	0.314	2.908	1.08
113	0.45	0.73	0.31	0.48	1.174	0.208	3.306	2.75
114	0.45	0.36	0.37	0.49	1.188	0.228	3.444	3.33
115	0.41	1.73	0.15	0.43	1.022	0.083	4.253	6.74
116	0.40	2.35	0.18	0.43	1.022	0.097	4.010	5.72
117	0.41	0.80	0.23	0.43	1.028	0.125	3.861	5.09
118	0.40	2.17	0.16	0.42	1.003	0.091	4.141	6.26
119	0.39	3.13	0.16	0.41	0.955	0.085	4.284	6.87
120	0.40	2.95	0.14	0.42	0.988	0.081	4.333	7.07
121	0.39	3.55	0.14	0.41	0.948	0.072	4.522	7.87
122	0.42	0.27	0.22	0.43	1.037	0.112	4.338	7.10
123	0.39	3.03	0.13	0.40	0.930	0.077	4.543	7.96
124	0.42	0.70	0.21	0.44	1.072	0.119	3.875	5.15
125	0.39	4.98	0.10	0.40	0.915	0.059	5.029	10.00
126	0.41	1.16	0.22	0.43	1.008	0.119	3.866	5.11
127	0.41	1.89	0.17	0.43	1.034	0.091	4.084	6.03
128	0.40	2.05	0.20	0.42	0.970	0.102	4.033	5.81
129	0.41	0.57	0.16	0.43	1.022	0.099	4.256	6.75
130	0.42	1.72	0.19	0.44	1.062	0.129	3.761	4.67
131	0.41	2.29	0.20	0.43	1.026	0.137	3.744	4.60
132	0.41	2.73	0.23	0.43	1.008	0.142	3.705	4.43
133	0.44	1.29	0.55	0.49	1.180	0.267	2.995	1.45
134	0.43	0.31	0.40	0.44	1.030	0.233	3.745	4.60
135	0.44	0.59	0.16	0.46	1.121	0.132	3.944	5.44
136	0.43	0.33	0.28	0.44	1.041	0.185	3.873	5.14
137	0.43	0.28	0.35	0.45	1.071	0.216	3.789	4.79
138	0.40	2.79	0.17	0.41	0.968	0.116	4.004	5.69
139	0.45	0.90	0.28	0.47	1.150	0.215	3.303	2.74
140	0.46	1.96	0.48	0.50	1.201	0.292	2.889	1.00
141	0.42	1.85	0.18	0.43	1.047	0.130	3.797	4.82
142	0.41	2.47	0.19	0.43	1.017	0.121	3.854	5.06
143	0.43	0.25	0.32	0.46	1.110	0.196	3.872	5.14
144	0.46	0.84	0.31	0.48	1.193	0.216	3.230	2.43
145	0.42	1.07	0.29	0.45	1.107	0.151	3.505	3.59
146	0.42	1.66	0.28	0.44	1.057	0.151	3.537	3.73
147	0.43	0.50	0.37	0.46	1.091	0.200	3.502	3.58
148	0.42	0.58	0.47	0.46	1.089	0.211	3.400	3.15
149	0.43	0.44	0.37	0.47	1.155	0.191	3.489	3.52
150	0.42	0.71	0.27	0.44	1.057	0.141	3.710	4.45
151	0.40	4.14	0.16	0.41	0.973	0.086	4.250	6.72
152	0.41	1.89	0.27	0.44	1.041	0.145	3.589	3.94
153	0.42	1.16	0.35	0.45	1.085	0.173	3.414	3.21
154	0.44	0.40	0.26	0.46	1.140	0.167	3.696	4.40
155	0.42	1.28	0.34	0.45	1.064	0.175	3.438	3.31
156	0.41	1.74	0.25	0.44	1.032	0.136	3.662	4.25
157	0.42	1.63	0.23	0.45	1.081	0.128	3.664	4.26
158	0.45	1.25	0.41	0.50	1.242	0.228	3.022	1.56
159	0.43	0.31	0.28	0.46	1.125	0.170	3.814	4.89

Table B.12. Motions and Seakeeping Index for the Series of Hull Forms, V=10 Knots, Heading Angle 90 Deg.

HULL	Heave [m/m]	Roll [deg/m]	Pitch [deg/m]	Vert.Mot. at FP [m/m]	Vert.Acc. at FP [m/s^2/m]	Rel.Mot. at FP [m/m]	Sum	Index
01	0.39	3.83	0.10	0.40	0.910	0.053	4.729	8.82
02	0.40	2.31	0.15	0.42	0.994	0.065	4.146	6.46
03	0.39	3.99	0.10	0.40	0.915	0.054	4.681	8.63
04	0.40	2.56	0.20	0.43	1.019	0.090	3.761	4.91
05	0.41	1.83	0.18	0.43	1.029	0.082	3.853	5.28
06	0.39	3.81	0.12	0.41	0.950	0.054	4.462	7.74
07	0.39	4.64	0.11	0.39	0.897	0.059	4.598	8.29
08	0.41	2.05	0.19	0.43	1.034	0.086	3.788	5.02
09	0.40	2.55	0.16	0.42	0.999	0.081	3.953	5.68
10	0.40	3.06	0.18	0.42	0.994	0.074	3.955	5.69
11	0.41	1.98	0.17	0.43	1.017	0.091	3.831	5.19
12	0.40	3.07	0.18	0.43	1.003	0.084	3.843	5.24
13	0.40	3.04	0.17	0.42	0.990	0.087	3.889	5.43
14	0.40	2.57	0.17	0.43	1.009	0.085	3.864	5.32
15	0.40	2.33	0.16	0.43	1.003	0.080	3.960	5.71
16	0.41	2.07	0.19	0.43	1.028	0.101	3.710	4.70
17	0.41	2.36	0.17	0.43	1.024	0.084	3.857	5.29
18	0.39	4.02	0.12	0.41	0.945	0.057	4.456	7.72
19	0.40	2.57	0.20	0.42	1.009	0.080	3.842	5.23
20	0.40	2.60	0.19	0.41	0.960	0.060	4.152	6.49
21	0.40	1.97	0.24	0.42	1.012	0.068	3.893	5.44
22	0.40	2.69	0.16	0.41	0.973	0.062	4.183	6.62
23	0.41	2.09	0.20	0.43	1.019	0.076	3.875	5.37
24	0.40	2.41	0.26	0.42	1.014	0.071	3.826	5.17
25	0.41	1.68	0.14	0.43	1.009	0.088	3.962	5.72
26	0.40	2.12	0.13	0.42	0.984	0.081	4.089	6.23
27	0.41	1.89	0.14	0.42	0.996	0.082	4.021	5.96
28	0.41	1.62	0.17	0.43	1.019	0.078	3.927	5.58
29	0.41	1.87	0.14	0.42	0.999	0.088	3.989	5.83
30	0.40	2.13	0.13	0.42	0.984	0.076	4.124	6.38
31	0.41	1.33	0.17	0.43	1.034	0.094	3.837	5.22
32	0.40	2.06	0.14	0.42	0.975	0.072	4.142	6.45
33	0.41	1.41	0.17	0.43	1.024	0.103	3.799	5.06
34	0.41	1.83	0.16	0.42	0.996	0.078	3.996	5.86
35	0.41	1.38	0.20	0.43	1.039	0.094	3.757	4.89
36	0.41	1.64	0.16	0.43	1.009	0.084	3.950	5.67
37	0.40	2.30	0.16	0.43	1.014	0.088	3.870	5.35
38	0.40	2.86	0.15	0.41	0.950	0.080	4.084	6.21
39	0.40	2.83	0.13	0.41	0.950	0.082	4.121	6.36
40	0.39	3.48	0.14	0.41	0.950	0.057	4.356	7.32
41	0.41	1.47	0.20	0.42	1.014	0.061	4.067	6.14
42	0.42	0.80	0.19	0.44	1.047	0.082	3.908	5.50
43	0.40	1.67	0.25	0.42	1.004	0.074	3.854	5.28
44	0.43	0.34	0.32	0.45	1.108	0.091	3.903	5.48
45	0.38	4.12	0.13	0.39	0.901	0.057	4.502	7.91
46	0.44	0.78	0.38	0.46	1.166	0.135	3.307	3.07
47	0.43	0.60	0.29	0.46	1.136	0.117	3.547	4.04
48	0.40	2.23	0.22	0.41	0.965	0.061	4.081	6.20
49	0.41	1.41	0.12	0.42	1.014	0.070	4.213	6.74
50	0.43	0.66	0.33	0.45	1.136	0.114	3.485	3.79
51	0.40	2.68	0.12	0.42	0.978	0.061	4.315	7.15
52	0.43	0.78	0.25	0.46	1.123	0.128	3.481	3.78
53	0.39	3.88	0.13	0.41	0.950	0.067	4.244	6.86
54	0.40	2.46	0.12	0.42	0.988	0.057	4.358	7.32
55	0.42	0.75	0.53	0.42	1.043	0.073	3.758	4.90
56	0.42	0.71	0.16	0.43	1.037	0.084	4.029	5.99
57	0.42	1.78	0.17	0.42	0.999	0.074	3.998	5.87
58	0.42	1.38	0.15	0.42	1.019	0.084	3.955	5.69
59	0.42	1.35	0.25	0.42	1.030	0.082	3.761	4.91
60	0.42	0.60	0.48	0.42	1.020	0.074	3.851	5.27
61	0.42	0.99	0.46	0.41	0.999	0.069	3.828	5.18
62	0.42	0.71	0.23	0.42	1.030	0.081	3.897	5.46
63	0.42	0.90	0.24	0.42	1.024	0.087	3.814	5.12
64	0.42	0.88	0.15	0.43	1.024	0.086	4.009	5.91
65	0.43	0.26	0.49	0.42	1.052	0.096	4.065	6.14
66	0.42	1.20	0.52	0.42	1.043	0.074	3.665	4.52
67	0.42	1.02	0.28	0.42	1.028	0.070	3.865	5.33
68	0.42	0.43	0.15	0.43	1.044	0.099	4.122	6.37
69	0.43	0.42	0.23	0.43	1.043	0.096	3.963	5.72
70	0.41	2.08	0.22	0.41	0.959	0.068	4.000	5.88
71	0.43	0.23	0.42	0.43	1.058	0.097	4.167	6.55
72	0.43	0.35	0.24	0.43	1.054	0.094	4.035	6.02
73	0.48	2.05	0.62	0.48	1.261	0.192	2.796	1.00
74	0.45	1.22	0.37	0.44	1.106	0.135	3.259	2.87
75	0.44	0.62	0.45	0.44	1.098	0.125	3.447	3.64
76	0.46	1.21	0.55	0.45	1.141	0.137	3.140	2.40
77	0.40	2.54	0.28	0.40	0.969	0.070	3.885	5.41
78	0.45	0.92	0.30	0.45	1.138	0.120	3.369	3.32
79	0.40	2.59	0.16	0.41	0.954	0.072	4.094	6.25
80	0.47	1.93	0.44	0.47	1.210	0.178	2.933	1.55
81	0.44	0.46	0.30	0.44	1.081	0.117	3.683	4.59
82	0.40	2.54	0.18	0.41	0.959	0.071	4.034	6.01
83	0.43	0.44	0.32	0.43	1.052	0.104	3.802	5.07
84	0.46	1.07	0.28	0.45	1.141	0.127	3.334	3.18
85	0.40	2.71	0.18	0.41	0.971	0.060	4.158	6.51
86	0.42	1.39	0.17	0.42	1.022	0.074	3.986	5.82
87	0.42	1.24	0.14	0.42	1.024	0.073	4.095	6.26
88	0.42	1.01	0.20	0.42	1.043	0.070	3.969	5.75
89	0.39	4.82	0.10	0.40	0.941	0.058	4.571	8.18
90	0.42	0.74	0.21	0.43	1.068	0.097	3.783	5.00
91	0.43	0.48	0.23	0.45	1.113	0.112	3.749	4.86
92	0.40	3.57	0.17	0.41	0.979	0.076	4.003	5.89
93	0.42	1.57	0.16	0.42	1.024	0.077	3.981	5.80
94	0.44	0.45	0.26	0.45	1.121	0.126	3.663	4.51
95	0.39	4.11	0.10	0.40	0.941	0.049	4.762	8.96
96	0.43	0.52	0.29	0.45	1.126	0.130	3.559	4.09
97	0.41	2.05	0.11	0.42	0.999	0.068	4.301	7.09
98	0.43	0.59	0.18	0.44	1.096	0.115	3.772	4.95
99	0.42	1.22	0.15	0.43	1.062	0.092	3.855	5.29
100	0.41	2.61	0.18	0.41	0.994	0.067	4.026	5.98
101	0.43	0.59	0.28	0.43	1.052	0.099	3.755	4.88
102	0.41	1.62	0.35	0.41	1.009	0.101	3.583	4.19
103	0.42	0.93	0.17	0.43	1.039	0.151	3.673	4.55
104	0.42	1.19	0.38	0.43	1.052	0.116	3.469	3.73
105	0.41	2.76	0.14	0.42	1.004	0.094	3.921	5.55
106	0.44	0.20	0.38	0.43	1.077	0.136	4.141	6.44
107	0.44	0.19	0.28	0.45	1.126	0.134	4.199	6.68
108	0.43	0.50	0.41	0.43	1.086	0.129	3.569	4.13
109	0.40	3.56	0.14	0.41	0.973	0.105	3.905	5.49
110	0.46	1.35	0.28	0.47	1.204	0.193	3.077	2.14
111	0.43	0.22	0.23	0.44	1.077	0.171	4.108	6.31
112	0.45	1.49	0.27	0.45	1.095	0.234	3.161	2.48
113	0.45	0.73	0.22	0.45	1.121	0.150	3.474	3.75
114	0.44	0.34	0.17	0.45	1.121	0.168	3.824	5.16
115	0.41	1.80	0.12	0.42	1.009	0.057	4.337	7.32
116	0.40	2.44	0.13	0.42	1.009	0.071	4.145	6.46
117	0.42	0.86	0.24	0.43	1.047	0.089	3.780	4.99
118	0.40	2.26	0.12	0.41	0.994	0.064	4.302	7.10
119	0.39	3.23	0.15	0.40	0.954	0.059	4.302	7.10
120	0.40	3.03	0.10	0.41	0.973	0.059	4.537	8.05
121	0.39	3.65	0.14	0.40	0.941	0.050	4.508	7.93
122	0.42	0.29	0.33	0.43	1.068	0.081	4.139	6.44
123	0.39	3.13	0.17	0.40	0.941	0.052	4.355	7.31
124	0.42	0.75	0.21	0.43	1.077	0.085	3.837	5.21
125	0.39	5.05	0.08	0.39	0.910	0.047	5.020	10.00
126	0.41	1.25	0.23	0.42	1.024	0.084	3.809	5.10
127	0.41	1.95	0.11	0.42	1.012	0.068	4.264	6.94
128	0.40	2.17	0.20	0.41	0.984	0.071	3.982	5.80
129	0.42	0.61	0.21	0.42	1.024	0.068	4.120	6.36
130	0.42	1.77	0.14	0.42	1.009	0.091	3.947	5.66
131	0.41	2.35	0.11	0.41	0.979	0.098	4.100	6.28
132	0.40	2.78	0.13	0.41	0.970	0.106	3.985	5.82
133	0.44	1.29	0.45	0.46	1.164	0.203	3.048	2.02
134	0.42	0.30	0.22	0.42	1.004	0.163	4.020	5.96
135	0.43	0.62	0.10	0.43	1.058	0.092	4.260	6.93
136	0.43	0.39	0.33	0.42	1.034	0.128	3.801	5.07
137	0.43	0.32	0.18	0.42	1.024	0.152	4.063	6.13
138	0.40	2.88	0.21	0.40	0.950	0.079	3.926	5.58
139	0.45	0.90	0.22	0.44	1.096	0.151	3.442	3.61
140	0.46	1.94	0.27	0.46	1.146	0.213	3.093	2.20
141	0.41	1.90	0.11	0.41	0.997	0.093	4.130	6.40
142	0.41	2.54	0.16	0.41	0.984	0.083	3.964	5.73
143	0.43	0.30	0.26	0.44	1.081	0.139	3.895	5.45
144	0.45	0.83	0.16	0.45	1.115	0.150	3.585	4.20
145	0.42	1.14	0.20	0.44	1.083	0.113	3.616	4.32
146	0.41	1.75	0.16	0.43	1.032	0.112	3.760	4.90
147	0.43	0.50	0.33	0.45	1.108	0.147	3.514	3.91
148	0.42	0.64	0.27	0.45	1.085	0.160	3.502	3.86
149	0.43	0.48	0.22	0.45	1.115	0.148	3.646	4.44
150	0.42	0.78	0.31	0.43	1.054	0.098	3.664	4.52
151	0.39	4.23	0.11	0.40	0.950	0.063	4.424	7.59
152	0.41	2.00	0.16	0.42	1.019	0.104	3.789	5.02
153	0.42	1.27	0.26	0.44	1.083	0.127	3.473	3.74
154	0.44	0.41	0.25	0.45	1.126	0.118	3.736	4.80
155	0.42	1.39	0.22	0.43	1.052	0.127	3.557	4.08
156	0.41	1.86	0.20	0.42	1.022	0.095	3.751	4.87
157	0.42	1.72	0.13	0.43	1.037	0.092	3.937	5.62
158	0.45	1.23	0.26	0.48	1.219	0.175	3.137	2.38
159	0.43	0.35	0.18	0.44	1.096	0.122	3.971	5.76

Table B.13. Motions and Seakeeping Index for the Series of Hull Forms, V=15 Knots, Heading Angle 90 Deg.

HULL	Heave [m/m]	Roll [deg/m]	Pitch [deg/m]	Vert.Mot. at FP [m/m]	Vert.Acc. at FP [m/s^2/m]	Rel.Mot. at FP [m/m]	Sum	Index
01	0.39	3.89	0.11	0.39	0.895	0.042	4.547	8.78
02	0.40	2.38	0.16	0.41	0.971	0.041	4.205	7.42
03	0.39	4.05	0.11	0.39	0.905	0.043	4.559	8.83
04	0.40	2.65	0.18	0.41	0.994	0.059	3.891	6.16
05	0.41	1.91	0.17	0.42	1.009	0.054	3.948	6.39
06	0.39	3.88	0.11	0.40	0.935	0.040	4.501	8.60
07	0.38	4.71	0.11	0.38	0.880	0.052	4.429	8.31
08	0.41	2.13	0.18	0.42	1.009	0.055	3.908	6.23
09	0.40	2.62	0.12	0.41	0.974	0.056	4.152	7.21
10	0.40	3.15	0.16	0.41	0.965	0.050	4.093	6.97
11	0.41	2.05	0.13	0.42	0.990	0.062	4.025	6.70
12	0.40	3.16	0.15	0.41	0.979	0.058	4.017	6.66
13	0.40	3.12	0.12	0.41	0.965	0.061	4.133	7.13
14	0.40	2.65	0.13	0.41	0.986	0.059	4.072	6.89
15	0.40	2.40	0.12	0.41	0.979	0.056	4.143	7.17
16	0.41	2.14	0.14	0.42	0.999	0.069	3.939	6.36
17	0.40	2.43	0.13	0.42	0.994	0.057	4.060	6.84
18	0.39	4.09	0.09	0.40	0.922	0.045	4.593	8.97
19	0.40	2.66	0.20	0.41	0.984	0.051	3.938	6.35
20	0.40	2.67	0.23	0.40	0.956	0.038	4.155	7.22
21	0.41	2.04	0.28	0.41	1.003	0.042	3.950	6.40
22	0.40	2.77	0.17	0.40	0.954	0.041	4.214	7.45
23	0.41	2.17	0.20	0.41	0.996	0.048	3.954	6.42
24	0.40	2.49	0.28	0.41	0.999	0.044	3.907	6.23
25	0.41	1.75	0.12	0.42	0.994	0.058	4.118	7.07
26	0.40	2.19	0.11	0.41	0.965	0.055	4.249	7.59
27	0.41	1.96	0.15	0.41	0.984	0.053	4.078	6.91
28	0.41	1.68	0.19	0.42	1.005	0.049	3.972	6.49
29	0.41	1.94	0.12	0.41	0.984	0.058	4.136	7.14
30	0.40	2.21	0.14	0.41	0.965	0.050	4.184	7.33
31	0.41	1.40	0.18	0.42	1.022	0.061	3.863	6.05
32	0.40	2.12	0.15	0.41	0.965	0.047	4.160	7.24
33	0.41	1.49	0.14	0.42	1.012	0.068	3.930	6.32
34	0.41	1.89	0.17	0.41	0.984	0.050	4.032	6.72
35	0.41	1.44	0.22	0.42	1.035	0.062	3.758	5.63
36	0.41	1.69	0.16	0.42	0.999	0.054	4.006	6.62
37	0.40	2.39	0.14	0.41	0.994	0.059	4.043	6.77
38	0.40	2.96	0.15	0.40	0.950	0.051	4.118	7.07
39	0.40	2.93	0.12	0.40	0.941	0.054	4.229	7.51
40	0.39	3.56	0.13	0.40	0.935	0.042	4.394	8.17
41	0.41	1.52	0.23	0.41	0.996	0.039	4.110	7.04
42	0.42	0.84	0.23	0.42	1.030	0.054	3.916	6.26
43	0.41	1.74	0.30	0.41	1.009	0.047	3.849	6.00
44	0.43	0.35	0.42	0.44	1.117	0.068	3.822	5.89
45	0.38	4.19	0.14	0.39	0.892	0.044	4.388	8.15
46	0.44	0.79	0.51	0.46	1.205	0.112	3.146	3.19
47	0.43	0.61	0.37	0.45	1.147	0.090	3.440	4.36
48	0.40	2.31	0.27	0.40	0.969	0.038	4.092	6.97
49	0.41	1.47	0.16	0.41	0.999	0.044	4.164	7.25
50	0.44	0.67	0.46	0.46	1.172	0.094	3.308	3.84
51	0.40	2.74	0.11	0.41	0.956	0.044	4.441	8.36
52	0.44	0.78	0.35	0.45	1.162	0.100	3.313	3.86
53	0.39	3.95	0.11	0.40	0.925	0.050	4.403	8.21
54	0.40	2.52	0.11	0.41	0.965	0.041	4.456	8.42
55	0.42	0.79	0.63	0.42	1.054	0.059	3.620	5.08
56	0.42	0.75	0.23	0.41	1.005	0.053	3.984	6.53
57	0.41	1.86	0.23	0.40	0.974	0.047	3.964	6.45
58	0.41	1.43	0.21	0.41	0.990	0.053	3.932	6.33
59	0.42	1.41	0.33	0.41	1.009	0.053	3.754	5.62
60	0.42	0.63	0.58	0.41	1.033	0.055	3.766	5.66
61	0.42	1.04	0.56	0.41	1.010	0.051	3.736	5.54
62	0.42	0.75	0.32	0.41	1.012	0.052	3.879	6.12
63	0.42	0.95	0.33	0.41	1.009	0.056	3.781	5.73
64	0.42	0.92	0.22	0.41	0.999	0.054	3.951	6.40
65	0.43	0.28	0.62	0.42	1.079	0.073	3.940	6.36
66	0.42	1.26	0.60	0.41	1.048	0.059	3.550	4.80
67	0.42	1.07	0.36	0.41	1.005	0.047	3.856	6.02
68	0.42	0.46	0.21	0.42	1.024	0.063	4.051	6.80
69	0.43	0.46	0.34	0.42	1.033	0.063	3.900	6.20
70	0.41	2.14	0.29	0.39	0.941	0.046	3.965	6.46
71	0.43	0.25	0.55	0.42	1.058	0.069	4.105	7.02
72	0.43	0.38	0.35	0.42	1.030	0.061	4.005	6.62
73	0.49	2.06	0.90	0.49	1.353	0.177	2.598	1.00
74	0.46	1.24	0.57	0.44	1.127	0.100	3.141	3.17
75	0.45	0.63	0.62	0.43	1.124	0.096	3.330	3.92
76	0.46	1.23	0.75	0.45	1.186	0.114	2.997	2.60
77	0.40	2.62	0.34	0.39	0.946	0.047	3.888	6.15
78	0.45	0.93	0.44	0.44	1.119	0.085	3.316	3.87
79	0.40	2.65	0.21	0.39	0.931	0.049	4.028	6.71
80	0.48	1.94	0.70	0.47	1.272	0.153	2.744	1.59
81	0.44	0.46	0.45	0.43	1.088	0.083	3.605	5.02
82	0.40	2.61	0.24	0.39	0.931	0.048	4.000	6.60
83	0.43	0.48	0.45	0.42	1.058	0.072	3.728	5.51
84	0.46	1.07	0.43	0.44	1.132	0.092	3.241	3.57
85	0.40	2.80	0.23	0.40	0.966	0.038	4.153	7.21
86	0.42	1.45	0.23	0.41	1.014	0.047	3.946	6.38
87	0.42	1.30	0.19	0.41	1.014	0.046	4.023	6.69
88	0.42	1.06	0.26	0.42	1.024	0.044	3.963	6.45
89	0.39	4.90	0.10	0.39	0.925	0.044	4.565	8.86
90	0.43	0.80	0.28	0.43	1.078	0.067	3.659	5.24
91	0.43	0.52	0.29	0.44	1.113	0.080	3.655	5.22
92	0.40	3.66	0.18	0.40	0.969	0.051	4.000	6.60
93	0.42	1.64	0.20	0.41	1.014	0.049	3.939	6.36
94	0.44	0.48	0.37	0.44	1.141	0.094	3.514	4.66
95	0.39	4.19	0.12	0.39	0.925	0.036	4.599	8.99
96	0.44	0.58	0.38	0.45	1.160	0.102	3.393	4.18
97	0.41	2.12	0.15	0.41	0.984	0.043	4.223	7.49
98	0.43	0.65	0.23	0.43	1.096	0.081	3.680	5.32
99	0.42	1.28	0.17	0.42	1.048	0.063	3.856	6.02
100	0.41	2.68	0.22	0.40	0.969	0.044	4.017	6.67
101	0.43	0.62	0.37	0.42	1.043	0.065	3.726	5.51
102	0.42	1.69	0.44	0.41	1.015	0.068	3.528	4.72
103	0.42	0.97	0.18	0.42	1.024	0.104	3.679	5.32
104	0.42	1.25	0.48	0.42	1.063	0.080	3.404	4.22
105	0.41	2.82	0.16	0.40	0.979	0.063	3.917	6.27
106	0.44	0.21	0.53	0.43	1.107	0.098	4.049	6.79
107	0.44	0.21	0.35	0.44	1.113	0.095	4.121	7.08
108	0.43	0.53	0.53	0.43	1.107	0.093	3.473	4.50
109	0.40	3.63	0.15	0.40	0.956	0.073	3.933	6.33
110	0.46	1.36	0.41	0.46	1.205	0.146	2.967	2.48
111	0.43	0.25	0.31	0.43	1.083	0.121	3.952	6.41
112	0.46	1.50	0.27	0.45	1.132	0.179	3.100	3.01
113	0.45	0.74	0.34	0.44	1.113	0.105	3.361	4.05
114	0.44	0.35	0.19	0.44	1.096	0.118	3.862	6.05
115	0.41	1.85	0.15	0.41	0.994	0.036	4.353	8.02
116	0.40	2.51	0.12	0.41	0.994	0.049	4.211	7.44
117	0.42	0.90	0.31	0.43	1.062	0.062	3.669	5.28
118	0.40	2.34	0.14	0.41	0.984	0.041	4.301	7.80
119	0.40	3.32	0.17	0.40	0.956	0.038	4.273	7.69
120	0.40	3.10	0.10	0.40	0.964	0.041	4.575	8.89
121	0.39	3.75	0.16	0.39	0.935	0.035	4.430	8.31
122	0.43	0.29	0.43	0.43	1.092	0.064	4.015	6.66
123	0.40	3.22	0.22	0.40	0.939	0.034	4.320	7.87
124	0.42	0.77	0.27	0.43	1.083	0.060	3.739	5.56
125	0.39	5.12	0.08	0.39	0.905	0.039	4.852	10.00
126	0.42	1.31	0.29	0.42	1.039	0.058	3.704	5.42
127	0.41	2.01	0.11	0.41	0.999	0.047	4.340	7.96
128	0.40	2.26	0.25	0.41	0.994	0.046	3.921	6.28
129	0.42	0.62	0.28	0.42	1.039	0.046	4.034	6.74
130	0.42	1.82	0.19	0.41	0.990	0.060	3.866	6.06
131	0.41	2.41	0.13	0.40	0.954	0.068	4.062	6.85
132	0.40	2.84	0.12	0.40	0.954	0.075	4.051	6.80
133	0.45	1.32	0.60	0.46	1.200	0.164	2.925	2.31
134	0.43	0.32	0.35	0.42	1.043	0.114	3.832	5.93
135	0.43	0.65	0.16	0.41	1.014	0.060	4.074	6.89
136	0.43	0.42	0.48	0.42	1.053	0.088	3.688	5.35
137	0.43	0.35	0.25	0.41	1.018	0.104	3.946	6.38
138	0.40	2.97	0.28	0.39	0.941	0.051	3.885	6.14
139	0.45	0.91	0.39	0.43	1.088	0.105	3.308	3.84
140	0.47	1.94	0.46	0.45	1.185	0.164	2.897	2.20
141	0.41	1.96	0.14	0.40	0.969	0.063	4.026	6.70
142	0.41	2.61	0.21	0.40	0.956	0.054	3.919	6.28
143	0.43	0.34	0.36	0.43	1.081	0.098	3.775	5.70
144	0.45	0.83	0.27	0.43	1.083	0.101	3.442	4.37
145	0.42	1.20	0.20	0.43	1.073	0.080	3.621	5.09
146	0.41	1.81	0.13	0.42	1.014	0.077	3.937	6.35
147	0.44	0.52	0.48	0.45	1.160	0.114	3.343	3.98
148	0.43	0.69	0.25	0.44	1.111	0.120	3.464	4.46
149	0.43	0.52	0.14	0.44	1.101	0.109	3.852	6.01
150	0.42	0.82	0.40	0.43	1.068	0.069	3.570	4.88
151	0.39	4.32	0.11	0.39	0.935	0.044	4.448	8.39
152	0.41	2.09	0.17	0.41	1.009	0.070	3.813	5.85
153	0.42	1.35	0.29	0.43	1.088	0.091	3.407	4.23
154	0.44	0.43	0.35	0.44	1.126	0.086	3.634	5.14
155	0.42	1.47	0.25	0.43	1.058	0.088	3.505	4.62
156	0.41	1.95	0.24	0.42	1.020	0.063	3.699	5.40
157	0.41	1.79	0.12	0.42	1.014	0.061	4.053	6.81
158	0.46	1.24	0.32	0.47	1.230	0.137	3.038	2.76
159	0.44	0.39	0.25	0.43	1.096	0.085	3.833	5.93

Table B.14. Motions and Seakeeping Index for the Series of Hull Forms, V=0 Knots, Heading Angle 135 Deg.

