RESEARCH

Maine
Department of
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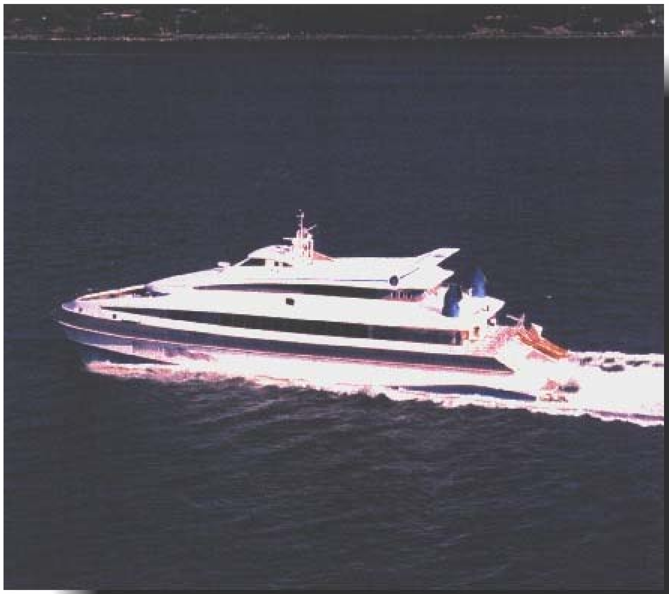

Fast Ferry Operations and Issues
Phase 2
Report ME 99-5A

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This report will identify fast vessels likely to operate in Maine waters and discuss methods to manage the wake-wash issues surrounding fast ferries.

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Executive Summary

All fast ferry types depend upon the reduction of surface tension and resistance by either reducing hull drag or by creating dynamic lift. There are four main types of fast ferries, each achieve lift and/or reduce drag in distinct ways:

- Monohull vessels, which are able to reach high speeds with planing hulls.
- Catamarans, which depend upon the hydrodynamic advantage gained by narrow efficient hulls. Wavepiercers and surface effect ships (SES) are hybrid catamaran designs. SES hulls create dynamic lift with air cushions. Wavepiercers are hull designs which cut through short waves efficiency.
- Hydrofoils, which operate with the hull clear of the water using dynamic lift provided by submerged of surface piercing foils at speed.
- Hovercraft, in which the hull is lifted clear of the water by an air cushion

Fast ferries hull forms have been developing for years resulting in the parallel development of materials. Aluminum and lightweight composite materials are two examples of materials that have undergone advances in recent years. New aluminum alloys and improved joining technology have led to stronger and lighter vessels. The use of composites for vessel interiors is increasing, and will contribute to reducing vessel weight.

Propulsion technology has gone through an equal transformation in recent years. Gas turbines and diesel engines, which are lighter and capable of producing more horsepower, are constantly being developed. When properly sized and coupled to the propellers, or propulsors, they can easily produce vessel speeds in excess of 50 knots.

The quality of the ride is of utmost concern with fast ferries. Pitching, heaving, and rolling can all lead to levels of motions sickness which are not acceptable. The use of computer controlled trim tabs and/or t-foils help eliminate most of these motions and reduce sickness.

The development in the design and the operation of high-speed vessels has created a need for revamping the regulations governing their design and safety. Both the U.S. Coast Guard and the international communities are working to create new regulations in these areas. The result of all of the factors will be vessels which can offer passengers superior comfort and ride quality with maximum safety.

When new fast ferry routes are being planned, a key issue to be addressed is the effect of the wake-wash produced by these high speed vessels. Effective management of wake-wash requires an understanding of how it creates a risk for shoreline property structures and the environment. Site evaluations can establish threshold limits for each, and then vessels operators should be required to demonstrate that the proposed vessel and operational techniques can meet those limits.

Introduction

Fast ferries have only really come to prominence in the 1990s with the development of larger car-carrying catamarans and monohulls, but have in fact been in existence for more than forty years. The features which distinguish this new breed of fast ferries are their speed, light construction, and design characteristics. With the evolution of the fast ferry, new methods of control have come into being. Management, operation, environmental, and safety are all issues that are being dealt with on national and international levels.

This report will identify fast vessels likely to operate in Maine waters and discuss methods to manage the wake-wash issues surrounding fast ferries. Only vessels capable of carrying 50-300 passengers and maintaining speeds of 28 knots or better when fully loaded will be considered. All vessel types considered must conform to the current Jones Act laws; that is, they must be built in the U.S., and manned by crews licensed by the U.S. Coast Guard. The report will also be looking at the current IMO High-speed Craft Codes (HSC CODE) as they pertain to fast ferries.

Fast Ferries

Basic Service Considerations

The fast ferry market is most notable for its diversity. Fast ferry craft may be found operating in many capacities, such as commuter service in large cities and for leisure purposes in tourist areas. By their very nature, all ferry services form part of a continuous transport system. In their many varying roles, the fast ferry can be an alternative or a supplement to highway and railroad options.

The notion that a particular fast ferry is suited for routes with closely defined characteristics has been proven wrong. A number of vessels that have failed in one service have found success in another, often with totally different environmental and operating conditions. Before a high-speed ferry is put on a new service, though, the following considerations should be weighed:

- Ability to meet the current regulatory requirements. (The vessel may have to be reclassed.)
- Knowledge of the route.
- Frequency of the service requirements. In Maine's case this includes seasonal variations.
- Sustainable speed at sea, seakeeping and comfort.
- Maximum allowable speeds in close waters and port entrances.
- Maneuverability requirements when navigating and when docking and undocking.
- Vessel maintenance and overhaul considerations.
- Manning and management considerations.
- Wake/wash effects.
- Air pollution considerations.

Infrastructure-Berthing Requirements

In general, most vessels of the same class will have similar berthing requirements. About 85% of the fast ferries in service today are side loading. The remaining vessels load from the front or rear and were designed for specific applications. Most of the vessels are adaptable to existing berthing arrangements with little or no modifications.

Ideally, the loading platform would be floating and at a height close to the main deck, so that the passengers can embark and disembark with relative ease. The main deck is usually between 2 to 4 meters above water level. Some other issues that must be addressed when considering berthing are:

- The number and location of the mooring lines.
- The requirement for utility connections.
- Vessel draft requirements.
- Suitable space for maneuvering the vessel

Most fast ferries are highly maneuverable and need very little space to approach or leave a berthing area.

Ride Quality

The question of passenger comfort is of prime importance. The ability of a vessel to cope with bad weather from the point of view of strength is not always matched by an acceptable level of comfort. Although a standard exists on motion sickness, the minimum standard alone would probably not be enough to overcome passenger reluctance to use a service if the discomfort extends beyond a limited period. Most operators will curtail operations with seas in the 10 to 12-foot ranges. As one operator's representative said, "It's better to cancel a trip than to risk passenger dissatisfaction."

Motion sickness can be influenced by physical and psychological factors such as those listed below and should be taken into consideration when choosing a design:

- Confined spaces.
- The snowball effect of exposure to sick passengers.
- Consumption of inappropriate food and drink.
- Anxiety at the possibility of experiencing motion sickness.

