HSVA
NewsWave

The Hamburg Ship Model Basin Newsletter 2005/2

Mega Yachts

Mega Yachts represent a niche within the shipbuilding industry. All Mega Yachts have in common their tailor made design not only with regard to the interior, but also to its passenger/crew ratio, which is well above one. The complexity of their designs makes them comparable to naval and cruise vessels. Generally the vessels have in common demanding requirements on hydrostatic and hydrodynamic performance, the structural design and the development of special features with emphasis mainly on low noise and less vibrations at any speed.

Therefore extensive tank tests are required to optimize the underwater hull form for low resistance over a large speed range and good seakeeping behaviour. With regard to the propulsion system, one has to select between fixed pitch or controllable pitch propellers in twin or triple screw arrangement, Z-drives, podded drives, waterjets or more and more common, different combinations of these propulsors.

HSVA worked with every generation of Yachts and Mega Yachts and accumulated a vast amount of experience regarding the complex hydrodynamic questions.

HSVA will continue to work with yards and owners on the development of new, even bigger and more comfortable vessels and on new technologies in this innovative and high profile market section.

Jürgen Friesch, Managing Director

HSVA bids FAREWELL to Dr. Gerhard Jensen

HSVA would like to wish a fond farewell to Dr. Gerhard Jensen, who took on a new assignment as Managing Director at Schottel GmbH & Co. KG, the famous manufacturer of propulsion systems, etc. in Spay, Germany.

During the last 18 months, Dr. Jensen was acting part time for HSVA, parallel to his work as professor at the Technical University of Hamburg-Harburg.

I would like to give my warmest thank to Dr. Jensen for his devotion to his task here at HSVA, helping us to come through heavy waters in 2004. Again, as during his first engagement at HSVA, Dr. Jensen has left his mark.

I wish him all the best for his future.

Jürgen Friesch

MEGAYACHTS AT HSVA

by Friedrich Mewis

Engineering, consulting and model testing for large yachts has been an important part of HSVA's business for the last few decades.

Since 1985 HSVA has grown to be the leading model basin for hydrodynamic testing of megayachts. A survey yields that most of the worlds' 20 largest yachts built since 1985 were investigated at HSVA, and indeed all of the megayachts exceeding 100 m in length were tested in our facilities.

Our colleague Mr. Manfred Fritsch, who worked at HSVA from 1962 to 2003, played a major roll in this development.

Manfred Fritsch (retired)

Towards the end of Mr. Fritsch's career at HSVA he worked closely together with Mr. Alexander Mrugowski (see "Member of Staff" in this issue) who was appointed to succeed him as Project Manager. Mr. Fritsch is still active as an advisor to HSVA in his special areas of expertise.

The worlds largest private yacht OCTOPUS was built by the Fr. Lürssen Werft in Bremen and was handed over to her owner in 2003. The hydrodynamic properties of this vessel including resistance, propulsion, cavitation, manoeuvring and seakeeping have been investigated and optimised extensive by HSVA using advanced CFD- and model testing methods. The investigations also considered handling of the yachts' tender in waves. In co-operation with the Technical University Hamburg-Harburg (TUHH), wind tunnel tests were performed in order to optimise the superstructure and the funnel.

The OCTOPUS is 126.2 m long and has numerous very special features including its own marina in the stern which can accommodate a 20 m tender boat as well as a submarine.

Just like commercial vessels it is common practice to optimise the ship lines and propulsors of megayachts for high efficiency and low required power, although the speed of these vessels is usually less than 25 knots. It is often of even more importance however that certain comfort criteria are met regarding noise, vibrations and ship motions both underway and at rest. Additional factors of importance are for instance

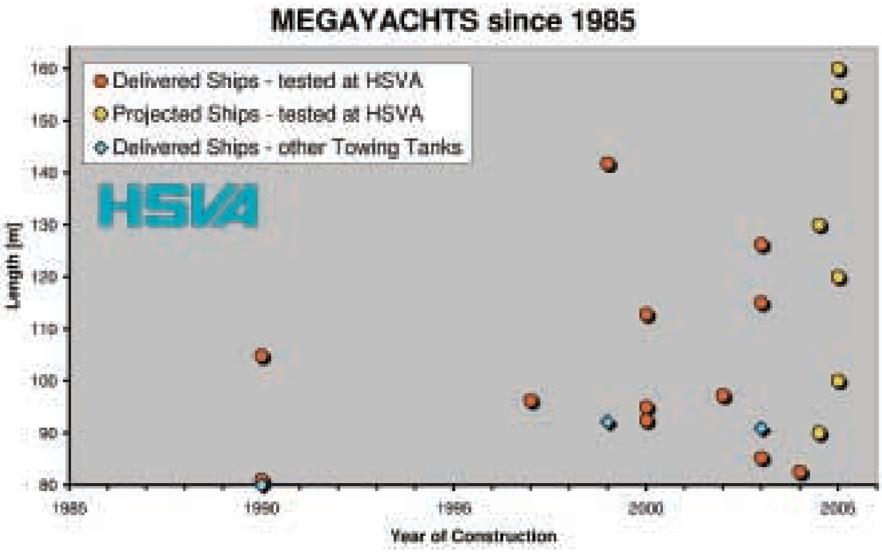


Fig. 1 Length of megayachts

Fig. 2 OCTOPUS model in the wind tunnel

funnel smoke propagation and wind turbulence, which are investigated with the help of wind tunnel tests.