HULL	Heave [m/m]	Roll [deg/m]	Pitch [deg/m]	Vert.Mot. at FP [m/m]	Vert.Acc. at FP [m/s^2/m]	Rel.Mot. at FP [m/m]	Sum	Index
01	0.24	1.49	2.32	0.54	1.262	0.434	5.003	8.40
02	0.26	1.56	2.56	0.61	1.475	0.542	4.404	5.76
03	0.24	1.60	2.31	0.54	1.252	0.439	4.983	8.31
04	0.27	1.99	2.78	0.70	1.712	0.664	3.879	3.45
05	0.27	1.53	2.67	0.65	1.593	0.603	4.158	4.68
06	0.23	1.74	2.32	0.58	1.373	0.513	4.709	7.10
07	0.24	1.80	2.28	0.54	1.250	0.439	4.978	8.29
08	0.27	1.68	2.73	0.68	1.657	0.629	4.025	4.10
09	0.25	1.69	2.44	0.63	1.500	0.592	4.343	5.50
10	0.26	1.92	2.62	0.64	1.561	0.582	4.183	4.79
11	0.27	1.72	2.57	0.67	1.623	0.651	4.076	4.32
12	0.26	2.08	2.62	0.70	1.690	0.678	3.968	3.84
13	0.26	2.12	2.51	0.69	1.652	0.686	4.022	4.08
14	0.25	1.86	2.50	0.69	1.646	0.682	4.084	4.36
15	0.25	1.57	2.43	0.62	1.479	0.583	4.408	5.78
16	0.27	1.92	2.66	0.74	1.798	0.757	3.798	3.10
17	0.25	1.75	2.50	0.68	1.633	0.677	4.125	4.53
18	0.23	1.62	2.17	0.56	1.299	0.511	4.896	7.93
19	0.28	1.82	2.77	0.65	1.594	0.573	4.091	4.39
20	0.28	1.44	2.64	0.55	1.320	0.428	4.722	7.16
21	0.28	1.47	2.80	0.60	1.453	0.485	4.389	5.70
22	0.27	1.49	2.62	0.59	1.432	0.485	4.518	6.26
23	0.27	1.54	2.74	0.63	1.555	0.554	4.211	4.91
24	0.29	1.78	2.87	0.62	1.521	0.515	4.200	4.87
25	0.27	1.63	2.70	0.74	1.774	0.751	3.827	3.22
26	0.27	1.71	2.61	0.71	1.690	0.714	3.939	3.72
27	0.28	1.74	2.76	0.71	1.714	0.692	3.871	3.42
28	0.28	1.55	2.86	0.70	1.720	0.657	3.912	3.60
29	0.27	1.76	2.70	0.74	1.774	0.754	3.793	3.08
30	0.27	1.62	2.67	0.68	1.631	0.650	4.038	4.15
31	0.29	1.53	2.96	0.78	1.906	0.782	3.616	2.30
32	0.27	1.59	2.67	0.64	1.538	0.580	4.203	4.88
33	0.29	1.85	2.87	0.81	1.953	0.839	3.521	1.88
34	0.28	1.66	2.81	0.68	1.661	0.635	3.965	3.83
35	0.29	1.80	3.00	0.75	1.853	0.738	3.625	2.34
36	0.27	1.75	2.78	0.72	1.735	0.699	3.854	3.34
37	0.27	2.15	2.75	0.76	1.840	0.774	3.680	2.58
38	0.29	2.01	2.84	0.70	1.701	0.663	3.818	3.18
39	0.29	2.15	2.78	0.72	1.739	0.704	3.763	2.94
40	0.25	1.80	2.49	0.61	1.462	0.541	4.438	5.91
41	0.27	1.21	2.81	0.63	1.531	0.531	4.325	5.42
42	0.28	1.10	2.89	0.66	1.614	0.576	4.165	4.71
43	0.30	1.34	2.92	0.61	1.491	0.505	4.269	5.17
44	0.31	0.87	3.22	0.67	1.682	0.571	4.071	4.30
45	0.26	1.85	2.51	0.55	1.311	0.438	4.734	7.22
46	0.33	0.96	3.35	0.72	1.788	0.655	3.772	2.98
47	0.31	1.26	3.29	0.79	1.959	0.759	3.526	1.90
48	0.29	1.34	2.80	0.58	1.389	0.452	4.532	6.32
49	0.27	1.58	2.74	0.74	1.764	0.731	3.848	3.32
50	0.33	0.89	3.34	0.72	1.783	0.644	3.828	3.23
51	0.24	1.48	2.32	0.61	1.423	0.574	4.588	6.57
52	0.33	1.08	3.42	0.82	2.027	0.799	3.434	1.50
53	0.25	2.35	2.51	0.68	1.618	0.662	4.083	4.35
54	0.23	1.39	2.32	0.61	1.421	0.567	4.637	6.79
55	0.30	0.50	3.05	0.56	1.351	0.408	5.091	8.79
56	0.26	0.76	2.74	0.69	1.651	0.652	4.301	5.31
57	0.26	1.36	2.76	0.70	1.671	0.664	4.032	4.13
58	0.27	1.09	2.76	0.70	1.686	0.666	4.082	4.34
59	0.28	1.02	2.96	0.68	1.652	0.610	4.105	4.45
60	0.30	0.42	2.99	0.54	1.301	0.391	5.367	10.00
61	0.30	0.51	2.91	0.53	1.258	0.382	5.301	9.71
62	0.28	0.69	2.90	0.65	1.578	0.569	4.436	5.90
63	0.28	0.88	2.93	0.67	1.618	0.597	4.215	4.93
64	0.26	0.88	2.72	0.69	1.641	0.654	4.235	5.02
65	0.31	0.53	3.05	0.57	1.374	0.441	4.902	7.95
66	0.30	0.77	3.09	0.58	1.400	0.427	4.691	7.03
67	0.27	0.78	2.90	0.65	1.578	0.568	4.388	5.69
68	0.27	0.91	2.81	0.71	1.711	0.688	4.077	4.32
69	0.29	0.77	3.01	0.69	1.675	0.624	4.165	4.71
70	0.27	0.87	2.71	0.57	1.364	0.451	4.792	7.47
71	0.30	0.41	3.02	0.59	1.422	0.468	5.058	8.64
72	0.28	0.60	2.93	0.67	1.618	0.596	4.444	5.94
73	0.35	1.02	3.64	0.74	1.831	0.668	3.622	2.32
74	0.31	0.68	3.09	0.64	1.535	0.550	4.372	5.62
75	0.32	0.62	3.16	0.63	1.514	0.534	4.430	5.88
76	0.32	0.70	3.17	0.62	1.500	0.517	4.417	5.82
77	0.28	1.08	2.76	0.57	1.364	0.446	4.676	6.96
78	0.28	0.56	3.05	0.70	1.705	0.633	4.348	5.52
79	0.26	1.25	2.64	0.62	1.470	0.536	4.432	5.89
80	0.34	1.05	3.50	0.75	1.825	0.689	3.632	2.37
81	0.31	0.67	3.12	0.68	1.656	0.616	4.198	4.86
82	0.27	1.16	2.70	0.61	1.467	0.519	4.460	6.01
83	0.31	0.72	3.16	0.66	1.624	0.573	4.226	4.98
84	0.29	0.64	3.11	0.71	1.734	0.657	4.163	4.71
85	0.28	1.62	2.77	0.63	1.502	0.542	4.240	5.04
86	0.28	1.24	2.80	0.65	1.568	0.589	4.172	4.74
87	0.27	1.07	2.68	0.65	1.550	0.608	4.271	5.18
88	0.28	1.07	2.85	0.66	1.599	0.589	4.201	4.87
89	0.24	2.10	2.41	0.68	1.576	0.689	4.155	4.67
90	0.31	1.28	3.12	0.76	1.861	0.738	3.635	2.38
91	0.31	1.18	3.14	0.77	1.876	0.745	3.651	2.45
92	0.28	2.16	2.75	0.70	1.656	0.670	3.878	3.45
93	0.28	1.33	2.82	0.70	1.699	0.674	3.941	3.72
94	0.33	1.07	3.18	0.72	1.764	0.678	3.761	2.93
95	0.24	1.82	2.41	0.63	1.466	0.589	4.415	5.81
96	0.33	1.23	3.29	0.77	1.876	0.737	3.548	2.00
97	0.26	1.37	2.58	0.69	1.625	0.681	4.099	4.42
98	0.30	1.22	3.04	0.78	1.901	0.787	3.612	2.28
99	0.27	1.31	2.75	0.74	1.774	0.748	3.864	3.39
100	0.26	1.10	2.63	0.61	1.447	0.528	4.333	6.33
101	0.28	0.67	2.87	0.62	1.472	0.523	4.609	6.66
102	0.31	0.99	2.92	0.58	1.364	0.458	4.564	6.47
103	0.31	1.01	2.80	0.76	1.744	0.776	3.829	3.24
104	0.31	1.04	3.04	0.61	1.461	0.505	4.302	5.31
105	0.27	1.25	2.63	0.68	1.599	0.662	4.141	4.60
106	0.32	0.80	3.02	0.60	1.411	0.496	4.479	6.10
107	0.31	0.91	3.02	0.67	1.628	0.606	4.100	4.42
108	0.32	0.92	3.09	0.63	1.491	0.525	4.270	5.17
109	0.27	1.38	2.58	0.70	1.601	0.703	4.049	4.20
110	0.33	1.18	3.18	0.72	1.734	0.675	3.732	2.80
111	0.34	1.09	3.06	0.75	1.757	0.737	3.691	2.63
112	0.39	1.38	3.14	0.83	1.877	0.857	3.321	1.00
113	0.31	0.85	2.91	0.64	1.514	0.562	4.309	5.34
114	0.30	0.95	2.88	0.76	1.791	0.770	3.830	3.24
115	0.26	1.53	2.64	0.70	1.652	0.688	4.046	4.19
116	0.25	1.68	2.56	0.75	1.743	0.777	3.900	3.55
117	0.31	1.24	3.05	0.68	1.633	0.605	3.953	3.78
118	0.26	1.66	2.66	0.71	1.690	0.710	3.947	3.75
119	0.28	2.12	2.76	0.67	1.593	0.614	4.003	4.00
120	0.25	1.64	2.43	0.70	1.607	0.710	4.141	4.61
121	0.26	2.00	2.69	0.64	1.525	0.566	4.197	4.85
122	0.31	0.74	3.05	0.60	1.447	0.484	4.530	6.32
123	0.28	1.66	2.72	0.58	1.364	0.465	4.507	6.22
124	0.29	1.35	3.03	0.74	1.808	0.715	3.745	2.86
125	0.23	2.07	2.22	0.62	1.389	0.602	4.569	6.49
126	0.31	1.37	3.03	0.68	1.633	0.605	3.919	3.63
127	0.25	1.35	2.45	0.69	1.594	0.705	4.190	4.82
128	0.30	1.59	2.93	0.65	1.553	0.562	4.048	4.20
129	0.29	0.91	2.88	0.62	1.475	0.519	4.417	5.82
130	0.26	0.87	2.58	0.63	1.464	0.570	4.368	6.48
131	0.26	0.99	2.46	0.67	1.538	0.663	4.362	5.58
132	0.27	1.18	2.52	0.70	1.603	0.716	4.127	4.55
133	0.35	1.22	3.15	0.63	1.497	0.550	4.045	4.19
134	0.35	1.16	3.08	0.72	1.679	0.698	3.727	2.78
135	0.23	0.51	2.33	0.61	1.397	0.584	5.121	8.92
136	0.33	0.84	2.99	0.60	1.421	0.507	4.417	5.82
137	0.32	1.05	2.95	0.73	1.713	0.715	3.823	3.21
138	0.28	1.21	2.73	0.58	1.360	0.468	4.594	6.60
139	0.31	0.80	2.94	0.62	1.479	0.548	4.369	5.61
140	0.36	1.34	3.29	0.75	1.791	0.732	3.520	1.87
141	0.25	0.87	2.41	0.65	1.480	0.632	4.568	6.49
142	0.27	1.13	2.68	0.62	1.479	0.549	4.404	5.76
143	0.31	0.89	3.00	0.66	1.557	0.589	4.166	4.71
144	0.30	0.84	2.95	0.69	1.651	0.645	4.108	4.46
145	0.29	1.35	2.89	0.74	1.779	0.728	3.787	3.05
146	0.30	1.57	2.73	0.78	1.831	0.811	3.651	2.45
147	0.36	1.04	3.25	0.69	1.656	0.620	3.844	3.30
148	0.36	1.60	3.17	0.80	1.909	0.798	3.362	1.18
149	0.31	1.34	2.80	0.79	1.874	0.833	3.613	2.28
150	0.32	1.05	3.15	0.63	1.538	0.519	4.175	4.76
151	0.25	1.94	2.41	0.66	1.534	0.656	4.218	4.95
152	0.30	1.67	2.84	0.74	1.767	0.729	3.714	2.73
153	0.32	1.61	3.13	0.76	1.842	0.733	3.550	2.00
154	0.31	0.99	3.13	0.73	1.795	0.690	3.824	3.21
155	0.33	1.68	3.14	0.80	1.938	0.799	3.411	1.40
156	0.30	1.48	2.94	0.69	1.661	0.639	3.882	3.47
157	0.27	1.36	2.63	0.73	1.743	0.747	3.908	3.58
158	0.33	1.01	3.25	0.81	1.986	0.809	3.519	1.87
159	0.31	0.96	2.98	0.72	1.752	0.693	3.894	3.52

Table B.15. Motions and Seakeeping Index for the Series of Hull Forms, V=5 Knots, Heading Angle 135 Deg.

HULL	Heave [m/m]	Roll [deg/m]	Pitch [deg/m]	Vert.Mot. at FP [m/m]	Vert.Acc. at FP [m/s^2/m]	Rel.Mot. at FP [m/m]	Sum	Index
01	0.28	3.68	2.14	0.56	1.830	0.569	5.396	10.00
02	0.31	4.40	2.39	0.64	2.143	0.690	4.668	5.47
03	0.29	3.81	2.12	0.55	1.809	0.562	5.395	10.00
04	0.34	4.27	2.46	0.70	2.339	0.775	4.366	3.59
05	0.33	4.37	2.46	0.68	2.259	0.736	4.469	4.23
06	0.28	4.08	2.18	0.61	2.046	0.654	5.022	7.67
07	0.28	4.14	2.09	0.55	1.830	0.581	5.355	9.75
08	0.33	4.34	2.50	0.70	2.329	0.759	4.378	3.66
09	0.31	4.24	2.24	0.65	2.138	0.717	4.704	5.69
10	0.32	4.34	2.38	0.66	2.196	0.713	4.594	5.01
11	0.33	4.29	2.36	0.69	2.293	0.771	4.438	4.03
12	0.32	4.35	2.35	0.71	2.333	0.781	4.428	3.97
13	0.32	4.35	2.28	0.70	2.303	0.787	4.473	4.25
14	0.31	4.42	2.31	0.71	2.348	0.797	4.431	3.99
15	0.31	4.25	2.25	0.65	2.149	0.717	4.693	5.63
16	0.34	4.37	2.39	0.75	2.468	0.848	4.227	2.72
17	0.31	4.44	2.33	0.71	2.371	0.799	4.413	3.88
18	0.28	3.77	2.09	0.61	2.138	0.664	5.042	7.80
19	0.33	4.26	2.51	0.66	2.227	0.714	4.504	4.45
20	0.32	4.18	2.39	0.56	1.847	0.585	5.067	7.96
21	0.33	4.23	2.58	0.62	2.076	0.651	4.680	5.54
22	0.31	4.16	2.41	0.61	2.028	0.632	4.850	6.60
23	0.33	4.28	2.52	0.66	2.207	0.702	4.530	4.61
24	0.33	4.26	2.63	0.64	2.159	0.678	4.565	4.82
25	0.34	4.43	2.41	0.75	2.443	0.843	4.212	2.62
26	0.33	4.33	2.34	0.72	2.337	0.809	4.357	3.53
27	0.34	4.33	2.45	0.71	2.343	0.794	4.318	3.29
28	0.34	4.24	2.59	0.72	2.392	0.783	4.278	3.04
29	0.34	4.44	2.40	0.75	2.430	0.842	4.217	2.66
30	0.33	4.22	2.40	0.69	2.274	0.762	4.448	4.10
31	0.36	4.44	2.58	0.77	2.512	0.864	4.058	1.67
32	0.33	4.21	2.41	0.65	2.164	0.712	4.588	4.97
33	0.36	4.50	2.51	0.80	2.578	0.905	3.997	1.29
34	0.34	4.21	2.52	0.69	2.304	0.760	4.379	3.67
35	0.36	4.21	2.61	0.75	2.430	0.828	4.148	2.23
36	0.34	4.42	2.48	0.72	2.381	0.804	4.271	3.00
37	0.35	4.64	2.45	0.77	2.521	0.868	4.098	1.92
38	0.35	4.11	2.46	0.69	2.255	0.760	4.415	3.89
39	0.34	4.19	2.41	0.71	2.278	0.784	4.380	3.67
40	0.30	4.23	2.29	0.63	2.101	0.672	4.825	6.44
41	0.33	4.06	2.62	0.65	2.181	0.677	4.578	4.91
42	0.35	4.05	2.67	0.68	2.269	0.721	4.399	3.79
43	0.35	3.85	2.65	0.63	2.071	0.665	4.636	5.27
44	0.38	3.10	3.01	0.71	2.345	0.735	4.319	3.30
45	0.30	4.15	2.26	0.56	1.894	0.590	5.143	8.43
46	0.41	2.82	2.95	0.73	2.346	0.789	4.279	3.04
47	0.39	3.52	2.88	0.79	2.537	0.860	4.012	1.38
48	0.33	4.08	2.56	0.59	1.999	0.624	4.803	6.31
49	0.34	4.58	2.53	0.76	2.498	0.848	4.127	2.10
50	0.40	3.29	3.00	0.73	2.344	0.776	4.187	2.47
51	0.29	4.17	2.20	0.65	2.128	0.708	4.825	6.44
52	0.42	3.46	2.90	0.80	2.533	0.874	3.951	1.00
53	0.30	4.51	2.27	0.69	2.279	0.768	4.538	4.66
54	0.28	4.08	2.23	0.65	2.164	0.708	4.812	6.37
55	0.35	2.48	2.94	0.59	1.948	0.603	5.043	7.81
56	0.34	3.88	2.53	0.71	2.307	0.774	4.389	3.73
57	0.33	4.14	2.52	0.71	2.341	0.787	4.354	3.51
58	0.34	3.91	2.53	0.72	2.350	0.792	4.345	3.45
59	0.34	3.91	2.64	0.68	2.216	0.734	4.442	4.06
60	0.35	3.35	2.88	0.58	1.931	0.589	4.901	6.92
61	0.34	2.51	2.77	0.56	1.817	0.571	5.252	9.11
62	0.35	3.85	2.64	0.67	2.200	0.716	4.485	4.33
63	0.35	3.53	2.63	0.67	2.206	0.731	4.503	4.44
64	0.33	3.68	2.49	0.71	2.297	0.779	4.439	4.04
65	0.36	2.27	2.85	0.59	1.880	0.609	5.133	8.36
66	0.34	3.70	2.95	0.60	1.995	0.603	4.751	5.99
67	0.33	3.42	2.66	0.67	2.221	0.719	4.552	4.75
68	0.35	3.65	2.53	0.73	2.375	0.812	4.311	3.24
69	0.36	3.42	2.67	0.69	2.248	0.751	4.424	3.95
70	0.32	3.31	2.51	0.59	2.004	0.618	4.970	7.35
71	0.36	1.92	2.80	0.61	1.986	0.637	5.171	8.60
72	0.35	2.90	2.67	0.68	2.210	0.732	4.595	5.01
73	0.43	3.50	3.28	0.75	2.366	0.804	3.992	1.26
74	0.39	3.11	2.82	0.64	2.040	0.692	4.594	5.01
75	0.38	2.62	2.85	0.63	2.024	0.682	4.735	5.89
76	0.38	3.43	2.97	0.64	2.043	0.679	4.530	4.61
77	0.32	3.95	2.50	0.58	1.879	0.599	4.988	7.46
78	0.37	2.88	2.85	0.72	2.364	0.785	4.363	3.57
79	0.32	3.95	2.36	0.62	1.984	0.657	4.866	6.70
80	0.43	3.81	3.06	0.73	2.309	0.801	4.039	1.55
81	0.38	3.10	2.76	0.68	2.174	0.740	4.471	4.24
82	0.32	3.85	2.43	0.62	2.007	0.651	4.843	6.56
83	0.38	2.81	2.77	0.66	2.108	0.700	4.634	5.25
84	0.38	3.26	2.85	0.73	2.379	0.798	4.235	2.77

HULL	Heave [m/m]	Roll [deg/m]	Pitch [deg/m]	Vert.Mot. at FP [m/m]	Vert.Acc. at FP [m/s^2/m]	Rel.Mot. at FP [m/m]	Sum	Index
85	0.33	4.27	2.45	0.63	2.050	0.675	4.684	5.57
86	0.35	4.13	2.49	0.66	2.147	0.718	4.519	4.54
87	0.35	4.05	2.43	0.68	2.208	0.745	4.480	4.29
88	0.35	4.00	2.62	0.68	2.274	0.739	4.400	3.80
89	0.30	4.17	2.14	0.69	2.233	0.781	4.645	5.32
90	0.39	4.13	2.66	0.75	2.419	0.830	4.086	1.84
91	0.39	3.82	2.70	0.77	2.480	0.848	4.060	1.68
92	0.34	4.17	2.30	0.67	2.154	0.751	4.546	4.71
93	0.35	4.14	2.50	0.71	2.318	0.785	4.313	3.26
94	0.41	3.66	2.68	0.71	2.261	0.783	4.239	2.79
95	0.29	4.19	2.21	0.65	2.146	0.717	4.770	6.10
96	0.41	3.84	2.70	0.74	2.320	0.816	4.127	2.10
97	0.33	4.32	2.34	0.71	2.287	0.792	4.407	3.84
98	0.39	4.15	2.57	0.78	2.482	0.871	4.030	1.49
99	0.35	4.14	2.41	0.75	2.415	0.843	4.227	2.72
100	0.31	3.47	2.36	0.62	2.062	0.660	4.913	6.99
101	0.35	2.71	2.54	0.62	1.991	0.663	4.939	7.15
102	0.35	3.18	2.52	0.57	1.793	0.598	5.099	8.15
103	0.38	3.59	2.20	0.69	2.080	0.805	4.538	4.66
104	0.36	3.16	2.61	0.60	1.898	0.639	4.879	6.78
105	0.33	3.63	2.23	0.66	2.127	0.747	4.697	5.65
106	0.38	3.04	2.62	0.59	1.845	0.633	4.929	7.09
107	0.37	3.53	2.56	0.66	2.098	0.720	4.543	4.69
108	0.37	2.94	2.65	0.61	1.919	0.655	4.846	6.58
109	0.33	3.52	2.10	0.66	2.008	0.753	4.814	6.38
110	0.41	4.25	2.63	0.69	2.136	0.768	4.247	2.85
111	0.40	3.77	2.37	0.68	2.065	0.782	4.439	4.04
112	0.45	4.64	2.20	0.70	1.982	0.823	4.317	3.28
113	0.38	4.15	2.50	0.62	1.946	0.683	4.624	5.19
114	0.39	4.08	2.35	0.72	2.199	0.826	4.299	3.17
115	0.33	4.31	2.40	0.72	2.337	0.792	4.371	3.62
116	0.32	4.14	2.26	0.75	2.397	0.853	4.349	3.48
117	0.37	3.48	2.59	0.66	2.137	0.723	4.510	4.49
118	0.33	4.32	2.34	0.72	2.312	0.802	4.385	3.70
119	0.34	4.09	2.37	0.67	2.214	0.735	4.529	4.60
120	0.31	3.98	2.21	0.71	2.300	0.805	4.538	4.66
121	0.32	4.18	2.37	0.64	2.131	0.691	4.689	5.60
122	0.37	2.77	2.71	0.61	1.969	0.615	4.904	6.94
123	0.33	3.98	2.37	0.58	1.877	0.608	5.002	7.55
124	0.36	4.05	2.65	0.74	2.420	0.820	4.160	2.30
125	0.28	3.93	2.01	0.63	2.028	0.706	5.044	7.81
126	0.37	3.52	2.57	0.66	2.103	0.707	4.556	4.77
127	0.32	3.90	2.20	0.71	2.274	0.805	4.526	4.58
128	0.36	3.64	2.48	0.63	2.027	0.676	4.696	5.64
129	0.36	3.37	2.59	0.64	2.095	0.664	4.683	5.56
130	0.32	3.25	2.28	0.63	2.022	0.694	4.901	6.92
131	0.32	3.31	2.15	0.66	2.080	0.757	4.805	6.32
132	0.33	3.30	2.09	0.67	2.082	0.776	4.786	6.20
133	0.40	3.96	2.53	0.60	1.813	0.659	4.725	5.82
134	0.40	3.97	2.36	0.64	1.904	0.732	4.588	4.97
135	0.30	2.69	2.24	0.66	2.124	0.737	4.962	7.30
136	0.37	3.28	2.57	0.58	1.817	0.630	4.929	7.09
137	0.39	3.74	2.32	0.67	2.059	0.769	4.500	4.42
138	0.33	3.72	2.36	0.57	1.858	0.608	5.053	7.87
139	0.39	3.40	2.56	0.61	1.912	0.670	4.739	5.91
140	0.43	4.27	2.59	0.69	2.062	0.781	4.247	2.84
141	0.31	3.15	2.16	0.66	2.065	0.742	4.887	6.83
142	0.33	3.61	2.33	0.62	1.984	0.666	4.880	6.79
143	0.38	3.35	2.49	0.64	1.987	0.700	4.673	5.50
144	0.39	3.57	2.56	0.69	2.183	0.764	4.384	3.70
145	0.37	4.11	2.41	0.73	2.329	0.816	4.265	2.95
146	0.38	4.35	2.31	0.77	2.419	0.879	4.130	2.11
147	0.42	3.36	2.70	0.66	2.043	0.719	4.468	4.22
148	0.44	4.01	2.40	0.74	2.253	0.838	4.159	2.30
149	0.40	4.16	2.33	0.79	2.449	0.902	4.065	1.71
150	0.39	3.48	2.73	0.63	2.018	0.657	4.622	5.18
151	0.31	4.25	2.16	0.67	2.168	0.758	4.665	5.45
152	0.37	4.28	2.36	0.71	2.253	0.803	4.312	3.25
153	0.39	4.06	2.53	0.72	2.242	0.800	4.247	2.84
154	0.39	3.74	2.74	0.73	2.369	0.806	4.160	2.30
155	0.40	4.16	2.55	0.75	2.350	0.846	4.101	1.93
156	0.37	4.08	2.46	0.67	2.147	0.740	4.450	4.11
157	0.35	4.28	2.37	0.75	2.445	0.851	4.205	2.58
158	0.43	3.52	2.70	0.80	2.505	0.891	3.971	1.13
159	0.39	3.85	2.57	0.72	2.288	0.797	4.247	2.85

Table B.16. Motions and Seakeeping Index for the Series of Hull Forms, V=10 Knots, Heading Angle 135 Deg.

HULL	Heave [m/m]	Roll [deg/m]	Pitch [deg/m]	Vert.Mot. at FP [m/m]	Vert.Acc. at FP [m/s^2/m]	Rel.Mot. at FP [m/m]	Sum	Index
01	0.30	4.22	1.94	0.54	2.183	0.616	5.058	9.22
02	0.34	3.94	2.28	0.63	2.623	0.750	4.359	5.17
03	0.31	4.23	1.88	0.52	2.067	0.595	5.193	10.00
04	0.36	3.46	2.32	0.68	2.850	0.821	4.144	3.91
05	0.35	3.67	2.32	0.66	2.731	0.784	4.229	4.41
06	0.30	4.26	2.00	0.59	2.469	0.705	4.708	7.19
07	0.30	4.38	1.90	0.52	2.099	0.623	5.136	9.67
08	0.36	3.60	2.36	0.68	2.852	0.814	4.118	3.77
09	0.34	3.77	2.06	0.62	2.556	0.755	4.484	5.89
10	0.34	3.84	2.24	0.64	2.623	0.757	4.369	5.22
11	0.36	3.50	2.18	0.67	2.741	0.804	4.248	4.52
12	0.34	3.76	2.16	0.67	2.756	0.805	4.271	4.66
13	0.34	3.72	2.07	0.66	2.693	0.798	4.349	5.11
14	0.34	3.85	2.11	0.68	2.765	0.816	4.262	4.60
15	0.34	3.83	2.08	0.62	2.538	0.750	4.488	5.91
16	0.36	3.53	2.15	0.71	2.862	0.851	4.135	3.86
17	0.34	3.91	2.14	0.69	2.818	0.823	4.220	4.36
18	0.30	4.13	1.89	0.58	2.461	0.671	4.840	7.96
19	0.36	3.54	2.42	0.66	2.765	0.783	4.194	4.21
20	0.34	4.05	2.38	0.57	2.348	0.676	4.582	6.46
21	0.36	3.62	2.61	0.64	2.682	0.750	4.217	4.34
22	0.34	3.98	2.30	0.60	2.512	0.704	4.488	5.91
23	0.36	3.65	2.43	0.65	2.750	0.776	4.192	4.19
24	0.36	3.47	2.67	0.66	2.790	0.776	4.133	3.85
25	0.37	3.63	2.17	0.71	2.867	0.854	4.094	3.63
26	0.36	3.68	2.13	0.69	2.795	0.831	4.185	4.15
27	0.37	3.47	2.25	0.69	2.799	0.826	4.150	3.95
28	0.37	3.36	2.44	0.70	2.906	0.832	4.045	3.34
29	0.37	3.62	2.18	0.71	2.860	0.855	4.096	3.64
30	0.36	3.63	2.22	0.67	2.752	0.804	4.215	4.33
31	0.39	3.37	2.36	0.74	2.951	0.879	3.950	2.79
32	0.36	3.57	2.28	0.64	2.674	0.773	4.287	4.75
33	0.39	3.41	2.24	0.75	2.975	0.899	3.949	2.78
34	0.37	3.37	2.38	0.68	2.796	0.809	4.144	3.92
35	0.39	2.96	2.45	0.72	2.896	0.860	4.017	3.18
36	0.37	3.38	2.30	0.70	2.847	0.837	4.107	3.70
37	0.38	3.60	2.22	0.74	2.995	0.881	3.982	2.98
38	0.37	3.43	2.31	0.66	2.713	0.800	4.208	4.29
39	0.36	3.41	2.21	0.67	2.685	0.802	4.260	4.59
40	0.32	4.20	2.08	0.61	2.534	0.724	4.548	6.26
41	0.36	3.35	2.49	0.65	2.632	0.741	4.293	4.78
42	0.38	2.94	2.59	0.67	2.803	0.788	4.139	3.89
43	0.38	3.14	2.69	0.64	2.661	0.761	4.185	4.16
44	0.42	2.04	2.97	0.71	2.868	0.811	4.079	3.54
45	0.32	4.23	2.19	0.57	2.427	0.676	4.658	6.90
46	0.43	2.43	2.93	0.72	2.826	0.849	3.929	2.67
47	0.42	2.38	2.72	0.76	2.966	0.887	3.911	2.56
48	0.36	3.81	2.59	0.61	2.566	0.724	4.292	4.77
49	0.38	3.64	2.30	0.73	2.949	0.867	3.985	2.99
50	0.43	2.91	2.92	0.71	2.743	0.822	3.911	2.57
51	0.32	4.23	2.02	0.63	2.617	0.756	4.495	5.95
52	0.45	2.96	2.65	0.75	2.866	0.878	3.823	2.05
53	0.33	4.12	2.06	0.66	2.708	0.794	4.355	5.14
54	0.31	4.20	2.05	0.63	2.629	0.750	4.491	5.93
55	0.37	2.65	3.03	0.62	2.460	0.707	4.352	5.13
56	0.37	3.31	2.30	0.67	2.657	0.790	4.242	4.48
57	0.36	3.95	2.32	0.68	2.741	0.813	4.143	3.91
58	0.37	2.85	2.32	0.69	2.759	0.816	4.227	4.40
59	0.37	2.84	2.51	0.66	2.659	0.783	4.258	4.58
60	0.37	3.04	2.99	0.60	2.437	0.690	4.354	5.13
61	0.37	3.00	2.87	0.58	2.303	0.671	4.495	5.96
62	0.37	3.26	2.50	0.65	2.629	0.767	4.238	4.46
63	0.38	3.05	2.50	0.66	2.662	0.785	4.210	4.30
64	0.37	3.28	2.30	0.68	2.722	0.810	4.203	4.26
65	0.39	1.82	2.94	0.61	2.375	0.707	4.595	6.53
66	0.37	2.45	3.04	0.63	2.495	0.702	4.380	5.29
67	0.36	3.15	2.55	0.66	2.687	0.778	4.215	4.33
68	0.37	3.03	2.31	0.69	2.739	0.824	4.183	4.14
69	0.38	2.86	2.52	0.67	2.666	0.792	4.198	4.23
70	0.34	3.73	2.44	0.59	2.458	0.688	4.494	5.95
71	0.38	1.19	2.80	0.62	2.432	0.717	4.931	8.48
72	0.38	2.15	2.51	0.66	2.598	0.774	4.402	5.42
73	0.46	4.23	3.23	0.73	2.737	0.848	3.641	1.00
74	0.41	3.26	2.75	0.63	2.413	0.745	4.212	4.31
75	0.41	2.13	2.87	0.64	2.462	0.751	4.348	5.10
76	0.41	3.52	2.98	0.64	2.460	0.752	4.095	3.63
77	0.35	3.78	2.46	0.58	2.350	0.684	4.532	6.17
78	0.40	2.73	2.69	0.70	2.762	0.825	4.042	3.33
79	0.34	3.76	2.19	0.59	2.351	0.703	4.606	6.60
80	0.45	4.39	2.92	0.70	2.623	0.827	3.786	1.84
81	0.40	2.44	2.64	0.66	2.554	0.781	4.258	4.58
82	0.34	3.74	2.28	0.60	2.365	0.701	4.562	6.34
83	0.41	2.21	2.73	0.64	2.535	0.760	4.320	4.94
84	0.41	3.44	2.66	0.70	2.734	0.826	3.952	2.80