Ride quality on all hull types can be improved by the addition of computer controlled trim tabs and/or inverted t-foils. These fixtures are designed to reduce vertical acceleration caused by vessel pitch, heave and roll which are instrumental in causing passenger discomfort and motion sickness. The use of computer simulation and tank testing can accurately predict the reduction in vertical acceleration by the use of different combinations of either trim tabs or t-foils. T-foils can be designed to be retractable so that they do not increase the vessel's draft for maneuvering.

A quiet environment, free from machinery noise and vibration, ranks right after ride quality and safety for passenger comfort. Mounts that effectively isolate inherent engine rumble, gear boxes that don't whine, propellers that don't sing or cavitate, exhaust systems that muffle sound effectively, and ventilation systems that lessen air flow noise are all essential to achieve the low noise levels that are expected today.

Internal noise levels will depend on where the measurements are taken. In almost all classes of vessels, when noise level measurements are taken, the results will be the same. The forward and interior areas are inherently less noisy than the after areas and outer areas. Noise levels in the 60-75dBA range are achievable in properly designed passenger spaces (Kennell 130).

Hull Types

There are many different types of high-speed craft, but these can conveniently be categorized within four main types. The four types are:

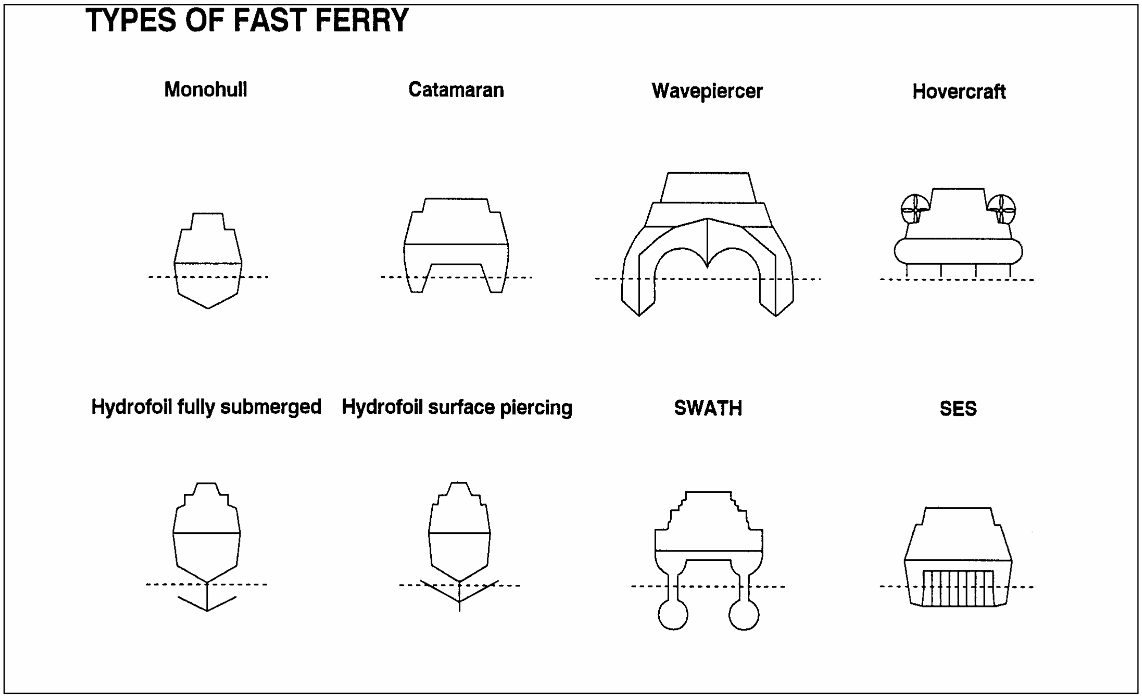
- Catamarans
- Monohulls
- Hydrofoils
- Hovercraft and Surface Effect Ships (SES)

Many hybrid designs exist within these basic categories, but all fast ferries depend upon the reduction of the surface tension and hull resistance by achieving dynamic lift and/or minimizing drag. Reducing hull resistance is accomplished by the use of lightweight materials to ultimately reduce the hull's wetted area and by the effective use of coatings.

Coatings not only serve to reduce hull resistance, but will also help reduce hull deterioration. Dynamic lift is created by hull geometry or lifting the hulls out of the water with air cushions (Ryle 24).

The different types of hull forms can be seen in Fig. 1. A brief description of each of the different hull types follows.

Figure 1
Types of Fast Ferries



Source: Drewry Shipping Consultants Ltd.

For the purpose of this report, the basic hull shape categorizes the vessels. It should be remembered, though, that each category contains a range of designs with varying performance characteristics and capabilities, rather than a single, standard type.

Monohull fast ferries are long, deep veed craft, usually with very narrow beams. Monohulls with the same capacity as the other vessels shown will be much longer. In order for them to reach high-speed they will usually have planing or semi-planing hulls.
Planing refers to hull shapes that allow the vessel to achieve dynamic lift as the vessel speed increases. A full planing hull might have 2-3 feet of hull in the water at full speed. At maneuvering speeds they have approximately the same draft as a comparable catamaran, 4-6 feet.

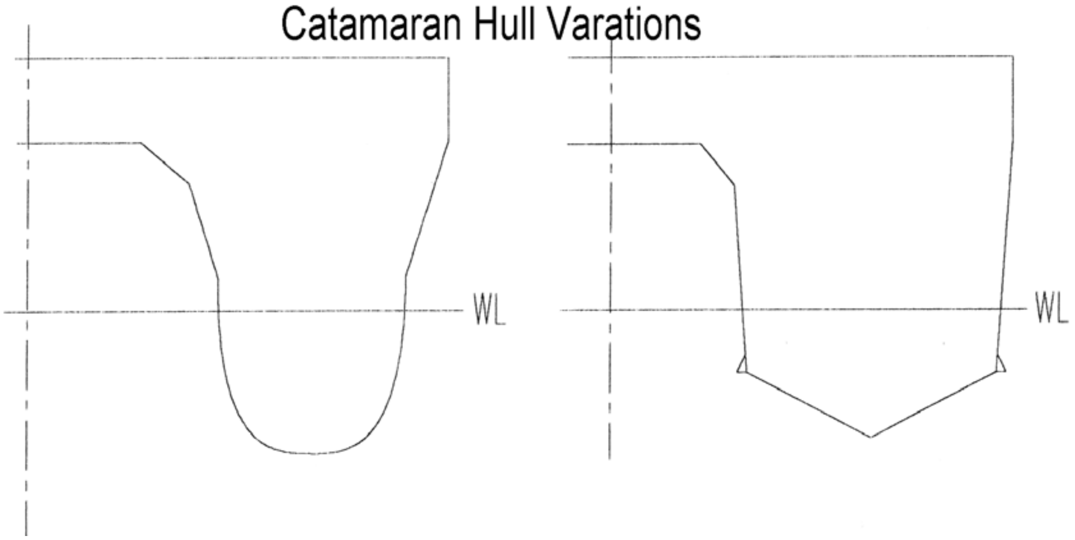
Another term when referring to a monohull is chine. This refers to the area of the vessel around the bilge turn, side plating to bottom plating. A hard chine vessel refers to a hull form that has a distinction between side plating and bottom plating verses a vessel that is rounded in this area. It is generally felt that the hard chine hull has better seakeeping ability.