HSVA's experienced staff, well equipped facilities and advanced design tools provide an excellent platform for hydrodynamic developments of megayachts. This infrastructure is well appreciated by shipyards and design offices involved in megayacht engineering and designing.

Almost all megayachts are twin screw vessels. Recent developments in megayacht propulsion also consider highly sophisticated innovative propulsion solutions for better manoeuvrability and low speed performance.

The trend to larger megayachts seems to be unbroken. Megayachts are not just large yachts, they are “real” ships with all consequences for shipyards, naval architects and engineers involved in their design.

Fig. 3 OCTOPUS

Fig 1: Artist's impression of a motor yacht with two sets of stabilising fins.

Seakeeping Studies for Exceptional Passenger Comfort

On Motion Damping Systems for Ship's at Anchor

by Kay-Enno Brink

Motion Damping Systems for ship's at anchor have recently become a very popular feature of large and luxurious motor yachts. Thereby the reduction of undesirable roll motions is the main request of the demanding ship owners which want to enjoy a comfortable time when lying at anchor. Over the past month HSVA conducted several extensive seakeeping investigations for different motor yacht projects which featured stabilising fin arrangements for the reduction of roll motions with the yacht at rest.

Due to the hull form geometry of common vessels the natural roll damping is low compared to the damping of the remaining ship motions. As a matter of this fact even small waves may cause considerable roll motions at resonance frequencies (when the exciting wave period of encounter is close to the natural roll motion period of the ship). This phenomenon becomes especially apparent for ship's at rest when the natural roll damping is smallest.

Recently several motor yacht designs were studied which feature active roll damping systems consisting of two sets of stabilising fins. Such a four fin arrangement, as shown in Figure 1, is optionally used in the common way with the yacht at speed or in a specific zero speed roll damping mode.

Different test procedures are applied by HSVA in order to derive the capabilities of the active zero speed roll damping systems designed and manufactured by QUANTUM Control's. In a first series of calm water model tests roll motions are excited and damped by the action of the stabilising fins. This forced roll motion test procedure, which is repeated during full scale trials, already allows an assessment of the system's damping capabilities in an early design stage.

Subsequently forced roll motion tests are performed in calm water. Thereby harmonic roll motions of the motor yacht are excited by a specific mechanism in the model. With the help of the comparative investigation of passive and active roll damping systems the high efficiency of the stabilising fin arrangement can be demonstrated. Normalised motion responses of a large motor yacht are exemplarily shown in Figure 2 as a function of excitation frequency.

Finally the efficiency of the active stabilising fin arrangement is determined in a number of model tests in irregular seas. Results found during model tests of a motor yacht are exemplarily given in the bar diagram of Figure 3 for three different seaway periods. Thereby a reduction of roll motion response by more than 70 % becomes apparent for the case that the exciting seaway period equals the ship's natural roll motion period.

Of course, the zero speed roll damping capabilities of a stabilising fin arrangement are not the only matter of particular interest. In fact, various other aspects are typically studied during accurate model test campaigns which always include the optimisation of the fin alignment for minimum added ship resistance. Beside this, the roll damping capabilities of the stabilising fin arrangement are normally tested for the vessel at speed and in some cases the pitch-control option is also a matter of additional interest.