HULL	Heave [m/m]	Roll [deg/m]	Pitch [deg/m]	Vert.Mot. at FP [m/m]	Vert.Acc. at FP [m/s^2/m]	Rel.Mot. at FP [m/m]	Sum	Index
85	0.36	3.71	2.28	0.61	2.430	0.726	4.456	5.73
86	0.37	3.29	2.30	0.64	2.521	0.759	4.347	5.09
87	0.38	3.40	2.19	0.65	2.581	0.777	4.319	4.93
88	0.38	3.06	2.44	0.67	2.684	0.785	4.209	4.30
89	0.32	4.08	1.85	0.64	2.561	0.785	4.551	6.28
90	0.41	3.12	2.41	0.72	2.802	0.850	4.001	3.09
91	0.42	2.75	2.45	0.73	2.826	0.860	4.007	3.12
92	0.36	3.59	2.00	0.63	2.464	0.769	4.489	5.92
93	0.38	3.47	2.24	0.67	2.668	0.807	4.200	4.24
94	0.43	3.04	2.47	0.68	2.593	0.810	4.100	3.66
95	0.32	4.20	1.98	0.62	2.484	0.742	4.578	6.44
96	0.43	2.94	2.47	0.70	2.642	0.833	4.053	3.39
97	0.36	3.92	2.07	0.67	2.634	0.806	4.285	4.74
98	0.41	3.34	2.25	0.72	2.765	0.865	4.021	3.20
99	0.38	3.58	2.07	0.70	2.713	0.842	4.184	4.15
100	0.33	3.73	2.14	0.59	2.396	0.697	4.641	6.80
101	0.37	2.09	2.37	0.60	2.346	0.714	4.704	7.17
102	0.37	2.56	2.48	0.57	2.188	0.667	4.747	7.41
103	0.38	2.96	1.86	0.62	2.255	0.779	4.649	6.85
104	0.38	2.22	2.58	0.60	2.323	0.707	4.605	6.59
105	0.35	3.71	1.96	0.62	2.441	0.759	4.536	6.19
106	0.39	2.21	2.60	0.59	2.246	0.700	4.630	6.74
107	0.39	2.65	2.36	0.63	2.414	0.751	4.439	5.63
108	0.39	2.14	2.63	0.61	2.334	0.720	4.560	6.33
109	0.34	3.61	1.78	0.59	2.196	0.740	4.818	7.83
110	0.43	4.43	2.38	0.64	2.377	0.778	4.151	3.96
111	0.41	2.82	2.13	0.63	2.307	0.777	4.477	5.85
112	0.44	4.60	1.91	0.61	2.090	0.779	4.471	5.82
113	0.40	3.64	2.31	0.59	2.220	0.714	4.488	5.91
114	0.40	3.79	2.00	0.65	2.356	0.799	4.371	5.23
115	0.36	3.56	2.14	0.69	2.751	0.812	4.221	4.37
116	0.35	3.69	1.95	0.69	2.765	0.849	4.268	4.64
117	0.40	2.53	2.45	0.65	2.537	0.773	4.328	4.98
118	0.36	3.66	2.10	0.68	2.717	0.819	4.252	4.54
119	0.36	3.37	2.16	0.65	2.674	0.779	4.326	4.97
120	0.34	3.76	1.93	0.66	2.707	0.814	4.384	5.31
121	0.34	3.76	2.16	0.62	2.524	0.736	4.477	5.85
122	0.39	1.97	2.62	0.60	2.322	0.685	4.669	6.96
123	0.35	3.56	2.26	0.57	2.330	0.685	4.620	6.68
124	0.40	2.89	2.41	0.71	2.843	0.849	4.057	3.41
125	0.30	3.96	1.77	0.59	2.435	0.735	4.825	7.86
126	0.39	2.59	2.38	0.63	2.430	0.742	4.455	5.72
127	0.35	3.67	1.89	0.66	2.602	0.805	4.440	5.64
128	0.37	2.79	2.32	0.61	2.417	0.727	4.509	6.03
129	0.38	2.37	2.45	0.62	2.454	0.716	4.527	6.14
130	0.35	3.24	2.04	0.59	2.332	0.722	4.688	7.07
131	0.35	3.55	1.86	0.61	2.335	0.758	4.673	6.98
132	0.34	3.44	1.77	0.60	2.293	0.762	4.758	7.48
133	0.41	3.55	2.49	0.59	2.160	0.709	4.451	5.70
134	0.41	3.00	2.20	0.59	2.145	0.735	4.587	6.49
135	0.34	3.47	2.04	0.63	2.473	0.765	4.519	6.09
136	0.39	2.36	2.55	0.57	2.177	0.685	4.691	7.09
137	0.41	2.82	2.05	0.62	2.320	0.767	4.516	6.08
138	0.35	3.70	2.23	0.56	2.257	0.668	4.698	7.13
139	0.40	3.45	2.37	0.58	2.167	0.699	4.528	6.14
140	0.44	4.56	2.36	0.63	2.257	0.775	4.192	4.20
141	0.34	3.35	1.88	0.61	2.335	0.751	4.701	7.15
142	0.35	3.75	2.12	0.59	2.334	0.705	4.626	6.71
143	0.40	2.35	2.28	0.61	2.285	0.731	4.607	6.60
144	0.41	3.68	2.29	0.64	2.444	0.776	4.239	4.47
145	0.39	3.34	2.09	0.68	2.631	0.823	4.249	4.33
146	0.39	3.57	2.00	0.69	2.611	0.845	4.229	4.41
147	0.44	2.66	2.60	0.64	2.369	0.758	4.278	4.69
148	0.45	3.01	2.07	0.68	2.484	0.828	4.232	4.43
149	0.42	3.75	1.90	0.71	2.611	0.864	4.177	4.11
150	0.41	2.50	2.60	0.62	2.369	0.713	4.437	5.62
151	0.33	4.11	1.90	0.63	2.515	0.773	4.534	6.18
152	0.39	3.42	2.06	0.66	2.542	0.805	4.313	4.90
153	0.40	2.94	2.28	0.67	2.541	0.812	4.238	4.46
154	0.42	3.08	2.52	0.70	2.713	0.831	4.016	3.18
155	0.42	3.04	2.28	0.70	2.651	0.845	4.106	3.70
156	0.39	3.23	2.24	0.64	2.493	0.771	4.341	5.06
157	0.38	3.79	2.06	0.70	2.746	0.841	4.169	4.06
158	0.45	3.85	2.34	0.74	2.720	0.877	3.873	2.34
159	0.41	3.39	2.29	0.67	2.594	0.812	4.140	3.89

Table B.17. Motions and Seakeeping Index for the Series of Hull Forms, V=15 Knots, Heading Angle 135 Deg.

HULL	Heave [m/m]	Roll [deg/m]	Pitch [deg/m]	Vert.Mot. at FP [m/m]	Vert.Acc. at FP [m/s^2/m]	Rel.Mot. at FP [m/m]	Sum	Index
01	0.31	3.86	1.91	0.53	2.580	0.669	4.846	8.88
02	0.36	3.15	2.28	0.63	3.067	0.791	4.175	4.93
03	0.31	3.82	1.83	0.51	2.444	0.642	5.022	9.93
04	0.38	2.58	2.31	0.68	3.303	0.852	4.005	3.93
05	0.37	2.78	2.29	0.66	3.167	0.818	4.083	4.38
06	0.31	3.73	1.98	0.59	2.948	0.748	4.501	6.85
07	0.30	3.83	1.83	0.51	2.387	0.652	5.035	10.00
08	0.38	2.69	2.35	0.68	3.286	0.845	3.984	3.80
09	0.35	2.96	2.02	0.61	2.943	0.781	4.367	6.06
10	0.35	3.03	2.23	0.63	3.055	0.792	4.209	5.13
11	0.37	2.57	2.15	0.65	3.146	0.827	4.151	4.78
12	0.35	2.92	2.11	0.66	3.168	0.827	4.171	4.90
13	0.35	2.86	2.01	0.64	3.099	0.815	4.261	5.44
14	0.35	2.96	2.06	0.66	3.182	0.835	4.164	4.86
15	0.35	3.03	2.05	0.61	2.918	0.775	4.368	6.07
16	0.37	2.57	2.07	0.68	3.226	0.859	4.101	4.49
17	0.35	3.02	2.08	0.67	3.235	0.843	4.123	4.62
18	0.31	3.68	1.88	0.58	2.950	0.730	4.581	7.33
19	0.38	2.69	2.44	0.66	3.219	0.823	4.014	3.98
20	0.36	3.38	2.49	0.59	2.822	0.738	4.270	5.49
21	0.38	2.76	2.73	0.66	3.217	0.814	3.938	3.53
22	0.35	3.29	2.29	0.60	2.893	0.743	4.322	5.79
23	0.38	2.79	2.45	0.66	3.207	0.819	4.007	3.94
24	0.38	2.62	2.80	0.68	3.342	0.838	3.860	3.07
25	0.38	2.69	2.09	0.68	3.236	0.863	4.055	4.22
26	0.38	2.80	2.07	0.67	3.163	0.844	4.118	4.59
27	0.38	2.55	2.20	0.67	3.160	0.842	4.078	4.36
28	0.39	2.47	2.43	0.70	3.343	0.864	3.916	3.40
29	0.38	2.67	2.10	0.68	3.217	0.862	4.052	4.21
30	0.38	2.80	2.17	0.66	3.131	0.827	4.109	4.54
31	0.40	2.39	2.30	0.72	3.313	0.890	3.904	3.33
32	0.38	2.78	2.30	0.64	3.104	0.810	4.114	4.57
33	0.40	2.37	2.15	0.72	3.324	0.899	3.941	3.55
34	0.39	2.50	2.39	0.68	3.228	0.841	4.001	3.90
35	0.40	1.98	2.44	0.71	3.313	0.884	3.936	3.52
36	0.38	2.40	2.26	0.69	3.242	0.857	4.026	4.05
37	0.39	2.60	2.15	0.71	3.395	0.891	3.930	3.49
38	0.38	2.63	2.31	0.66	3.128	0.829	4.064	4.27
39	0.37	2.57	2.17	0.65	3.067	0.818	4.178	4.95
40	0.33	3.57	2.05	0.60	2.986	0.764	4.380	6.14
41	0.37	2.56	2.48	0.64	3.049	0.787	4.127	4.65
42	0.39	1.87	2.63	0.68	3.252	0.833	4.031	4.08
43	0.41	2.32	2.81	0.67	3.159	0.822	3.927	3.47
44	0.44	1.38	2.99	0.71	3.294	0.858	3.955	3.63
45	0.34	3.68	2.25	0.58	2.871	0.732	4.377	6.12
46	0.45	2.13	3.00	0.73	3.224	0.889	3.703	2.15
47	0.43	1.72	2.70	0.75	3.333	0.907	3.825	2.87
48	0.39	3.08	2.72	0.64	3.061	0.788	3.994	3.86
49	0.39	2.62	2.21	0.70	3.317	0.877	3.950	3.60
50	0.45	2.31	2.93	0.70	3.078	0.852	3.782	2.61
51	0.33	3.58	1.96	0.62	3.025	0.784	4.357	6.01
52	0.46	2.42	2.59	0.73	3.155	0.887	3.753	2.44
53	0.34	3.37	2.03	0.65	3.137	0.816	4.226	5.23
54	0.33	3.53	2.01	0.62	3.061	0.782	4.345	5.93
55	0.40	1.77	3.14	0.64	2.930	0.776	4.107	4.55
56	0.38	2.53	2.21	0.65	3.005	0.807	4.180	4.96
57	0.37	3.06	2.26	0.66	3.108	0.829	4.071	4.32
58	0.38	2.02	2.27	0.67	3.153	0.835	4.157	4.82
59	0.38	2.06	2.50	0.66	3.046	0.814	4.133	4.68
60	0.40	2.50	3.09	0.62	2.872	0.756	4.061	4.25
61	0.39	2.14	2.99	0.61	2.745	0.740	4.209	5.13
62	0.38	2.56	2.47	0.64	2.983	0.795	4.121	4.61
63	0.39	2.11	2.49	0.66	3.060	0.816	4.100	4.48
64	0.38	2.27	2.25	0.66	3.109	0.830	4.138	4.71
65	0.41	1.08	3.08	0.63	2.846	0.774	4.426	6.41
66	0.39	1.82	3.13	0.64	2.913	0.764	4.130	4.66
67	0.38	2.23	2.53	0.66	3.075	0.810	4.106	4.52
68	0.38	2.06	2.24	0.66	3.048	0.829	4.198	5.07
69	0.40	1.87	2.51	0.66	3.032	0.818	4.143	4.74
70	0.36	3.13	2.47	0.60	2.885	0.735	4.271	5.49
71	0.40	0.78	2.86	0.63	2.856	0.772	4.765	8.41
72	0.39	1.54	2.46	0.64	2.924	0.797	4.319	5.78
73	0.48	3.98	3.24	0.73	3.049	0.881	3.509	1.00
74	0.43	3.05	2.76	0.63	2.737	0.783	4.019	4.01
75	0.43	1.80	2.95	0.65	2.849	0.800	4.079	4.36
76	0.43	3.27	3.03	0.66	2.834	0.803	3.862	3.08
77	0.37	3.12	2.53	0.60	2.823	0.745	4.236	5.29
78	0.42	2.50	2.63	0.69	3.085	0.846	3.893	3.27
79	0.35	3.08	2.20	0.59	2.756	0.745	4.411	6.32
80	0.46	3.99	2.89	0.69	2.892	0.848	3.702	2.14
81	0.42	1.87	2.63	0.65	2.883	0.807	4.132	4.67
82	0.35	3.10	2.29	0.59	2.778	0.745	4.355	5.99
83	0.42	1.39	2.82	0.65	2.916	0.799	4.231	5.26
84	0.42	3.02	2.58	0.68	3.009	0.840	3.874	3.15
85	0.37	2.89	2.28	0.61	2.825	0.764	4.292	5.62
86	0.39	2.44	2.27	0.63	2.889	0.789	4.234	5.28
87	0.39	2.39	2.10	0.63	2.889	0.789	4.303	5.68
88	0.39	2.10	2.40	0.66	3.058	0.814	4.131	4.67
89	0.33	3.43	1.71	0.60	2.831	0.782	4.577	7.30
90	0.42	2.21	2.33	0.70	3.102	0.860	3.976	3.76
91	0.42	1.92	2.39	0.71	3.140	0.870	3.988	3.83
92	0.36	2.81	1.89	0.60	2.749	0.778	4.476	6.71
93	0.39	2.56	2.13	0.65	2.953	0.815	4.189	5.01
94	0.43	2.31	2.43	0.67	2.867	0.825	4.043	4.15
95	0.33	3.56	1.88	0.60	2.806	0.757	4.519	6.96
96	0.44	2.18	2.42	0.68	2.917	0.846	4.009	3.95
97	0.37	3.04	1.95	0.63	2.909	0.808	4.293	5.63
98	0.42	2.36	2.13	0.68	3.003	0.857	4.078	4.36
99	0.38	2.63	1.91	0.65	2.939	0.832	4.264	5.46
100	0.34	3.21	2.10	0.58	2.765	0.728	4.500	6.85
101	0.38	1.53	2.37	0.60	2.715	0.751	4.543	7.10
102	0.38	1.96	2.58	0.58	2.600	0.719	4.478	6.72
103	0.38	2.15	1.76	0.58	2.467	0.768	4.730	8.20
104	0.39	1.57	2.68	0.61	2.742	0.756	4.384	6.16
105	0.36	3.15	1.89	0.60	2.760	0.772	4.468	6.66
106	0.41	1.66	2.69	0.60	2.639	0.749	4.388	6.18
107	0.39	1.94	2.35	0.62	2.754	0.778	4.342	5.91
108	0.40	1.40	2.72	0.62	2.739	0.768	4.395	6.23
109	0.34	3.08	1.67	0.55	2.441	0.737	4.848	8.90
110	0.43	3.80	2.31	0.62	2.607	0.786	4.133	4.68
111	0.40	1.98	2.10	0.61	2.567	0.782	4.468	6.66
112	0.42	3.90	1.90	0.58	2.300	0.770	4.484	6.75
113	0.40	3.06	2.29	0.58	2.521	0.741	4.374	6.10
114	0.40	3.00	1.86	0.60	2.525	0.781	4.478	6.71
115	0.39	2.61	2.04	0.68	3.243	0.840	4.083	4.39
116	0.36	2.84	1.79	0.65	3.067	0.843	4.305	5.70
117	0.41	1.80	2.48	0.65	2.945	0.811	4.176	4.93
118	0.37	2.74	2.05	0.66	3.160	0.839	4.154	4.80
119	0.36	2.55	2.16	0.64	3.055	0.800	4.236	5.29
120	0.35	3.02	1.79	0.63	3.001	0.810	4.401	6.26
121	0.35	3.02	2.13	0.61	2.927	0.768	4.332	5.85
122	0.40	1.49	2.65	0.60	2.657	0.734	4.470	6.67
123	0.37	2.83	2.30	0.58	2.764	0.738	4.370	6.08
124	0.41	1.96	2.32	0.69	3.163	0.860	4.047	4.18
125	0.31	3.41	1.65	0.56	2.748	0.746	4.793	8.58
126	0.39	1.78	2.35	0.61	2.749	0.767	4.399	6.25
127	0.35	2.86	1.73	0.61	2.832	0.796	4.529	7.02
128	0.38	1.99	2.31	0.60	2.771	0.759	4.392	6.21
129	0.40	1.59	2.47	0.63	2.958	0.778	4.304	5.69
130	0.35	2.75	1.92	0.56	2.538	0.726	4.682	7.92
131	0.35	3.08	1.74	0.57	2.610	0.756	4.677	7.89
132	0.34	2.94	1.63	0.56	2.491	0.750	4.840	8.85
133	0.42	2.86	2.55	0.59	2.473	0.747	4.277	5.53
134	0.41	2.15	2.23	0.58	2.432	0.750	4.507	6.89
135	0.35	2.16	1.95	0.60	2.764	0.773	4.556	7.17
136	0.40	1.60	2.64	0.58	2.554	0.731	4.505	6.87
137	0.41	1.98	1.99	0.59	2.565	0.768	4.535	7.05
138	0.36	3.09	2.27	0.57	2.669	0.713	4.462	6.62
139	0.41	2.82	2.32	0.57	2.402	0.720	4.462	6.62
140	0.44	4.04	2.33	0.61	2.469	0.781	4.165	4.87
141	0.34	2.85	1.75	0.57	2.578	0.750	4.714	8.11
142	0.35	3.18	2.03	0.56	2.560	0.717	4.598	7.42
143	0.40	1.61	2.24	0.59	2.547	0.750	4.579	7.31
144	0.41	2.91	2.22	0.61	2.671	0.779	4.250	5.37
145	0.39	2.42	1.94	0.64	2.838	0.816	4.334	5.87
146	0.38	2.55	1.88	0.64	2.813	0.822	4.351	5.97
147	0.44	2.13	2.64	0.64	2.653	0.785	4.144	4.74
148	0.45	2.16	2.00	0.65	2.730	0.826	4.250	5.37
149	0.41	2.86	1.69	0.64	2.744	0.831	4.372	6.09
150	0.42	1.61	2.61	0.61	2.708	0.752	4.361	6.02
151	0.34	3.41	1.77	0.60	2.799	0.776	4.533	7.04
152	0.39	2.46	1.97	0.63	2.804	0.805	4.343	5.92
153	0.41	1.99	2.22	0.65	2.817	0.820	4.243	5.33
154	0.43	2.36	2.46	0.69	3.013	0.848	3.954	3.62
155	0.43	2.06	2.23	0.67	2.947	0.849	4.108	4.53
156	0.39	2.32	2.19	0.62	2.804	0.787	4.290	5.61
157	0.38	2.84	1.89	0.65	2.964	0.826	4.263	5.45
158	0.45	3.42	2.19	0.69	2.887	0.862	3.920	3.42
159	0.42	2.55	2.20	0.65	2.839	0.815	4.146	4.76

Table B.18. Motions and Seakeeping Index for the Series of Hull Forms, V=0 Knots, Heading Angle 180 Deg.

HULL	Heave [m/m]	Pitch [deg/m]	Vert.Mot. at FP [m/m]	Vert.Acc. at FP [m/s^2/m]	Rel.Mot. at FP [m/m]	Sum	Index
01	0.18	2.18	0.48	0.961	0.518	4.701	9.08
02	0.19	2.40	0.54	1.107	0.608	4.196	6.89
03	0.18	2.19	0.48	0.961	0.526	4.675	8.97
04	0.20	2.68	0.63	1.323	0.721	3.679	4.64
05	0.19	2.52	0.58	1.195	0.658	3.955	5.84
06	0.17	2.09	0.50	0.982	0.570	4.636	8.80
07	0.18	2.14	0.48	0.941	0.523	4.744	9.27
08	0.20	2.59	0.60	1.253	0.683	3.833	5.31
09	0.18	2.21	0.54	1.063	0.629	4.296	7.32
10	0.19	2.50	0.57	1.190	0.650	3.988	5.99
11	0.19	2.33	0.58	1.156	0.675	4.035	6.19
12	0.19	2.42	0.60	1.224	0.712	3.914	5.67
13	0.18	2.25	0.58	1.156	0.702	4.062	6.31
14	0.18	2.22	0.58	1.128	0.692	4.141	6.65
15	0.18	2.19	0.53	1.038	0.619	4.365	7.62
16	0.19	2.39	0.63	1.262	0.756	3.810	5.21
17	0.18	2.21	0.57	1.116	0.686	4.181	6.82
18	0.16	1.92	0.48	0.898	0.556	4.913	10.00
19	0.20	2.76	0.60	1.285	0.662	3.761	5.00
20	0.21	2.75	0.53	1.133	0.550	4.100	6.47
21	0.21	2.92	0.57	1.250	0.602	3.826	5.29
22	0.20	2.56	0.54	1.146	0.581	4.118	6.55
23	0.20	2.70	0.58	1.239	0.640	3.862	5.44
24	0.22	3.01	0.60	1.323	0.636	3.675	4.63
25	0.19	2.47	0.64	1.277	0.760	3.748	4.95
26	0.19	2.39	0.61	1.219	0.732	3.863	5.45
27	0.20	2.64	0.63	1.308	0.737	3.668	4.60
28	0.20	2.80	0.64	1.357	0.725	3.610	4.35
29	0.20	2.48	0.64	1.284	0.764	3.721	4.83
30	0.20	2.54	0.60	1.234	0.700	3.830	5.30
31	0.21	2.86	0.70	1.469	0.811	3.381	3.35
32	0.20	2.61	0.58	1.210	0.656	3.889	5.56
33	0.20	2.66	0.70	1.433	0.831	3.446	3.63
34	0.20	2.76	0.62	1.321	0.707	3.658	4.56
35	0.21	3.01	0.70	1.501	0.800	3.324	3.11
36	0.20	2.65	0.64	1.321	0.742	3.667	4.59
37	0.19	2.50	0.65	1.307	0.767	3.702	4.75
38	0.22	2.86	0.65	1.395	0.743	3.486	3.81
39	0.21	2.70	0.65	1.361	0.760	3.538	4.04
40	0.18	2.35	0.55	1.107	0.615	4.226	7.02
41	0.20	2.81	0.59	1.254	0.630	3.828	5.29
42	0.21	2.91	0.61	1.317	0.664	3.672	4.62
43	0.23	3.19	0.61	1.343	0.638	3.570	4.17
44	0.24	3.48	0.66	1.508	0.688	3.302	3.01
45	0.20	2.55	0.52	1.093	0.554	4.238	7.07
46	0.25	3.75	0.72	1.651	0.773	3.020	1.79
47	0.23	3.43	0.75	1.668	0.833	3.055	1.94
48	0.22	3.02	0.57	1.245	0.587	3.805	5.19
49	0.19	2.48	0.63	1.253	0.735	3.800	5.17
50	0.25	3.67	0.70	1.611	0.755	3.076	2.03
51	0.17	2.07	0.52	0.991	0.609	4.554	8.44
52	0.25	3.60	0.78	1.746	0.864	2.902	1.28
53	0.18	2.29	0.59	1.166	0.699	4.053	6.27
54	0.17	2.05	0.51	0.985	0.601	4.595	8.62
55	0.23	3.37	0.56	1.256	0.537	3.799	5.17
56	0.19	2.47	0.58	1.156	0.661	4.011	6.09
57	0.19	2.52	0.59	1.199	0.680	3.926	5.72
58	0.19	2.51	0.59	1.199	0.679	3.919	5.69
59	0.21	2.93	0.62	1.314	0.674	3.662	4.57
60	0.23	3.30	0.54	1.207	0.516	3.901	5.61
61	0.23	3.23	0.53	1.167	0.508	3.974	5.93
62	0.20	2.84	0.59	1.236	0.630	3.830	5.30
63	0.21	2.89	0.60	1.283	0.659	3.720	4.82
64	0.19	2.47	0.58	1.164	0.664	3.996	6.02
65	0.24	3.44	0.57	1.285	0.565	3.676	4.63
66	0.23	3.44	0.58	1.304	0.558	3.693	4.71
67	0.20	2.83	0.59	1.236	0.634	3.837	5.33
68	0.19	2.55	0.60	1.209	0.688	3.870	5.48
69	0.21	2.98	0.62	1.327	0.679	3.615	4.37
70	0.20	2.73	0.53	1.128	0.543	4.144	6.66
71	0.22	3.23	0.57	1.265	0.574	3.753	4.97
72	0.20	2.83	0.59	1.243	0.644	3.798	5.16
73	0.25	3.99	0.72	1.643	0.747	3.035	1.85
74	0.22	3.20	0.59	1.294	0.621	3.644	4.50
75	0.24	3.46	0.61	1.366	0.633	3.480	3.78
76	0.23	3.37	0.59	1.326	0.608	3.599	4.30
77	0.21	2.88	0.54	1.173	0.556	4.007	6.07
78	0.20	2.90	0.61	1.287	0.663	3.721	4.83
79	0.19	2.55	0.55	1.137	0.602	4.097	6.46
80	0.24	3.69	0.70	1.560	0.744	3.144	2.32
81	0.22	3.19	0.63	1.370	0.678	3.500	3.87
82	0.20	2.64	0.56	1.165	0.595	4.044	6.23
83	0.23	3.36	0.63	1.404	0.664	3.449	3.65
84	0.21	2.97	0.62	1.311	0.679	3.641	4.48
85	0.21	2.78	0.58	1.224	0.639	3.834	5.32
86	0.21	2.75	0.59	1.235	0.661	3.797	5.16
87	0.20	2.50	0.57	1.141	0.649	4.005	6.06
88	0.20	2.76	0.59	1.245	0.657	3.807	5.20
89	0.18	2.15	0.58	1.092	0.702	4.200	6.91
90	0.23	3.14	0.70	1.513	0.796	3.246	2.77
91	0.22	3.14	0.70	1.507	0.796	3.264	2.85
92	0.21	2.70	0.63	1.308	0.733	3.640	4.48
93	0.20	2.68	0.62	1.278	0.716	3.696	4.72
94	0.25	3.35	0.69	1.513	0.759	3.198	2.56
95	0.18	2.17	0.54	1.038	0.631	4.370	7.65
96	0.25	3.53	0.74	1.649	0.825	3.000	1.70
97	0.19	2.33	0.58	1.141	0.697	4.023	6.14
98	0.22	2.94	0.70	1.458	0.806	3.339	3.17
99	0.19	2.49	0.63	1.244	0.747	3.775	5.06
100	0.19	2.49	0.54	1.097	0.592	4.188	6.85
101	0.21	2.88	0.57	1.196	0.602	3.895	5.58
102	0.23	3.24	0.57	1.247	0.578	3.739	4.91
103	0.22	2.70	0.67	1.321	0.788	3.502	3.88
104	0.24	3.40	0.61	1.343	0.624	3.526	3.98
105	0.19	2.46	0.59	1.166	0.693	3.945	5.80
106	0.24	3.33	0.58	1.283	0.600	3.628	4.43
107	0.22	3.07	0.62	1.317	0.670	3.590	4.26
108	0.24	3.45	0.62	1.366	0.638	3.470	3.74
109	0.20	2.43	0.61	1.181	0.728	3.860	5.43
110	0.23	3.24	0.65	1.405	0.713	3.379	3.35
111	0.24	3.21	0.70	1.477	0.793	3.198	2.56
112	0.29	3.44	0.79	1.636	0.900	2.839	1.00
113	0.22	2.92	0.57	1.205	0.616	3.813	5.23
114	0.21	2.67	0.64	1.281	0.755	3.619	4.39
115	0.18	2.40	0.60	1.175	0.709	3.969	5.91
116	0.18	2.27	0.62	1.185	0.762	3.941	5.78
117	0.24	3.25	0.65	1.425	0.713	3.356	3.25
118	0.19	2.45	0.62	1.219	0.734	3.848	5.38
119	0.21	2.74	0.61	1.273	0.697	3.706	4.77
120	0.18	2.14	0.58	1.088	0.709	4.187	6.85
121	0.20	2.64	0.59	1.215	0.655	3.885	5.54
122	0.24	3.38	0.60	1.328	0.619	3.544	4.06
123	0.22	2.86	0.56	1.181	0.591	3.907	5.63
124	0.21	2.98	0.68	1.429	0.770	3.416	3.51
125	0.17	1.96	0.52	0.961	0.631	4.625	8.75
126	0.24	3.25	0.66	1.438	0.720	3.326	3.11
127	0.18	2.14	0.57	1.069	0.700	4.209	6.95
128	0.24	3.14	0.63	1.362	0.684	3.466	3.72
129	0.22	3.00	0.58	1.249	0.625	3.726	4.85
130	0.19	2.37	0.54	1.053	0.603	4.264	7.18
131	0.19	2.15	0.55	1.044	0.661	4.270	7.21
132	0.19	2.27	0.59	1.122	0.715	4.020	6.13
133	0.26	3.67	0.62	1.399	0.647	3.352	3.23
134	0.27	3.37	0.69	1.482	0.776	3.131	2.27
135	0.17	1.98	0.50	0.932	0.584	4.710	9.12
136	0.25	3.35	0.59	1.300	0.617	3.554	4.10
137	0.23	2.94	0.66	1.350	0.747	3.437	3.60
138	0.21	2.83	0.55	1.152	0.572	4.000	6.04
139	0.22	3.00	0.57	1.215	0.612	3.778	5.08
140	0.26	3.49	0.70	1.520	0.777	3.115	2.20
141	0.18	2.08	0.53	0.995	0.631	4.448	7.98
142	0.20	2.59	0.56	1.137	0.611	4.048	6.25
143	0.23	3.14	0.61	1.312	0.665	3.555	4.11
144	0.21	2.78	0.60	1.225	0.662	3.774	5.06
145	0.21	2.76	0.65	1.342	0.753	3.567	4.16
146	0.21	2.46	0.65	1.276	0.785	3.639	4.47
147	0.28	3.74	0.69	1.572	0.744	3.043	1.89
148	0.28	3.38	0.76	1.638	0.858	2.921	1.36
149	0.21	2.50	0.66	1.288	0.787	3.609	4.34
150	0.25	3.52	0.63	1.435	0.653	3.368	3.30
151	0.18	2.15	0.56	1.067	0.676	4.242	7.09
152	0.22	2.74	0.66	1.350	0.763	3.505	3.89
153	0.24	3.28	0.72	1.566	0.808	3.139	2.30
154	0.22	3.14	0.67	1.453	0.749	3.360	3.26
155	0.24	3.22	0.75	1.613	0.852	3.063	1.97
156	0.23	3.02	0.65	1.385	0.723	3.451	3.66
157	0.19	2.32	0.61	1.185	0.732	3.912	5.66
158	0.23	3.21	0.73	1.560	0.822	3.159	2.39
159	0.22	2.91	0.65	1.361	0.732	3.495	3.85

Table B.19. Motions and Seakeeping Index for the Series of Hull Forms, V=5 Knots, Heading Angle 180 Deg.