Most monohulls are constructed with traditional shipbuilding techniques and materials. Generally they have higher power requirements at high speeds than comparable catamaran, due largely to the increase in draft over the catamaran. For vessels with the same capacities, monohull will be longer, which could create a problem in some ports.

Catamarans refer to vessels with two hulls which, in one form or another, depend on the hydrodynamic advantage gained by narrow efficient hulls and the cushion of air that is naturally generated between the hulls. Figure 2 shows two variations in hull shapes. The design on the right will give the vessel more hydrodynamic lift and has better seakeeping ability.

Another hybrid catamaran hull form is the wavepiercer. This design came into prominence in the 1990s and is distinguished by a longer more efficient waterline hull length that gives the vessel the ability to pierce short waves.

Figure 2



Catamaran Hull Varations

Source: Nigel Gee Associates LTD

Yet another variation is the SES catamaran hull. With this vessel, the forward portion of the hull is shaped like the standard catamaran. Approximately 2/3 of the hull is indented, which provides a pocket for a cushion of air. Fans maintain the air cushion, and this in turn gives the vessel a tremendous amount of dynamic lift. Although this technology has proven itself extremely fuel-efficient in smaller vessels, it is unproven with larger vessels.

Catamarans are known for providing a large stable platform, adding to passenger comfort, particularly when the vessel has ride control. Because of their shallow drafts, power consumption at all speeds is the best of all the hull forms. To reduce weight, catamarans are made with aluminum hulls and superstructures, which limit vessel lengths to a maximum of 130 meters.

A SWATH (Small Waterplane Area, Twin Hull) really falls into the catamaran category. SWATH vessels have two submarine-like lower hulls completely submerged below the water line. Above water, a SWATH resembles a catamaran. One or two relatively thin vertical members or struts connect its haunch areas to each submerged hull, which gives the SWATH vessels an extremely small water plane area. The longitudinal cross-section of each strut is somewhat streamlined to decrease wave making resistance.

Although the propulsion equipment of SWATH vessels can be located in the pods, this means that they are limited to submerged type propellers. The SWATH has excellent seakeeping, but consumes excessive power at high-speeds. To date, the SWATH technology is limited to speeds of 28 knots or less. Another disadvantage of SWATH vessels is its draft. For vessels in the 200 to 300 passenger range, the increase in draft over catamarans or monohulls is 1 to 3 feet.

Hydrofoils refer to a class of vessel that operates with its hull clear of the water, using dynamic lift provided by the foils at high-speed. The foils may be fully submerged or, more usually, surface piercing. The foils give the hydrofoils a big draft disadvantage when the vessel's hull is in the water, although, some hydrofoils are built with retractable foils. Another significant disadvantage is its limited seakeeping ability in rough seas.

Hovercraft and SES type vessels can be broadly put together in the same category. Both of these vessels rely on air cushions to dynamically support the vessel and reduce drag. The difference is the means of keeping the air cushion contained and the method of propulsion. A hovercraft has a flexible containment system that extends 8-10 inches into the water and uses large air fans for propulsion. The SES has solid hull like sidewalls and a flexible skirt fore and aft. The hulls provide an area that can be utilized for more conventional types of propulsors.

It is widely believed that because of the aging nature of the existing worldwide hydrofoil and hovercraft fleets a considerable replacement demand should be created. It is also believed that most of this replacement demand will be with monohull and catamaran designs.

The advantages and disadvantages of each hull type are summarized in Table 1.

Structural Design

The USCG has final design approval of vessels produced in the United States. If a vessel is also classed by one of the major Classification Societies, it will have to meet their design approval. A Classification Society, in very basic terms, provides owner/operators with insurance protection. Each society has its own design criteria for high-speed craft. For example, a vessel classed by the American Bureau of Shipping (ABS) must conform to their Classification of High-speed Craft. The USCG will generally work with the societies on structural design matters and in some cases will defer to their design requirements.

As previously stated, part of a high-speed ferry's ability to obtain high-speed is the reduction of vessel weight. Major parts of the weight reduction come from the use of less and lighter scantlings. A scantling is the dimensions of the frame, girders, and plating that go into a vessel’s structure. Classification Societies and the USCG permit the reductions in the scantlings of these craft by limiting the sea and weather conditions in which the vessel can operate. A craft that was originally designed for certain ambient conditions may not be allowed, or suitable, for operation in another service.