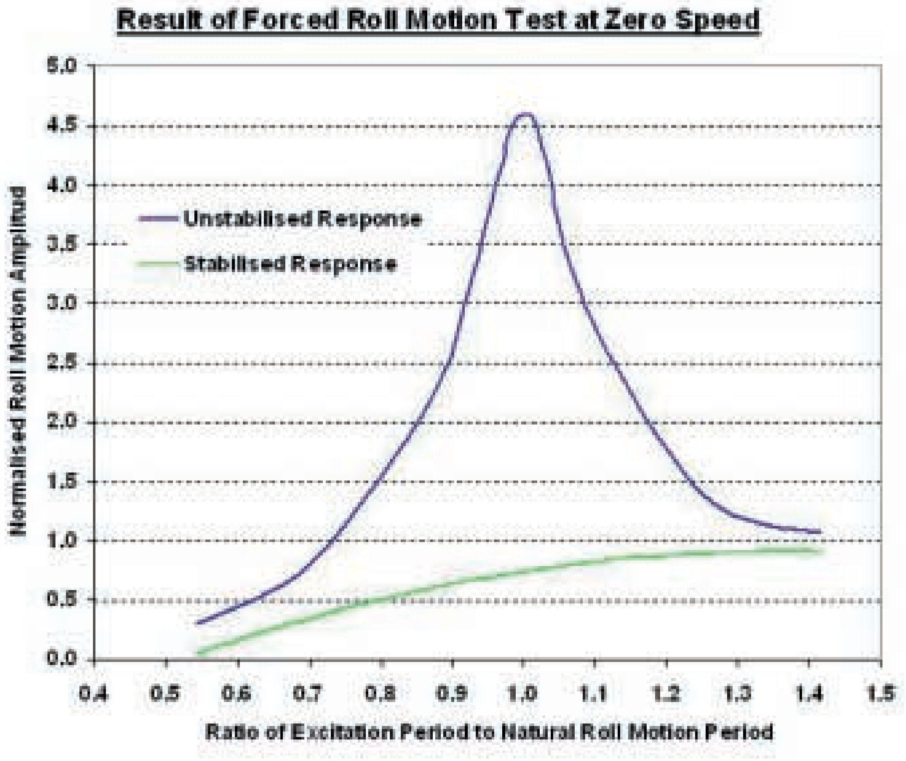


Fig 2: Harmonic roll motion response with active and passive roll damping arrangement

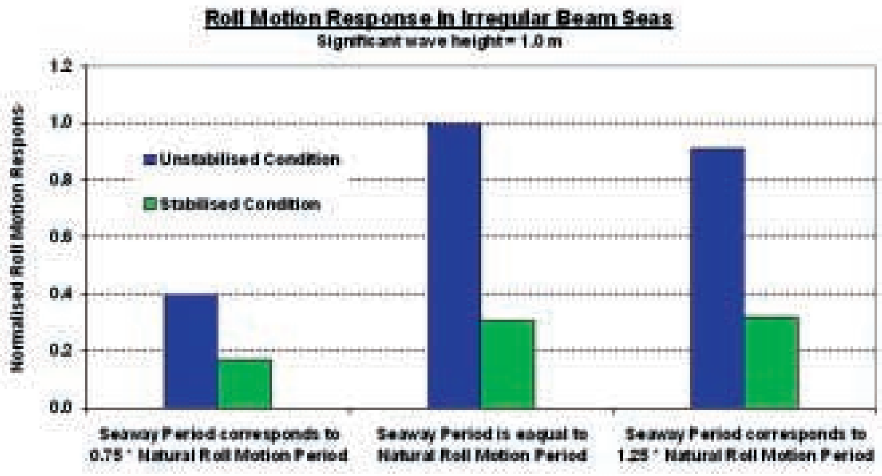


Fig 3: Comparative representation of roll motion response in irregular seas

Summing up it may be said that HSVA's comprehensive model test procedures allow for the dedicated investigation of motion damping systems and the accurate determination of motion responses to be expected aboard the projected yacht. This enables the ship yards to meet and/or to improve passenger comfort requirements and therewith to achieve perfect customer satisfaction.

FREE SURFACE COMPUTATIONS IN YACHT DESIGN

by Scott Gatchell, Jochen Laudan

In custom-designed yachts, sometimes the only limit to a design feature is the customer's imagination. In some instances, free surfaces may appear in unusual places, and require special attention. This article describes two recent uses of free surface capturing methods for yacht design.

One project simulated the sloshing-reduction measures in a large basin during regular pitch motions. Another project simulated overflow from a swimming pool for evaluating the associated pump performance requirements, in both regular and irregular pitch motions.

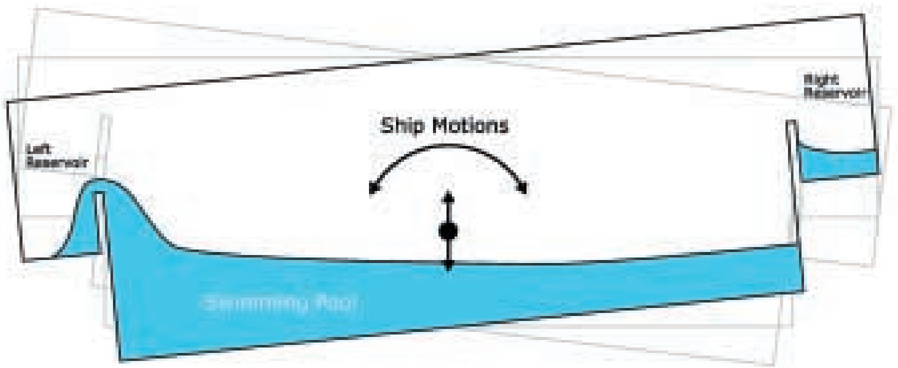


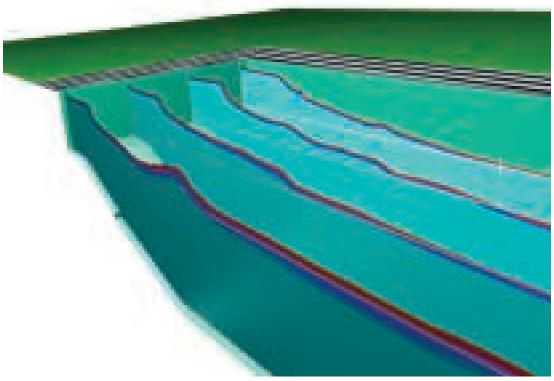
Fig. 2: Generic sketch of pool cross-section, ship motions and expected overflow

