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DYNAMIC POSITIONING CONFERENCE

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Thrusters

Voith Schneider Propeller - An Efficient Propulsion System for DP Controlled Vessels

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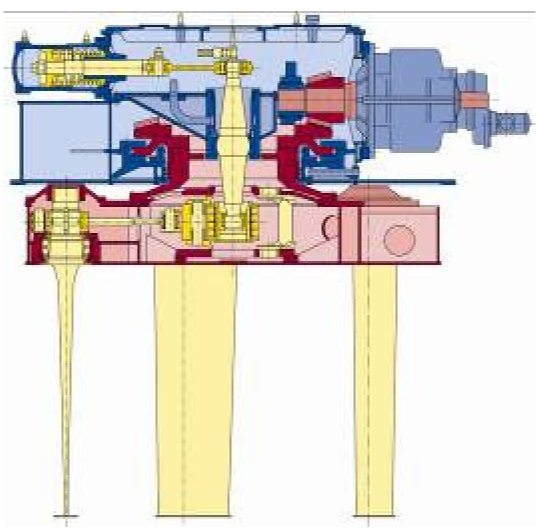
1. Introduction

The Voith Schneider Propeller (VSP) offers a very fast and precise thrust control. The thrust is produced by rotating and additionally oscillating blades. The thrust is controlled by means of a kinematic gear and a control rod. The thrust follows the motion of the control rod immediately via an X/Y-logic. That means, the thrust can “over zero” steered in any direction very fast. The very fast and precise thrust control offers an efficient force for the DP-system of the ship.
The faster the propulsion system can counteract a disturbance created by environmental forces the less energy is necessary to keep the vessel in the relevant watch circle.
The paper will present the latest results of studies on the Voith Schneider Propeller in dynamic positioning applications. These investigations have been carried out by using experimental methods and computational fluid dynamics. Studies were conducted on the influence of the Voith Schneider Propeller on stern slamming conditions, the roll damping capabilities of the VSP and the impact of air ventilation. For the latter the results are compared to azimuth thrusters.
The results show that the VSP has an alliviating impact on pressure loads due to stern slamming.
The VSP influences positively the slamming behaviour of a vessel because of its vertical rotating axis. Furthermore the VSP is less prone to thrust losses due to ventilation effects compared to thruster- type propellers. Additionally the Voith Schneider Propeller can be used to reduce the roll motion of the vessel. The necessary logic, called Voith Roll Stabilization, can be combined with the DP system of the vessel and the steering system, including the auto pilot.

1. The technical and hydrodynamical principle of the VSP

For a better understanding of the later presented hydrodynamical investigations, a short explanation of the technical principle of the VSP is required. A detailed description about the technology and theory can be found in [1] - [7].

The thrust of a VSP can be applied via a very fast X/Y-logic. Figure 1 shows the sectional drawing of a VSP and figure 2 the installation of two VSPs in a Offshore Support Vessel.



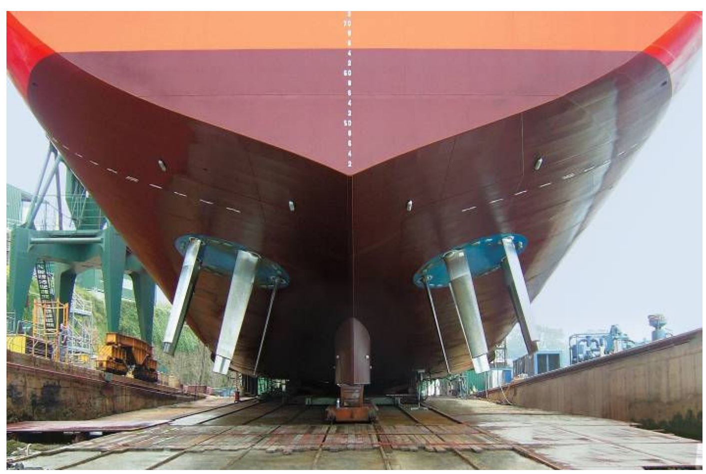
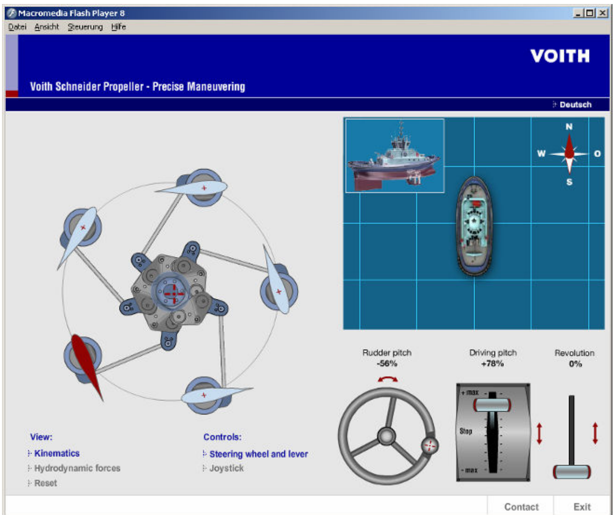


Fig.1 Sectional drawing of a VSP **Fig. 2 Two VSP installed in a Offshore Support Vessel**

The thrust is created by vertically mounted blades in a rotor casing. While the rotor casing is rotating, the blades are oscillating. The blades oscillation is steered by the law of intersecting normals. Figure 3 shows the mechanical principle of the VSP and figure 4 the corresponding hydrodynamic thrust creation. A descriptive simulation program showing the technology of the VSP and the hydrodynamics can be downloaded at www.voithturbo.com/marine.



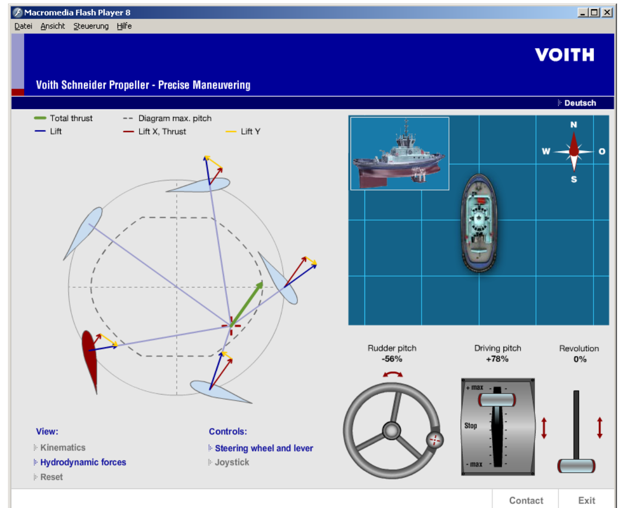


Fig. 3 Mechanical principle of the VSP **Fig. 4 Hydrodynamic principle of the VSP**

Fig. 5 shows the forces acting at the propeller for selected blade positions as a function of the cycloid path for a stationary observer. Lift changes during revolution due to the nonstationary flow at the propeller blades. The forces acting across the desired direction of thrust cancel each other, whereas the forces acting in thrust direction are added over the propeller circumference.