HULL	Heave [m/m]	Pitch [deg/m]	Vert.Mot. at FP [m/m]	Vert.Acc. at FP [m/s^2/m]	Rel.Mot. at FP [m/m]	Sum	Index
01	0.22	2.16	0.53	1.772	0.650	4.741	9.37
02	0.25	2.41	0.61	1.989	0.749	4.174	6.33
03	0.23	2.17	0.52	1.757	0.652	4.724	9.27
04	0.27	2.54	0.68	2.214	0.826	3.810	4.38
05	0.26	2.51	0.65	2.121	0.789	3.951	5.13
06	0.21	2.12	0.57	1.868	0.713	4.592	8.57
07	0.22	2.08	0.51	1.668	0.656	4.860	10.00
08	0.27	2.55	0.67	2.194	0.811	3.851	4.60
09	0.25	2.22	0.61	1.933	0.761	4.267	6.83
10	0.26	2.43	0.63	2.064	0.776	4.055	5.69
11	0.26	2.35	0.65	2.092	0.805	3.989	5.34
12	0.25	2.35	0.67	2.147	0.823	3.965	5.21
13	0.25	2.23	0.65	2.073	0.817	4.070	5.77
14	0.24	2.26	0.66	2.098	0.822	4.064	5.74
15	0.25	2.21	0.60	1.938	0.761	4.262	6.80
16	0.27	2.36	0.70	2.229	0.866	3.815	4.41
17	0.24	2.27	0.66	2.107	0.823	4.065	5.75
18	0.22	2.02	0.56	1.970	0.720	4.558	8.39
19	0.28	2.62	0.64	2.147	0.782	3.886	4.79
20	0.27	2.56	0.56	1.847	0.683	4.302	7.01
21	0.28	2.77	0.61	2.071	0.738	3.963	5.20
22	0.26	2.49	0.59	1.967	0.715	4.206	6.50
23	0.27	2.62	0.64	2.122	0.770	3.927	5.01
24	0.28	2.82	0.64	2.156	0.765	3.850	4.59
25	0.27	2.42	0.71	2.244	0.867	3.767	4.15
26	0.27	2.35	0.68	2.152	0.838	3.902	4.87
27	0.28	2.51	0.68	2.211	0.838	3.782	4.24
28	0.28	2.69	0.70	2.307	0.841	3.690	3.74
29	0.28	2.42	0.71	2.240	0.866	3.765	4.14
30	0.27	2.45	0.66	2.134	0.808	3.912	4.93
31	0.30	2.67	0.75	2.384	0.900	3.521	2.84
32	0.27	2.49	0.63	2.065	0.773	3.996	5.38
33	0.30	2.54	0.76	2.403	0.922	3.523	2.85
34	0.28	2.62	0.67	2.215	0.819	3.775	4.19
35	0.30	2.76	0.73	2.370	0.883	3.522	2.84
36	0.28	2.54	0.69	2.244	0.847	3.750	4.06
37	0.28	2.46	0.73	2.316	0.884	3.673	3.65
38	0.29	2.59	0.67	2.191	0.825	3.759	4.11
39	0.29	2.49	0.68	2.162	0.835	3.796	4.31
40	0.23	2.32	0.60	2.004	0.742	4.283	6.91
41	0.27	2.75	0.64	2.161	0.758	3.900	4.87
42	0.29	2.83	0.67	2.224	0.793	3.730	3.96
43	0.30	2.92	0.63	2.139	0.760	3.788	4.26
44	0.33	3.30	0.71	2.406	0.819	3.415	2.27
45	0.25	2.38	0.55	1.893	0.688	4.401	7.55
46	0.36	3.28	0.73	2.411	0.867	3.297	1.64
47	0.33	3.11	0.78	2.537	0.921	3.255	1.41
48	0.28	2.81	0.60	2.055	0.724	3.977	5.28
49	0.27	2.52	0.71	2.282	0.870	3.723	3.92
50	0.36	3.31	0.73	2.387	0.854	3.322	1.77
51	0.22	2.13	0.59	1.896	0.748	4.465	7.89
52	0.37	3.13	0.80	2.523	0.931	3.178	1.00
53	0.24	2.25	0.65	2.086	0.811	4.115	6.01
54	0.21	2.16	0.60	1.929	0.751	4.448	7.80
55	0.29	3.21	0.59	2.001	0.703	3.927	5.01
56	0.26	2.51	0.67	2.106	0.812	3.916	4.95
57	0.26	2.50	0.67	2.128	0.822	3.912	4.93
58	0.27	2.52	0.67	2.145	0.824	3.867	4.69
59	0.28	2.75	0.66	2.128	0.797	3.816	4.41
60	0.30	3.15	0.57	1.968	0.687	3.993	5.36
61	0.30	3.04	0.56	1.860	0.671	4.117	6.02
62	0.28	2.73	0.64	2.088	0.776	3.878	4.75
63	0.28	2.73	0.65	2.103	0.788	3.838	4.53
64	0.26	2.47	0.66	2.077	0.807	3.953	5.15
65	0.31	3.14	0.59	1.937	0.706	3.925	5.00
66	0.29	3.22	0.60	2.041	0.708	3.893	4.83
67	0.27	2.74	0.64	2.117	0.781	3.883	4.77
68	0.28	2.52	0.68	2.170	0.838	3.791	4.28
69	0.30	2.79	0.67	2.151	0.808	3.735	3.98
70	0.26	2.60	0.57	1.921	0.697	4.232	6.64
71	0.30	3.04	0.61	1.999	0.726	3.893	4.83
72	0.28	2.75	0.65	2.092	0.788	3.843	4.56
73	0.38	3.60	0.75	2.396	0.876	3.208	1.16
74	0.32	3.02	0.63	2.020	0.762	3.764	4.14
75	0.33	3.12	0.63	2.048	0.764	3.714	3.87
76	0.32	3.21	0.63	2.043	0.758	3.723	3.92
77	0.26	2.67	0.57	1.890	0.697	4.215	6.55
78	0.29	2.93	0.69	2.250	0.832	3.622	3.38
79	0.25	2.42	0.59	1.896	0.732	4.247	6.72
80	0.36	3.31	0.72	2.289	0.860	3.341	1.87
81	0.32	2.94	0.66	2.122	0.803	3.671	3.64
82	0.26	2.51	0.59	1.934	0.730	4.191	6.42
83	0.32	3.01	0.65	2.083	0.774	3.707	3.83
84	0.31	2.94	0.70	2.252	0.841	3.573	3.12
85	0.28	2.56	0.61	2.002	0.757	4.027	5.54
86	0.29	2.58	0.64	2.056	0.782	3.911	4.92
87	0.28	2.44	0.64	2.050	0.788	3.962	5.20
88	0.28	2.70	0.66	2.175	0.801	3.800	4.33
89	0.23	2.05	0.63	1.953	0.801	4.307	7.04
90	0.33	2.79	0.74	2.365	0.880	3.451	2.46
91	0.33	2.84	0.75	2.409	0.899	3.404	2.21
92	0.28	2.36	0.65	2.043	0.806	3.963	5.20
93	0.29	2.55	0.68	2.177	0.831	3.773	4.18
94	0.35	2.89	0.70	2.248	0.847	3.487	2.65
95	0.23	2.14	0.60	1.922	0.760	4.383	7.45
96	0.36	2.93	0.74	2.331	0.881	3.377	2.07
97	0.26	2.29	0.65	2.065	0.819	4.004	5.42
98	0.33	2.65	0.75	2.356	0.902	3.469	2.56
99	0.28	2.39	0.70	2.196	0.861	3.784	4.24
100	0.24	2.35	0.58	1.893	0.722	4.342	7.23
101	0.28	2.65	0.60	1.924	0.736	4.063	5.74
102	0.30	2.77	0.57	1.848	0.697	4.119	6.04
103	0.31	2.25	0.66	1.937	0.837	3.931	5.03
104	0.31	2.87	0.60	1.924	0.729	3.945	5.11
105	0.26	2.22	0.61	1.933	0.783	4.191	6.42
106	0.32	2.89	0.59	1.890	0.723	3.959	5.18
107	0.31	2.70	0.63	2.018	0.780	3.848	4.58
108	0.32	2.92	0.61	1.944	0.742	3.878	4.74
109	0.27	2.11	0.61	1.836	0.793	4.254	6.76
110	0.35	2.81	0.67	2.078	0.820	3.632	3.43
111	0.34	2.55	0.67	2.028	0.837	3.717	3.88
112	0.39	2.42	0.69	1.948	0.864	3.671	3.64
113	0.31	2.65	0.60	1.879	0.742	4.000	5.40
114	0.31	2.39	0.68	2.017	0.848	3.815	4.41
115	0.26	2.35	0.67	2.124	0.824	3.947	5.12
116	0.25	2.18	0.68	2.095	0.855	4.001	5.40
117	0.33	2.80	0.66	2.134	0.798	3.696	3.77
118	0.26	2.33	0.67	2.114	0.833	3.942	5.09
119	0.29	2.45	0.65	2.161	0.802	3.867	4.69
120	0.24	2.11	0.64	1.994	0.815	4.201	6.47
121	0.26	2.44	0.62	2.038	0.763	4.085	5.86
122	0.33	2.97	0.61	1.997	0.716	3.860	4.65
123	0.28	2.54	0.57	1.899	0.704	4.189	6.41
124	0.30	2.75	0.72	2.336	0.868	3.553	3.01
125	0.21	1.90	0.56	1.743	0.734	4.750	9.41
126	0.32	2.76	0.65	2.094	0.786	3.746	4.04
127	0.25	2.11	0.64	1.979	0.811	4.176	6.34
128	0.31	2.68	0.62	2.032	0.759	3.879	4.75
129	0.31	2.77	0.62	2.065	0.746	3.871	4.71
130	0.25	2.27	0.59	1.833	0.739	4.329	7.16
131	0.25	2.07	0.60	1.829	0.779	4.344	7.24
132	0.26	2.03	0.61	1.826	0.792	4.311	7.06
133	0.35	2.86	0.59	1.842	0.735	3.905	4.89
134	0.35	2.57	0.63	1.882	0.793	3.846	4.57
135	0.23	2.11	0.59	1.830	0.755	4.470	7.91
136	0.33	2.84	0.58	1.852	0.717	4.001	5.41
137	0.33	2.43	0.65	1.966	0.812	3.844	4.57
138	0.27	2.51	0.56	1.855	0.697	4.270	6.85
139	0.32	2.73	0.60	1.870	0.737	3.971	5.25
140	0.37	2.81	0.68	2.031	0.832	3.590	3.21
141	0.24	2.06	0.59	1.799	0.764	4.436	7.73
142	0.26	2.37	0.58	1.853	0.727	4.266	6.82
143	0.33	2.68	0.62	1.983	0.773	3.850	4.60
144	0.32	2.64	0.66	2.058	0.806	3.763	4.13
145	0.31	2.48	0.69	2.198	0.848	3.714	3.87
146	0.32	2.30	0.72	2.192	0.887	3.688	3.73
147	0.38	3.02	0.67	2.102	0.804	3.551	3.00
148	0.39	2.60	0.73	2.225	0.885	3.449	2.45
149	0.33	2.32	0.73	2.211	0.898	3.629	3.42
150	0.34	3.02	0.63	2.077	0.756	3.710	3.84
151	0.24	2.09	0.62	1.930	0.786	4.291	6.95
152	0.31	2.44	0.68	2.124	0.841	3.760	4.11
153	0.34	2.71	0.71	2.230	0.859	3.546	2.97
154	0.33	2.90	0.72	2.320	0.862	3.475	2.59
155	0.35	2.71	0.74	2.298	0.892	3.447	2.44
156	0.32	2.62	0.66	2.114	0.806	3.760	4.12
157	0.28	2.32	0.69	2.181	0.859	3.829	4.48
158	0.36	2.85	0.78	2.426	0.925	3.290	1.60
159	0.33	2.68	0.69	2.204	0.842	3.613	3.33

Table B.20. Motions and Seakeeping Index for the Series of Hull Forms, V=10 Knots, Heading Angle 180 Deg.

HULL	Heave [m/m]	Pitch [deg/m]	Vert.Mot. at FP [m/m]	Vert.Acc. at FP [m/s^2/m]	Rel.Mot. at FP [m/m]	Sum	Index
01	0.25	1.87	0.49	2.095	0.649	4.693	9.09
02	0.28	2.20	0.58	2.454	0.765	4.028	5.28
03	0.26	1.83	0.48	1.985	0.629	4.802	9.72
04	0.30	2.27	0.63	2.687	0.822	3.750	3.69
05	0.30	2.25	0.61	2.567	0.788	3.869	4.37
06	0.24	1.90	0.54	2.300	0.724	4.447	7.68
07	0.24	1.81	0.47	1.944	0.662	4.851	10.00
08	0.30	2.30	0.63	2.685	0.816	3.747	3.67
09	0.28	1.98	0.56	2.346	0.758	4.191	6.21
10	0.28	2.18	0.59	2.461	0.771	4.017	5.22
11	0.30	2.10	0.61	2.528	0.797	3.920	4.66
12	0.28	2.08	0.61	2.559	0.800	3.958	4.88
13	0.28	1.97	0.60	2.468	0.790	4.066	5.50
14	0.28	2.00	0.61	2.520	0.804	4.005	5.15
15	0.28	2.00	0.56	2.316	0.755	4.205	6.30
16	0.30	2.05	0.64	2.614	0.830	3.834	4.17
17	0.28	2.02	0.62	2.554	0.808	3.981	5.01
18	0.25	1.83	0.54	2.444	0.706	4.400	7.42
19	0.30	2.39	0.61	2.651	0.801	3.765	3.77
20	0.29	2.38	0.53	2.268	0.715	4.140	5.92
21	0.31	2.61	0.60	2.601	0.778	3.757	3.72
22	0.28	2.27	0.56	2.412	0.738	4.089	5.63
23	0.30	2.40	0.61	2.630	0.794	3.782	3.87
24	0.31	2.68	0.62	2.716	0.803	3.652	3.13
25	0.31	2.09	0.64	2.644	0.834	3.786	3.89
26	0.30	2.05	0.62	2.591	0.819	3.872	4.38
27	0.31	2.20	0.63	2.639	0.825	3.764	3.77
28	0.31	2.39	0.65	2.758	0.837	3.627	2.98
29	0.31	2.09	0.64	2.644	0.837	3.775	3.83
30	0.30	2.16	0.61	2.590	0.806	3.848	4.25
31	0.33	2.30	0.68	2.782	0.866	3.561	2.60
32	0.30	2.24	0.59	2.538	0.786	3.883	4.45
33	0.33	2.16	0.68	2.761	0.871	3.601	2.83
34	0.31	2.34	0.63	2.656	0.818	3.720	3.51
35	0.33	2.41	0.67	2.756	0.859	3.543	2.50
36	0.31	2.23	0.64	2.677	0.835	3.719	3.51
37	0.32	2.14	0.67	2.772	0.856	3.661	3.18
38	0.32	2.29	0.62	2.601	0.813	3.762	3.76
39	0.31	2.17	0.61	2.549	0.803	3.852	4.27
40	0.26	2.02	0.56	2.399	0.745	4.216	6.36
41	0.30	2.46	0.60	2.549	0.766	3.830	4.14
42	0.32	2.57	0.63	2.684	0.798	3.651	3.12
43	0.33	2.72	0.61	2.610	0.793	3.638	3.04
44	0.36	2.97	0.67	2.817	0.828	3.369	1.50
45	0.27	2.20	0.53	2.368	0.719	4.210	6.33
46	0.38	2.94	0.68	2.749	0.861	3.316	1.20
47	0.36	2.69	0.71	2.845	0.885	3.333	1.29
48	0.31	2.62	0.58	2.521	0.763	3.800	3.97
49	0.31	2.20	0.66	2.701	0.849	3.692	3.36
50	0.38	2.92	0.66	2.662	0.834	3.389	1.62
51	0.26	1.92	0.57	2.408	0.761	4.260	6.61
52	0.39	2.62	0.70	2.748	0.874	3.337	1.32
53	0.27	1.98	0.60	2.512	0.798	4.071	5.53
54	0.25	1.93	0.57	2.397	0.757	4.277	6.71
55	0.32	3.02	0.58	2.412	0.748	3.748	3.68
56	0.30	2.18	0.60	2.427	0.784	3.931	4.72
57	0.29	2.21	0.62	2.526	0.811	3.869	4.37
58	0.30	2.22	0.62	2.555	0.811	3.827	4.13
59	0.31	2.46	0.61	2.543	0.800	3.774	3.82
60	0.32	3.00	0.56	2.401	0.734	3.793	3.94
61	0.32	2.87	0.55	2.251	0.716	3.928	4.71
62	0.31	2.44	0.60	2.502	0.785	3.812	4.04
63	0.32	2.44	0.61	2.532	0.800	3.755	3.72
64	0.30	2.19	0.61	2.503	0.806	3.869	4.37
65	0.33	2.95	0.57	2.340	0.745	3.776	3.84
66	0.32	3.02	0.59	2.445	0.749	3.736	3.61
67	0.30	2.48	0.61	2.555	0.796	3.783	3.88
68	0.31	2.21	0.62	2.525	0.817	3.813	4.05
69	0.32	2.47	0.61	2.532	0.803	3.725	3.54
70	0.28	2.39	0.54	2.357	0.724	4.089	5.63
71	0.33	2.77	0.57	2.364	0.750	3.808	4.02
72	0.32	2.44	0.60	2.449	0.788	3.813	4.05
73	0.40	3.18	0.68	2.635	0.858	3.282	1.00
74	0.35	2.71	0.58	2.298	0.765	3.769	3.80
75	0.35	2.86	0.59	2.386	0.779	3.669	3.22
76	0.35	2.94	0.60	2.367	0.776	3.663	3.19
77	0.29	2.44	0.54	2.285	0.727	4.073	5.54
78	0.34	2.60	0.64	2.591	0.828	3.588	2.76
79	0.28	2.13	0.54	2.210	0.727	4.243	6.51
80	0.39	2.87	0.65	2.495	0.834	3.457	2.01
81	0.34	2.60	0.61	2.436	0.797	3.695	3.37
82	0.28	2.22	0.55	2.244	0.731	4.173	6.11
83	0.35	2.70	0.60	2.470	0.787	3.669	3.22
84	0.34	2.57	0.64	2.562	0.828	3.590	2.77
85	0.30	2.24	0.56	2.316	0.753	4.042	5.36
86	0.32	2.24	0.59	2.380	0.774	3.925	4.69
87	0.31	2.11	0.59	2.419	0.782	3.952	4.84
88	0.32	2.38	0.61	2.530	0.797	3.774	3.82
89	0.26	1.74	0.57	2.364	0.778	4.326	6.99
90	0.35	2.35	0.66	2.655	0.848	3.563	2.61
91	0.35	2.40	0.67	2.680	0.856	3.523	2.39
92	0.30	1.94	0.57	2.317	0.778	4.112	5.77
93	0.32	2.17	0.61	2.510	0.811	3.827	4.13
94	0.37	2.45	0.63	2.480	0.820	3.619	2.93
95	0.26	1.87	0.55	2.274	0.754	4.342	7.08
96	0.37	2.45	0.65	2.532	0.842	3.551	2.55
97	0.30	1.96	0.60	2.417	0.798	4.024	5.26
98	0.35	2.18	0.66	2.590	0.855	3.640	3.06
99	0.31	1.98	0.63	2.529	0.827	3.873	4.39
100	0.27	2.04	0.53	2.205	0.720	4.346	7.10
101	0.31	2.32	0.55	2.221	0.740	4.065	5.49
102	0.31	2.49	0.53	2.143	0.712	4.108	5.74
103	0.32	1.80	0.56	2.082	0.776	4.249	6.55
104	0.33	2.59	0.56	2.277	0.744	3.909	4.60
105	0.29	1.87	0.56	2.236	0.762	4.250	6.56
106	0.34	2.60	0.55	2.187	0.734	3.947	4.82
107	0.33	2.33	0.57	2.281	0.766	3.935	4.75
108	0.34	2.63	0.56	2.277	0.753	3.863	4.33
109	0.28	1.70	0.53	2.024	0.746	4.515	8.07
110	0.36	2.34	0.59	2.253	0.787	3.825	4.12
111	0.35	2.10	0.57	2.196	0.790	3.974	4.97
112	0.37	1.91	0.56	1.992	0.778	4.132	5.88
113	0.33	2.28	0.54	2.098	0.732	4.100	5.69
114	0.33	1.91	0.58	2.158	0.791	4.089	5.63
115	0.30	2.03	0.62	2.316	0.802	3.934	4.74
116	0.29	1.83	0.62	2.486	0.819	4.046	5.38
117	0.35	2.44	0.60	2.460	0.792	3.733	3.59
118	0.30	2.01	0.62	2.510	0.809	3.944	4.80
119	0.31	2.12	0.60	2.564	0.796	3.881	4.44
120	0.29	2.04	0.61	3.362	0.818	3.759	3.74
121	0.29	2.11	0.57	2.390	0.759	4.085	5.61
122	0.35	2.60	0.55	2.229	0.711	3.934	4.74
123	0.31	2.26	0.53	2.266	0.722	4.121	5.82
124	0.34	2.35	0.65	2.684	0.848	3.599	2.82
125	0.24	1.65	0.52	2.202	0.734	4.640	8.79
126	0.33	2.37	0.58	2.355	0.767	3.871	4.38
127	0.28	1.76	0.58	2.333	0.785	4.231	6.44
128	0.32	2.32	0.57	2.361	0.757	3.931	4.72
129	0.32	2.45	0.57	2.365	0.740	3.915	4.63
130	0.28	1.95	0.53	2.166	0.739	4.327	6.99
131	0.28	1.73	0.54	2.099	0.754	4.436	7.62
132	0.28	1.65	0.53	2.038	0.753	4.530	8.16
133	0.36	2.52	0.54	2.098	0.740	3.970	4.95
134	0.35	2.19	0.54	2.061	0.755	4.079	5.58
135	0.27	1.88	0.55	2.210	0.760	4.310	6.90
136	0.34	2.56	0.53	2.116	0.720	4.034	5.31
137	0.35	2.00	0.56	2.180	0.774	4.047	5.39
138	0.30	2.21	0.52	2.184	0.710	4.233	6.46
139	0.34	2.33	0.53	2.056	0.723	4.103	5.71
140	0.38	2.33	0.58	2.142	0.784	3.863	4.34
141	0.27	1.75	0.54	2.088	0.749	4.465	7.79
142	0.29	2.05	0.53	2.196	0.732	4.263	6.63
143	0.34	2.26	0.56	2.196	0.757	3.990	5.06
144	0.35	2.22	0.58	2.292	0.783	3.888	4.48
145	0.33	2.02	0.61	2.453	0.817	3.875	4.41
146	0.33	1.90	0.62	2.368	0.820	3.945	4.81
147	0.39	2.62	0.60	2.321	0.783	3.669	3.22
148	0.39	2.06	0.62	2.370	0.827	3.744	3.65
149	0.35	1.81	0.63	2.361	0.833	3.918	4.65
150	0.36	2.61	0.58	2.323	0.750	3.789	3.91
151	0.27	1.79	0.56	2.276	0.769	4.314	6.92
152	0.33	2.01	0.60	2.382	0.803	3.931	4.72
153	0.35	2.26	0.62	2.437	0.821	3.737	3.61
154	0.36	2.47	0.65	2.577	0.835	3.569	2.65
155	0.36	2.25	0.64	2.534	0.843	3.637	3.04
156	0.33	2.23	0.59	2.407	0.791	3.860	4.32
157	0.31	1.94	0.62	2.492	0.820	3.922	4.67
158	0.38	2.29	0.67	2.559	0.865	3.530	2.43
159	0.35	2.24	0.62	2.446	0.814	3.742	3.64

Table B.21. Motions and Seakeeping Index for the Series of Hull Forms, V=15 Knots, Heading Angle 180 Deg.

HULL	Heave [m/m]	Pitch [deg/m]	Vert.Mot. at FP [m/m]	Vert.Acc. at FP [m/s^2/m]	Rel.Mot. at FP [m/m]	Sum	Index
01	0.25	1.78	0.46	2.487	0.668	4.556	8.72
02	0.29	2.09	0.55	2.881	0.771	3.893	5.95
03	0.25	1.76	0.45	2.401	0.657	4.636	9.05
04	0.31	2.12	0.59	3.125	0.819	3.671	5.03
05	0.31	2.09	0.57	2.916	0.787	3.801	5.57
06	0.25	1.81	0.51	2.724	0.735	4.296	7.63
07	0.24	1.65	0.44	2.138	0.658	4.865	10.00
08	0.31	2.14	0.59	3.062	0.813	3.688	5.10
09	0.29	1.84	0.53	2.940	0.760	4.039	6.56
10	0.29	2.05	0.55	2.806	0.773	3.936	6.13
11	0.31	1.96	0.57	3.203	0.784	3.792	5.53
12	0.29	1.92	0.57	2.901	0.792	3.925	6.08
13	0.28	1.83	0.55	2.846	0.775	4.021	6.48
14	0.29	1.86	0.57	3.126	0.795	3.884	5.91
15	0.28	1.87	0.53	2.867	0.751	4.070	6.69
16	0.30	1.86	0.58	2.930	0.805	3.854	5.79
17	0.29	1.87	0.57	2.944	0.802	3.912	6.03
18	0.24	1.60	0.47	2.486	0.678	4.663	9.16
19	0.31	2.24	0.58	2.952	0.801	3.710	5.19
20	0.30	2.31	0.52	2.668	0.737	3.956	6.21
21	0.32	2.53	0.58	3.067	0.795	3.598	4.72
22	0.28	2.11	0.52	2.677	0.739	4.051	6.61
23	0.31	2.24	0.57	2.942	0.794	3.719	5.22
24	0.33	2.68	0.60	3.324	0.816	3.434	4.04
25	0.44	2.25	0.76	10.712	0.887	2.705	1.00
26	0.31	1.87	0.57	2.912	0.798	3.871	5.86
27	0.32	2.01	0.58	2.929	0.804	3.774	5.46
28	0.32	2.23	0.61	3.071	0.827	3.605	4.75
29	0.31	1.94	0.59	3.238	0.819	3.707	5.18
30	0.31	1.98	0.57	2.868	0.792	3.844	5.75
31	0.33	2.09	0.62	3.042	0.841	3.597	4.72
32	0.31	2.11	0.56	2.839	0.782	3.824	5.66
33	0.33	1.95	0.62	2.993	0.835	3.670	5.02
34	0.32	2.20	0.59	3.074	0.811	3.651	4.94
35	0.34	2.23	0.62	3.159	0.843	3.518	4.39
36	0.32	2.10	0.60	3.218	0.819	3.632	4.86
37	0.32	1.95	0.62	3.061	0.835	3.669	5.02
38	0.32	2.12	0.57	2.864	0.800	3.755	5.38
39	0.31	1.99	0.56	2.799	0.786	3.875	5.88
40	0.27	1.89	0.53	2.770	0.749	4.141	6.99
41	0.31	2.28	0.56	2.901	0.769	3.769	5.43
42	0.32	2.43	0.59	3.167	0.805	3.558	4.55
43	0.35	2.63	0.59	3.066	0.807	3.490	4.27
44	0.37	2.76	0.62	3.159	0.826	3.341	3.65
45	0.28	2.09	0.51	2.679	0.733	4.092	6.78
46	0.38	2.74	0.63	2.970	0.851	3.331	3.61
47	0.36	2.46	0.65	3.079	0.858	3.380	3.81
48	0.32	2.51	0.56	2.855	0.776	3.685	5.09
49	0.32	1.98	0.60	2.957	0.823	3.723	5.24
50	0.38	2.68	0.61	2.817	0.818	3.443	4.07
51	0.26	1.78	0.53	2.739	0.755	4.185	7.17
52	0.39	2.34	0.62	2.837	0.834	3.472	4.20
53	0.27	1.85	0.56	2.910	0.785	3.999	6.39
54	0.26	1.83	0.54	2.805	0.756	4.149	7.02
55	0.33	2.86	0.56	2.715	0.768	3.636	4.88
56	0.30	1.99	0.55	2.690	0.762	3.965	6.25
57	0.30	2.02	0.57	2.790	0.793	3.878	5.89
58	0.31	2.08	0.58	3.289	0.804	3.690	5.10
59	0.31	2.28	0.57	2.838	0.790	3.752	5.36
60	0.33	2.82	0.54	2.659	0.745	3.722	5.24
61	0.33	2.73	0.53	2.521	0.736	3.813	5.62
62	0.31	2.25	0.55	2.741	0.776	3.817	5.64
63	0.33	2.26	0.57	2.784	0.794	3.735	5.29
64	0.31	2.03	0.57	2.865	0.792	3.826	5.67
65	0.34	2.83	0.55	2.640	0.763	3.663	4.99
66	0.32	2.82	0.56	2.664	0.755	3.700	5.15
67	0.31	2.29	0.57	2.829	0.790	3.764	5.41
68	0.31	2.03	0.57	3.227	0.800	3.721	5.23
69	0.32	2.28	0.57	2.765	0.792	3.740	5.31
70	0.29	2.26	0.52	2.692	0.733	3.991	6.36
71	0.33	2.61	0.55	2.633	0.760	3.751	5.36
72	0.32	2.22	0.55	2.650	0.775	3.842	5.74
73	0.39	2.90	0.62	2.769	0.839	3.353	3.70
74	0.35	2.50	0.54	2.493	0.760	3.787	5.51
75	0.35	2.69	0.56	2.670	0.781	3.624	4.83
76	0.35	2.73	0.56	2.571	0.779	3.647	4.93
77	0.30	2.33	0.53	2.631	0.745	3.924	6.08
78	0.34	2.36	0.59	2.783	0.809	3.631	4.86
79	0.29	2.00	0.51	2.528	0.730	4.161	7.07
80	0.38	2.59	0.59	2.604	0.808	3.561	4.57
81	0.34	2.38	0.56	2.619	0.783	3.735	5.29
82	0.29	2.09	0.51	2.582	0.734	4.090	6.77
83	0.37	2.56	0.56	2.756	0.785	3.602	4.74
84	0.34	2.32	0.58	2.698	0.802	3.677	5.05
85	0.30	2.08	0.53	2.579	0.751	4.009	6.44
86	0.32	2.07	0.54	2.647	0.764	3.917	6.05
87	0.31	1.89	0.54	2.607	0.763	4.022	6.49
88	0.32	2.18	0.57	2.784	0.786	3.780	5.48
89	0.26	1.57	0.51	2.814	0.749	4.318	7.72
90	0.35	2.10	0.60	2.809	0.821	3.647	4.92
91	0.35	2.17	0.61	2.825	0.826	3.623	4.82
92	0.30	1.71	0.52	2.480	0.754	4.226	7.34
93	0.32	1.92	0.56	2.715	0.786	3.908	6.01
94	0.36	2.22	0.57	2.684	0.791	3.699	5.14
95	0.26	1.69	0.51	2.585	0.741	4.335	7.79
96	0.36	2.20	0.59	2.647	0.811	3.670	5.02
97	0.30	1.74	0.54	2.573	0.771	4.128	6.93
98	0.34	1.92	0.58	2.685	0.811	3.809	5.60
99	0.31	1.71	0.56	2.618	0.788	4.052	6.61
100	0.27	1.89	0.50	2.612	0.723	4.254	7.45
101	0.31	2.16	0.51	2.479	0.741	4.032	6.53
102	0.31	2.38	0.50	2.470	0.721	4.009	6.43
103	0.31	1.59	0.49	2.222	0.738	4.429	8.18
104	0.33	2.47	0.53	2.542	0.750	3.848	5.76
105	0.29	1.72	0.52	2.579	0.760	4.186	7.17
106	0.34	2.47	0.52	2.410	0.739	3.908	6.01
107	0.32	2.15	0.53	2.510	0.757	3.956	6.21
108	0.34	2.49	0.54	2.526	0.757	3.812	5.61
109	0.27	1.49	0.47	2.185	0.717	4.665	9.17
110	0.35	2.13	0.53	2.578	0.758	3.878	5.89
111	0.33	1.91	0.52	2.356	0.761	4.084	6.75
112	0.34	1.73	0.49	2.094	0.738	4.330	7.77
113	0.33	2.09	0.49	2.316	0.725	4.133	6.95
114	0.32	1.67	0.50	2.250	0.748	4.307	7.67
115	0.33	1.83	0.59	3.018	0.800	3.773	5.45
116	0.29	1.59	0.55	2.686	0.787	4.151	7.03
117	0.34	2.29	0.56	2.736	0.788	3.714	5.20
118	0.30	1.85	0.57	2.837	0.793	3.934	6.12
119	0.30	1.99	0.55	2.802	0.778	3.929	6.10
120	0.28	1.75	0.55	3.251	0.774	3.980	6.31
121	0.29	1.97	0.53	2.874	0.758	3.995	6.38
122	0.33	2.40	0.51	2.405	0.711	3.988	6.35
123	0.31	2.13	0.51	2.641	0.735	4.002	6.41
124	0.34	2.10	0.60	2.978	0.816	3.651	4.94
125	0.24	1.48	0.48	2.548	0.725	4.614	8.95
126	0.33	2.17	0.54	2.655	0.755	3.876	5.88
127	0.28	1.54	0.52	2.546	0.752	4.358	7.89
128	0.32	2.13	0.53	2.621	0.749	3.943	6.16
129	0.34	2.26	0.55	2.766	0.759	3.759	5.39
130	0.28	1.74	0.48	2.428	0.710	4.381	7.99
131	0.28	1.55	0.48	2.339	0.731	4.509	8.52
132	0.27	1.47	0.47	2.302	0.727	4.624	9.00
133	0.35	2.34	0.51	2.276	0.734	3.995	6.38
134	0.34	2.05	0.50	2.320	0.732	4.103	6.83
135	0.28	1.71	0.51	2.432	0.741	4.327	7.76
136	0.33	2.44	0.51	2.407	0.729	3.951	6.19
137	0.34	1.81	0.52	2.377	0.753	4.109	6.85
138	0.29	2.09	0.49	2.519	0.715	4.158	7.06
139	0.33	2.10	0.48	2.184	0.709	4.207	7.26
140	0.36	2.10	0.52	2.236	0.753	4.022	6.49
141	0.28	1.55	0.48	2.309	0.727	4.533	8.62
142	0.29	1.86	0.49	2.460	0.719	4.275	7.54
143	0.33	2.06	0.51	2.369	0.736	4.072	6.70
144	0.33	1.99	0.52	2.394	0.753	4.039	6.56
145	0.32	1.75	0.54	2.330	0.779	4.070	6.69
146	0.31	1.67	0.54	2.501	0.774	4.134	6.95
147	0.38	2.43	0.56	2.480	0.774	3.717	5.22
148	0.37	1.82	0.55	2.481	0.790	3.909	6.02
149	0.33	1.52	0.54	2.413	0.774	4.212	7.28
150	0.35	2.40	0.53	2.534	0.744	3.817	5.64
151	0.27	1.59	0.51	2.538	0.750	4.367	7.93
152	0.32	1.78	0.54	2.573	0.774	4.045	6.58
153	0.34	2.03	0.56	2.580	0.792	3.851	5.78
154	0.35	2.23	0.59	2.717	0.810	3.658	4.97
155	0.37	2.11	0.58	2.721	0.814	3.680	5.06
156	0.33	2.03	0.55	3.156	0.775	3.755	5.38
157	0.31	1.69	0.55	2.668	0.781	4.067	6.68
158	0.37	1.97	0.59	2.568	0.813	3.765	5.42
159	0.34	1.98	0.55	2.544	0.782	3.886	5.92