Table 1
High Speed Vessel Types: Advantages and Disadvantages

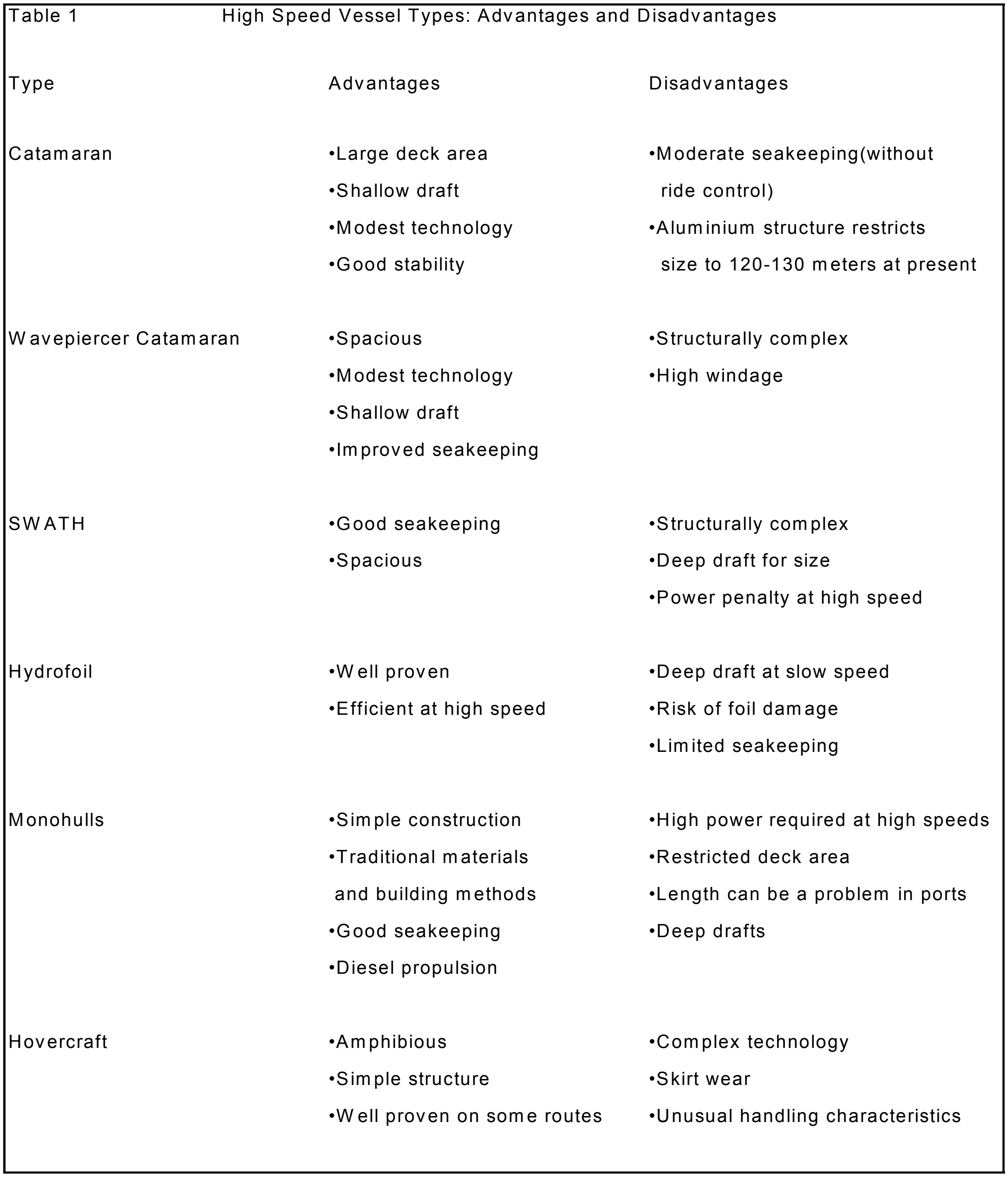


Table 1 High Speed Vessel Types: Advantages and Disadvantages

Type	Advantages	Disadvantages
Catamaran	•Large deck area •Shallow draft •Modest technology •Good stability	•Moderate seakeeping(without ride control) •Aluminium structure restricts size to 120-130 meters at present
Wavepiercer Catamaran	•Spacious •Modest technology •Shallow draft •Improved seakeeping	•Structurally complex •High windage
SWATH	•Good seakeeping •Spacious	•Structurally complex •Deep draft for size •Power penalty at high speed
Hydrofoil	•Well proven •Efficient at high speed	•Deep draft at slow speed •Risk of foil damage •Limited seakeeping
Monohulls	•Simple construction •Traditional materials and building methods •Good seakeeping •Diesel propulsion	•High power required at high speeds •Restricted deck area •Length can be a problem in ports •Deep drafts
Hovercraft	•Amphibious •Simple structure •Well proven on some routes	•Complex technology •Skirt wear •Unusual handling characteristics

Source: Drewry Consultants

Materials

Three main material types are used in the construction of fast ferries. Each material has strengths and weaknesses; however, they are all excellent in certain applications. The three materials are marine grade aluminum alloys, fiber-reinforced plastics/composites (FRP), and high tensile steels.

Aluminum alloys are by far the most extensively used materials for high-speed craft; however, very few of the aluminum alloys can stand up to the rigors of marine use. 5000 and 6000 series alloys are commonly used for marine construction; 5000 series is used for hull plating, and 6000 series is used for extrusions. Both use magnesium as an alloy, which gives it a high corrosion resistance quality. Aluminum has a higher degree of reactivity than steel or fiber reinforced materials when exposed to salt water. Because of this it is more susceptible to electrolytic corrosion. Recently there have been improvements in aluminum alloy properties that have led to increases in welded strength and the ability to resist corrosion. One such material, aluminum alloy number 5383, has increased the welded strength by 15% over the traditional aluminum hull plating.

The use of these marine grade aluminum alloys has been on the increase because they are relativity inexpensive, lightweight, widely available, easy to fabricate in a broad range of climate conditions, and have low maintenance costs. As more demands are put on materials, due largely to higher operating speeds and harsher environmental conditions, greater attention must be given to the adequacy of the design and production detailing through improved workmanship. New methods of fusion welding and joining technology such as Friction Stir Welding (FSW) and adhesive bonding will help with these challenges.

A FRPs base consists of glass fibers woven into mats. The mats are then laminated, creating tough, fiber reinforced panels. By using different diameters of glass fiber and by increasing or decreasing the tightness of the weave, mats of different densities are created. It is the density of the mats which determines the load bearing qualities of the final product. Other manmade materials can be used in a similar manner as glass fibers resulting in improvements in strength but most often with substantial cost increases. This manufacturing process allows the material to be easily formed into complex shapes that would be difficult to accomplish with aluminum plate.

It is important to note that the laminates used to bind the panels needs to cure in controlled environments. Humidity and temperature can affect the cure rate, thus the strength of the panels. Climate-controlled facilities are expensive to build and maintain, so this process can be cost prohibitive. The strength of FRP can be enhanced by the use of core materials such as urethane foams. The core materials are sandwiched between layers of FRP to produce stiffened panels.

FRPs have had a major impact on the marine industry in recent years. For years, they have been used successfully in small passenger vessels, where cost advantages are achieved through series production. By using these lightweight materials, operators of Sub-chapter H vessels have been successful at increasing the speed, lowering fuel consumption, and simplifying maintenance. The USCG is currently looking into the possibility of applying this technology to Sub-chapter K vessels which currently have to be built of steel or equivalent. Sub-chapter H and K vessels are defined in the Current Regulations section on page 12. Acceptance of FRPs by the Classifications Societies has also been very slow due to their demand for margins of safety.

Although it is possible to use high tensile steels for high-speed ferries, the weight of the material is generally prohibitive for smaller vessels. Several large monohull car fast ferries have been constructed with high tensile steel.

Innovative composite panels for interior spaces are also used. Generally, the USCG has required interior panels to be lined with aluminum for fire retarding ability. However, there are other composite panels that meet all the requirements for fire restricting materials according to the HSC CODE rules for high-speed craft. One manufacturer uses a three dimensional glass fiber material that is impregnated with resin and then stretched before it cures. The result is an extremely light panel that is in service on several European fast ferries. The USCG may at some point approve the use of such panels for US built vessels.

Propulsion Methods

The speed, power, and fuel consumption of a craft are of prime interest to all parties involved in the development and operation of a marine craft. The initial cost of both the engines and propulsors must be considered along with reliability, maintenance, and operating expenses. In addition, environmental factors such as draft, vibration, noise, and emissions all influence the selection of both the engine and the propulsor.

A design-decision matrix for each vessel design may have combinations of requirements that necessitate unique solutions. No engine-propulsor combination is likely to be the best solution for all marine applications. The combination of the hydrodynamic characteristics of the hull and the propulsor results in a speed-thrust relationship suited for the environment in which the vessel operates. The operating conditions such as whether the vessel is at constant speed, accelerating, or decelerating all determine the power and RPM requirements.

There are three popular propulsor types: submerged propellers, surface propellers, and flush inlet waterjets. Engine technology design has been rapidly changing in recent years, and will continue to develop as the market for high-speed applications continues. The current trend is to use medium or high-speed diesels, and/or gas turbine engines that are geared to match optimal propulsor speed. Important powering considerations for high-speed fast ferries consist of the following:

- Competitive capital cost.
- Safety and social acceptance: fire, exhaust emissions, water pollution, noise, wake-wash.
- High power to weight ratios.
- Compact size.
- Performance, durability and reliability.
- Fuel efficiency.
- Maintenance frequency and cost requirements.
- Ease of operation while in service.
- It must have economic flexibility across the range of speeds for the service that it is intended.