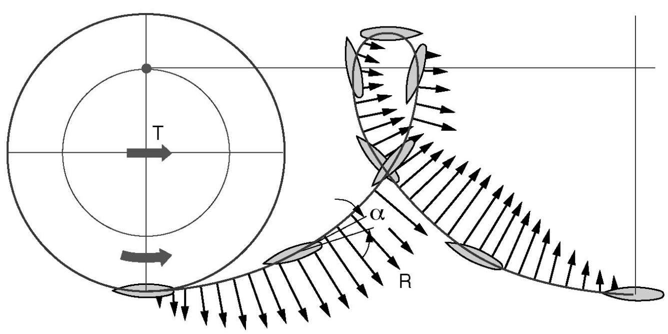


Fig. 5 Lift generation on a blade as a function of the cycloidal blade path

The thrust of the Voith Schneider Propeller can be adjusted in an ideal way by the X/Y-logic. Figure 7 explains this by some examples. The thrust can be steered extremely fast. From full ahead to full astern, a size VSP 36R5/300-2 (3800 kW input power) achieves this in 5 seconds.
A different thrust value in longitudinal and transversal direction is just achieved by changing the amplitude and the phase angle of the oscillation blade of the VSP. This is done by moving the steering point via the kinematic that is shown in figure 1 and figure 3.

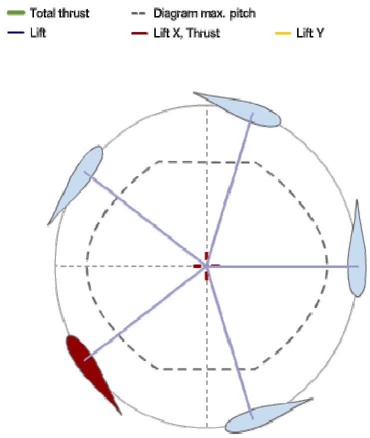


Fig. 7.1: No thrust demand from the DP system

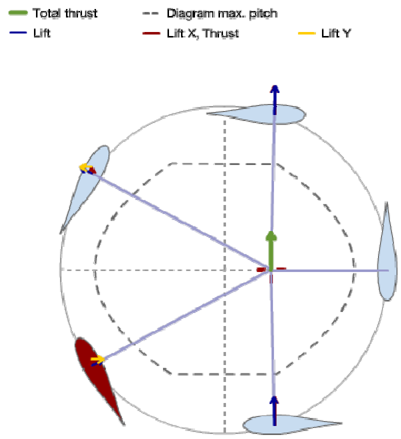


Fig. 7.2: 39% Thrust demand (ahead)

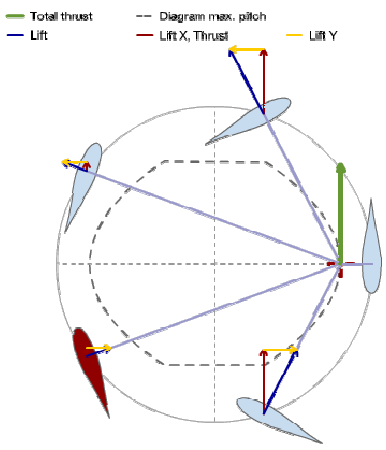


Fig. 7.3: 100% Thrust demand (ahead)

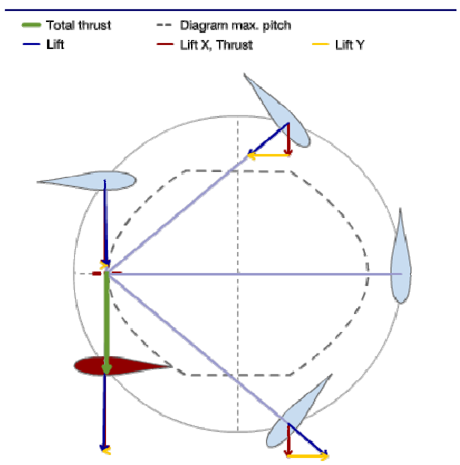


Fig. 7.4: 100% Thrust demand (astern)

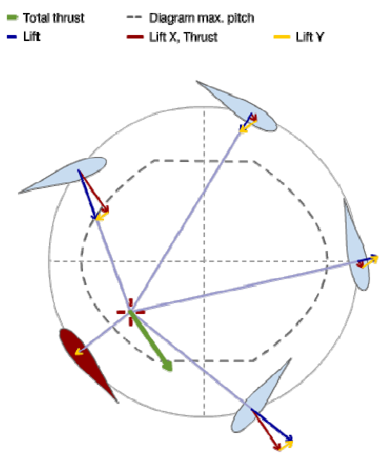


Fig. 7.5: 58% Thrust demand (astern); 41% thrust demand (port)

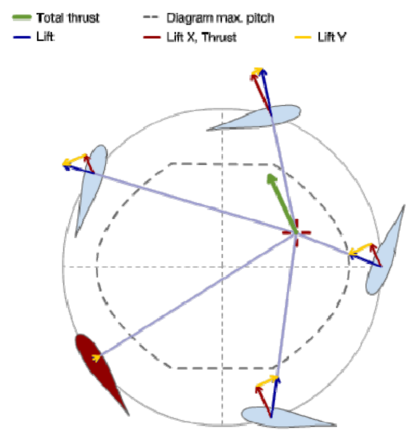


Fig. 7.6: 57% Thrust demand (ahead); 27% thrust demand (starboard)

The VSP offers a high efficiency for a steerable thruster. The reasons for that is the high aspect ratio of the blades; and that only the thrust producing blades are protruding outside the ship's hull. The free running curves of a VSP without propeller guard are shown in Fig. 8. The influence of the pitch is clearly visible and works similar to a normal controllable pitch screw propeller. The higher the pitch the higher is the maximum achievable efficiency.