Table B.22a. Seakeeping Index for the Data Base Hulls

HULL	INDEX	CP	Cwp	Cvp	L/B	B/T	$L/\nabla^{1/3}$	%LCB	CPXLCB	%LCF
125	10.00	0.603	0.757	0.526	3.775	4.000	5.230	-2.510	-1.513	-5.469
18	9.72	0.654	0.761	0.544	3.922	3.850	5.230	-0.709	-0.463	-3.408
135	9.61	0.581	0.784	0.661	4.584	3.183	5.054	-1.967	-1.143	-4.282
07	9.61	0.704	0.798	0.558	3.375	4.000	4.676	-0.681	-0.480	-2.948
06	9.20	0.683	0.776	0.557	3.756	3.850	5.009	-2.151	-1.469	-1.973
03	9.04	0.731	0.806	0.574	3.506	3.850	4.676	-0.663	-0.485	-2.956
01	8.78	0.746	0.821	0.575	3.576	3.775	4.676	-0.622	-0.464	-2.367
54	8.72	0.653	0.749	0.609	4.261	3.520	5.196	-2.597	-1.695	-3.117
141	8.60	0.514	0.752	0.610	4.053	3.600	5.054	-1.073	-0.551	-4.761
51	8.33	0.638	0.740	0.602	4.167	3.600	5.196	-2.273	-1.451	-3.083
95	8.18	0.664	0.775	0.572	3.662	3.850	4.884	-2.720	-1.805	-5.342
127	7.89	0.541	0.726	0.492	4.234	2.853	5.230	-1.828	-0.989	-6.230
130	7.83	0.570	0.781	0.650	3.653	3.600	4.555	-1.426	-0.812	-4.182
131	7.81	0.493	0.738	0.596	3.891	3.750	5.054	-0.624	-0.308	-4.967
100	7.79	0.563	0.782	0.639	3.247	3.850	4.330	-2.436	-1.372	-4.650
89	7.58	0.600	0.733	0.547	3.750	4.000	5.196	-3.033	-1.821	-6.617
15	7.42	0.593	0.718	0.523	3.830	3.213	5.009	-0.771	-0.457	-4.187
151	7.40	0.573	0.727	0.567	3.648	4.000	5.054	-2.152	-1.232	-5.995
09	7.20	0.581	0.711	0.517	3.756	3.277	5.009	-0.719	-0.418	-4.327
101	7.03	0.562	0.786	0.634	3.167	3.064	3.949	-1.829	-1.028	-4.303
40	7.00	0.650	0.747	0.608	3.579	3.850	4.773	-2.765	-1.797	-3.257
113	6.96	0.561	0.789	0.631	3.497	2.508	3.949	-0.096	-0.054	-3.601
106	6.93	0.579	0.799	0.644	2.778	2.769	3.464	-1.040	-0.602	-3.800
61	6.89	0.618	0.787	0.701	2.614	3.355	3.464	-0.097	-0.060	-1.250
142	6.88	0.565	0.778	0.648	3.221	3.850	4.295	-1.504	-0.850	-4.298
70	6.84	0.583	0.761	0.684	3.117	3.850	4.157	-0.058	-0.034	-1.667
56	6.76	0.427	0.648	0.589	3.819	3.191	4.960	-0.594	-0.253	-2.230
120	6.70	0.547	0.720	0.502	4.027	3.191	5.230	-2.983	-1.632	-6.793
60	6.64	0.612	0.785	0.696	2.667	3.191	3.464	-0.360	-0.220	-1.400
116	6.63	0.514	0.696	0.488	4.027	3.000	5.230	-3.841	-1.975	-7.853
02	6.52	0.635	0.744	0.540	3.576	3.213	4.676	-1.493	-0.948	-3.331
132	6.52	0.480	0.723	0.592	3.790	3.850	5.054	-1.008	-0.484	-5.687
107	6.51	0.508	0.756	0.597	3.167	2.769	3.949	-1.781	-0.904	-5.268
71	6.49	0.597	0.768	0.694	2.965	3.064	3.698	-1.564	-0.934	-1.646
22	6.46	0.663	0.767	0.547	3.292	3.277	4.390	-0.698	-0.463	-3.295
139	6.44	0.599	0.789	0.677	3.496	2.503	3.853	-0.049	-0.030	-3.037
122	6.43	0.674	0.808	0.552	2.778	2.400	3.464	-1.340	-0.903	-3.600
102	6.34	0.577	0.795	0.644	2.500	3.404	3.464	-1.565	-0.902	-4.050
45	6.29	0.699	0.787	0.620	3.083	4.000	4.271	-1.496	-1.046	-1.819
17	6.29	0.568	0.690	0.521	4.000	3.213	5.230	-3.089	-1.753	-3.607
87	6.28	0.636	0.772	0.551	3.732	2.787	4.503	-0.900	-0.573	-4.558
115	6.24	0.578	0.736	0.519	3.889	2.880	4.849	-3.504	-2.024	-6.536
138	6.23	0.606	0.802	0.674	2.781	4.000	3.853	-1.362	-0.826	-3.621
157	6.17	0.542	0.713	0.547	4.053	3.064	5.054	-1.518	-0.822	-6.441
97	6.16	0.604	0.741	0.544	3.917	3.064	4.884	-2.163	-1.306	-5.980
79	6.11	0.511	0.707	0.646	3.294	4.000	4.564	-1.078	-0.551	-1.874
136	6.07	0.575	0.789	0.651	2.667	3.000	3.464	-0.570	-0.328	-3.750
133	6.06	0.500	0.736	0.606	2.778	2.400	3.464	-0.760	-0.380	-2.550
14	6.03	0.556	0.684	0.515	3.922	3.277	5.230	-2.844	-1.583	-3.852
58	5.95	0.400	0.627	0.570	3.580	3.404	4.960	-0.503	-0.201	-2.510
109	5.94	0.486	0.728	0.593	3.481	4.000	4.823	-2.147	-1.045	-6.598
64	5.93	0.419	0.641	0.583	3.744	3.255	4.960	-0.649	-0.272	-2.335
105	5.92	0.521	0.748	0.619	3.506	3.850	4.676	-2.930	-1.527	-6.250
110	5.90	0.486	0.751	0.575	3.499	2.172	3.949	-0.798	-0.388	-4.961
143	5.87	0.539	0.765	0.629	3.090	2.880	3.853	-1.209	-0.652	-4.520
82	5.83	0.526	0.718	0.655	3.200	4.000	4.434	-1.141	-0.600	-1.766
13	5.80	0.536	0.671	0.505	3.775	3.404	5.230	-1.990	-1.066	-4.544
129	5.78	0.644	0.794	0.537	3.113	2.499	3.845	-0.973	-0.627	-3.881
77	5.76	0.591	0.763	0.693	2.848	4.000	3.945	-2.388	-1.412	-2.201
62	5.75	0.483	0.692	0.624	3.373	3.191	4.382	-0.470	-0.227	-1.649
99	5.72	0.587	0.727	0.539	4.048	2.787	4.884	-2.567	-1.506	-6.548
123	5.67	0.656	0.799	0.543	2.775	3.200	3.845	-1.162	-0.762	-3.791
72	5.66	0.498	0.698	0.636	3.556	3.064	4.434	-0.727	-0.362	-1.727
55	5.64	0.600	0.772	0.693	2.614	3.255	3.464	-1.750	-1.049	-1.300
10	5.63	0.599	0.717	0.529	3.375	3.404	4.676	-2.096	-1.256	-3.564
05	5.62	0.597	0.724	0.522	3.576	3.020	4.676	-2.063	-1.231	-3.709
20	5.61	0.724	0.804	0.570	3.013	3.277	4.018	-0.879	-0.637	-2.537
108	5.61	0.541	0.770	0.624	2.597	2.962	3.464	-2.395	-1.297	-5.000
65	5.59	0.564	0.750	0.671	2.614	3.060	3.464	-1.085	-0.611	-1.350
114	5.56	0.493	0.736	0.595	4.144	2.606	4.676	-1.841	-0.907	-6.213
11	5.55	0.546	0.684	0.506	3.756	3.080	5.009	-0.806	-0.440	-4.808
67	5.54	0.488	0.687	0.635	3.307	3.355	4.382	-1.874	-0.915	-2.321
118	5.53	0.555	0.723	0.508	3.729	3.000	4.843	-3.494	-1.940	-7.029
104	5.50	0.542	0.774	0.622	2.500	3.200	3.464	-2.160	-1.171	-4.900
144	5.48	0.537	0.766	0.625	3.893	2.505	4.295	-0.730	-0.392	-4.218
68	5.44	0.394	0.621	0.566	3.744	3.060	4.960	-0.370	-0.146	-2.370
53	5.43	0.575	0.688	0.583	3.750	4.000	5.196	-2.690	-1.546	-4.150
78	5.42	0.517	0.709	0.652	3.932	2.604	4.434	-1.836	-0.950	-2.273
12	5.32	0.559	0.683	0.518	3.615	3.404	5.009	-3.188	-1.783	-3.790
41	5.29	0.661	0.756	0.610	3.425	3.064	4.271	-2.368	-1.565	-2.832
121	5.25	0.620	0.765	0.536	3.121	3.404	4.324	-3.064	-1.901	-5.480
149	5.24	0.502	0.692	0.522	4.313	2.506	5.054	-0.411	-0.206	-6.646
86	5.24	0.657	0.778	0.564	3.386	2.880	4.222	-1.891	-1.242	-4.977
74	5.23	0.558	0.748	0.666	3.499	2.501	3.945	0.009	0.005	-1.840

Table B.22b. Seakeeping Index for the Data Base Hulls

HULL	INDEX	CP	Cwp	Cvp	L/B	B/T	$L/\nabla^{1/3}$	%LCB	CPXLCB	%LCF
85	5.12	0.673	0.784	0.573	3.071	3.277	4.096	-2.372	-1.597	-4.910
88	5.09	0.679	0.784	0.578	3.499	2.787	4.222	-2.744	-1.862	-5.059
92	5.06	0.590	0.732	0.538	3.250	3.404	4.503	-2.388	-1.408	-6.404
57	5.05	0.432	0.660	0.584	3.744	3.355	4.960	-1.358	-0.586	-2.510
145	5.04	0.565	0.724	0.562	3.653	2.880	4.555	-2.376	-1.342	-6.425
76	4.98	0.596	0.767	0.694	3.280	2.501	3.698	-1.560	-0.929	-1.646
146	4.93	0.489	0.684	0.514	3.891	3.000	5.054	-0.795	-0.389	-6.886
103	4.88	0.475	0.719	0.586	3.750	3.064	4.676	-1.867	-0.886	-6.769
128	4.82	0.575	0.754	0.504	2.775	2.803	3.845	-0.793	-0.456	-5.052
75	4.82	0.539	0.726	0.662	2.965	2.766	3.698	-0.759	-0.409	-1.458
63	4.77	0.474	0.681	0.622	3.307	3.255	4.382	-1.162	-0.551	-2.282
23	4.72	0.623	0.734	0.537	3.292	3.080	4.390	-1.905	-1.187	-3.334
93	4.68	0.616	0.748	0.550	3.611	2.880	4.503	-2.312	-1.423	-5.865
84	4.67	0.497	0.695	0.638	3.932	2.501	4.434	-1.203	-0.598	-2.078
69	4.67	0.446	0.660	0.603	3.307	3.060	4.382	-0.755	-0.336	-2.203
111	4.62	0.490	0.730	0.595	3.285	2.769	4.096	-2.101	-1.029	-6.474
81	4.54	0.479	0.685	0.624	3.333	2.766	4.157	-0.383	-0.184	-1.667
66	4.53	0.573	0.752	0.681	2.500	3.404	3.464	-2.445	-1.402	-1.950
08	4.51	0.585	0.705	0.525	3.506	3.080	4.676	-2.489	-1.456	-3.597
150	4.48	0.660	0.791	0.601	2.667	2.778	3.464	-1.335	-0.881	-4.150
59	4.47	0.453	0.664	0.610	3.163	3.404	4.382	-1.854	-0.840	-2.835
140	4.46	0.508	0.745	0.608	3.496	2.122	3.853	-1.380	-0.701	-5.104
159	4.43	0.590	0.745	0.570	3.666	2.506	4.295	-1.323	-0.781	-5.387
126	4.41	0.568	0.746	0.504	2.883	2.567	3.845	-1.356	-0.770	-5.502
16	4.40	0.523	0.659	0.502	3.922	3.080	5.230	-2.705	-1.415	-4.476
137	4.38	0.483	0.728	0.592	3.444	2.880	4.295	-0.706	-0.341	-5.347
32	4.36	0.617	0.730	0.590	3.581	3.246	4.590	-1.068	-0.659	-2.590
119	4.24	0.583	0.745	0.518	3.121	3.200	4.324	-2.724	-1.589	-6.001
48	4.22	0.687	0.777	0.617	2.883	3.277	3.845	-1.712	-1.175	-2.124
19	4.17	0.600	0.718	0.529	3.169	3.200	4.390	-2.071	-1.242	-3.554
49	4.09	0.543	0.661	0.574	4.167	3.064	5.196	-1.037	-0.563	-2.917
21	4.08	0.681	0.769	0.561	3.013	3.080	4.018	-2.164	-1.473	-2.540
152	4.07	0.528	0.708	0.537	3.416	3.080	4.555	-1.278	-0.675	-6.501
37	4.06	0.489	0.615	0.555	3.750	3.404	5.196	-1.733	-0.848	-4.683
117	3.98	0.583	0.752	0.512	2.960	2.500	3.845	-1.671	-0.974	-5.412
83	3.97	0.492	0.694	0.633	2.958	3.080	3.945	-0.834	-0.410	-1.850
134	3.93	0.479	0.723	0.591	2.967	2.778	3.853	-0.849	-0.407	-5.599
147	3.90	0.619	0.766	0.582	2.778	2.400	3.464	-0.970	-0.600	-4.850
26	3.88	0.545	0.674	0.564	4.054	3.246	5.196	-1.257	-0.685	-3.583
30	3.86	0.584	0.702	0.581	3.784	3.246	4.849	-1.432	-0.836	-3.214
04	3.72	0.563	0.692	0.515	3.375	3.200	4.676	-3.119	-1.756	-2.938
154	3.65	0.618	0.745	0.597	3.500	2.506	4.101	-3.146	-1.945	-5.978
156	3.61	0.587	0.741	0.570	3.075	3.080	4.101	-1.774	-1.040	-5.725
158	3.54	0.564	0.720	0.564	3.893	2.123	4.295	-2.496	-1.408	-6.476
112	3.53	0.469	0.712	0.585	3.630	2.172	4.096	-2.118	-0.993	-7.193
94	3.49	0.613	0.749	0.546	3.230	2.322	3.897	-1.769	-1.084	-5.583
124	3.44	0.573	0.731	0.518	3.501	2.499	4.324	-4.150	-2.378	-6.962
44	3.42	0.630	0.737	0.597	3.153	2.514	3.845	-0.815	-0.514	-2.169
80	3.39	0.485	0.689	0.628	3.499	2.170	3.945	-0.478	-0.232	-1.674
42	3.38	0.635	0.739	0.600	3.503	2.816	4.271	-2.255	-1.433	-3.076
98	3.34	0.568	0.715	0.531	3.732	2.488	4.503	-3.154	-1.792	-7.173
34	3.24	0.598	0.713	0.586	3.581	3.149	4.590	-1.743	-1.043	-3.307
91	3.21	0.606	0.727	0.557	3.499	2.488	4.222	-3.999	-2.423	-7.069
43	3.21	0.645	0.748	0.602	2.883	3.080	3.845	-1.721	-1.110	-2.619
153	3.21	0.543	0.707	0.553	3.075	2.852	4.101	-2.660	-1.445	-7.034
24	3.09	0.655	0.747	0.555	2.900	3.200	4.018	-3.030	-1.986	-2.530
90	3.09	0.586	0.724	0.541	3.386	2.571	4.222	-3.326	-1.950	-6.905
36	3.08	0.578	0.694	0.581	3.862	3.085	4.849	-2.525	-1.460	-4.107
73	3.07	0.517	0.709	0.651	3.280	2.170	3.698	-1.335	-0.690	-2.020
29	3.05	0.529	0.659	0.560	4.054	3.149	5.196	-1.707	-0.902	-4.017
148	3.01	0.502	0.689	0.524	3.157	2.500	4.101	-0.904	-0.453	-6.949
27	2.95	0.566	0.687	0.576	3.784	3.149	4.849	-1.829	-1.036	-3.679
25	2.94	0.540	0.667	0.565	4.138	3.085	5.196	-2.020	-1.090	-4.150
28	2.84	0.611	0.715	0.597	3.655	3.085	4.590	-3.166	-1.934	-4.137
96	2.56	0.593	0.725	0.547	3.125	2.400	3.897	-3.591	-2.129	-7.050
50	2.55	0.588	0.705	0.582	3.153	2.347	3.845	-0.775	-0.456	-2.484
39	2.33	0.524	0.659	0.555	3.500	3.404	4.849	-0.893	-0.468	-3.500
38	1.91	0.554	0.680	0.568	3.313	3.404	4.590	-1.181	-0.654	-3.420
155	1.79	0.519	0.689	0.542	3.221	2.852	4.295	-2.823	-1.464	-7.565
33	1.79	0.497	0.631	0.549	4.054	2.960	5.196	-2.583	-1.284	-5.017
31	1.61	0.532	0.657	0.566	3.784	2.960	4.849	-3.025	-1.611	-4.857
46	1.53	0.599	0.710	0.589	3.097	2.347	3.776	-2.124	-1.272	-3.433
35	1.43	0.563	0.679	0.579	3.581	2.960	4.590	-3.396	-1.911	-4.892
47	1.33	0.574	0.681	0.589	3.500	2.500	4.243	-3.306	-1.899	-4.740
52	1.00	0.530	0.657	0.562	3.503	2.347	4.271	-1.399	-0.741	-3.643

Table B.23a. Added Resistance Index for the Data Base Hulls, Heading Angle 180 Deg.

HULL	INDEX	CP	Cwp	Cvp	L/B	B/T	$L/\nabla^{1/3}$	%LCB	CPXLCB	%LCF
112	10.00	0.469	0.712	0.585	3.630	2.172	4.096	-2.118	-0.993	-7.193
140	9.42	0.508	0.745	0.608	3.496	2.122	3.853	-1.380	-0.701	-5.104
135	9.19	0.581	0.784	0.661	4.584	3.183	5.054	-1.967	-1.143	-4.282
113	8.13	0.561	0.789	0.631	3.497	2.508	3.949	-0.096	-0.054	-3.601
114	8.06	0.493	0.736	0.595	4.144	2.606	4.676	-1.841	-0.907	-6.213
141	8.03	0.514	0.752	0.610	4.053	3.600	5.054	-1.073	-0.551	-4.761
76	8.03	0.596	0.767	0.694	3.280	2.501	3.698	-1.560	-0.929	-1.646
110	7.94	0.486	0.751	0.575	3.499	2.172	3.949	-0.798	-0.388	-4.961
139	7.88	0.599	0.789	0.677	3.496	2.503	3.853	-0.049	-0.030	-3.037
134	7.87	0.479	0.723	0.591	2.967	2.778	3.853	-0.849	-0.407	-5.599
80	7.72	0.485	0.689	0.628	3.499	2.170	3.945	-0.478	-0.232	-1.674
74	7.68	0.558	0.748	0.666	3.499	2.501	3.945	0.009	0.005	-1.840
103	7.63	0.475	0.719	0.586	3.750	3.064	4.676	-1.867	-0.886	-6.769
73	7.53	0.517	0.709	0.651	3.280	2.170	3.698	-1.335	-0.690	-2.020
133	7.53	0.500	0.736	0.606	2.778	2.400	3.464	-0.760	-0.380	-2.550
106	7.51	0.579	0.799	0.644	2.778	2.769	3.464	-1.040	-0.602	-3.800
111	7.39	0.490	0.730	0.595	3.285	2.769	4.096	-2.101	-1.029	-6.474
131	7.32	0.493	0.738	0.596	3.891	3.750	5.054	-0.624	-0.308	-4.967
144	7.30	0.537	0.766	0.625	3.893	2.505	4.295	-0.730	-0.392	-4.218
101	7.21	0.562	0.786	0.634	3.167	3.064	3.949	-1.829	-1.028	-4.303
158	7.17	0.564	0.720	0.564	3.893	2.123	4.295	-2.496	-1.408	-6.476
107	7.16	0.508	0.756	0.597	3.167	2.769	3.949	-1.781	-0.904	-5.268
136	7.09	0.575	0.789	0.651	2.667	3.000	3.464	-0.570	-0.328	-3.750
108	7.09	0.541	0.770	0.624	2.597	2.962	3.464	-2.395	-1.297	-5.000
78	6.98	0.517	0.709	0.652	3.932	2.604	4.434	-1.836	-0.950	-2.273
130	6.92	0.570	0.781	0.650	3.653	3.600	4.555	-1.426	-0.812	-4.182
132	6.84	0.480	0.723	0.592	3.790	3.850	5.054	-1.008	-0.484	-5.687
84	6.83	0.497	0.695	0.638	3.932	2.501	4.434	-1.203	-0.598	-2.078
143	6.77	0.539	0.765	0.629	3.090	2.880	3.853	-1.209	-0.652	-4.520
75	6.70	0.539	0.726	0.662	2.965	2.766	3.698	-0.759	-0.409	-1.458
109	6.70	0.486	0.728	0.593	3.481	4.000	4.823	-2.147	-1.045	-6.598
137	6.70	0.483	0.728	0.592	3.444	2.880	4.295	-0.706	-0.341	-5.347
71	6.56	0.597	0.768	0.694	2.965	3.064	3.698	-1.564	-0.934	-1.646
149	6.52	0.502	0.692	0.522	4.313	2.506	5.054	-0.411	-0.206	-6.646
65	6.48	0.564	0.750	0.671	2.614	3.060	3.464	-1.085	-0.611	-1.350
104	6.47	0.542	0.774	0.622	2.500	3.200	3.464	-2.160	-1.171	-4.900
97	6.38	0.604	0.741	0.544	3.917	3.064	4.884	-2.163	-1.306	-5.980
105	6.36	0.521	0.748	0.619	3.506	3.850	4.676	-2.930	-1.527	-6.250
81	6.29	0.479	0.685	0.624	3.333	2.766	4.157	-0.383	-0.184	-1.667
102	6.28	0.577	0.795	0.644	2.500	3.404	3.464	-1.565	-0.902	-4.050
54	6.27	0.653	0.749	0.609	4.261	3.520	5.196	-2.597	-1.695	-3.117
51	6.24	0.638	0.740	0.602	4.167	3.600	5.196	-2.273	-1.451	-3.083
56	6.20	0.427	0.648	0.589	3.819	3.191	4.960	-0.594	-0.253	-2.230
159	6.14	0.590	0.745	0.570	3.666	2.506	4.295	-1.323	-0.781	-5.387
68	6.13	0.394	0.621	0.566	3.744	3.060	4.960	-0.370	-0.146	-2.370
127	6.06	0.541	0.726	0.492	4.234	2.853	5.230	-1.828	-0.989	-6.230
154	6.05	0.618	0.745	0.597	3.500	2.506	4.101	-3.146	-1.945	-5.978
55	6.03	0.600	0.772	0.693	2.614	3.255	3.464	-1.750	-1.049	-1.300
157	6.01	0.542	0.713	0.547	4.053	3.064	5.054	-1.518	-0.822	-6.441
61	5.99	0.618	0.787	0.701	2.614	3.355	3.464	-0.097	-0.060	-1.250
147	5.96	0.619	0.766	0.582	2.778	2.400	3.464	-0.970	-0.600	-4.850
72	5.91	0.498	0.698	0.636	3.556	3.064	4.434	-0.727	-0.362	-1.727
95	5.91	0.664	0.775	0.572	3.662	3.850	4.884	-2.720	-1.805	-5.342
125	5.89	0.603	0.757	0.526	3.775	4.000	5.230	-2.510	-1.513	-5.469
98	5.83	0.568	0.715	0.531	3.732	2.488	4.503	-3.154	-1.792	-7.173
64	5.81	0.419	0.641	0.583	3.744	3.255	4.960	-0.649	-0.272	-2.335
94	5.78	0.613	0.749	0.546	3.230	2.322	3.897	-1.769	-1.084	-5.583
06	5.76	0.683	0.776	0.557	3.756	3.850	5.009	-2.151	-1.469	-1.973
99	5.76	0.587	0.727	0.539	4.048	2.787	4.884	-2.567	-1.506	-6.548
100	5.76	0.563	0.782	0.639	3.247	3.850	4.330	-2.436	-1.372	-4.650
86	5.75	0.657	0.778	0.564	3.386	2.880	4.222	-1.891	-1.242	-4.977
142	5.74	0.565	0.778	0.648	3.221	3.850	4.295	-1.504	-0.850	-4.298
151	5.71	0.573	0.727	0.567	3.648	4.000	5.054	-2.152	-1.232	-5.995
60	5.70	0.612	0.785	0.696	2.667	3.191	3.464	-0.360	-0.220	-1.400
69	5.69	0.446	0.660	0.603	3.307	3.060	4.382	-0.755	-0.336	-2.203
118	5.64	0.555	0.723	0.508	3.729	3.000	4.843	-3.494	-1.940	-7.029
88	5.63	0.679	0.784	0.578	3.499	2.787	4.222	-2.744	-1.862	-5.059
91	5.62	0.606	0.727	0.557	3.499	2.488	4.222	-3.999	-2.423	-7.069
67	5.62	0.488	0.687	0.635	3.307	3.355	4.382	-1.874	-0.915	-2.321
07	5.59	0.704	0.798	0.558	3.375	4.000	4.676	-0.681	-0.480	-2.948
57	5.58	0.432	0.660	0.584	3.744	3.355	4.960	-1.358	-0.586	-2.510
122	5.56	0.674	0.808	0.552	2.778	2.400	3.464	-1.340	-0.903	-3.600
66	5.55	0.573	0.752	0.681	2.500	3.404	3.464	-2.445	-1.402	-1.950
62	5.53	0.483	0.692	0.624	3.373	3.191	4.382	-0.470	-0.227	-1.649
79	5.52	0.511	0.707	0.646	3.294	4.000	4.564	-1.078	-0.551	-1.874
82	5.52	0.526	0.718	0.655	3.200	4.000	4.434	-1.141	-0.600	-1.766
77	5.50	0.591	0.763	0.693	2.848	4.000	3.945	-2.388	-1.412	-2.201
01	5.47	0.746	0.821	0.575	3.576	3.775	4.676	-0.622	-0.464	-2.367
96	5.47	0.593	0.725	0.547	3.125	2.400	3.897	-3.591	-2.129	-7.050
129	5.46	0.644	0.794	0.537	3.113	2.499	3.845	-0.973	-0.627	-3.881
46	5.46	0.599	0.710	0.589	3.097	2.347	3.776	-2.124	-1.272	-3.433
47	5.45	0.574	0.681	0.589	3.500	2.500	4.243	-3.306	-1.899	-4.740
17	5.42	0.568	0.690	0.521	4.000	3.213	5.230	-3.089	-1.753	-3.607
152	5.39	0.528	0.708	0.537	3.416	3.080	4.555	-1.278	-0.675	-6.501

Table B.23b. Added Resistance Index for the Data Base Hulls, Heading Angle 180 Deg.