Engines

The diesel engine continues to dominate the small fast ferry market, except where very high-speeds are demanded. That service generally requires the use of gas turbines. There are tradeoffs for the use of either type of power plant. The initial cost of the gas turbine is more, as are its operational costs (it burns a higher grade of fuel). But savings can be realized on lubricating oil and maintenance costs, provided that a suitable maintenance program is followed. Significant revenue gains can be achieved from the reduced weight of the gas turbine, which can see a power to weight ratio of up to ten times that of a comparable diesel. The lifespan of a properly maintained gas turbine will exceed that of a diesel. Although service frequency is about the same for both, a more dedicated approach to care for the gas turbine is necessary.

In recent years there have been tremendous advances in the technology of both the diesel and the gas turbine. This is particularly true of the diesel, where advances have led to significant weight reductions while increasing the power output.

Propulsors

Current trends for design of the system are related to the vessel displacement and speed. Smaller vessels use fixed-pitched, submerged propellers. In smaller vessels, submerged propellers can produce speeds up to 60 knots. Surface propellers are fitted to vessels designed for high-speeds or to those with draft restrictions. Waterjet propulsion methods are being used more frequently, and their applications are expected to increase. In general, waterjet propulsors are appropriate when the vessel's normal operating speeds exceed 25 knots and when vibration and noise must be kept to a minimum, or when there are operational draft considerations.

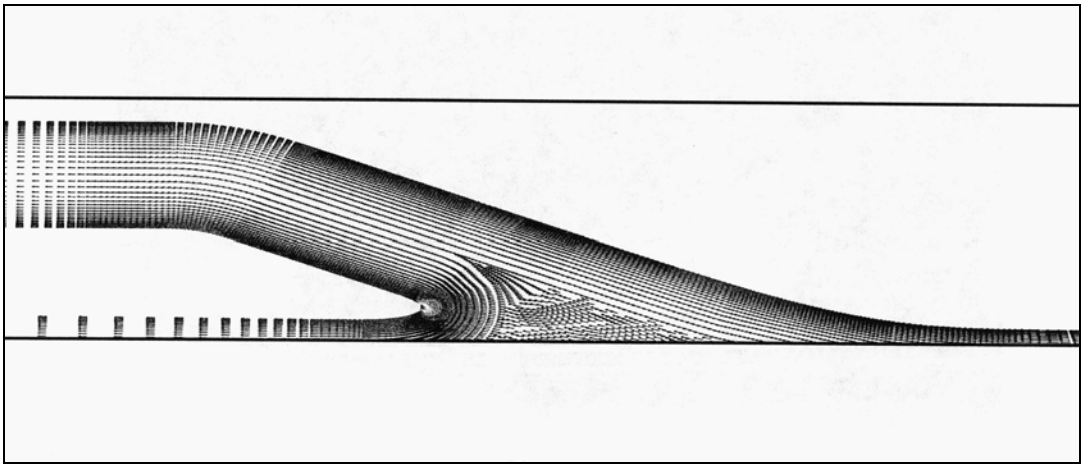
Unless efficiency calculations are done on identical hull vessels, it is difficult to make assumptions on whether one propulsor type is better than another. However, at speeds above 25kts the waterjet is generally considered more fuel efficient than submerged and surface piercing propellers.

A waterjet consists of a duct formed by the hull's structure which channels water to a rotating impeller that propels the water through a nozzle situated at the transom (see Figures 3 and 4).

A hydraulically actuated direction nozzle provides directional control over the water being discharged. Reversing is facilitated by means of a bucket flap, which reverses the water jet flow. The reversing bucket allows the vessel to be stopped from full ahead within a few boat lengths. Originally, waterjet propelled vessels were hard to maneuver at slower speeds. More recent designs have proven to have excellent maneuvering characteristics, particularly when used with twin hull type vessels.

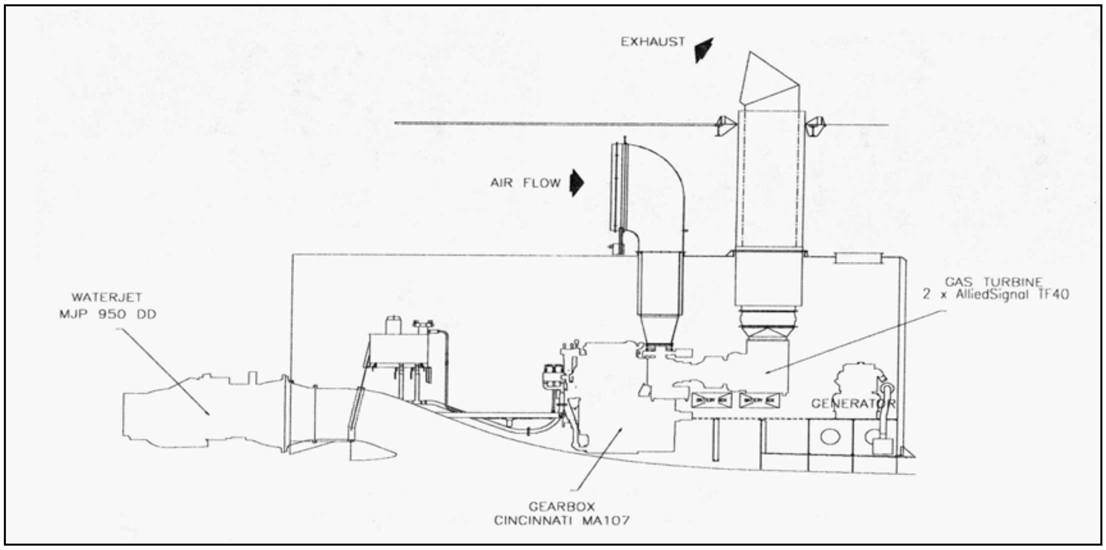
Conventional submerged propeller types can be used on vessels up to about 60kts depending on the displacement. They do have an obvious drawback compared to either the surface propellers or waterjet; the propeller and the rudder are situated below the hull. Where draft is a consideration, this type of propulsion is not as practical as other options. All things being equal, submerged propellers are inherently more expensive to operate because of the increased resistance of the propeller and rudder. Cavitation becomes a major problem on fully submerged propellers as speeds increase. Even with increasingly efficient propeller designs, cavitation prevents speeds in excess of 35kts.

Figure 3
Model for a High-Speed Catamaran Water Inlet Design



Source: Nigel Gee Associates LTD

Figure 4
Machinery Arrangement High-Speed Catamaran



Source: Nigel Gee Associates LTD

Surface-piercing propellers are popularly associated with the high-speed racing market, particularly where speeds in excess of 50 knots are required. The concept of a surface propeller is relatively simple. Instead of using a propeller that is fully immersed in the water, only the bottom blades are in the water and doing work. With surface drives, there is no drag from the propeller shaft or rudder, and the turbulence that is created around the submerged propeller hub is avoided.