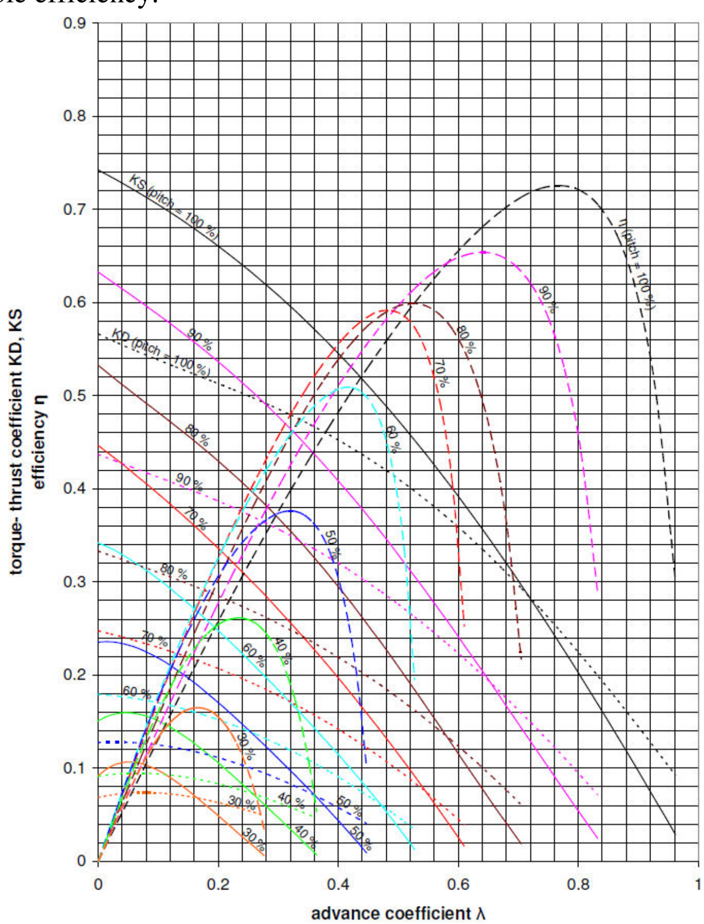


Fig. 8: Typical free running curves of a VSP

The definition of the coefficients for a VSP can be found in the following table. Voith is using a system that differs by constant factors from the coefficients known from the screw propeller theory.

	Voith definition	Coefficients by analogy with screw propellers	Conversion
Advance ratio	$\lambda = \frac{V_A}{\pi n D}$	$J = \frac{V_A}{nD}$	$J = \lambda\pi$
Thrust coefficient	$k_S = \frac{T}{\frac{\rho}{2} D L u^2}$	$k_T = \frac{T}{\rho n^2 D^3 L}$	$k_T = k_S \frac{\pi^2}{2}$
Torque coefficient	$k_D = \frac{2M}{\frac{\rho}{2} D^2 L u^2}$	$k_Q = \frac{M}{\rho n^2 D^4 L}$	$k_Q = k_D \frac{\pi^2}{4}$
Open-water efficiency ratio	$\eta_0 = \frac{k_S}{k_D} \lambda$	$\eta_0 = \frac{k_T}{k_Q} \frac{J}{2\pi}$	-
Peripheral velocity of VSP blades: $u = \pi n D$			

Table 1: Hydrodynamic coefficients for the VSP

The forces in longitudinal and transversal direction of a VSP which can be achieved for different thrust and speed directions are plotted in fig. 9. Obviously the forward thrust is reduced with increasing speed but the steering forces are clearly growing with a higher speed.

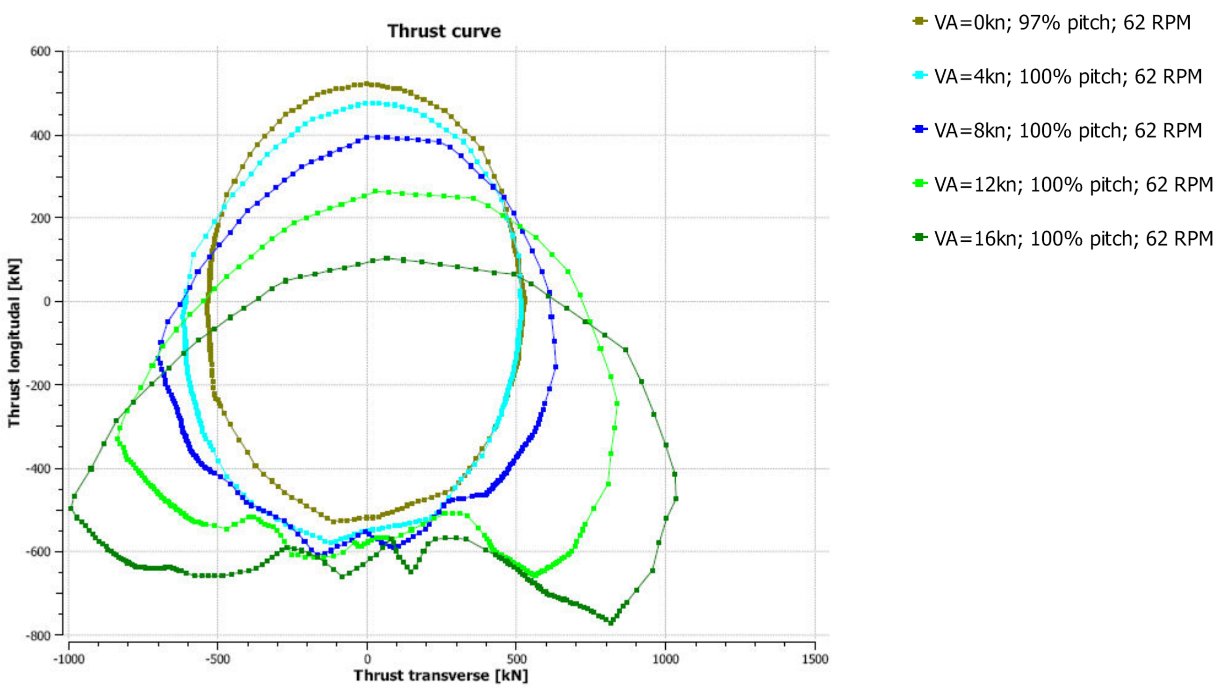


Fig. 9: Typical thrust plot for different speeds; VSP 36R6/300-2 (3800 kW Input Power)

2. Reduction of slamming induced pressures by the VSP

A vessel under DP conditions can be faced the situation that waves are creating servere slamming. Figure 10 shows an OSV (LOA 90m), propelled by two VSPs, which was tested in the Ship Model Basin Vienna in maximum wave heights of 8 m.

Fig. 10: Testing of stern slamming for a OSV under DP conditions

Fig. 11 and 12 illustrate the positions of the sensors to measure the slamming pressure. The sensors were positioned near the VSPs and at the transom. The numbering of the sensors can be found in fig. 12.

Fig. 11: Ship model and position of the pressure sensors

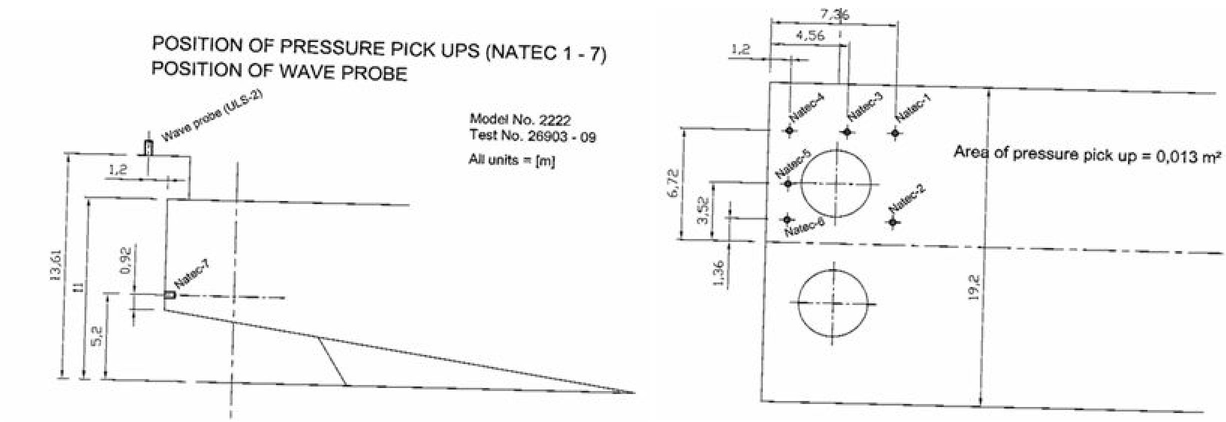


Fig. 12: Numbering of the pressure sensors

The measurements have shown a very interesting effect. Even if the VSP does not produce any thrust, that means it works with zero pitch and a constant rpm, there is a clear reduction of the the slamming pressures. Fig. 13 explains this clearly. There the maximum slamming pressure in kPa is shown for the individual measuring points as defined in fig. 12. The measurements have been done for a still standing VSP (VSP off) and the running VSP with zero pitch (VSP on). In the second case, no thrust has been produced. Especially the pressure sensors positioned near the VSP (Nr. 5, 6 and 7) recorded a remarkable reduction.