HULL	INDEX	CP	Cwp	Cvp	L/B	B/T	$L/\nabla^{1/3}$	%LCB	CPXLCB	%LCF
145	5.39	0.565	0.724	0.562	3.653	2.880	4.555	-2.376	-1.342	-6.425
116	5.35	0.514	0.696	0.488	4.027	3.000	5.230	-3.841	-1.975	-7.853
59	5.34	0.453	0.664	0.610	3.163	3.404	4.382	-1.854	-0.840	-2.835
89	5.33	0.600	0.733	0.547	3.750	4.000	5.196	-3.033	-1.821	-6.617
85	5.32	0.673	0.784	0.573	3.071	3.277	4.096	-2.372	-1.597	-4.910
126	5.31	0.568	0.746	0.504	2.883	2.567	3.845	-1.356	-0.770	-5.502
14	5.31	0.556	0.684	0.515	3.922	3.277	5.230	-2.844	-1.583	-3.852
58	5.30	0.400	0.627	0.570	3.580	3.404	4.960	-0.503	-0.201	-2.510
153	5.29	0.543	0.707	0.553	3.075	2.852	4.101	-2.660	-1.445	-7.034
93	5.24	0.616	0.748	0.550	3.611	2.880	4.503	-2.312	-1.423	-5.865
49	5.24	0.543	0.661	0.574	4.167	3.064	5.196	-1.037	-0.563	-2.917
63	5.24	0.474	0.681	0.622	3.307	3.255	4.382	-1.162	-0.551	-2.282
09	5.15	0.581	0.711	0.517	3.756	3.277	5.009	-0.719	-0.418	-4.327
138	5.14	0.606	0.802	0.674	2.781	4.000	3.853	-1.362	-0.826	-3.621
148	5.09	0.502	0.689	0.524	3.157	2.500	4.101	-0.904	-0.453	-6.949
117	5.09	0.583	0.752	0.512	2.960	2.500	3.845	-1.671	-0.974	-5.412
40	5.06	0.650	0.747	0.608	3.579	3.850	4.773	-2.765	-1.797	-3.257
90	5.06	0.586	0.724	0.541	3.386	2.571	4.222	-3.326	-1.950	-6.905
124	5.05	0.573	0.731	0.518	3.501	2.499	4.324	-4.150	-2.378	-6.962
41	5.00	0.661	0.756	0.610	3.425	3.064	4.271	-2.368	-1.565	-2.832
26	5.00	0.545	0.674	0.564	4.054	3.246	5.196	-1.257	-0.685	-3.583
15	4.98	0.593	0.718	0.523	3.830	3.213	5.009	-0.771	-0.457	-4.187
29	4.97	0.529	0.659	0.560	4.054	3.149	5.196	-1.707	-0.902	-4.017
02	4.95	0.635	0.744	0.540	3.576	3.213	4.676	-1.493	-0.948	-3.331
33	4.95	0.497	0.631	0.549	4.054	2.960	5.196	-2.583	-1.284	-5.017
20	4.91	0.724	0.804	0.570	3.013	3.277	4.018	-0.879	-0.637	-2.537
36	4.90	0.578	0.694	0.581	3.862	3.085	4.849	-2.525	-1.460	-4.107
128	4.82	0.575	0.754	0.504	2.775	2.803	3.845	-0.793	-0.456	-5.052
115	4.81	0.578	0.736	0.519	3.889	2.880	4.849	-3.504	-2.024	-6.536
13	4.80	0.536	0.671	0.505	3.775	3.404	5.230	-1.990	-1.066	-4.544
53	4.77	0.575	0.688	0.583	3.750	4.000	5.196	-2.690	-1.546	-4.150
11	4.76	0.546	0.684	0.506	3.756	3.080	5.009	-0.806	-0.440	-4.808
16	4.73	0.523	0.659	0.502	3.922	3.080	5.230	-2.705	-1.415	-4.476
35	4.73	0.563	0.679	0.579	3.581	2.960	4.590	-3.396	-1.911	-4.892
42	4.71	0.635	0.739	0.600	3.503	2.816	4.271	-2.255	-1.433	-3.076
32	4.70	0.617	0.730	0.590	3.581	3.246	4.590	-1.068	-0.659	-2.590
70	4.63	0.583	0.761	0.684	3.117	3.850	4.157	-0.058	-0.034	-1.667
92	4.62	0.590	0.732	0.538	3.250	3.404	4.503	-2.388	-1.408	-6.404
52	4.59	0.530	0.657	0.562	3.503	2.347	4.271	-1.399	-0.741	-3.643
05	4.58	0.597	0.724	0.522	3.576	3.020	4.676	-2.063	-1.231	-3.709
31	4.57	0.532	0.657	0.566	3.784	2.960	4.849	-3.025	-1.611	-4.857
37	4.55	0.489	0.615	0.555	3.750	3.404	5.196	-1.733	-0.848	-4.683
27	4.54	0.566	0.687	0.576	3.784	3.149	4.849	-1.829	-1.036	-3.679
30	4.53	0.584	0.702	0.581	3.784	3.246	4.849	-1.432	-0.836	-3.214
121	4.53	0.620	0.765	0.536	3.121	3.404	4.324	-3.064	-1.901	-5.480
28	4.50	0.611	0.715	0.597	3.655	3.085	4.590	-3.166	-1.934	-4.137
50	4.50	0.588	0.705	0.582	3.153	2.347	3.845	-0.775	-0.456	-2.484
34	4.47	0.598	0.713	0.586	3.581	3.149	4.590	-1.743	-1.043	-3.307
12	4.47	0.559	0.683	0.518	3.615	3.404	5.009	-3.188	-1.783	-3.790
21	4.47	0.681	0.769	0.561	3.013	3.080	4.018	-2.164	-1.473	-2.540
156	4.44	0.587	0.741	0.570	3.075	3.080	4.101	-1.774	-1.040	-5.725
146	4.41	0.489	0.684	0.514	3.891	3.000	5.054	-0.795	-0.389	-6.886
22	4.29	0.663	0.767	0.547	3.292	3.277	4.390	-0.698	-0.463	-3.295
10	4.29	0.599	0.717	0.529	3.375	3.404	4.676	-2.096	-1.256	-3.564
44	4.26	0.630	0.737	0.597	3.153	2.514	3.845	-0.815	-0.514	-2.169
45	4.24	0.699	0.787	0.620	3.083	4.000	4.271	-1.496	-1.046	-1.819
08	4.24	0.585	0.705	0.525	3.506	3.080	4.676	-2.489	-1.456	-3.597
123	4.23	0.656	0.799	0.543	2.775	3.200	3.845	-1.162	-0.762	-3.791
25	4.16	0.540	0.667	0.565	4.138	3.085	5.196	-2.020	-1.090	-4.150
48	4.13	0.687	0.777	0.617	2.883	3.277	3.845	-1.712	-1.175	-2.124
23	4.12	0.623	0.734	0.537	3.292	3.080	4.390	-1.905	-1.187	-3.334
43	4.11	0.645	0.748	0.602	2.883	3.080	3.845	-1.721	-1.110	-2.619
04	4.09	0.563	0.692	0.515	3.375	3.200	4.676	-3.119	-1.756	-2.938
24	4.05	0.655	0.747	0.555	2.900	3.200	4.018	-3.030	-1.986	-2.530
83	4.01	0.492	0.694	0.633	2.958	3.080	3.945	-0.834	-0.410	-1.850
18	3.95	0.654	0.761	0.544	3.922	3.850	5.230	-0.709	-0.463	-3.408
19	3.88	0.600	0.718	0.529	3.169	3.200	4.390	-2.071	-1.242	-3.554
39	3.88	0.524	0.659	0.555	3.500	3.404	4.849	-0.893	-0.468	-3.500
150	3.86	0.660	0.791	0.601	2.667	2.778	3.464	-1.335	-0.881	-4.150
38	3.73	0.554	0.680	0.568	3.313	3.404	4.590	-1.181	-0.654	-3.420
155	3.49	0.519	0.689	0.542	3.221	2.852	4.295	-2.823	-1.464	-7.565
119	3.48	0.583	0.745	0.518	3.121	3.200	4.324	-2.724	-1.589	-6.001
87	3.22	0.636	0.772	0.551	3.732	2.787	4.503	-0.900	-0.573	-4.558
120	3.06	0.547	0.720	0.502	4.027	3.191	5.230	-2.983	-1.632	-6.793
03	1.00	0.731	0.806	0.574	3.506	3.850	4.676	-0.663	-0.485	-2.956

Table B.24a. Calm Water Resistance Index for the Data Base Hulls

HULL	INDEX	CP	Cwp	Cvp	L/B	B/T	$L/\nabla^{1/3}$	%LCB	CPXLCB	%LCF
16	10.00	0.523	0.659	0.502	3.922	3.080	5.230	-2.705	-1.415	-4.476
37	9.54	0.489	0.615	0.555	3.750	3.404	5.196	-1.733	-0.848	-4.683
13	9.37	0.536	0.671	0.505	3.775	3.404	5.230	-1.990	-1.066	-4.544
33	9.26	0.497	0.631	0.549	4.054	2.960	5.196	-2.583	-1.284	-5.017
12	8.96	0.559	0.683	0.518	3.615	3.404	5.009	-3.188	-1.783	-3.790
14	8.84	0.556	0.684	0.515	3.922	3.277	5.230	-2.844	-1.583	-3.852
116	8.69	0.514	0.696	0.488	4.027	3.000	5.230	-3.841	-1.975	-7.853
04	8.64	0.563	0.692	0.515	3.375	3.200	4.676	-3.119	-1.756	-2.938
148	8.62	0.502	0.689	0.524	3.157	2.500	4.101	-0.904	-0.453	-6.949
17	8.42	0.568	0.690	0.521	4.000	3.213	5.230	-3.089	-1.753	-3.607
52	8.33	0.530	0.657	0.562	3.503	2.347	4.271	-1.399	-0.741	-3.643
68	8.21	0.394	0.621	0.566	3.744	3.060	4.960	-0.370	-0.146	-2.370
120	8.07	0.547	0.720	0.502	4.027	3.191	5.230	-2.983	-1.632	-6.793
58	8.03	0.400	0.627	0.570	3.580	3.404	4.960	-0.503	-0.201	-2.510
08	7.99	0.585	0.705	0.525	3.506	3.080	4.676	-2.489	-1.456	-3.597
57	7.94	0.432	0.660	0.584	3.744	3.355	4.960	-1.358	-0.586	-2.510
31	7.93	0.532	0.657	0.566	3.784	2.960	4.849	-3.025	-1.611	-4.857
29	7.82	0.529	0.659	0.560	4.054	3.149	5.196	-1.707	-0.902	-4.017
126	7.81	0.568	0.746	0.504	2.883	2.567	3.845	-1.356	-0.770	-5.502
127	7.69	0.541	0.726	0.492	4.234	2.853	5.230	-1.828	-0.989	-6.230
25	7.67	0.540	0.667	0.565	4.138	3.085	5.196	-2.020	-1.090	-4.150
19	7.64	0.600	0.718	0.529	3.169	3.200	4.390	-2.071	-1.242	-3.554
11	7.64	0.546	0.684	0.506	3.756	3.080	5.009	-0.806	-0.440	-4.808
10	7.64	0.599	0.717	0.529	3.375	3.404	4.676	-2.096	-1.256	-3.564
155	7.59	0.519	0.689	0.542	3.221	2.852	4.295	-2.823	-1.464	-7.565
64	7.56	0.419	0.641	0.583	3.744	3.255	4.960	-0.649	-0.272	-2.335
59	7.55	0.453	0.664	0.610	3.163	3.404	4.382	-1.854	-0.840	-2.835
53	7.50	0.575	0.688	0.583	3.750	4.000	5.196	-2.690	-1.546	-4.150
05	7.50	0.597	0.724	0.522	3.576	3.020	4.676	-2.063	-1.231	-3.709
118	7.41	0.555	0.723	0.508	3.729	3.000	4.843	-3.494	-1.940	-7.029
146	7.39	0.489	0.684	0.514	3.891	3.000	5.054	-0.795	-0.389	-6.886
89	7.32	0.600	0.733	0.547	3.750	4.000	5.196	-3.033	-1.821	-6.617
39	7.30	0.524	0.659	0.555	3.500	3.404	4.849	-0.893	-0.468	-3.500
152	7.16	0.528	0.708	0.537	3.416	3.080	4.555	-1.278	-0.675	-6.501
56	7.15	0.427	0.648	0.589	3.819	3.191	4.960	-0.594	-0.253	-2.230
117	7.04	0.583	0.752	0.512	2.960	2.500	3.845	-1.671	-0.974	-5.412
125	7.03	0.603	0.757	0.526	3.775	4.000	5.230	-2.510	-1.513	-5.469
27	6.95	0.566	0.687	0.576	3.784	3.149	4.849	-1.829	-1.036	-3.679
69	6.95	0.446	0.660	0.603	3.307	3.060	4.382	-0.755	-0.336	-2.203
38	6.92	0.554	0.680	0.568	3.313	3.404	4.590	-1.181	-0.654	-3.420
119	6.91	0.583	0.745	0.518	3.121	3.200	4.324	-2.724	-1.589	-6.001
92	6.90	0.590	0.732	0.538	3.250	3.404	4.503	-2.388	-1.408	-6.404
26	6.90	0.545	0.674	0.564	4.054	3.246	5.196	-1.257	-0.685	-3.583
128	6.79	0.575	0.754	0.504	2.775	2.803	3.845	-0.793	-0.456	-5.052
23	6.76	0.623	0.734	0.537	3.292	3.080	4.390	-1.905	-1.187	-3.334
49	6.75	0.543	0.661	0.574	4.167	3.064	5.196	-1.037	-0.563	-2.917
36	6.72	0.578	0.694	0.581	3.862	3.085	4.849	-2.525	-1.460	-4.107
157	6.70	0.542	0.713	0.547	4.053	3.064	5.054	-1.518	-0.822	-6.441
99	6.70	0.587	0.727	0.539	4.048	2.787	4.884	-2.567	-1.506	-6.548
153	6.62	0.543	0.707	0.553	3.075	2.852	4.101	-2.660	-1.445	-7.034
115	6.62	0.578	0.736	0.519	3.889	2.880	4.849	-3.504	-2.024	-6.536
151	6.60	0.573	0.727	0.567	3.648	4.000	5.054	-2.152	-1.232	-5.995
35	6.57	0.563	0.679	0.579	3.581	2.960	4.590	-3.396	-1.911	-4.892
98	6.55	0.568	0.715	0.531	3.732	2.488	4.503	-3.154	-1.792	-7.173
109	6.50	0.486	0.728	0.593	3.481	4.000	4.823	-2.147	-1.045	-6.598
103	6.49	0.475	0.719	0.586	3.750	3.064	4.676	-1.867	-0.886	-6.769
149	6.43	0.502	0.692	0.522	4.313	2.506	5.054	-0.411	-0.206	-6.646
97	6.41	0.604	0.741	0.544	3.917	3.064	4.884	-2.163	-1.306	-5.980
09	6.39	0.581	0.711	0.517	3.756	3.277	5.009	-0.719	-0.418	-4.327
63	6.28	0.474	0.681	0.622	3.307	3.255	4.382	-1.162	-0.551	-2.282
145	6.27	0.565	0.724	0.562	3.653	2.880	4.555	-2.376	-1.342	-6.425
30	6.23	0.584	0.702	0.581	3.784	3.246	4.849	-1.432	-0.836	-3.214
02	6.21	0.635	0.744	0.540	3.576	3.213	4.676	-1.493	-0.948	-3.331
15	6.20	0.593	0.718	0.523	3.830	3.213	5.009	-0.771	-0.457	-4.187
67	6.20	0.488	0.687	0.635	3.307	3.355	4.382	-1.874	-0.915	-2.321
112	6.03	0.469	0.712	0.585	3.630	2.172	4.096	-2.118	-0.993	-7.193
34	6.02	0.598	0.713	0.586	3.581	3.149	4.590	-1.743	-1.043	-3.307
93	5.94	0.616	0.748	0.550	3.611	2.880	4.503	-2.312	-1.423	-5.865
114	5.79	0.493	0.736	0.595	4.144	2.606	4.676	-1.841	-0.907	-6.213
06	5.76	0.683	0.776	0.557	3.756	3.850	5.009	-2.151	-1.469	-1.973
121	5.74	0.620	0.765	0.536	3.121	3.404	4.324	-3.064	-1.901	-5.480
90	5.72	0.586	0.724	0.541	3.386	2.571	4.222	-3.326	-1.950	-6.905
51	5.70	0.638	0.740	0.602	4.167	3.600	5.196	-2.273	-1.451	-3.083
132	5.70	0.480	0.723	0.592	3.790	3.850	5.054	-1.008	-0.484	-5.687
94	5.68	0.613	0.749	0.546	3.230	2.322	3.897	-1.769	-1.084	-5.583
158	5.67	0.564	0.720	0.564	3.893	2.123	4.295	-2.496	-1.408	-6.476
47	5.62	0.574	0.681	0.589	3.500	2.500	4.243	-3.306	-1.899	-4.740
84	5.61	0.497	0.695	0.638	3.932	2.501	4.434	-1.203	-0.598	-2.078
95	5.57	0.664	0.775	0.572	3.662	3.850	4.884	-2.720	-1.805	-5.342
28	5.53	0.611	0.715	0.597	3.655	3.085	4.590	-3.166	-1.934	-4.137
111	5.52	0.490	0.730	0.595	3.285	2.769	4.096	-2.101	-1.029	-6.474
105	5.52	0.521	0.748	0.619	3.506	3.850	4.676	-2.930	-1.527	-6.250
156	5.51	0.587	0.741	0.570	3.075	3.080	4.101	-1.774	-1.040	-5.725
54	5.51	0.653	0.749	0.609	4.261	3.520	5.196	-2.597	-1.695	-3.117

Table B.24b. Calm Water Resistance Index for the Data Base Hulls

HULL	INDEX	CP	Cwp	Cvp	L/B	B/T	$L/\nabla^{1/3}$	%LCB	CPXLCB	%LCF
50	5.44	0.588	0.705	0.582	3.153	2.347	3.845	-0.775	-0.456	-2.484
40	5.39	0.650	0.747	0.608	3.579	3.850	4.773	-2.765	-1.797	-3.257
134	5.33	0.479	0.723	0.591	2.967	2.778	3.853	-0.849	-0.407	-5.599
46	5.31	0.599	0.710	0.589	3.097	2.347	3.776	-2.124	-1.272	-3.433
124	5.30	0.573	0.731	0.518	3.501	2.499	4.324	-4.150	-2.378	-6.962
159	5.28	0.590	0.745	0.570	3.666	2.506	4.295	-1.323	-0.781	-5.387
24	5.28	0.655	0.747	0.555	2.900	3.200	4.018	-3.030	-1.986	-2.530
137	5.24	0.483	0.728	0.592	3.444	2.880	4.295	-0.706	-0.341	-5.347
78	5.23	0.517	0.709	0.652	3.932	2.604	4.434	-1.836	-0.950	-2.273
81	5.18	0.479	0.685	0.624	3.333	2.766	4.157	-0.383	-0.184	-1.667
83	5.14	0.492	0.694	0.633	2.958	3.080	3.945	-0.834	-0.410	-1.850
72	5.14	0.498	0.698	0.636	3.556	3.064	4.434	-0.727	-0.362	-1.727
62	5.14	0.483	0.692	0.624	3.373	3.191	4.382	-0.470	-0.227	-1.649
32	5.09	0.617	0.730	0.590	3.581	3.246	4.590	-1.068	-0.659	-2.590
80	5.07	0.485	0.689	0.628	3.499	2.170	3.945	-0.478	-0.232	-1.674
79	5.07	0.511	0.707	0.646	3.294	4.000	4.564	-1.078	-0.551	-1.874
141	5.01	0.514	0.752	0.610	4.053	3.600	5.054	-1.073	-0.551	-4.761
21	5.01	0.681	0.769	0.561	3.013	3.080	4.018	-2.164	-1.473	-2.540
110	4.98	0.486	0.751	0.575	3.499	2.172	3.949	-0.798	-0.388	-4.961
42	4.89	0.635	0.739	0.600	3.503	2.816	4.271	-2.255	-1.433	-3.076
131	4.86	0.493	0.738	0.596	3.891	3.750	5.054	-0.624	-0.308	-4.967
87	4.85	0.636	0.772	0.551	3.732	2.787	4.503	-0.900	-0.573	-4.558
86	4.85	0.657	0.778	0.564	3.386	2.880	4.222	-1.891	-1.242	-4.977
107	4.78	0.508	0.756	0.597	3.167	2.769	3.949	-1.781	-0.904	-5.268
96	4.74	0.593	0.725	0.547	3.125	2.400	3.897	-3.591	-2.129	-7.050
18	4.72	0.654	0.761	0.544	3.922	3.850	5.230	-0.709	-0.463	-3.408
22	4.69	0.663	0.767	0.547	3.292	3.277	4.390	-0.698	-0.463	-3.295
82	4.68	0.526	0.718	0.655	3.200	4.000	4.434	-1.141	-0.600	-1.766
140	4.56	0.508	0.745	0.608	3.496	2.122	3.853	-1.380	-0.701	-5.104
129	4.54	0.644	0.794	0.537	3.113	2.499	3.845	-0.973	-0.627	-3.881
91	4.53	0.606	0.727	0.557	3.499	2.488	4.222	-3.999	-2.423	-7.069
85	4.43	0.673	0.784	0.573	3.071	3.277	4.096	-2.372	-1.597	-4.910
41	4.42	0.661	0.756	0.610	3.425	3.064	4.271	-2.368	-1.565	-2.832
73	4.39	0.517	0.709	0.651	3.280	2.170	3.698	-1.335	-0.690	-2.020
123	4.38	0.656	0.799	0.543	2.775	3.200	3.845	-1.162	-0.762	-3.791
135	4.36	0.581	0.784	0.661	4.584	3.183	5.054	-1.967	-1.143	-4.282
43	4.35	0.645	0.748	0.602	2.883	3.080	3.845	-1.721	-1.110	-2.619
44	4.27	0.630	0.737	0.597	3.153	2.514	3.845	-0.815	-0.514	-2.169
133	4.19	0.500	0.736	0.606	2.778	2.400	3.464	-0.760	-0.380	-2.550
88	4.16	0.679	0.784	0.578	3.499	2.787	4.222	-2.744	-1.862	-5.059
100	4.13	0.563	0.782	0.639	3.247	3.850	4.330	-2.436	-1.372	-4.650
154	3.99	0.618	0.745	0.597	3.500	2.506	4.101	-3.146	-1.945	-5.978
144	3.93	0.537	0.766	0.625	3.893	2.505	4.295	-0.730	-0.392	-4.218
130	3.92	0.570	0.781	0.650	3.653	3.600	4.555	-1.426	-0.812	-4.182
07	3.82	0.704	0.798	0.558	3.375	4.000	4.676	-0.681	-0.480	-2.948
142	3.80	0.565	0.778	0.648	3.221	3.850	4.295	-1.504	-0.850	-4.298
143	3.78	0.539	0.765	0.629	3.090	2.880	3.853	-1.209	-0.652	-4.520
147	3.73	0.619	0.766	0.582	2.778	2.400	3.464	-0.970	-0.600	-4.850
122	3.69	0.674	0.808	0.552	2.778	2.400	3.464	-1.340	-0.903	-3.600
45	3.65	0.699	0.787	0.620	3.083	4.000	4.271	-1.496	-1.046	-1.819
20	3.58	0.724	0.804	0.570	3.013	3.277	4.018	-0.879	-0.637	-2.537
75	3.54	0.539	0.726	0.662	2.965	2.766	3.698	-0.759	-0.409	-1.458
101	3.52	0.562	0.786	0.634	3.167	3.064	3.949	-1.829	-1.028	-4.303
48	3.52	0.687	0.777	0.617	2.883	3.277	3.845	-1.712	-1.175	-2.124
03	3.50	0.731	0.806	0.574	3.506	3.850	4.676	-0.663	-0.485	-2.956
77	3.30	0.591	0.763	0.693	2.848	4.000	3.945	-2.388	-1.412	-2.201
104	3.27	0.542	0.774	0.622	2.500	3.200	3.464	-2.160	-1.171	-4.900
01	3.26	0.746	0.821	0.575	3.576	3.775	4.676	-0.622	-0.464	-2.367
108	3.18	0.541	0.770	0.624	2.597	2.962	3.464	-2.395	-1.297	-5.000
150	2.98	0.660	0.791	0.601	2.667	2.778	3.464	-1.335	-0.881	-4.150
65	2.82	0.564	0.750	0.671	2.614	3.060	3.464	-1.085	-0.611	-1.350
66	2.80	0.573	0.752	0.681	2.500	3.404	3.464	-2.445	-1.402	-1.950
71	2.70	0.597	0.768	0.694	2.965	3.064	3.698	-1.564	-0.934	-1.646
76	2.69	0.596	0.767	0.694	3.280	2.501	3.698	-1.560	-0.929	-1.646
74	2.58	0.558	0.748	0.666	3.499	2.501	3.945	0.009	0.005	-1.840
102	2.57	0.577	0.795	0.644	2.500	3.404	3.464	-1.565	-0.902	-4.050
113	2.50	0.561	0.789	0.631	3.497	2.508	3.949	-0.096	-0.054	-3.601
138	2.48	0.606	0.802	0.674	2.781	4.000	3.853	-1.362	-0.826	-3.621
106	2.37	0.579	0.799	0.644	2.778	2.769	3.464	-1.040	-0.602	-3.800
55	2.35	0.600	0.772	0.693	2.614	3.255	3.464	-1.750	-1.049	-1.300
136	2.08	0.575	0.789	0.651	2.667	3.000	3.464	-0.570	-0.328	-3.750
70	2.05	0.583	0.761	0.684	3.117	3.850	4.157	-0.058	-0.034	-1.667
139	1.83	0.599	0.789	0.677	3.496	2.503	3.853	-0.049	-0.030	-3.037
60	1.40	0.612	0.785	0.696	2.667	3.191	3.464	-0.360	-0.220	-1.400
61	1.00	0.618	0.787	0.701	2.614	3.355	3.464	-0.097	-0.060	-1.250

APPENDIX C

RESULTS OF RESISTANCE PREDICTION AND MODEL TEST RESULTS

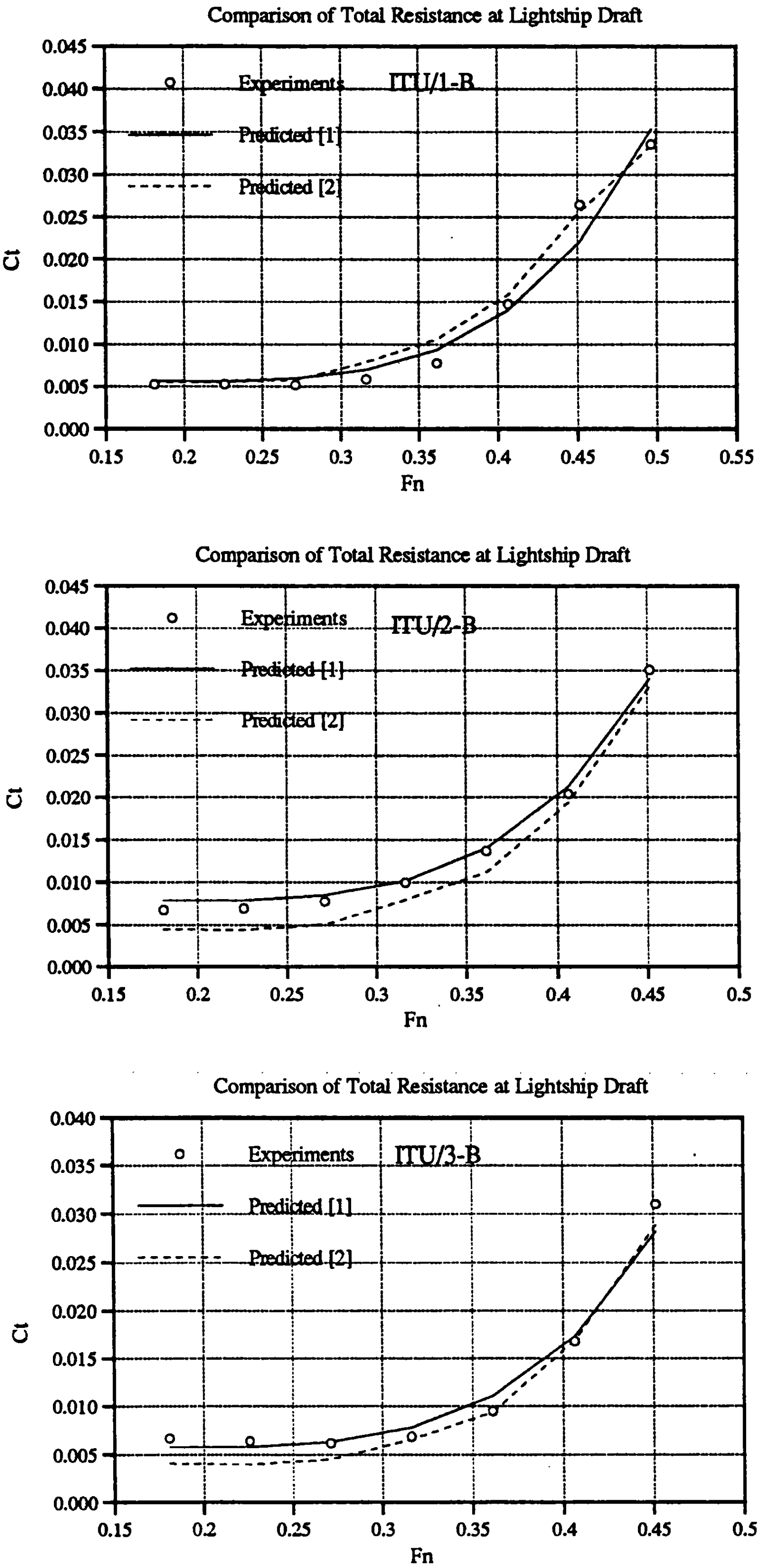
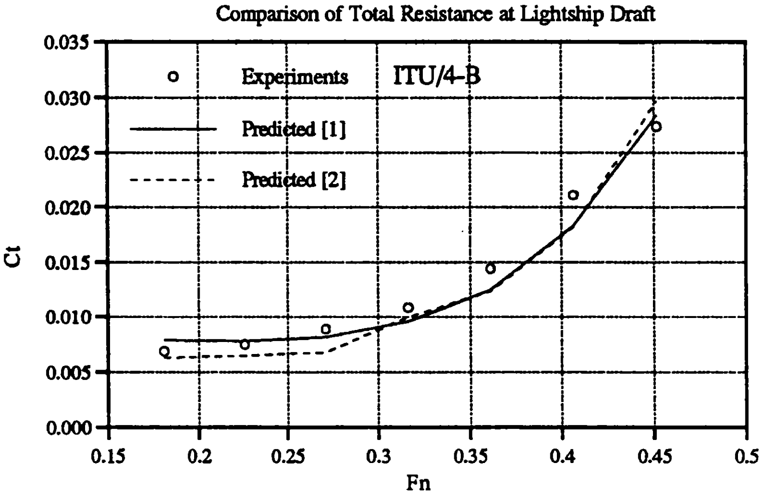
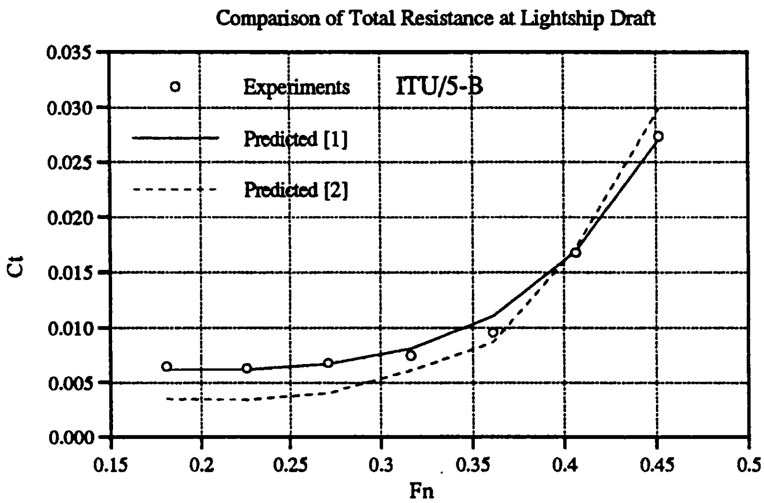