LARGE BASIN SLOSHING

A yacht design was to be equipped with a large basin. Due to the large free surface area and quantity of water, the main concern with this design was the possibility of excessive sloshing of the water as the ship pitches. This varies little from the usual tank sloshing problem, except for the size and complexity of the computational domain and the simulated duration.

The mesh generated was much larger than typical tank computations and the simulations were computed covering a time range of several pitching cycles. The ship motion was prescribed from other prediction methods; a single, regular pitch period was selected that would most likely cause extreme excitations of the water in the basin. The larger mesh and the long simulation time range meant large computation times.

Fig. 1: Free Surface at one instance during simulation



Once the computations were complete, the results were evaluated, and visualizations were created in the form of still images and videos. Figure 1 illustrates the water level along four longitudinal slices at one time instance. Further improvements were considered. The flow velocity profiles were analyzed, to determine the proper placement of simple wave-damping elements. A second set of computations was made to verify that these elements produced the desired effects.

SWIMMING-POOL OVERFLOW

Another problem, involving the water overflow from a swimming-pool, was computed for several regular and irregular pitch motions. These motions were prescribed from the ship's seakeeping behavior. The simulated overflow was collected and measured in reservoirs, to be "pumped" back through openings in the bottom of the swimming-pool. Figure 2 illustrates pool and reservoir arrangement, and the related motions.

Visualizations in the form of still images and full motion videos were made, in addition to the numerical statistics that were gathered. The graph in Figure 3 shows the volume flux into each of the end reservoirs. The peaks are offset by a half pitch period. With each period, the volume flux gradually rises, and finally levels off to a steady state. The results from the computations showed the overflow volume rates were higher than originally estimated, and pump performance specifications were adjusted, accordingly.

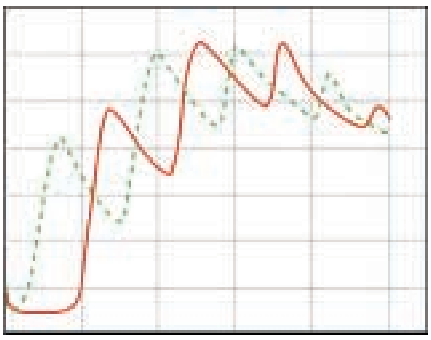


Fig. 3: Volume Flux over time
Left Reservoir, red
Right Reservoir, green

The new twisted rudder HSVA TW05
aims at improving propulsion efficiency and cavitation performance

by Heinrich Streckwall

Fig. 1: HSVA TW05 rudder (with bulb)

For the new AIDA cruise vessel project of Jos. L. Meyer Shipyard, HSVA was to design a twisted rudder in order to further improve the propulsion performance.

In the design philosophy for this full spade rudder HSVA put special emphasis on a smooth resultant flow at the leading edge, which finally led to a yet uncommon realization of twist.

Step one of the design was to calculate the resultant flow at the rudder as the sum of the velocity components in the ship's wake and in the propeller slipstream. In a second step, a smooth entrance of the flow to the rudder was assured by a combination of twist (i.e., an inclination of the nose-tail line) and camber. The sections below and above the propeller shaft height are twisted to different sides. The same holds for the direction of camber. The camber line shows a constant curvature all along the section from the nose to the tail (Figure 1 and Figure 2).

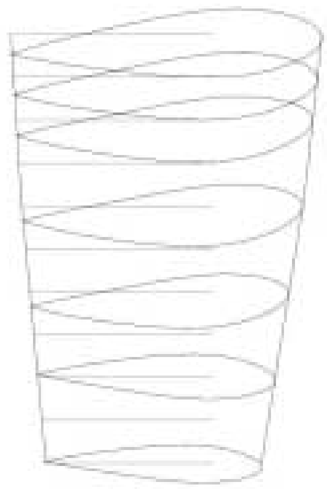


Fig. 2: Section geometry of HSVA TW05 visualized

To support the manufacturing accuracy of the rudder in the decisive leading edge area, the front of the rudder forms a straight line. The maximum offset of the sections above and below the propeller shaft height appears at the trailing edge.

The camber supports the local inclination of the nose, which has a welcome side effect on the flow entrance conditions and, in addition, assures that enough load is left on the rudder to regain rotational energy from the propeller slipstream.

Propulsion tests at HSVA confirmed that the TW05 rudder concept indeed leads roughly to a 2% reduction of the power demands. A rudder bulb introduced to establish a tight connection between rudder and propeller was found to have only negligible influence and was finally omitted.