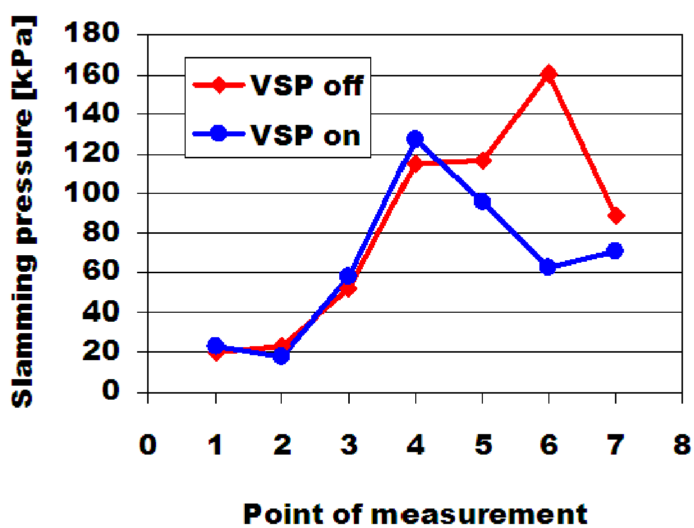


Fig. 13: Maximum slamming pressure at the measuring points defined in fig. 12, significant wave height Hs = 4.0m, draught of the vessel = 5.2 m

Fig. 14 illustrates also the influence of the running VSPs. There the number of slams occurring in 30 minutes for the measuring points Nr. 4, 5,6 and 7 for a significant wave height of Hs = 4.0 m are shown. The measurements have been carried out for a working VSP with zero pitch and a still standing VSP. Besides the maximal amplitude also the frequency of occurance of slamming impacts is reduced by the presence of the Voith Schneider Propeller.

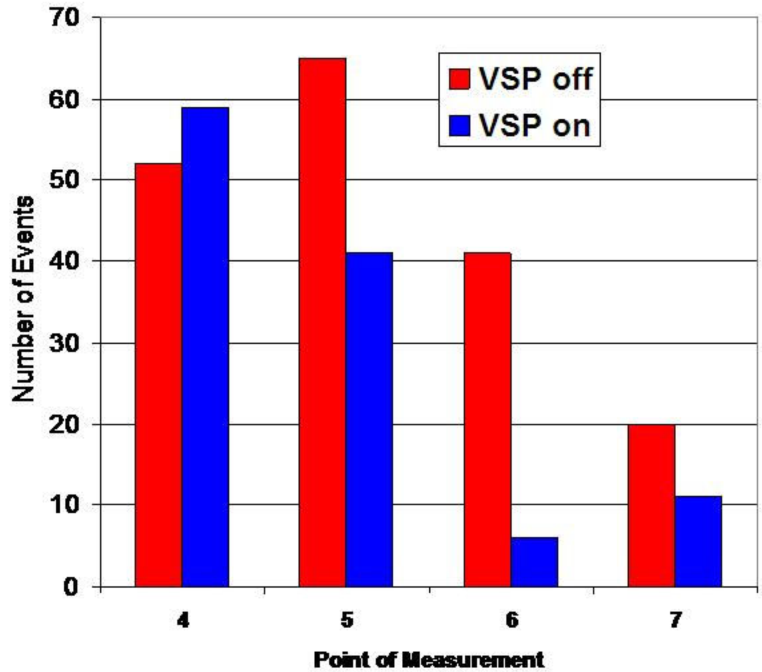


Fig. 14: Number of slams in 30 minutes at the measuring points defined in fig. 12, significant wave height Hs = 4.0m, draught of the vessel = 5.2

3. Influence of ventilation on propeller thrust

Large vertical ship motions induced by waves could expose the propulsion unit to the danger of ventilation. In this case entrapped air might reach the propeller plane or in extreme cases the propellers emerge at least partly from the water. This phenomenon has a significant influence on the propeller performance. Massive sudden breakdown of thrust and torque are the consequences while the strong fluctuation of the latter is believed to be responsible for potential mechanical failures of power transmission components. To study the influence of ventilation many investigations on thrusters [8-13] have been carried out.
Fig. 14 shows that the phenomenon of ventilation on a thruster at zero advance speed even occurs if the thruster is fully submerged.

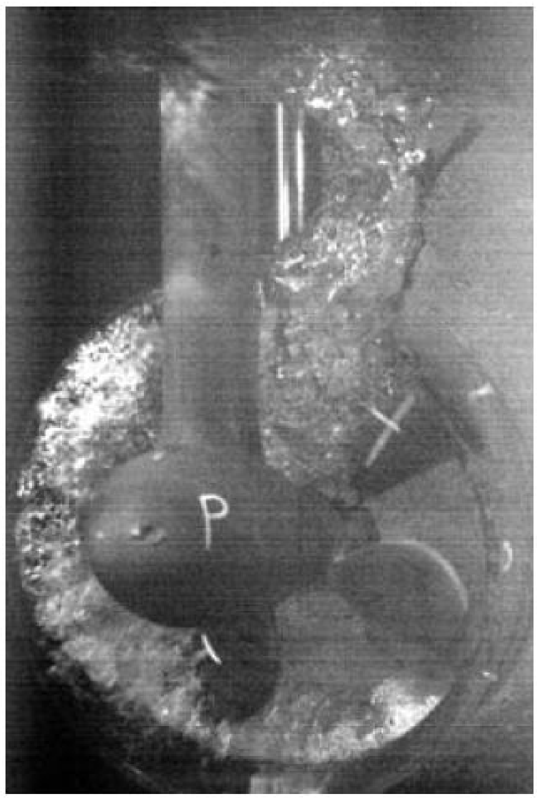


Fig. 14: Thruster in ventilating conditions at zero advance speed (photo taken from [10])

Within an experimental and numerical study Voith tested the impact of ventilation on the thrust of their two propeller types, namely the Voith Schneider Propeller and the thruster-type Voith Radial Propeller.
The diameter of the VSP was 200mm and the blade length was 150mm while the propeller diameter of the VRP was 210mm. Both propellers were adjusted to deliver the same thrust in full submerged conditions. The thrust and torque was measured for both propellers while emerging both units in discrete steps.
Fig. 15 and 16 show the model test arrangement for both propeller variants. In Fig. 18 the relative thrust compared to the full submerged conditions are shown. The values are shown as a function of h/d (defined in Fig. 17).
The Voith-Schneider-Propeller is less influenced by ventilation effects. The thrust for the VSP decreases more gradually with the emerging propeller while the thruster experiences a massive thrust reduction even before the propeller blades start to emerge.