Figure C.1a. Total Resistance versus Froude Number at Lightship Draft





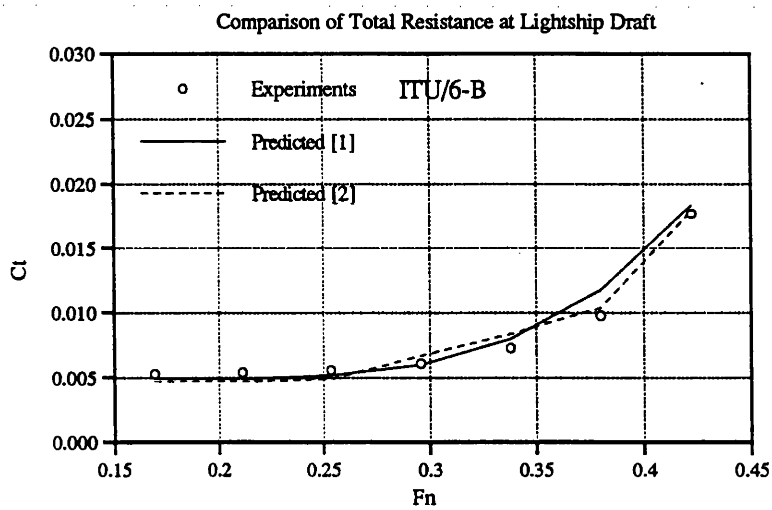


Figure C.1b. Total Resistance versus Froude Number at Lightship Draft

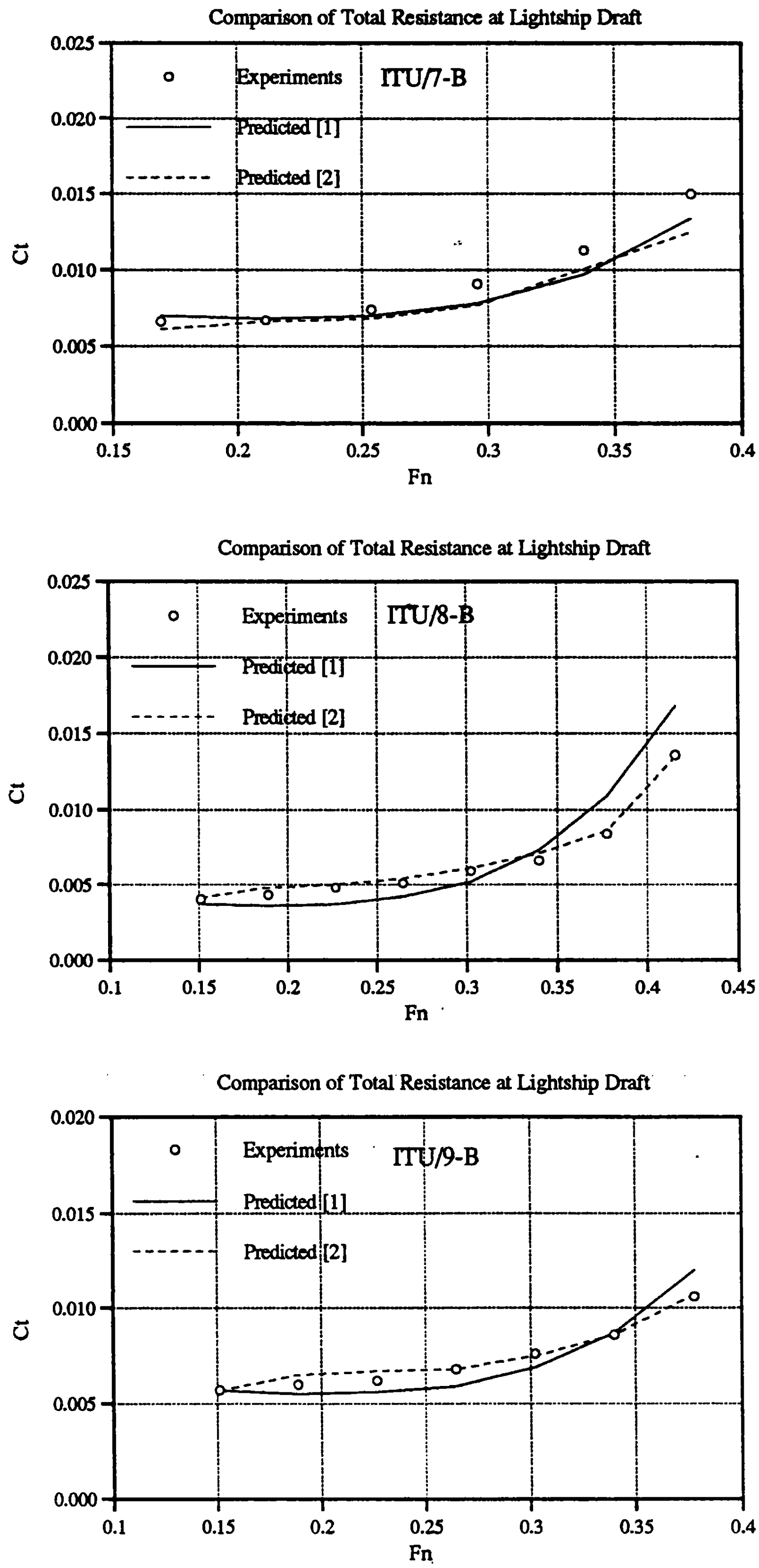
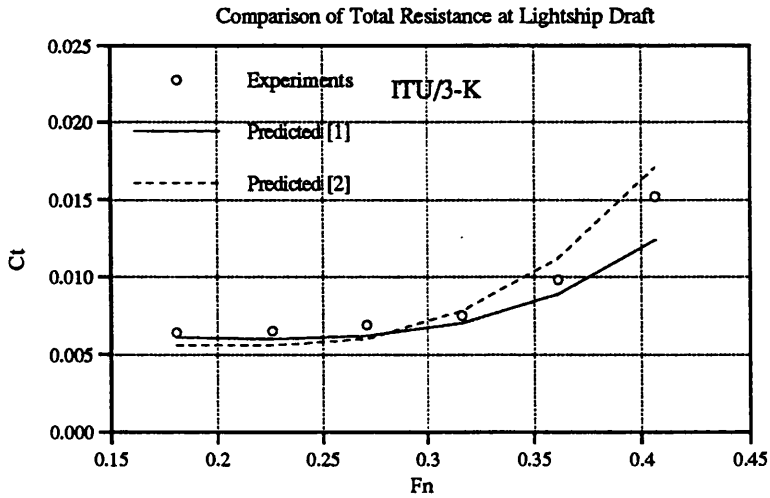
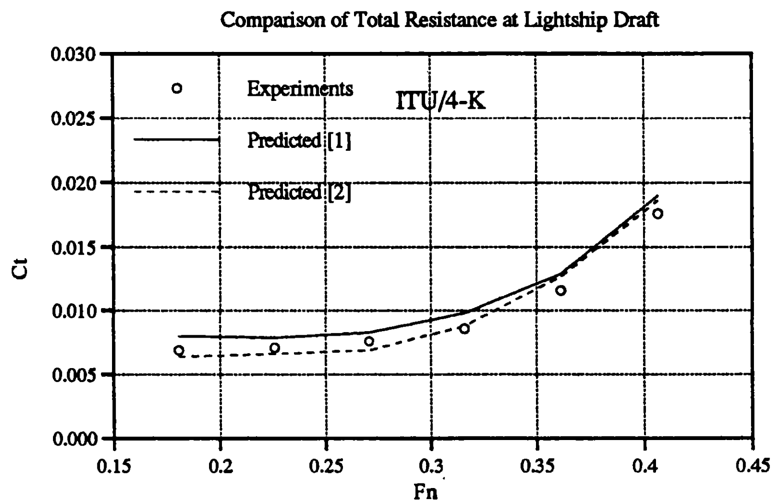


Figure C.1c. Total Resistance versus Froude Number at Lightship Draft





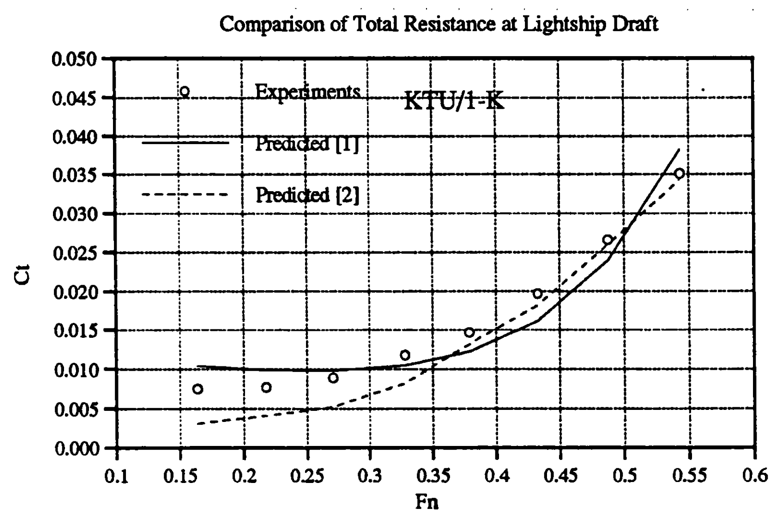
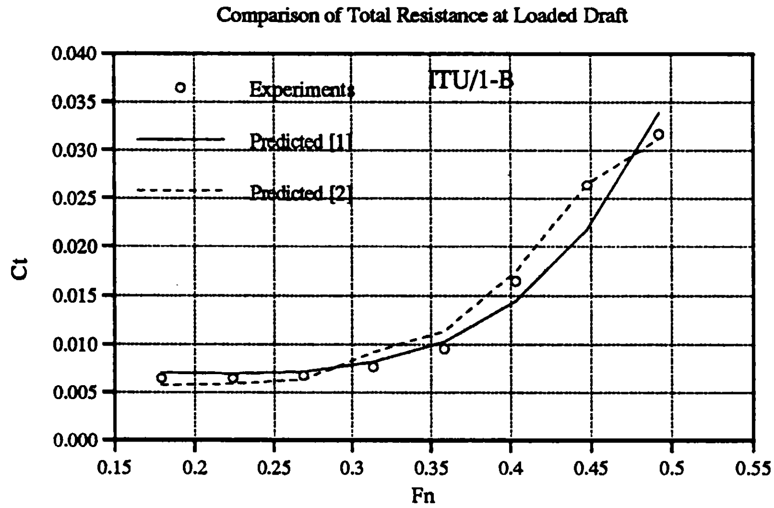
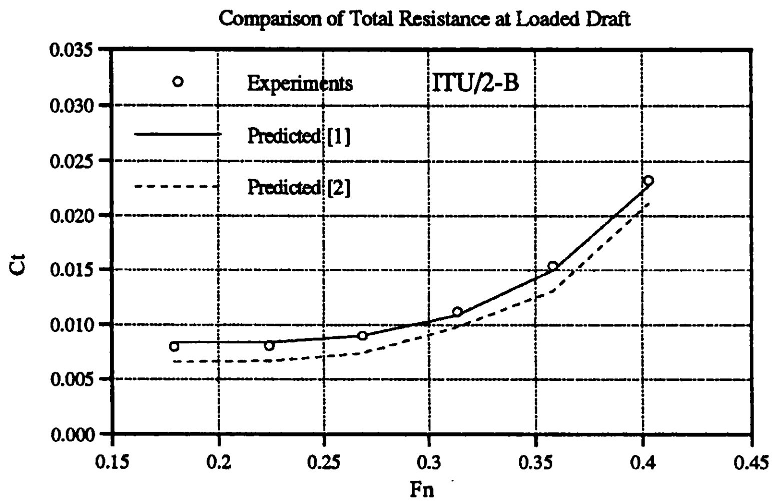


Figure C.1d. Total Resistance versus Froude Number at Lightship Draft





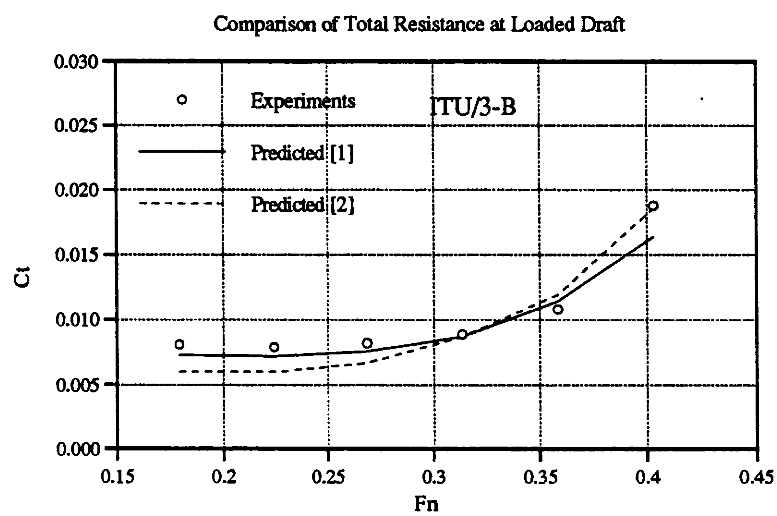
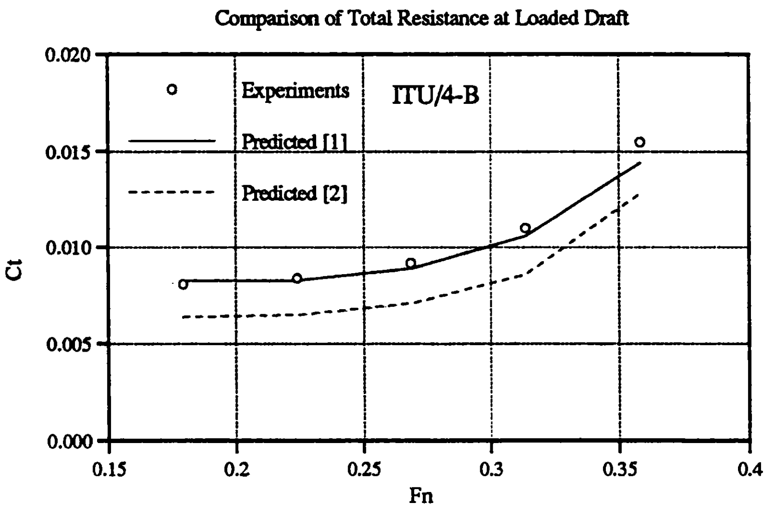
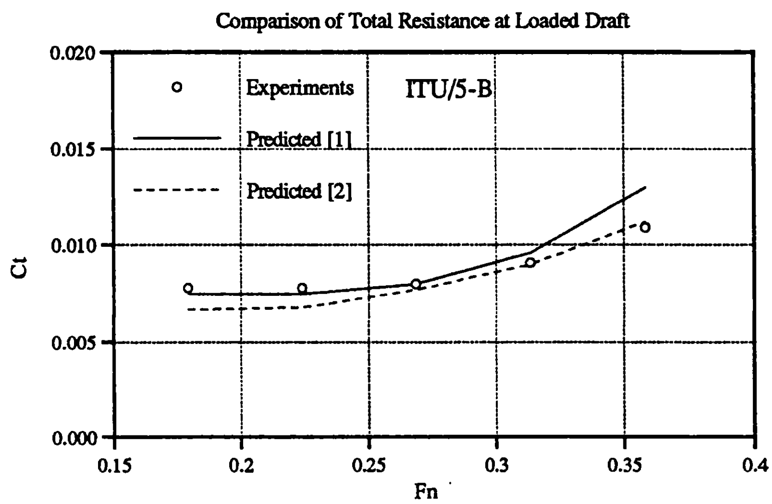


Figure C.2a. Total Resistance versus Froude Number at Loaded Draft





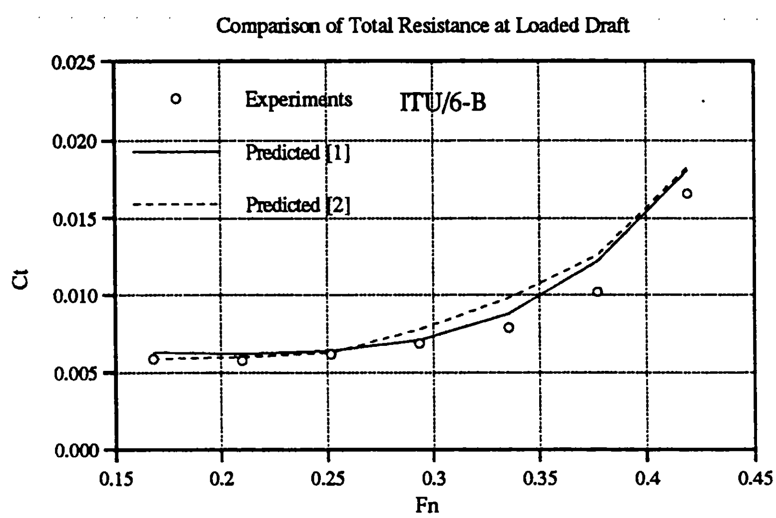
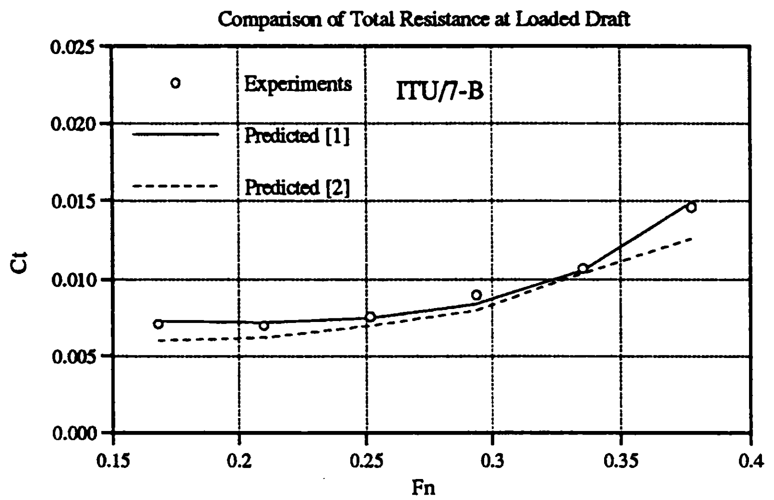
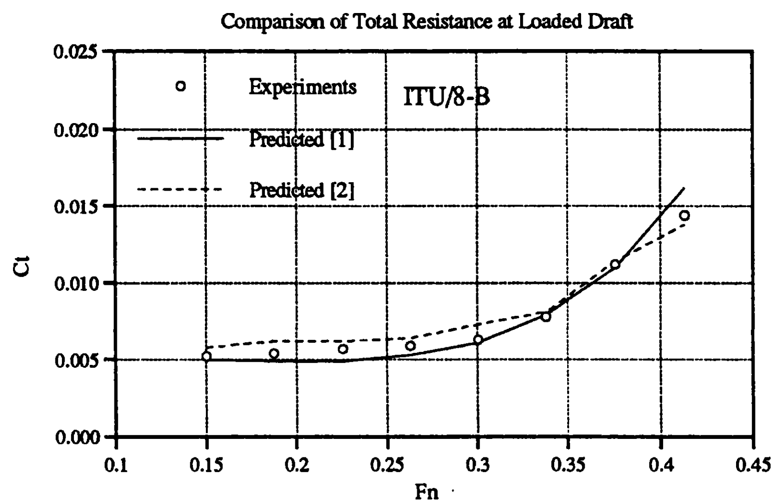


Figure C.2b. Total Resistance versus Froude Number at Loaded Draft





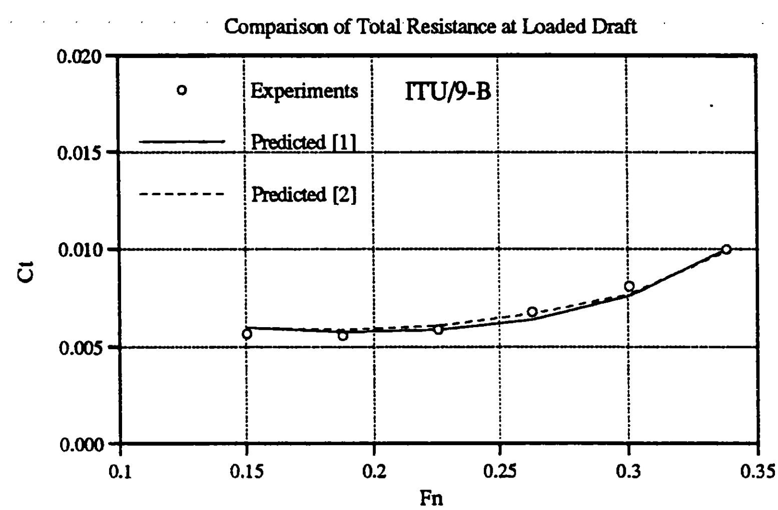


Figure C.2c. Total Resistance versus Froude Number at Loaded Draft

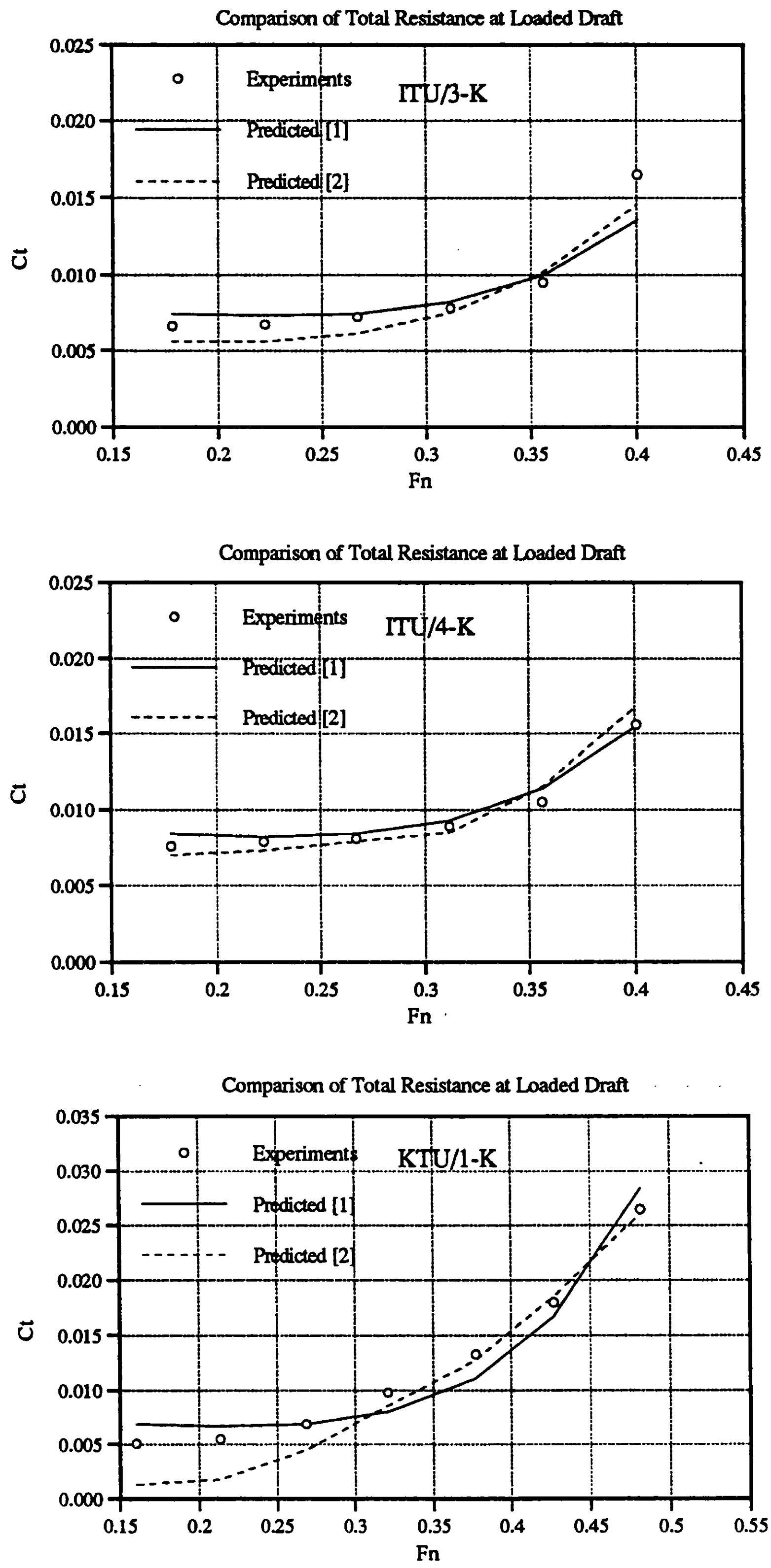


Figure C.2d. Total Resistance versus Froude Number at Loaded Draft

Table C.1a. Resistance Prediction Results and Model Test Results at Lightship Draft

Model ITU/1-B at Lightship Draft Temp=17 °C

Fn	Ct	Cf	Cr	Ct Predict.[1]	Ct Predict.[2]
0.181	0.0053	0.0043	0.0010	0.0053	0.0055
0.226	0.0053	0.0041	0.0012	0.0053	0.0056
0.271	0.0052	0.0040	0.0012	0.0057	0.0058
0.316	0.0059	0.0039	0.0020	0.0068	0.0089
0.361	0.0078	0.0038	0.0041	0.0092	0.0106
0.406	0.0147	0.0037	0.0111	0.0138	0.0158
0.452	0.0265	0.0036	0.0229	0.0220	0.0257
0.497	0.0336	0.0035	0.0301	0.0355	0.0334

Model ITU/2-B at Lightship Draft Temp=16.5 °C

Fn	Ct	Cf	Cr	Ct Predict.[1]	Ct Predict.[2]
0.181	0.0068	0.0043	0.0025	0.0080	0.0045
0.226	0.0070	0.0041	0.0029	0.0080	0.0044
0.271	0.0078	0.0040	0.0038	0.0085	0.0051
0.316	0.0100	0.0039	0.0061	0.0103	0.0106
0.361	0.0137	0.0038	0.0099	0.0141	0.0112
0.406	0.0204	0.0037	0.0167	0.0214	0.0194
0.452	0.0351	0.0036	0.0315	0.0341	0.0332

Model ITU/3-B at Lightship Draft Temp=16 °C

Fn	Ct	Cf	Cr	Ct Predict.[1]	Ct Predict.[2]
0.181	0.0067	0.0043	0.0024	0.0055	0.0041
0.226	0.0064	0.0041	0.0023	0.0055	0.0040
0.271	0.0062	0.0040	0.0022	0.0060	0.0045
0.316	0.0069	0.0039	0.0030	0.0075	0.0095
0.361	0.0095	0.0038	0.0058	0.0107	0.0094
0.406	0.0168	0.0037	0.0131	0.0168	0.0169
0.452	0.0310	0.0036	0.0274	0.0275	0.0289

Table C.1b. Resistance Prediction Results and Model Test Results at Lightship Draft

Model ITU/4-B at Lightship Draft Temp=16 °C

Fn	Ct	Cf	Cr	Ct Predict.[1]	Ct Predict.[2]
0.181	0.0069	0.0043	0.0025	0.0080	0.0063
0.226	0.0075	0.0041	0.0034	0.0079	0.0065
0.271	0.0089	0.0040	0.0049	0.0082	0.0068
0.316	0.0109	0.0039	0.0070	0.0095	0.0100
0.361	0.0144	0.0038	0.0106	0.0124	0.0124
0.406	0.0211	0.0037	0.0174	0.0180	0.0182
0.452	0.0274	0.0036	0.0238	0.0278	0.0297

Model ITU/5-B at Lightship Draft Temp=17 °C

Fn	Ct	Cf	Cr	Ct Predict.[1]	Ct Predict.[2]
0.181	0.0065	0.0043	0.0021	0.0060	0.0035
0.226	0.0063	0.0041	0.0022	0.0060	0.0034
0.271	0.0068	0.0040	0.0028	0.0065	0.0040
0.316	0.0075	0.0039	0.0036	0.0079	0.0097
0.361	0.0096	0.0038	0.0058	0.0109	0.0087
0.406	0.0168	0.0037	0.0132	0.0168	0.0172
0.452	0.0274	0.0036	0.0239	0.0271	0.0299

Model ITU/6-B at Lightship Draft Temp=21 °C

Fn	Ct	Cf	Cr	Ct Predict.[1]	Ct Predict.[2]
0.169	0.0053	0.0041	0.0012	0.0052	0.0047
0.211	0.0054	0.0039	0.0015	0.0051	0.0047
0.253	0.0056	0.0038	0.0018	0.0054	0.0049
0.296	0.0061	0.0037	0.0024	0.0063	0.0067
0.338	0.0073	0.0036	0.0037	0.0082	0.0084
0.380	0.0098	0.0035	0.0063	0.0119	0.0104
0.422	0.0177	0.0034	0.0143	0.0185	0.0179

Table C.1c. Resistance Prediction Results and Model Test Results at Lightship Draft

Model ITU/7-B at Lightship Draft Temp=20.5 °C

Fn	Ct	Cf	Cr	Ct Predict.[1]	Ct Predict.[2]
0.169	0.0066	0.0041	0.0025	0.0076	0.0061
0.211	0.0067	0.0039	0.0028	0.0074	0.0066
0.253	0.0074	0.0038	0.0036	0.0076	0.0068
0.296	0.0091	0.0037	0.0054	0.0083	0.0077
0.338	0.0113	0.0036	0.0077	0.0101	0.0101
0.380	0.0150	0.0035	0.0115	0.0136	0.0125

Model ITU/8-B at Lightship Draft Temp=18 °C

Fn	Ct	Cf	Cr	Ct Predict.[1]	Ct Predict.[2]
0.151	0.0040	0.0040	0.0002	0.0050	0.0049
0.189	0.0043	0.0038	0.0004	0.0049	0.0050
0.227	0.0048	0.0037	0.0011	0.0050	0.0050
0.264	0.0051	0.0036	0.0015	0.0054	0.0050
0.302	0.0059	0.0035	0.0025	0.0064	0.0065
0.340	0.0066	0.0034	0.0032	0.0083	0.0063
0.378	0.0084	0.0033	0.0051	0.0119	0.0086
0.416	0.0136	0.0033	0.0103	0.0177	0.0135