Though not yet proven by cavitation tests it is evident from the numerical analysis, that the rudder can withstand high ship speeds without showing cavitation (Figure 3). The general design concept of the HSVA TW05 allows to adjust the geometry to a demanded range of cavitation free rudder angles.

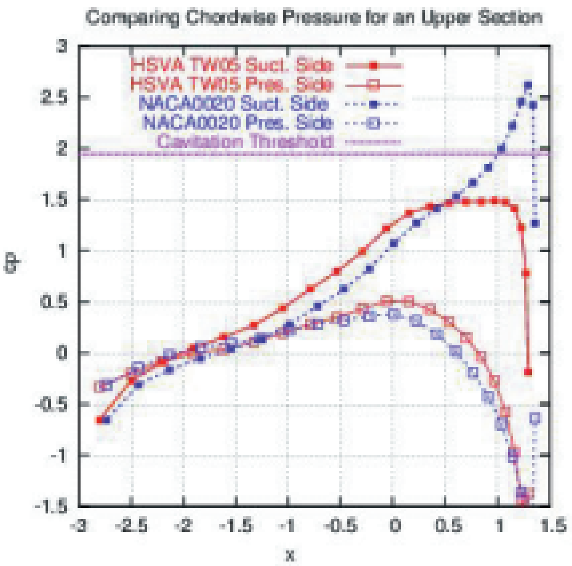


Fig. 3: Improved pressure at rudder nose

Propeller Induced Vibration Problems at Low Ship Speed

by Christian Johannsen

Controllable pitch (CP) propellers are a very efficient tool for easy adaptation of the propeller to varying ship operating conditions. Moderate pitch adjustments are possible to achieve the optimal rotational propeller and engine speed with respect to the overall efficiency.

Nevertheless, in some cases CP propellers are abused to maintain the same high propeller rotational speed over almost the whole speed range of the ship. This means extreme propeller pitch reduction to achieve low ship speeds, often resulting in severe face cavitation, causing strong vibration excitations.

With the classical fixed pitch (FP) propeller there is an almost constant relation between ship speed and rotational propeller speed. In opposite to that, the application of shaft generators, necessary for production of the enormous need of electric power of passenger ships or mega yachts, often requires a constantly high shaft speed even at low ship speed. Concepts are known, where even for harbour operation the full engine speed has to be maintained to operate the shaft generators. This means, the controllable pitch propeller has to operate at zero thrust setting with full propeller speed!

The hydrodynamic problem with those concepts will be explained in the following. For the experts it should be mentioned in advance that amplifying effects like wake and propeller slip are neglected here in order to draw the readers intention to the main mechanism in question. Doing so, the propeller behaves like a screw driven into wood, i.e. the propeller - and with the propeller the whole ship - advances by the distance P with every rotation (see Figure 1). This means, the ship speed would be $V = n \cdot P$, showing for example that a 50 % reduction of the ship speed V can either be achieved by a 50 % reduction of the propeller rotational speed *n* or by a 50 % pitch reduction. The fundamental problem with the second option is, that it is geometrically impossible, to reduce the pitch *P* by a radially constant percentage with a simple turning of the propeller blade. With an adjustment of the pitch of a CP propeller the blade is turned by a radially constant angle $\Delta\varphi$ as it can be seen in Figure 1. Since *P* and φ are in the geometrical relation $\tan \varphi = P / (2 \cdot \pi \cdot r)$, a pitch adjustment by $\Delta\varphi$ has a radially differing effect on *P*. For small pitch angles the relation $\Delta P_{(r)} \approx 2 \cdot \pi \cdot r \cdot \Delta\varphi$ applies, i.e. the change in pitch varies with the radius. The effect of this can be seen in Figure 2 for a propeller with an initial pitch of $P = D$. A pitch reduction by 12° is displayed here. While at the inner radii the pitch remains higher than the new mean pitch, the outer radii have got a too low pitch after the adjustment. Coming back to the image with the screw driven into wood, such a pitch reduced screw wouldn't slide into the wood precisely anymore. The same happens with the strongly pitch reduced CP propeller in water.

Of course, this is not a problem with small pitch adjustments as usual with CP propeller driven ships. Nevertheless, with strong pitch reductions the propeller pitch at the outer radii becomes significantly too low for the incoming water. Face cavitation as shown in Figure 3 can be the consequence. Besides the aggressiveness with respect to propeller erosion, this kind of cavitation is also known to be