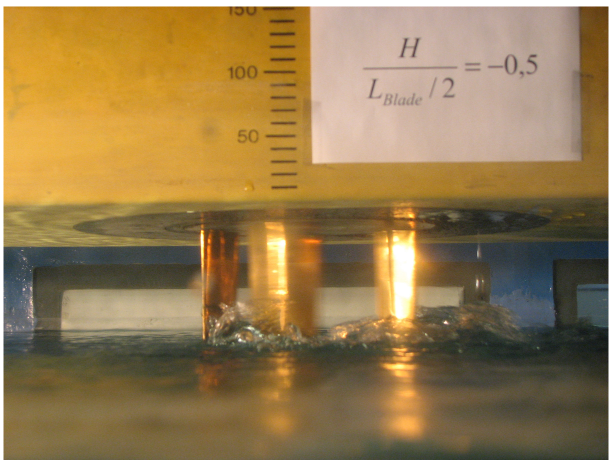


Fig. 15: VSP at h/d=0.5

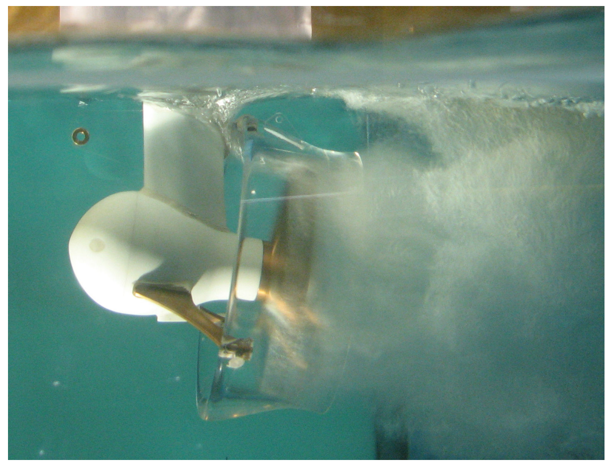


Fig. 16: VRP at h/d=0.04

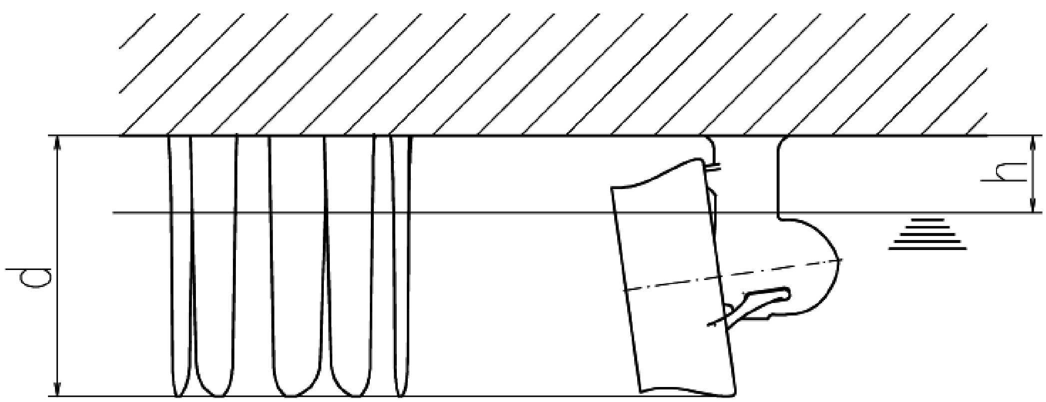


Fig. 17: Definition of the level of submergence h/d

To gain more insight into the flow phenomena CFD (Computational Fluid Dynamics) calculations have been carried out as well. A RANSE-solver with the finite volume approach is used for this study. The phase front of the flow is captured with the volume-of-fluid method. Fig. 19 and 20 show the free surface and the pressure distribution for the VSP and the VRP variant.

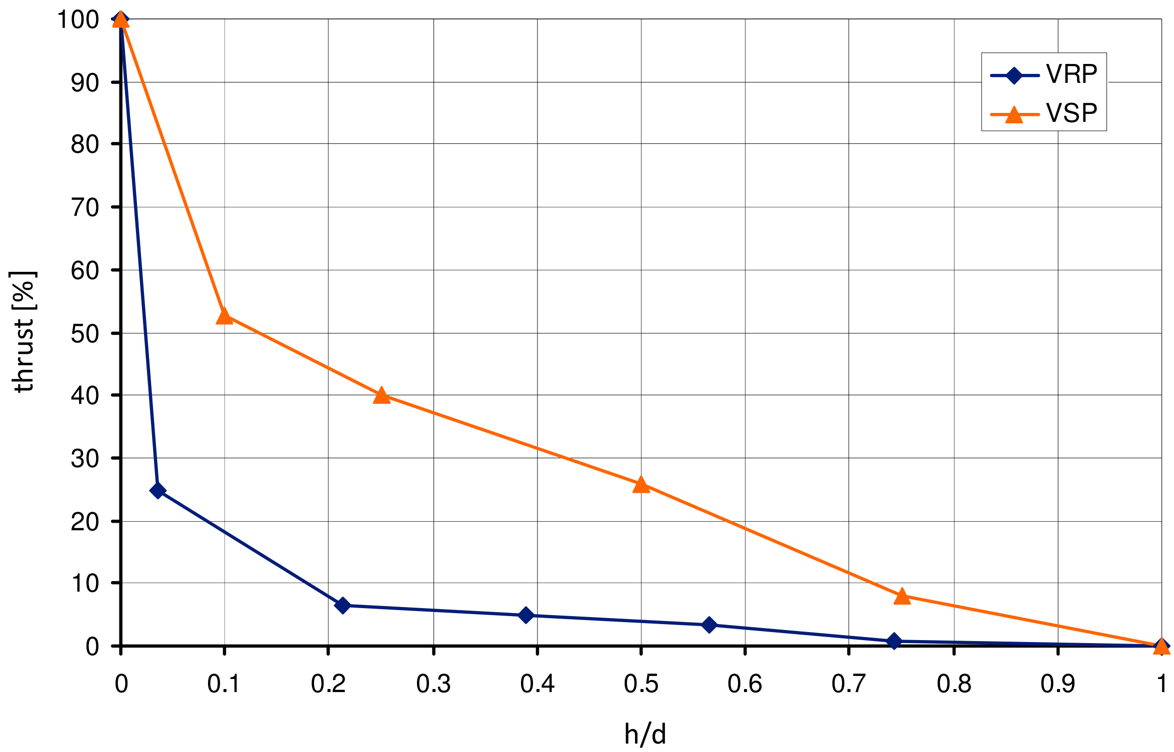


Fig. 18: thrust losses as a function of propeller immersion at equal nominal thrust