A factor that has kept surface drives from expanding to commercial vessels such as fast ferries is the varying loads. They are most efficient at a single draft. New designs that adjust the shaft height according to the load may make this option more viable in the future.

Once the correct propulsion system is decided upon it must be properly applied. This means the correct gear ratio, propeller or impeller size must be used. It should also be considered that the maximum efficiency is usually obtained with the minimum number of prime movers and propulsors. Four engines burn more fuel than two engines of equivalent power. Four propellers are less efficient than two if the right diameter, pitch and revolutions per minute are used. Many operators believe that the extra propulsion trains are necessary for purposes of redundancy. This gives the vessel opportunity to operate at speeds close to design speeds. It should be noted that vessels in the 200 to 300 passenger ranges have limited space and generally will not have the room for additional power trains.

Current Regulations

Developments in the design and operation of high-speed vessels in recent years have led to revamping of regulations governing their construction and safety. The United States Coast Guard (USCG) is the government body responsible for insuring that all vessels operating in US waters are built and operated under current legislation. There are two sub-chapters of the Code of Federal Regulation (CFR) Part 46 that apply to the sizes of vessels capable of carrying 200-300 passengers. Sub-chapter K pertains to high-speed vessels with a passenger capacity greater than 150 and that are less than 100 gross tons displacement. Sub-chapter K also specifies upper limits, above which vessels would be required to comply with specific sections of Sub-chapter H. They are:

- Vessels carrying > 600 passengers.
- Vessels > 200 feet in length.

The international standard to which high-speed vessels must be built is the High-speed Craft Code (HSC Code), which has been adopted by the International Maritime Organization (IMO). Any high-speed passenger vessel operating on international voyages must conform to the rules detailed in the HSC Code. National administrators such as the USCG are responsible for vessels operating domestically, although many countries have chosen to apply the HSC Code to vessels operating in local waters. As part of a growing trend to harmonize maritime rules and regulations worldwide, the USCG now accepts the HSC Code as an equivalent design to Sub-chapter K vessels, as long as it is adopted in its entirety. In effect, if a design meets the HSC Code, even though it does not meet all of the USCG Sub-chapter K regulations, then the USCG will accept the international standard. At the present time, they have not done this for vessels that fall into the Sub-chapter H category. Because each flag state is responsible for administering the Code, it is subject to varying interpretations. Vessels that ostensibly meet all the Code provisions can still be required to undergo costly modifications before being allowed to operate in certain countries.

New designs of fast ferries demand a different regulatory approach, one that accounts for their lightweight construction and higher speeds. In recognition of the need for lightweight materials to attain high-speed, the HSC Code allows for the use of alternative hull materials such as aluminum and composites as long as the level of safety is comparable to that of conventional ships. In addition to the normal provisions for lifesaving, fire protection, and evacuation, the new regulations place a great deal of emphasis on the reduction of hazardous situations in the first place. These safety concepts were originally reflected in the Code of Safety for Dynamically Supported Craft, which was adopted by the IMO in 1977, as part of the Safety of Life at Sea Convention (SOLAS). The HSC Code was written to build upon this requirement, and applies to any high-speed craft built after January 1, 1996.

An important aspect of the new High-Speed Craft Code is that it recognizes that a vessel's safety can be significantly increased by the infrastructure associated with regular routes. For example, the Code allows for two separate categories based on the route and passenger load. The division for the two categories, A and B, is based primarily on whether or not it can be demonstrated, in the event of an evacuation at any point on the route, that all passengers and crew can be rescued safely within certain time limits. For example, for a Category A vessel with a light passenger load and on a route where rescue assistance is readily available, the safety requirements may be relaxed. With Category B vessels on a route where rescue assistance is not available and the passenger load is high, additional passive and active protections are required. Increased stability and structural integrity are examples of the additional safety mechanisms that would be required for Category B vessels.

Addressing fire safety is a primary concern for regulatory bodies. The HSC Code devotes considerable space to this topic. The SOLAS philosophy pertaining to fire is to provide a safe refuge for those on board while a fire is attacked. This is accomplished with the use of zones protected by fire barriers. The need for zones is treated differently in the HSC Code. Category A vessels are not required to have zones because of their reliance on evacuation and rescue. Category B vessels are required to have at least two zones separated by non-combustible material. Each zone must have its own sprinkler and ventilation system. This is significant from a weight standpoint. Although dry sprinkler systems will meet the HSC, depending on the size of the vessel, dedicated pumps capable of delivering 600 to1000 gpm will add a tremendous amount of weight.

Another major area that the HSC CODE addresses is the training of operators. Each member of the crew is required to be type rated for the specific vessel and route. This is not a requirement of the USCG at this time. The USCG does, however, reserve the right to specify how many crewmembers are on each vessel. This is usually based on vessel type and route.

In December 2000, the Maritime Safety Committee adopted amendments to SOLAS chapter X for new ships. The 2000 HSC Code updates the 1994 HSC Code and will apply to all HSC built after the date of entry into service July 1, 2002. The original Code will continue to apply to existing high-speed craft.

Fast Ferry Wake-Wash Issues

When any vessel operates within a sheltered area, a wave phenomenon occurs that can lead to possible shore erosion or property damage. Vessels operating at high speeds can create waves (or wake) profiles that have different patterns than slower vessels. The energy associated with these wakes is typical of waves with long amplitudes. They can be difficult to see when at sea, but quite obvious when they reach shore. As a long wave approaches shallow water, the wavelength and speed is forced to decrease. The wave height decreases slightly in the intermediate depth zone, but then rises again in shallower water until finally breaking. In this situation, most of the wave energy is transferred to the shoreline and only a little is absorbed by the seabed.

Vessel Generated Wave

High speed vessels moving through the water generate two types of waves, divergent and transverse waves (see Figure 1). Diverging waves move out at a fixed angle from the centerline of travel and have wave periods of 3-5 seconds. They are relatively short and have concave crests. The transverse waves (often called Kelvin wake) move out from the stern perpendicular to the centerline of travel and have wave periods of 8-10 seconds. These long period waves are generally not visible from the vessel because of their low amplitude. Because these waves travel faster and contain more energy than short period waves their effects can be felt a longer distance from the vessel.