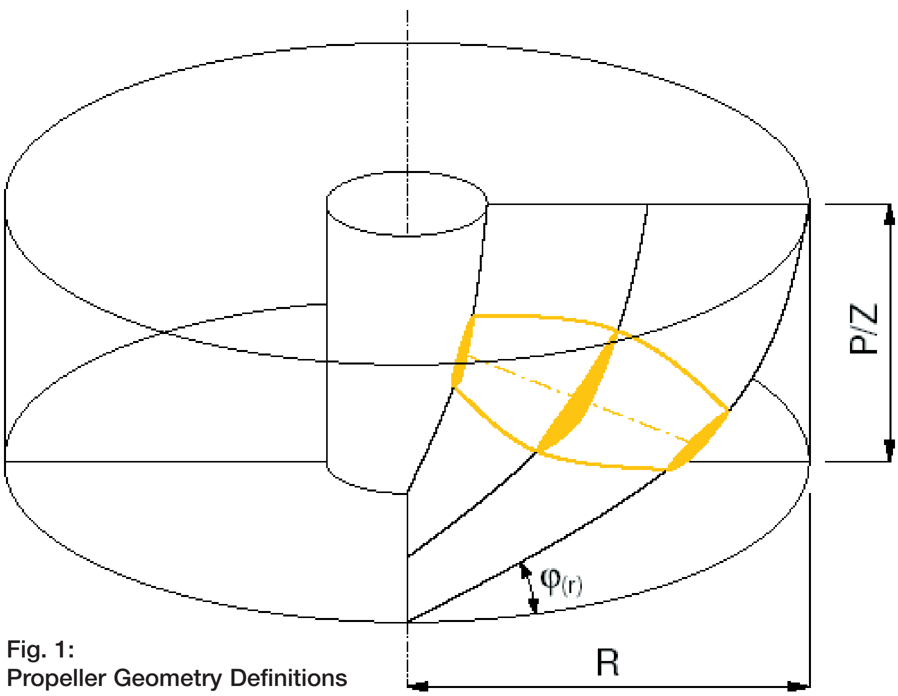


Fig. 1: Propeller Geometry Definitions

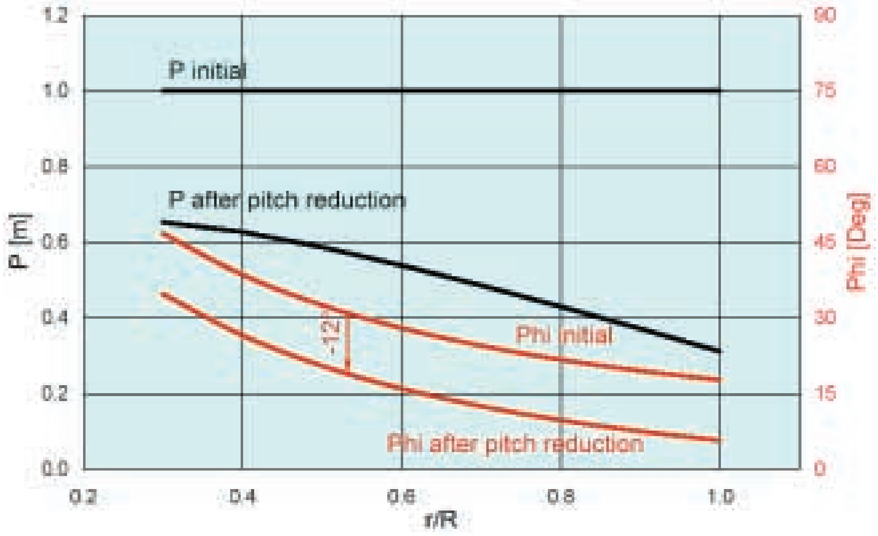


Fig. 2: Pitch and Pitch Angle before and after a 12° Pitch Adjustment

D *Propeller Diameter*
f *Excitation Frequency*
n *Rotational Propeller Speed*
P *Propeller Pitch*
R *Propeller Radius*
r *Radius Under Consideration*
V *Ship Speed*
V_A *Propeller Advance Speed*
$V_A \approx V$ *if neglecting the Wake*
Z *Number of Propeller Blades*
φ *Pitch Angle*