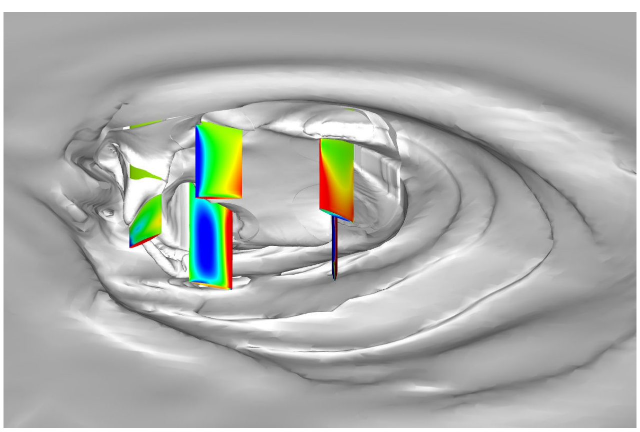


Fig. 19: CFD result for the VSP at h/d=0.5

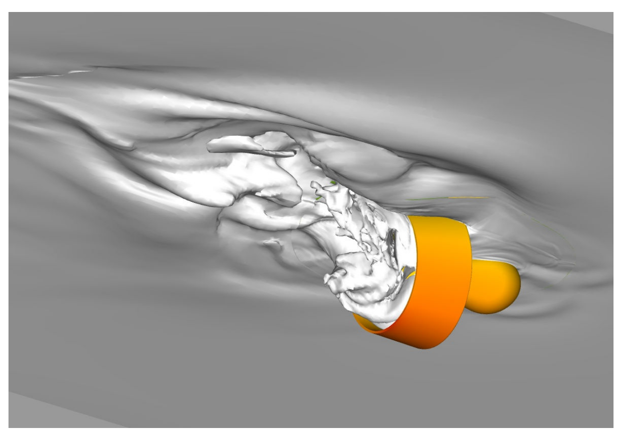


Fig. 20: CFD result for the VRP at h/d=0.5

In Fig.21 and 22 the quantitive comparison between calculation and experiments are depicted. These first results show that the general behaviour in ventilating conditions of the different propulsion systems is quite well predicted. Since the CFD calculation have been conducted prior to the model tests, the comparison between CFD and model test was done at a smaller rpm than the one in Fig. 18, where the same thrust of both propulsion systems was adjusted. The studies are currently evaluated in detail to better understand the effect of ventilation on propeller performance.

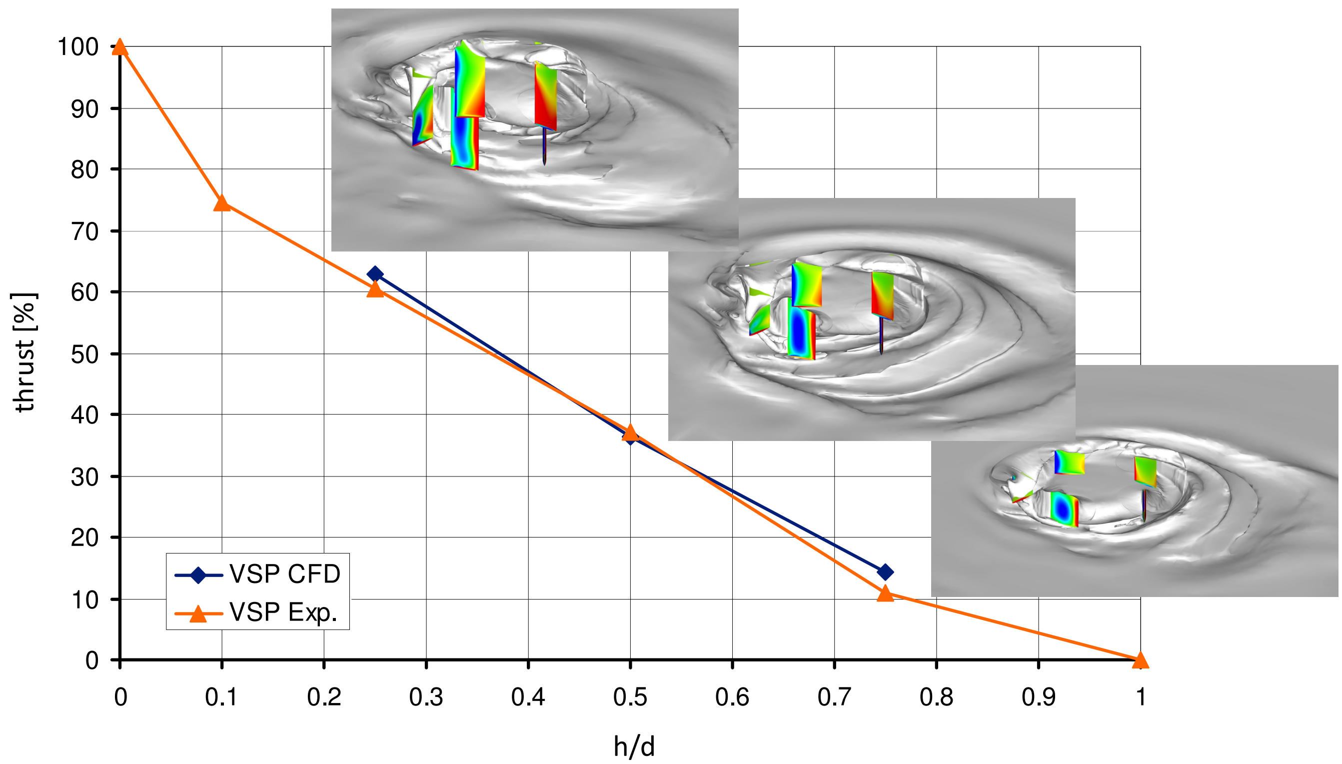


Fig. 21: Experimental and computational results for thrust reduction of the VSP at n=210rpm