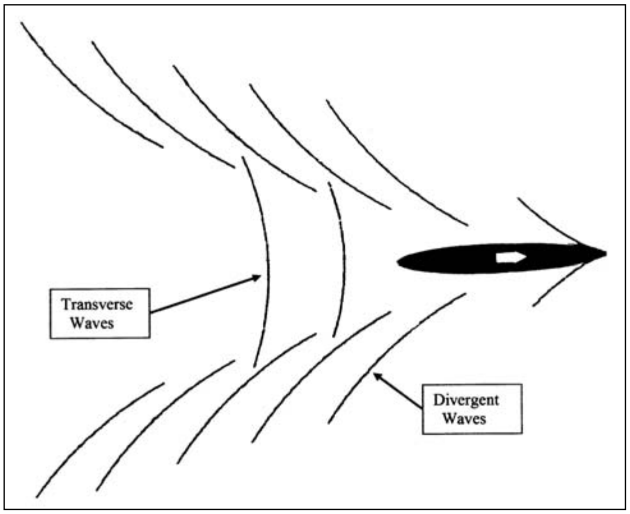
Froude Numbers

In ship design, a commonly used non-dimensional parameter is the ***length Froude number***. This is a ratio that determines the number of waves that are produced along a vessel in deep water and is primarily a function of the vessel length and speed. Another non-dimensional number using the same parameters, but accounting for the depth of the water, is the ***depth Froude number***. The depth Froude number indicates the characteristics of the wave patterns around vessels traveling in shallow waters. For a more complete explanation of Froude numbers, please see appendix A.

Critical Speeds

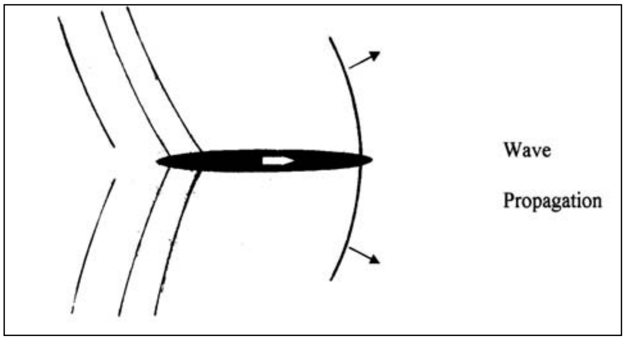
The maximum energy and speed that a wave contains corresponds to a depth Froude number known as critical speed. Critical speed is vessel specific, but is generally considered to be a depth Froude number greater than .8 but less than 1.4. Lower depth Froude numbers correspond to vessel operating speeds in the sub-critical range, and higher numbers are the result of vessels traveling at supercritical speeds. At sub-critical speeds the wake-wash generated by a vessel takes the form of a “V” shape combination of divergent and transverse waves (Figure 5), similar to the wake of a standard monohull at a similar speed. The formation of the divergent waves is a function of the shape of the hull, angle of entry, the vessel speed, and the speed to length ratio. Theses factors are significant in the development of the height and the energy the waves contain, particularly at low and intermediate speeds. At very low speeds the transverse waveform is usually small enough to be considered negligible.

Figure 5
Sub-critical Wave Pattern



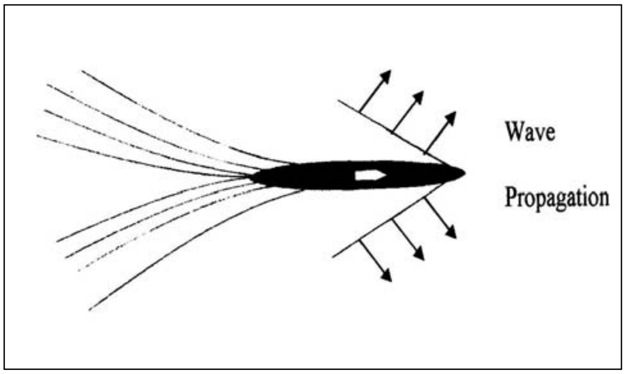
As the vessel approaches hump speed (the transition to critical speed) divergent and transverse waves increase in intensity. At critical speed the divergent and transverse wash wave crests are nearly perpendicular to the ship (Figure 6), and very high energy levels are continually being transmitted to the waves. Because of this, vessels should not operate at critical speeds for extended periods and should pass through critical speed as quickly as possible. Careful consideration should be given to where transitions through the critical speed range take place to avoid damage to beaches and seawalls.

Figure 6
Critical Speed Wave Pattern



Vessels should also avoid maneuvering in the critical speed range. A vessel normally creates more wash during maneuvers compared to running on a straight course. This wash is added to the high energy waves that have already been created at critical speed. Additionally, waves generated while maneuvering propagate in many directions, making prediction on where the bigger waves will reach shore more difficult.

Figure 7
Super Critical Wave Pattern



At supercritical speeds the wake pattern takes on a different character where the transverse waves are on the outside of the wash, traveling at speeds greater than the divergent waves (Figure 7). Because of the high energy levels they contain, and their nearly flat profile these are waves that can surprise people in small craft and on beaches because they arrive well before the visible divergent waves.

Reduced Wake-Wash Vessel Design

Several things can be done to reduce wake-wash or the effects of wake-wash. One is designing vessels for low wake. Some of the design characteristics to be taken into consideration with catamarans:

- Asymmetric demi-hulls
- Choosing suitable displacement distributions
- Increasing hull separations
- Fitting hulls with bulbous bows

In a recent Society of Naval Architects and Marine Engineers (SNAME) presentation, it was suggested that a design goal for low wake-wash should be reduce the hump speed. Since hump speed increases with the waterline length, reducing the waterline along with decreasing demi-hull beam of catamarans would lead to a reduction of both wave height and wave energy density. Reducing vessel length and fitting hulls with bulbous bows are design considerations for monohull vessels which can be used to reduce wake-wash. Such design considerations can make high speed operations possible in sensitive areas, such as in sheltered bays, rivers, and canals.

However, it should be noted that design characteristics that produce low wash profiles may not produce good sea keeping, the best utilization of space, or high transportation efficiency.

Sensitivity Assessment

It is clear that more a powerful wave may be created by fast ferries than by conventional ships, but how much wake-wash is acceptable? The question is further complicated by the fact that no individual situation is like any other. Variations of ship types and operations, seabed bathymetries, sediment compositions, weather conditions, as well as usage near shores, make each situation unique. Effective management of wake requires an understanding of how it creates risk for shoreline property structures, to small boats, to persons on the shoreline, and to the environment. All evaluations should therefore be site specific, risk based assessments of wake-wash effects of a specific hull type rather than generic standards. In certain locations shoreline erosion or disturbances of the sea bottom may be a consideration, and in other locations the effects of wake-wash on bathers, other boats, or shoreline structures may be the issue. To accurately assess the impact of a fast ferry operation, it will be necessary to establish what is at risk and a threshold limit of risk for each of those items. Essentially, this will establish what wake-wash is acceptable when compared to waves from all other sources like weather and other vessels. The wash height and the quantity of energy that is acceptable changes with each geographic area and there can be no one energy level or wave height standard that will fit all conditions.

Fast Ferries Operations Assessment

When new fast ferry operations are being considered, technical experts provided by the operator should meet with local authorities and representatives of the public to discuss the vessel operating profile and the evaluation of different routing alternatives. Local officials should be particularly interested in the wake characteristics of the proposed vessel. The evaluation process should include area sensitivity assessments. Once the sensitive areas have been identified, route economy and operational constraints can be effectively addressed.