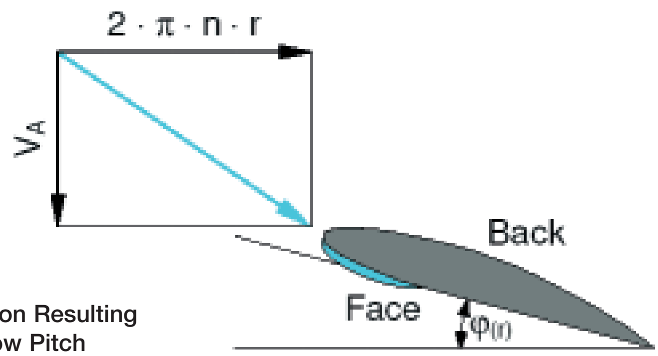


Fig 3: Face Cavitation Resulting from a too Low Pitch

the source of broad band vibration excitation. The hydrodynamic context between face cavitation and this broad band excitation is not fully understood so far. Nevertheless, severe problems have been reported from ships operating with this concept, i.e. maintaining high rotational propeller speeds at low ship speeds by application of strong propeller pitch reduction. Figure 4 shows a pressure pulse frequency spectrum of a ship at a speed reduced from design speed 27 kts to 12 kts by means of a strongly reduced propeller pitch. At the left margin two sharp peaks can be recognized as the first and second harmonic of propeller blade frequency. Those are the normal accompanying phenomena of an operating propeller. To predict their level and -if necessary- to propose remedies is daily work of HSVA's cavitation crew. These frequencies are known $(f = n \cdot Z,\ 2 \cdot n \cdot Z, \ldots)$ and distinct, i.e. the steel structure can be investigated to avoid resonance phenomena. Besides that, there is an extreme broad band excitation in Figure 4 from 40 to 180 Hz as a result of the unfavourable mechanism described above. Severe face cavitation occurred in this operating condition as it was proven by full scale propeller observations. Vibration problems were the consequence. Due to the wide range of excitation frequencies it is extremely difficult to fight against those vibrations by modifications of the steel structure.

This article should not at all be misunderstood as a pleading against the CP propeller in general. As mentioned at the beginning, the CP propeller has big advantages with respect to flexibility of ship operation, indeed. Nevertheless, a fixed pitch propeller generates highest vibration excitation at highest rotational speed. So it might be reasonable to do cavitation investigations with a FP propeller for maximum speed conditions only. This doesn't necessarily hold for a CP propeller acting at constant RPM over the whole speed range of the ship. So this article is no statement against the CP propeller but a pleading for additional cavitation tests whenever extreme CP propeller off-design conditions are part of the propulsion concept of a ship.

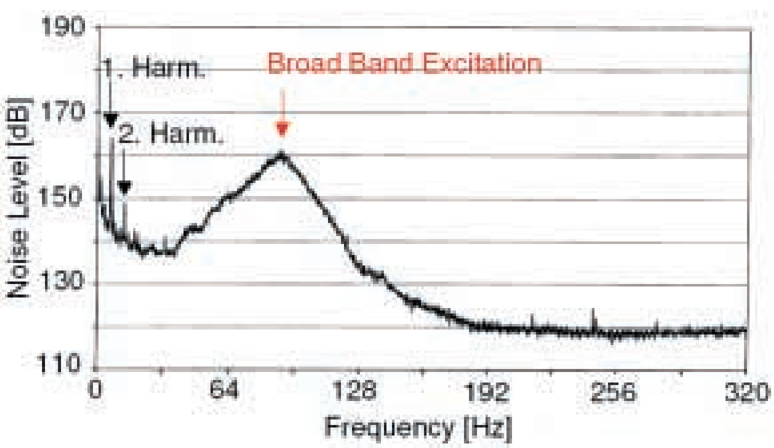


Fig 4: Broad Band Excitation of a Passenger Vessel at Low Speed

LNG-Carrier: Model Tests in Ice

by Walter Kuehnlein

Approximately on third of the world's known and not yet exploited reserves of natural gas are in Russia. The overwhelming majority of these reserves are in Arctic and Subarctic areas. But not only in Russia, but also in other areas like Canada, natural gas reserves are found in harsh and ice covered environments. As a consequence, the LNG ship technology is going towards Arctic LNG-Carriers. New developments in ice navigation, winterisation and tanker sizes are generating a new exiting challenge for shipping and ship building industries all over the world.

The existing ice class regulations should be only considered as a first guide for designing such vessels. But the in future performance of new developed vessels needs to be investigated in much more detail, therefore ice model tests are imperative.

At the Hamburg Ship Model Basin (HSVA) LNG-Carriers are investigated and developed not only for their use in ice, but also demands and requirements for open water performance are considered. With more than 90 years of experience and expertise of developing open water vessels and more than 50 years of experience and expertise in ice engineering HSVA has started 20 years ago to look closer into the hull shape design and power and navigation requirements of LNG-Carriers.

It is common practice guiding ships in ice-covered waters by using an icebreaker. The vessel is led through the ice by the icebreaker, with the icebreaker breaking the ice and the vessel following in the broken channel. This traditional way of guiding vessels in ice fails when the beam of the vessel (LNG-Carrier) is larger than the beam of the icebreaker, which is normally in the range of about 20 to 30 m. In the case that the LNG-Carrier's beam is larger than that of the icebreaker the vessel would have to widen the channel by breaking ice with its forward shoulders. This will increase the resistance dramatically. In this cases a possible way to guide such vessels would be the use of two icebreakers, with the first one breaking the channel and the second one widening it. The vessel follows in a channel of about 1.25 to 2 times the widths of its beam. In order to investigate the speed, resistance and power in different ice thicknesses a comprehensive ice model-testing program should be carried out.

For the model tests a parental level ice sheet of target ice thickness will be prepared according to HSVA's standard model ice preparation procedure. After a predefined level ice thickness has been reached, the air temperature in the ice tank will be raised in order to adjust the flexural strength of the model ice to the required value. In order to obtain a defined friction coefficient between the ice and the model hull, HSVA applies a special paint composition to the models of ice-going vessels. In order to achieve a most realistic wide ice channel the channel will be broken with the help of two HSVA stock icebreakers towed through the level ice as it is shown in Figure 1.