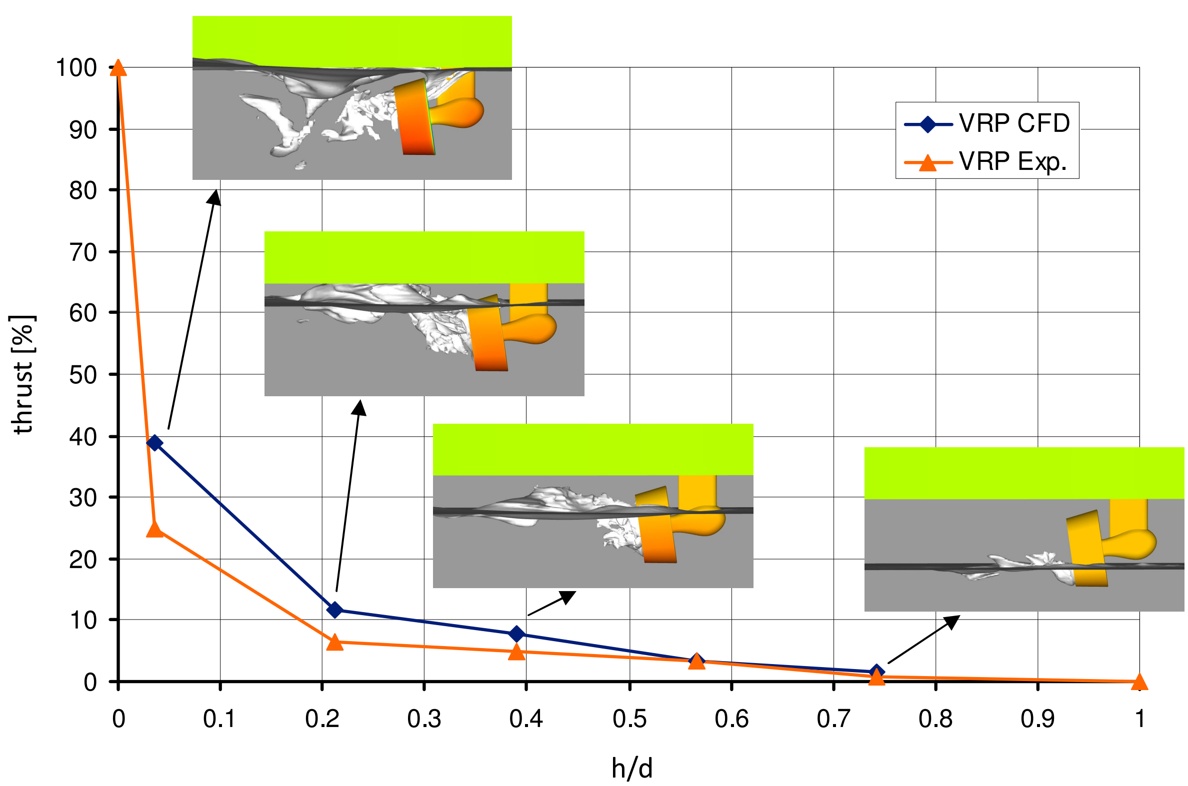


Fig. 22: Experimental and computational results for thrust reduction of the VRP

4. Active Roll Damping with Voith-Schneider-Propellers

Large roll amplitudes in high sea states could negatively affect the operability of duties and crews comfort and safety what on the other hand might lead to larger downtimes of the ship operations. To counteract the roll motions several active and passive systems with different degree of effect are widely used.
The VSP characteristic allowing fast and stepless control of thrust in magnitude and direction has led to a further functionality besides propulsion and steering. With minor scope of electronic components the Voith-Schneider-Propeller can additionally be used as an active roll stabilizer.

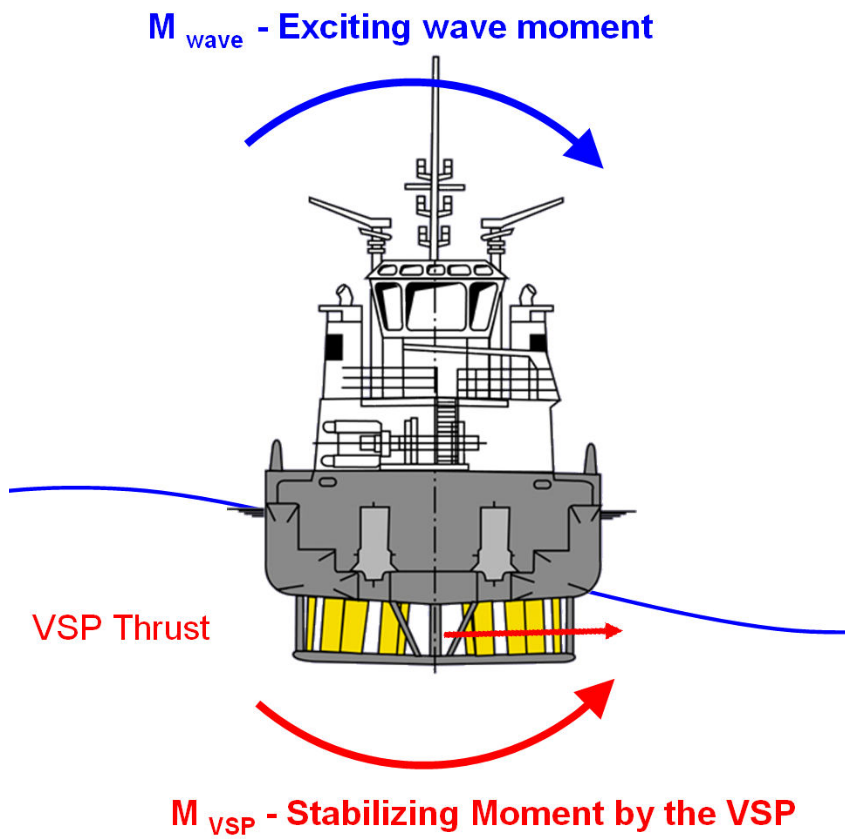


Fig. 23: Roll counteracting forces of the VSP

Fig. 23 shows the basic principle of roll stabilisation with VSP. The moment that initiates the roll motion is partly equalized by the transversal thrust of the VSP. Since the thrust magnitude of the VSP is equal in all directions for zero advance speed a counteracting moment can be generated by applying.side forces. This principle holds for cruising speeds as well, as steering forces can be generated very fast due to the x/y-steering logic of the VSP. Fig. 9 gave an idea about the transversal forces for different ship speeds.
To quantify the roll damping capability a test series with a 44m motor yacht have been carried out in a ship model basin. Fig. 24 shows the model test arrangement. The tests were conducted at zero advance speed at bow-quartering waves with a significant height of 1.5m and a peak period of 5 sec.
In Fig. 25 the time response of the roll angle with and without active Voith Roll Stabilisation (VRS) is shown. In this case a roll reduction of 64.9% was achieved. Within the test programme also alternative systems for roll damping namely passive fins and active zero speed fins have been tested. In Fig. 26 the significant roll angles for the different variants can be seen.
The “VRS OFF” mode means that the propellers are rotating at zero pitch. In this case the VSPs are acting as an passive roll damping systems and reduce the roll angle by a similar amount as the passive

fins do. In the “VRS ON” mode the Voith-Schneider-Propellers generate alternating side forces to counteract the roll motion with the effect already shown in Fig. 25. Currently the Voith-Roll-Stabilsation is implemented successfully on different offshore support vessels.