Vessel Operational Considerations

If the port has a traffic channel with associated rules, port authorities may have to revaluate the rules to accommodate a fast ferry. One of the most important issues is to establish where critical speed transition is to occur. Critical speed often needs to be passed somewhere near the port. How and where this change takes place makes a tremendous difference. The effects of passing through the critical speed range cannot be fully eliminated, but can be reduced to acceptable levels by using local features such as islands, sandbanks, or deep-water pockets as buffer zones. When vessels are traveling at supercritical speeds, it is important not to drop down to the critical speed range, even for a short while. If traffic indicates that a slowdown is necessary, a first step would be to drop down to a speed just above the lower critical speed range. If lower speeds are indicated, it is better to make a quick deceleration to the sub-critical range. In cases where weather can be a factor or the vessel experiences engine failure, the preferred routing may be impossible or to dangerous too follow. Contingency plans should be available for the vessel crews so that the vessel Captain is not forced to make decisions without having enough background data.

Methods of and Estimated Costs for Assessments

There are two separate issues that have to be accounted for when evaluating the effects of wake/wash: vessel specific data and area sensitivity. Simple sensitivity assessments can be done using volunteer labor by recording beach under various "acceptable" wave conditions, and using those observations to establish threshold limits for vessel operations. More detailed assessments would likely require the services of a consultant, with costs starting near $10,000.

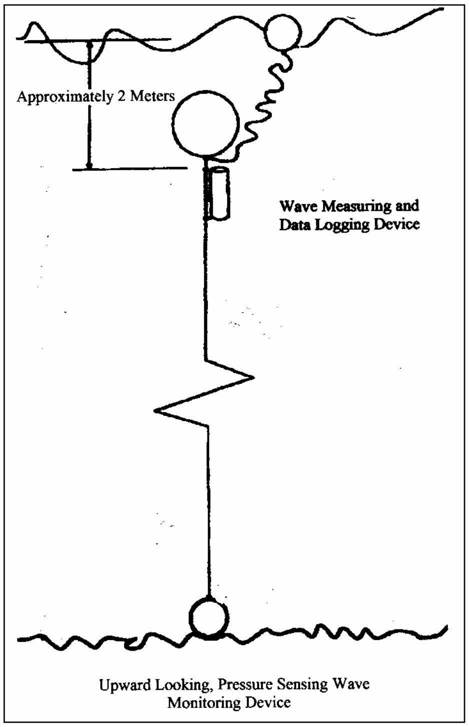
Vessel operators should be required to demonstrate that a proposed vessel and operational technique can meet the established threshold requirements. Any vessel can meet these requirements by reducing the vessel speed to no-wake conditions. However, at lower speeds it is unlikely that the operation would be profitable. A complete site evaluation should establish the maximum wake-wash acceptable for a specific site; what is acceptable under what conditions. At a minimum a site consultant would need the following data about the vessel in order to establish the risk free vessel speed:

- Wake-wash height at various speeds and distances from the centerline of vessel travel.

- Wake-wash energy density at each speed and distance.

Some of the information can be extracted from tank test data, especially when talking about deep water applications. In shallow water conditions, the evaluations would normally have to be done at the site. The wake-wash parameters could be measured both visually using anchored poles and a stop watch, and graphically using submerged pressure sensors plotting data (wave energy) against time. Figure 7 shows an arrangement of an upward looking pressure sensing device that can be used to gather the necessary data. If seasonal adjusted data is needed, then the cost of the evaluation would be adjusted accordingly.

Figure 7



Upward Looking, Pressure Sensing Wave Monitoring Device

Predicting a hull's performance in terms of wake-wash is paramount for a complete assessment. A vessels wave pattern can be calculated using standard ship wave theory and should be available from the vessel's manufacturer. Predicting the wave height, length, and energy contained is more difficult, largely because of the varying environmental conditions that can be encountered. The depth of the water, the type of bottom (hard or soft), and the slope of the sea bed toward shore are all factors to be accounted for. Simple vessel data that involves recording wave height and periods can be done with a yard stick and stop watch for negligible costs. Industry standard pricing for hull evaluation would start near $10,000, with more complex evaluations in which the hull is modeled and tank tested starting near $50,000. It should be noted that tank testing data is often available from vessel owner/manufacturer.

Appendix C contains a list of local and national companies that can do either hull evaluations or shoreline impact studies.

Conclusion

Based on the information presented in this report we expect catamarans will probably be seen in operation on the coast of Maine. Optimally, this hull form would be coupled with a gas turbine engine and water jet propulsors. Water jets are highly maneuverable and are the best solution for low draft situations. The gas turbine is quieter and produces a more environmentally friendly exhaust than the diesel.

It is unlikely that an operator will have vessels designed and built specifically to run on the coast of Maine, so it is possible that any of the hull designs and drive combinations discussed in this report could be seen. The vessel operators should be required to demonstrate that any proposed vessel can be operated safely and within established threshold limits for the protection of manmade shoreline structures and the environment.

Appendix A

Froude Number

The depth Froude number is given by the formula $F_{nL}=v/(g*L)^{0.5}$. This ratio is derived from deep water wave theory, and will indicate the wave characteristics around a vessel traveling in deep water at different speeds. V is the speed of the ship, g is a gravitational constant and L is the length of the ship in water. By exchanging the length of the vessel with the depth of the water, $F_{nL}=v/(g*d)^{0.5}$, the same ratio will indicate the characteristics of wave patterns around ships traveling in shallow waters. The maximum speed of a free harmonic wave corresponds to a depth Froude number and is know as the critical speed. The critical speed is always vessel specific but generally falls into the following range, $0.8<F_{nL}<1.4$. Lower values of the depth Froude numbers are called sub-critical speed, and higher are called supercritical.

Appendix B

Glossary of Terms

Critical Speed-	The speed at which maximum energy is being transmitted to the waves being produced. Generally considered to be vessel speeds that produce Froude numbers greater than .8 but less than 1.4
Depth Froude no.-	A different non-dimensional number that is used determine the characteristics of waves in shallow water.
Froude number-	A non-dimensional number that is used to determine the number and type of waves that will be produced along the side of vessels in deep water.
Period-	The time it takes two successive waves to pass a given point
Sub-critical Speed-	Vessel speeds that produce Froude numbers less than .8
Super-critical Speed-	Vessel speeds that produce Froude numbers greater than 1.4
Wake -	A disturbed column of water around and behind a vessel as it makes its way through the water. It would include all the different types of waves.
Wash-	A specific component of wake consisting of loose and broken water. It includes water thrown by the propulsion and waves that roll of the side of the vessel in a turbulent manner.
Wave Height-	Height of the wave from the crest to the trough
Wavelength-	Length of the wave from one point to the same point on the next wave.
Period-	The time it takes two successive waves to pass a given point

Appendix C

John J. McMullen Associates, Inc., Engineering and Management Services
Bath, Maine (207) 442-7773 Contact- Leroy Fournier

Epsilon Associates, Inc, Environmental Engineers, Maynard, MA.
(978) 897-7100 Contact- Les Smith

Hartman and Associates, Inc., Environmental Engineers, Orlando, Florida
(407) 839-3955 Contact- Jill Manning

Baker Engineering, Yarmouth, Maine (207) 846-9724 Contact- B. Baker

Normandeau Associates, Yarmouth, Maine (207) 846-3598 Contact- Marcia Bowen

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