Model ITU/9-B at Lightship Draft Temp=16.5 °C

Fn	Ct	Cf	Cr	Ct Predict.[1]	Ct Predict.[2]
0.151	0.0057	0.0040	0.0017	0.0073	0.0057
0.189	0.0060	0.0038	0.0022	0.0071	0.0065
0.227	0.0062	0.0037	0.0025	0.0071	0.0067
0.264	0.0068	0.0036	0.0032	0.0074	0.0068
0.302	0.0076	0.0035	0.0041	0.0082	0.0075
0.340	0.0086	0.0034	0.0052	0.0100	0.0086
0.378	0.0106	0.0034	0.0072	0.0132	0.0107

Table C.1d. Resistance Prediction Results and Model Test Results at Lightship Draft

Model ITU/3-K at Lightship Draft Temp=17 °C

Fn	Ct	Cf	Cr	Ct Predict.[1]	Ct Predict.[2]
0.181	0.0064	0.0043	0.0020	0.0059	0.0056
0.226	0.0065	0.0041	0.0023	0.0058	0.0056
0.271	0.0069	0.0040	0.0029	0.0060	0.0060
0.316	0.0075	0.0039	0.0037	0.0069	0.0095
0.361	0.0098	0.0038	0.0061	0.0088	0.0112
0.406	0.0152	0.0037	0.0115	0.0126	0.0171

Model ITU/4-K at Lightship Draft Temp=17 °C

Fn	Ct	Cf	Cr	Ct Predict.[1]	Ct Predict.[2]
0.181	0.0069	0.0043	0.0026	0.0080	0.0064
0.226	0.0071	0.0041	0.0030	0.0079	0.0066
0.271	0.0076	0.0040	0.0036	0.0083	0.0069
0.316	0.0086	0.0039	0.0047	0.0097	0.0102
0.361	0.0116	0.0038	0.0079	0.0127	0.0127
0.406	0.0176	0.0037	0.0139	0.0185	0.0186

Model KTU/1-K at Lightship Draft Temp=11.1 °C

Fn	Ct	Cf	Cr	Ct Predict.[1]	Ct Predict.[2]
0.164	0.0075	0.0044	0.0030	0.0075	0.0011
0.217	0.0077	0.0042	0.0035	0.0072	0.0017
0.271	0.0089	0.0040	0.0049	0.0072	0.0052
0.328	0.0118	0.0039	0.0080	0.0081	0.0161
0.379	0.0147	0.0037	0.0109	0.0101	0.0162
0.433	0.0197	0.0037	0.0160	0.0146	0.0182
0.487	0.0266	0.0036	0.0230	0.0234	0.0280
0.543	0.0351	0.0035	0.0316	0.0393	0.0343

Table C.2a. Resistance Prediction Results and Model Test Results at Loaded Draft

Model ITU/1-B at Loaded Draft Temp=17 °C

Fn	Ct	Cf	Cr	Ct Predict.[1]	Ct Predict.[2]
0.179	0.0065	0.0043	0.0022	0.0070	0.0059
0.224	0.0065	0.0041	0.0024	0.0069	0.0059
0.269	0.0068	0.0040	0.0028	0.0072	0.0064
0.313	0.0077	0.0038	0.0039	0.0081	0.0106
0.358	0.0096	0.0037	0.0059	0.0103	0.0114
0.403	0.0165	0.0037	0.0129	0.0144	0.0175
0.448	0.0264	0.0036	0.0228	0.0218	0.0265
0.493	0.0317	0.0035	0.0281	0.0341	0.0312

Model ITU/2-B at Loaded Draft Temp=16.5 °C

Fn	Ct	Cf	Cr	Ct Predict.[1]	Ct Predict.[2]
0.179	0.0080	0.0043	0.0037	0.0086	0.0066
0.224	0.0081	0.0041	0.0040	0.0085	0.0067
0.269	0.0090	0.0040	0.0050	0.0091	0.0074
0.313	0.0112	0.0038	0.0074	0.0109	0.0119
0.358	0.0154	0.0037	0.0117	0.0149	0.0131
0.403	0.0233	0.0037	0.0197	0.0225	0.0212

Model ITU/3-B at Loaded Draft Temp=16 °C

Fn	Ct	Cf	Cr	Ct Predict.[1]	Ct Predict.[2]
0.179	0.0081	0.0043	0.0037	0.0072	0.0060
0.224	0.0079	0.0041	0.0038	0.0071	0.0060
0.269	0.0082	0.0040	0.0042	0.0075	0.0067
0.313	0.0089	0.0039	0.0051	0.0086	0.0110
0.358	0.0108	0.0038	0.0070	0.0111	0.0119
0.403	0.0188	0.0037	0.0151	0.0160	0.0186

Table C.2b. Resistance Prediction Results and Model Test Results at Loaded Draft

Model ITU/4-B at Loaded Draft Temp=16.5 °C

Fn	Ct	Cf	Cr	Ct Predict.[1]	Ct Predict.[2]
0.179	0.0081	0.0043	0.0038	0.0084	0.0064
0.224	0.0084	0.0041	0.0043	0.0084	0.0065
0.269	0.0092	0.0040	0.0052	0.0089	0.0071
0.313	0.0110	0.0038	0.0072	0.0106	0.0117
0.358	0.0155	0.0037	0.0118	0.0142	0.0128

Model ITU/5-B at Loaded Draft Temp=17 °C

Fn	Ct	Cf	Cr	Ct Predict.[1]	Ct Predict.[2]
0.179	0.0078	0.0043	0.0035	0.0076	0.0067
0.224	0.0078	0.0041	0.0037	0.0076	0.0068
0.269	0.0080	0.0040	0.0041	0.0082	0.0077
0.313	0.0091	0.0038	0.0052	0.0099	0.0090
0.358	0.0109	0.0037	0.0072	0.0138	0.0112

Model ITU/6-B at Loaded Draft Temp=21 °C

Fn	Ct	Cf	Cr	Ct Predict.[1]	Ct Predict.[2]
0.168	0.0059	0.0041	0.0018	0.0063	0.0058
0.210	0.0058	0.0039	0.0018	0.0062	0.0059
0.252	0.0062	0.0038	0.0024	0.0063	0.0062
0.294	0.0069	0.0037	0.0032	0.0070	0.0080
0.335	0.0079	0.0036	0.0043	0.0087	0.0099
0.377	0.0102	0.0035	0.0067	0.0119	0.0126
0.419	0.0166	0.0034	0.0132	0.0176	0.0183

Table C.2c. Resistance Prediction Results and Model Test Results at Loaded Draft

Model ITU/7-B at Loaded Draft Temp=20.5 °C

Fn	Ct	Cf	Cr	Ct Predict.[1]	Ct Predict.[2]
0.168	0.0071	0.0041	0.0030	0.0073	0.0059
0.210	0.0070	0.0039	0.0031	0.0071	0.0062
0.252	0.0076	0.0038	0.0038	0.0074	0.0064
0.294	0.0090	0.0037	0.0054	0.0083	0.0079
0.335	0.0107	0.0036	0.0072	0.0105	0.0104
0.377	0.0146	0.0035	0.0111	0.0147	0.0126

Model ITU/8-B at Loaded Draft Temp=18 °C

Fn	Ct	Cf	Cr	Ct Predict.[1]	Ct Predict.[2]
0.150	0.0052	0.0040	0.0012	0.0055	0.0057
0.188	0.0054	0.0038	0.0016	0.0053	0.0060
0.225	0.0057	0.0037	0.0020	0.0053	0.0061
0.263	0.0059	0.0036	0.0024	0.0056	0.0063
0.301	0.0063	0.0035	0.0028	0.0065	0.0072
0.338	0.0078	0.0034	0.0044	0.0081	0.0081
0.376	0.0112	0.0033	0.0079	0.0111	0.0114
0.413	0.0144	0.0033	0.0111	0.0161	0.0138

Model ITU/9-B at Loaded Draft Temp=16.5 °C

Fn	Ct	Cf	Cr	Ct Predict.[1]	Ct Predict.[2]
0.150	0.0056	0.0040	0.0016	0.0063	0.0059
0.188	0.0057	0.0038	0.0019	0.0062	0.0064
0.225	0.0060	0.0037	0.0023	0.0062	0.0064
0.263	0.0069	0.0036	0.0033	0.0067	0.0066
0.301	0.0082	0.0035	0.0046	0.0079	0.0076
0.338	0.0102	0.0034	0.0067	0.0102	0.0088

Table C.2d. Resistance Prediction Results and Model Test Results at Loaded Draft

Model ITU/3-K at Loaded Draft Temp=17 °C

Fn	Ct	Cf	Cr	Ct Predict.[1]	Ct Predict.[2]
0.178	0.0066	0.0043	0.0023	0.0071	0.0056
0.222	0.0067	0.0041	0.0026	0.0070	0.0056
0.267	0.0072	0.0039	0.0032	0.0072	0.0059
0.311	0.0078	0.0038	0.0039	0.0081	0.0091
0.356	0.0095	0.0037	0.0058	0.0101	0.0102
0.400	0.0165	0.0036	0.0128	0.0141	0.0146

Model ITU/4-K at Loaded Draft Temp=17 °C

Fn	Ct	Cf	Cr	Ct Predict.[1]	Ct Predict.[2]
0.178	0.0076	0.0043	0.0033	0.0083	0.0060
0.223	0.0079	0.0041	0.0038	0.0081	0.0061
0.267	0.0081	0.0040	0.0041	0.0084	0.0065
0.312	0.0089	0.0038	0.0051	0.0093	0.0102
0.356	0.0105	0.0037	0.0067	0.0116	0.0115
0.401	0.0156	0.0037	0.0119	0.0161	0.0168

Model KTU/1-K at Loaded Draft Temp=14.5 °C

Fn	Ct	Cf	Cr	Ct Predict.[1]	Ct Predict.[2]
0.160	0.0051	0.0043	0.0008	0.0062	0.0013
0.214	0.0055	0.0041	0.0014	0.0060	0.0018
0.269	0.0069	0.0039	0.0030	0.0063	0.0045
0.321	0.0098	0.0038	0.0060	0.0075	0.0131
0.377	0.0133	0.0037	0.0096	0.0106	0.0128
0.427	0.0180	0.0036	0.0145	0.0165	0.0185
0.482	0.0265	0.0035	0.0230	0.0285	0.0261

REFERENCES

1. Hutchison, B.L. (1990), "Seakeeping Studies: A Status Report", Transactions SNAME, Vol.98.

2. Fyson, J. (1985), "Design of Small Fishing Vessels", Fishing News Book Ltd., FAO Publication.

3. International Maritime Organisation (IMO), (1975a), "Code of Safety for Fisherman and Fishing Vessels: Part A", London.

4. International Maritime Organisation (IMO), (1975b), "Code of Safety for Fisherman and Fishing Vessels: Part B", London.

5. International Maritime Organisation (IMO), (1977), "International Conference on Safety of Fishing Vessels", Torremolinos, Spain.

6. Nickum, G.C. (1978), "An Evaluation of Intact Stability Criteria", Marine Technology, Vol.15, July.

7. Dahle, E.A. and Kjearland, O. (1980), "The Capsizing of M/S Helland-Hansen- The Investigation and Recommendations for Preventing Similar Accidents", The Naval Architect, Vol.122, March.

8. Tupper, C.N. (1985), "Fishing and Ship Motions-Design Considerations Based on Observations of Operations", International Conference on Design, Construction and Operation of Commercial Fishing Vessels, Florida Institute of Technology, May.

9. Doust, D.J. (1962), "Optimised Trawler Forms", Transactions NECIES, Vol.79.

10. Doust, D.J. (1965), "Fishing Vessel Design and some related Technical and Economic Factors", National Physical Laboratory, Ship Rep. 69, July.

11. Doust, D.J., Hayes, J.K. and Tsuchiya, T. (1967), "A Statistical Analysis of FAO Resistance Data for Fishing Craft", FAO Fisheries Technical Paper.

12. Engvall, L.O. and Engstrom, J. (1969), "A Method for Selection of an Optimum Fishing Vessel for Investment Purposes", FAO Fisheries Technical Paper.

13. Pal, P.K. (1983), "Optimum Design of Trawlers", PRADS Conference, Tokyo.

14. Sheshappa, D.S., Digernes, T. and Endal, A. (1988), "A Computer Design Model for Optimising Fishing Vessel Designs Based on Techno-economic Analysis", World Symposium on Fishing Gear and Fishing Vessel Design, Canada.

15. Allievi, A.G., Calisal, S.M. and Rohling, G.F. (1986), "Motions and Stability of a Fishing Vessel in Transverse and Longitudinal Seaways", Transactions SNAME, Vol.94.

16. Karppinen, T. (1983), "Comparison of Theoretical Seakeeping Prediction with Model Test Results for a Wide Beam Fishing Vessel", 20th ATTC, Hoboken, August.

17. Frostad, R. and Jullumstro, E. (1988), "Modern Hull forms of Fishing Vessel", World Symposium on Fishing Gear and Fishing Vessel Design, Canada.

18. Goren, O. and Calisal, S.M. (1988), "Optimal hull forms for Fishing Vessels", SNAME Spring Meeting Star Symposium, Pittsburgh.

19. Ivanov, V.E. and Apollinariev, A.V. (1992), "Dialogue-Based Software Package of Request for Proposal for Fishing Vessel Design", PRADS Conference, Newcastle upon Tyne.

20. Bales, N.K. (1980), "Optimising the Seakeeping Performance of Destroyer Type Hulls", 13th Symposium on Naval Hydrodynamics, October, Tokyo.

21. van Wijngaarden, A.M. (1984), "The Optimum Form of a Small Hull for the North Sea Area", International Ship Building Progress, Vol.31, No.359.

22. Body Plan of Black Sea Fishing Vessel (1987), Surmene Shipyard, Turkey.

23. Kafali, K. (1980), "A Study of the Fishing Vessels Forms", Turkish Ship Research Institute, Publication No. 25, Technical University of Istanbul, Turkey.

24. van Oortmerssen, G. (1971), "A Power Prediction Method and its Application to Small Ships", International Shipbuilding Progress, Vol.18, No.207.

25. Kostov, D. and Kyulevcheliev, S. (1990), "Semi-Empirical Methods for Resistance Estimation in Hull Form Design", 19th ITTC.

26. Holtrop, J. and Mennen, G.G.J. (1982), "An Approximate Power Prediction Method", International Shipbuilding Progress, Vol.29, No.335, July.

27. Holtrop, J. (1984), "A Statistical Re-analysis of Resistance and Propulsion Data", International Shipbuilding Progress, Vol.31, No.363.

28. Hooke, R. and Jeeves, T.A. (1961), "Direct Search Solution of Numerical and Statistical Problems", Journal of the Association for Computing Machines, Vol.8, April.

29. Macdonald, K.E. and Telfer, E.V. (1938), "Seakindliness and Ship Design", Transactions NECIES, Vol.54.

30. Kent, J.L. (1950), "The Design of Seakindly Ships", Transactions NECIES, Vol.66.

31. St. Denis, M. (1983), "On the Empiric Design of Seakindly Ships", PRADS Conference, Tokyo.

32. St. Denis, M. (1976), "On the Environmental Operability of Seagoing Systems", SNAME T&R Bulletin, No.1-32.

33. Andrew, R.N. and Lloyd, A.R.J.M. (1981), "Full Scale Comparative Measurements on the Behaviour of two Frigates in Severe Head Seas", Transactions RINA, Vol.123.

34. Aartssen, G. (1969), "Service Performance and Trials at Sea", Appendix V, Performance Committee, Proceedings of 12th International Towing Tank Conference.

35. Hadler, J.B. and Sarchin, T.H. (1973), "Seakeeping Criteria and Specifications", SNAME Seakeeping Symposium.

36. Daidola, J.C. and Griffin, J.J. (1986), "Developments in the Design of Oceanographic Ships", Transactions SNAME, Vol.94.

37. Spouge, J.R. (1985), "The Prediction of Realistic Long-Term Ship Seakeeping Performance", Transactions NECIES, Vol.101.

38. Nordforsk (1987), "Assessment of Ship Performance in a Seaway", Nordforsk, Copenhagen.

39. Karppinen, T. (1987), "Criteria for Seakeeping Performance Predictions", Technical Research Centre of Finland.

40. Lewis, E.V. (1955), "Ship Speeds in Irregular Seas", Transactions SNAME, Vol.63.

41. Lloyd, A.R.J.M. (1988), "The Effect of Hull Form and Size on Seakeeping", CADMO Conference, Southampton.

42. Lewis, E.V. (1960), "Increasing the Sea Speed of Merchant Ships", Transactions SNAME, Vol.67.

43. Beukelman, W. and Huijser, A. (1977), "Variation of Parameters Determining Seakeeping", International Shipbuilding Progress, Vol.24, No.275.

44. Muntjewerf, J.J. (1963), "The Influence of Shipform and Length on the Behaviour of Destroyer Type Ships in Head and Bow Seas", International Shipbuilding Progress, Vol.10, No.102.

45. Abkowitz, M.A., Vassilopoulos, L.A. and Sellars, F.H. (1966), "Recent Developments in Seakeeping Research and Its Application to Design", Transactions SNAME, Vol.74.

46. Vossers, G., Swaan, W.A. and Rijken, H. (1961), "Experiments with Series 60 Models in Waves", Transactions SNAME, Vol.68.

47. Robson, B.L. (1987), "Systematic Series of High Speed Displacement Hull Forms for Naval Combatants", Transactions RINA, Vol.130.

48. Blok, J.J. and Beukelman, W. (1984), "The High-Speed Displacement Ship Systematic Series Hull Forms-Seakeeping Characteristics", Transactions SNAME, Vol.92.

49. Moor, D.I. (1970), "Effects on Performance in Still Water and Waves of some Geometric Changes to the Form of a Large Twin-Screw Ship", Transactions SNAME, Vol.78.

50. Schmitke, R.T. and Murdey, D.C. (1980), "Seakeeping and Resistance Trade-offs in Frigate Hull Form Design", 13th Symposium on Naval Hydrodynamics, Tokyo.

51. Swaan, W.A.and Vossers, G. (1961), "The Effect of Forebody Section Shape on Ship Behaviour in Waves", International Shipbuilding Progress, Vol.8, No.83.

52. Ewing, J.A. (1967), "The effect of Speed, Forebody Shape and Weight Distribution on Ship Motions", Transactions RINA, Vol.109.

53. Grim, O. (1960), "A Method for a More Precise Computation of Heaving and Pitching Motions both in Calm Water and in Waves", Proceedings of the 3rd Symposium on Naval Hydrodynamics, Scheveningen.

54. Yourkov, N. (1973), "Vertical Motions of Ships with Different Forms of Forebody", International Shipbuilding Progress, Vol.20, No.223.

55. Vossers, G. and Swaan, W.A. (1960), "Some Seakeeping Tests with a Victory Model", International Shipbuilding Progress, Vol.7, No.69.

56. Swaan, W.A. and Rijken, H. (1964), "Speed Loss at Sea as a Function of Longitudinal Weight Distribution", International Shipbuilding Progress, Vol.11, No.15.

57. LLoyd, A.R.J.M. (1983), "Deck Wetness Experiments", Proceedings of 20th ATTC.

58. LLoyd, A.R.J.M., Salsich, J. O. and Zseleczky, J.J. (1985), "The Effect of Bow Shape on Deck Wetness in Head Seas", Transactions RINA, Vol.128.

59. Mizoguchi, S. (1989), "Design of Freeboard Height with the Numerical Simulation on the Shipping Water", PRADS Conference, Varna.

60. Abkowitz, M.A. (1957), "Seakeeping Considerations in Design and Research", Transactions SNAME, Vol.64.

61. Moor, D.I. and Murdey, D.C. (1968), "Motions and Propulsion of Single Screw Models in Head Seas (Part 1)", Transactions RINA, Vol.110.

62. Bales, N.K and Cummins, W.E. (1970), "The Influence of Hull Form on Seakeeping", Transactions SNAME, Vol.78.

63. Loukakis, T.A. and Chryssostomidis, C. (1975), "Seakeeping Standard Series for Cruiser-Stern Ships", Transactions SNAME, Vol.83.

64. Walden, D.A. (1983), "Extension of the Bales Seakeeping Rank Factor Concept", Proceedings of 20th ATTC, Hoboken, August.

65. McCreight, K.K. (1983), "Estimating the Seakeeping Qualities of Destroyer Type Hulls", DTNSRDC Report, SPD-1074-01, January.

66. Enerhaugh, B. (1988), "The Effect of Lengthening of a Fishing Vessel on its Seakeeping Performance", World Symposium on Fishing Gear and Fishing Vessel Design, Canada.

67. Zborowski, A. and Sainsbury, S.R. (1988), "Small Vessel Hull Form Optimization for Heave and Pitch Performance", Marine Technology, Vol.25.

68. Takaki, M. (1989), "Effect of Hull Form on Ship Motions and Optimisation of Hull Forms for Seakeeping Performance", Journal of the Society of Naval Architects of Japan, Vol.166.

69. Kishev, R., Dimitrova, S. and Gaberova M. (1989), "A Generalised Procedure for Rank Optimisation Application to Ship Design", PRADS Conference, Varna.

70. Nabergoj, R. (1990), "Small Vessel Optimisation for Increased Seakeeping and Stability Performance", STAB Conference.

71. Bogdanov, P. and Kishev, R. (1990), "Relation of Ship Resistance in Waves to Ship Geometry by Rank Estimation Approach", 19th ITTC.

72. Grigoropoulos, G.J. and Loukakis, T.A. (1988), "A New Method for Developing Hull Forms with Superior Seakeeping Qualities", CADMO Conference, Southampton.

73. Lloyd, A.R.J.M. (1991), "The Seakeeping Design Package (SDP)", RINA Spring Meeting, London, April.

74. Loukakis, T. A., Perakis, N. and Papoulias, F.A. (1983), "The Effect of Some Hull Form Parameters on the Seakeeping Behaviour of Surface Ships", 12th Scientific and Methodological Seminar on Ship Hydrodynamics, Varna.

75. Guliev, J., Davidov, I. and Shepeta, V. (1989), "Design of Seagoing Dry Cargo Ships with Regard to their Seakeeping Characteristics", PRADS Conference, Varna.

76. Hearn, G.E., Hills, W. and Sarioz, K. (1990), "Making Seakeeping Analysis Work for the Designer-A New Practical Approach", 19th Scientific and Methodological Seminar on Ship Hydrodynamics, Varna, October.

77. Sarioz, K., Hearn, G.E.and Hills, W. (1992), "Practical Seakeeping for Design: An Optimised Approach", PRADS Conference, Newcastle upon Tyne.

78. Zborowski, A. and Lui, S.J. (1992), "Optimisation of Hull Form for Seakeeping Performance", PRADS Conference, Newcastle upon Tyne.

79. Boote, D. and Bruzzone, D. (1991), "A Method to Assess the Seakeeping Behaviour of a Merchant Ship in its Early Stage of Design", CADMO Conference.

80. Korvin-Kroukovsky, B.V. and Jacobs, W.R. (1957), "Pitching and Heaving Motions of a Ship in Regular Waves", Transactions SNAME, Vol.65.

81. Salvesen, N., Tuck, E.O. and Faltinsen, O. (1970), "Ship Motions and Sea Loads", Transactions SNAME, Vol.78.

82. Lewis, F.M. (1929), "The Inertia of the Water Surrounding a Vibrating Ship", Transactions SNAME, Vol.37.

83. Grim, O. (1953), "Berechnung der durch Schwingungen eines Schiffskorper Erzeugten Hydrodynamischen Krafte", Jahrbuch der Schiffbautechnischen Gesselschaft, Vol.47.

84. Frank, W. (1967), "Oscillation of Cylinders in or Below the Free Surface of Deep Fluids", DTNSRDC, Report No.2375.

85. Kobayashi, M. (1981), "On the Hydrodynamic Forces and Moments Acting on an Arbitrary Body with Constant Forward Speed", Journal of the Society of Naval Architects of Japan, Vol.150.

86. Inglis, R.B. and Price, W.G. (1981), "A Three Dimensional Ship Motion Theory-Comparison between Theoretical Prediction and Experimental Data of the Hydrodynamic Coefficients with Forward Speed", Transactions RINA, Vol.123.

87. Guevel, P. and Bougis, J. (1982), "Ship Motions with Forward Speed in Infinite Depth", International Ship Building Progress, Vol.29.

88. Meyers, W.G., Applebee, T.R. and Baitis, A.E. (1981), "Users's Manual for the Standard Ship Motion Program, SMP", DTNSRDC/SPD-0936-01, September.

89. Schmitke, R.T. and Whitten, B.W. (1981), "SHIPMO- A FORTRAN Program to Predict Ship Motions in Waves", Technical Memorandum 81/C, Defence Research Establishment Atlantic, October, Canada.

90. St. Denis, M. and Pierson, W.J. (1953), "On the Motions of Ships in Confused Sea", Transactions SNAME, Vol.61.

91. Frank, W. and Salvesen, N. (1970), "The Frank Close-Fit Ship Motion Computer Program", NSRDC Report 3289, June.

92. Ochi, M.K. and Motter, L. (1973), "Prediction of Slamming Characteristics and Hull Responses for Ship Design", Transactions SNAME, Vol.81.

93. Graham, R. and Trudelle, C. (1987), "SHIPMO4-An Updated User's Manual for the SHIPMO Computer Program Incorporating an Extended Hydrostatics Capability and an Improved Viscous Roll Damping Model", Technical Communication 87/304, Defence Research Establishment Atlantic, Canada, March.

94. Ando, S. (1982), "Wave Load Prediction for the SHIPMO Computer Program", Technical Memorandum 82/L, Defence Research Establishment Atlantic, Canada, October.

95. Bretschneider, C.L. (1957), "Review of Practical Methods for Observing and Forecasting Ocean Waves by Means of Wave Spectra and Statistics", Transactions American Geophysical Union, April.

96. Software for Seakeeping Predictions, SHIPMO-PC User Manual, Version 1.22, Sable Maritime Limited, Canada, 1992 June.

97. Chan, H.S. (1990), "A Three-Dimensional Technique for Predicting First and Second Order Hydrodynamic Forces on a Marine Vehicle Advancing in Waves", Ph.D. Thesis, Department of Naval Architecture and Ocean Engineering, University of Glasgow, Scotland.

98. Bhattacharyya, R. (1972), "Dynamics of Marine Vehicles", Chapter 11, John Wiley&Sons, New York.

99. Vossers, G. (1961), "Fundamentals of the Behaviour of Ships in Waves", Publication No.151a of the Netherlands Ship Model Basin.

100. Havelock, T.H. (1937), "The Resistance of a Ship Among Waves", Proc. of the Royal Society, Vol.161.

101. Maruo, H. (1957), "The Excess Resistance of a Ship in Rough Seas", International Ship Building Progress, Vol.4, No.35.

102. Joosen, W.P. (1966), "Added Resistance of a Ships in Waves", 6th Symposium on Naval Hydrodynamics, Washington, D.C.

103. Gerritisma, J. and Beukelman, W. (1972), "Analysis of the Resistance Increase in Waves of a Fast Cargo Ship", International Ship Building Progress, Vol.19, No.217.

104. Hanaoka, T. et al. (1963), "Researches on Seakeeping Qualities of Ships in Japan - Chapter 5, Resistance in Waves", The Society of Naval Architects of Japan, 60th Anniversary Series, Vol.8.

105. Loukakis, T.A. and Sclovounos, P.D. (1978), "Some Extensions of the Classical Approach to Strip Theory of Ship Motions, Including the Calculation of Mean Added Force and Moments", Journal of Ship Research, Vol.22, No.1.

106. SFOLDS Naval Architecture Design Analysis System (1980), BMT CORTEC Limited.

107. Lackenby, H. (1950), "On the Systematic Geometrical Variation of Ship Forms", Transactions INA, Vol.92.

108. Ozmen, G. and Incecik, A. (1993), "Optimising the Seakeeping Performance of Fishing Vessel Hull Forms for the Black Sea Area", IMAM Conference, Varna.

109. Diasamidze, I., "Black Sea Wave Characteristics", Private Communications.

110. Kayikci, O., Fisherman, Private Communications.

111. Lewis, E.V. (1989), "Principle of Naval Architecture", SNAME Publication, Vol.3.

112. Schneiders, C.C. (1989), "The Prediction of Ship Performance by Calculation or by Measurement", 7th Lips Propeller Symposium.

113. Hughes, G. (1954), "Friction and Form Resistance in Turbulent Flow, and a Proposed Formulation for Use in Model and Ship Correlation", Transactions INA, Vol.96.

114. Report of the Performance Committee (1978), Proceedings of 15th ITTC, The Netherlands, Wageningen.

115. Granville, P.S. (1956), "The Viscous Resistance of Surface Vessels and the Skin Friction of Flat Plates", Transactions SNAME, Vol.64.

116. Prohaska, C.W. (1966), "A Simple Method for Evaluation of the Form Factor and the Low Speed Wave Resistance", Proceedings of 11th ITTC, Tokyo.

117. Gross, A. and Watanabe, K. (1972), Report of the Performance Committee, Proceedings of 13th ITTC, September.

118. Michell, J.H. (1898), "The Wave Resistance of a Ships", Philosophical Magazine, Series 5, Vol.45.

119. Ridgley-Newitt, C. (1956), "The Resistance of Trawler Hull Forms of 0.65 Prismatic Coefficient", Transactions SNAME, Vol.64.

120. Ridgley-Newitt, C. (1963), "The Resistance of a High Displacement-Length Ratio Trawler Series", Transactions SNAME, Vol.71.

121. Ridgley-Newitt, C. (1967), "The Resistance of a High Displacement-Length Ratio Trawler Series", Transactions SNAME, Vol.75.

122. Todd, F.H. (1957), "Series 60-The Effect upon Resistance and Power of Variation in Ship Proportions", Transactions SNAME, Vol.65.

123. Doust, D.J. and O'Brien, T.P. (1959), "Resistance and Propulsion of Trawlers", Transactions NECIES, Vol.75.

124. Hayes, J.G. and Engvall, L.O. (1969), "Computer Aided Studies of Fishing Boat Hull Resistance", FAO Fisheries Technical Paper No. 87, Rome, December.

125. Tsuchiya, T. (1972), "New Statistical Regression Analysis for Fishing Boat Hull Resistance", Journal of the Society of Naval Architects of Japan, Vol.132.

126. Sabit, A.S. (1971), "Regression Analysis of the Resistance Results of BSRA. Series", International Shipbuilding Progress, Vol.18.

127. Sabit, A.S. (1971), "A Tabulated Analytical Procedure based on Regression Analysis for the Determination of the Form Coefficients and E.H.P. for Ships Designed According to Series 60", European Shipbuilding, No.2.

128. Havelock, T.H. (1909), "The Wave-making Resistance of Ships: A Theoretical and Practical Analysis", Proc. of the Royal Society, Vol.82.

129. Havelock, T.H. (1910), "The Wave-making Resistance of Ships: A Study of Certain Series of Model Experiments", Proc. of the Royal Society, Vol.84.

130. Pattullo, R.N.M. and Thomson, G.R. (1965), "The BSRA Trawler Series -Part.I", Transactions RINA, Vol.107.

131. Pattullo, R.N.M. and Thomson, G.R. (1968), "The BSRA Trawler Series - Part.II", Transactions RINA, Vol.110.

132. Ozmen, G. and Incecik, A. (1994), "A Statistical Analysis of Resistance Data for Small Fishing Vessels", International Conference on Ship and Marine Research, Rome.

133. Swift, P.M., Nowacki, H. and Fischer, J.P. (1973), "Estimation of Great Lakes Bulk Carrier Resistance Based on Model Test Data Regression", Marine Technology, October.

134. Andersen, P. and Guldhammer, H.E. (1986), "A Computer-Oriented Power Prediction Procedure", CADMO Conference.

135. Calisal, S.M. and McGreer, D.E. (1990), "Model Resistance Tests of a Systematic Series of Low L/B Vessels", SNAME, Pacific Northwest Section, May.

136. van Oortmerssen, G. and van Oossanen, P. (1988), "A New CAD System for the Design of Ships", CADMO Conference, Southampton.