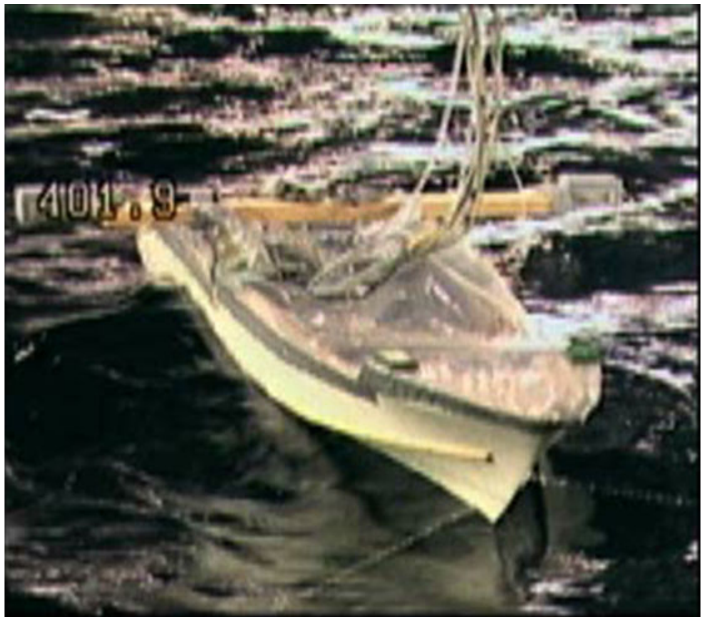


Fig. 24: setup for roll damping test of a 44m yacht

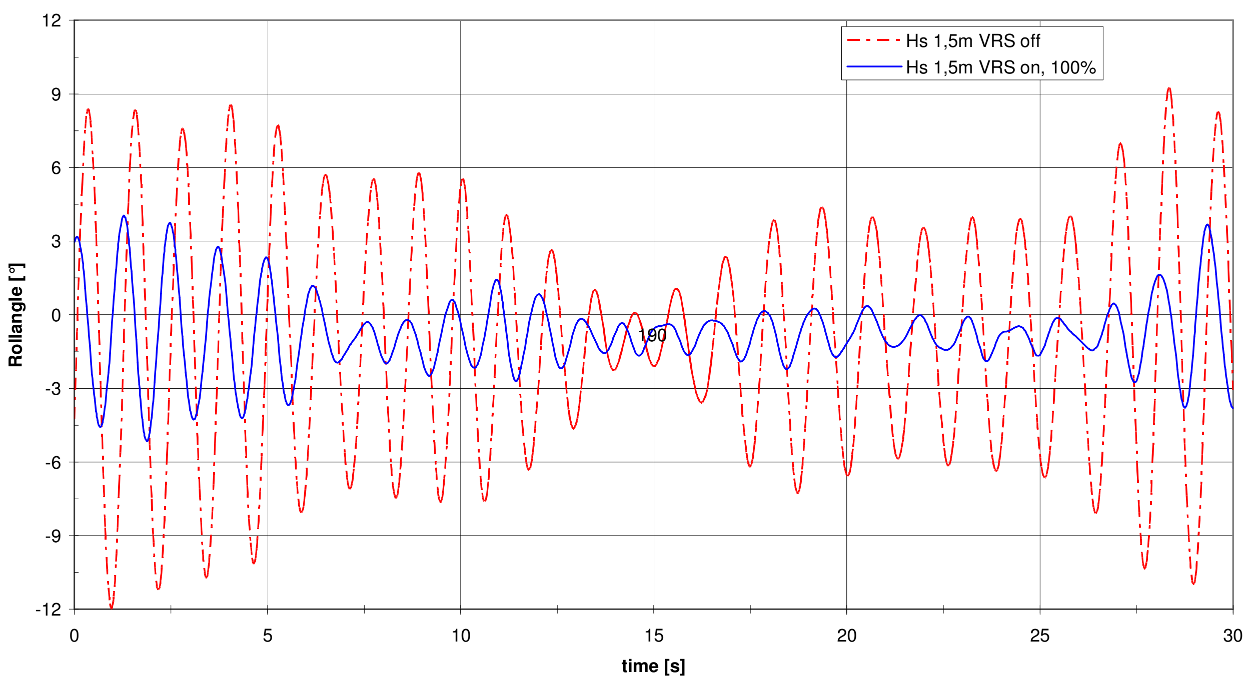


Fig. 25: model tests results on a 40m motor yacht with bow quartering waves at a significant heigth of 1.5m

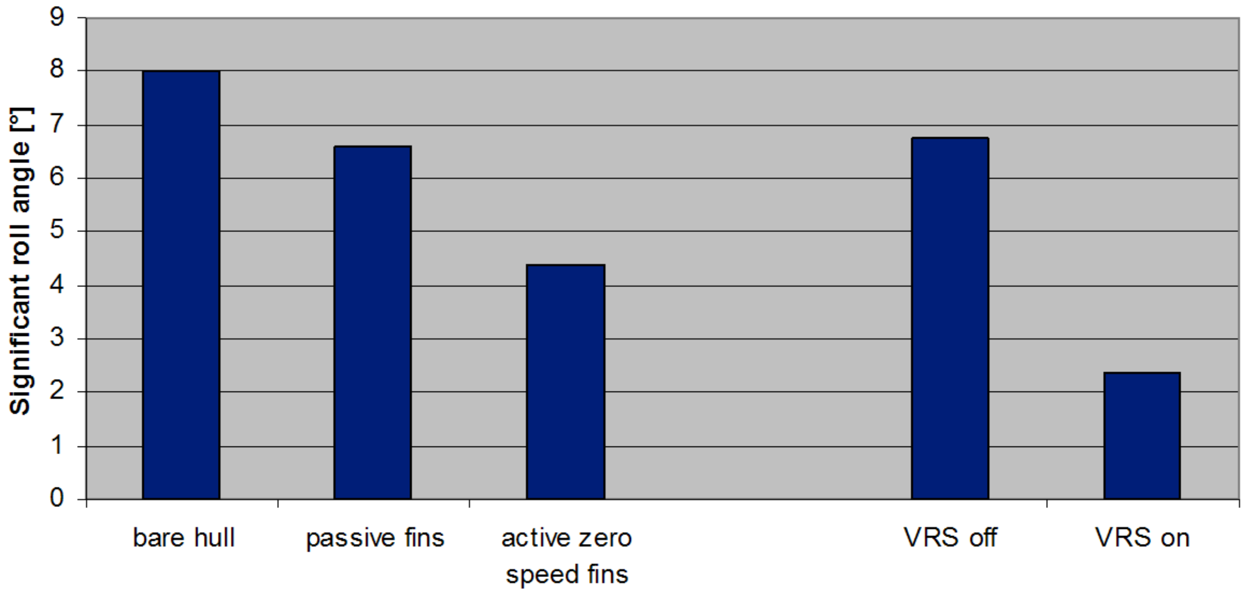


Fig. 26: roll angle for different roll damping systems on a 44m yacht

4. Conclusions

The basic principle of the Voith-Schneider-Propeller providing a controllable pitch characteristic and very fast and precise steering capabilities makes the system an efficient option for ships that have high demands on dynamic positioning performance.

Three physical phenomena that can have a large impact on dynamic positioning applications have been investigated with relation to the Voith-Schneider-Propeller. It was shown that the VSP has an alleviating impact on the pressure loads due to stern slamming. It is furthermore less prone to ventilation losses compared to azimuth thrusters. And finally the VSP provides besides propulsion and steering an effective functionality for roll damping.

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