The prime objectives of such ice model tests are to evaluate the icebreaking performance in a wide ice channel ahead, in level ice (thin ice) and to evaluate the ability to follow two icebreakers preparing the wide ice channel. Also propeller-ice-interactions and how the ice is transferred along and below the vessel are of special interest (see Figure 2). In order to achieve this task a series of model tests will be performed with the model of the

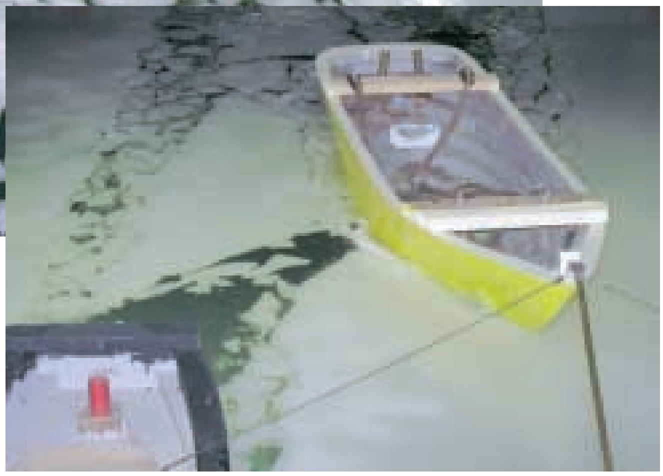


Fig. 1:
Generation of a wide Ice Channel using two HSVA Stock Icebreakers

LNG-Carrier. The test program should also include ice-breaking tests at loaded draft in ice. But model tests are not only performed in order to analyse the required power and thrust, it is also very important to investigate the manoeuvrability of the projected LNG-Carriers in ice.

In addition, even if model tests have shown that a vessel can transit through ice channels with the installed power, the engine might not be able to deliver the full power to the propeller. In the case of a fixed pitch propeller which is usually designed for compromise operation in ice and open waters, the engine might not be able to deliver the full power to the propeller, when the vessel is sailing at a low speed in ice and the propeller is therefore running correspondingly heavier. In these cases HSVA will also support you by finding the right engine or turbine in order to overcome this problem.

Model tests in ice are an important tool during the design phase for investigating the performance of LNG-Carriers in defined ice conditions. HSVA is able to offer individual tailor-made ice model tests in conjunction with open water tests on a highly experienced level. HSVA offers to accompany our clients from the first idea until the final realization of the projected vessel.

In conclusion, HSVA is offering a unique combination of CFD-tools, open water model testing, including cavitation tunnel, ice and environmental testing facilities with the know how of very experienced engineers.

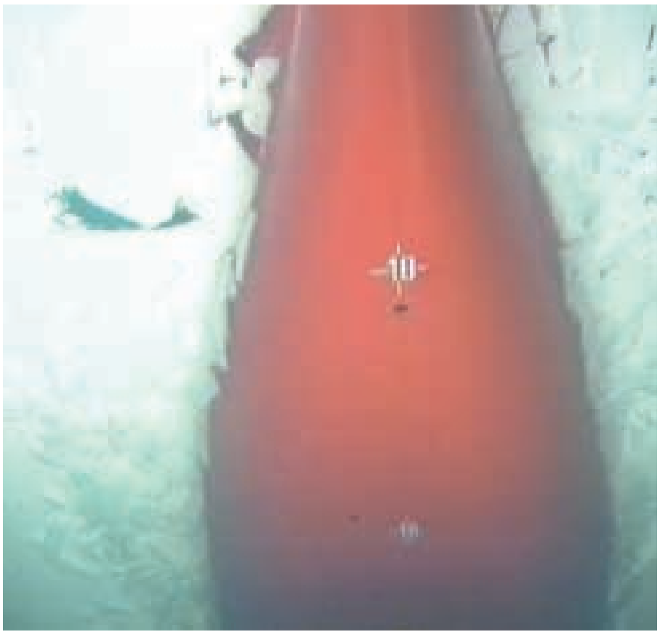


Fig. 2: Under Ice Observation during an Ice Model Test of a LNG Carrier (view from underneath)

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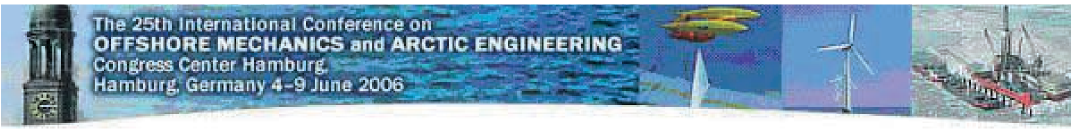

OMAE 2006

HSVA would like to invite you to join
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More than 400 technical papers shall be presented at the conference distributed in its symposia:

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- Safety and Reliability
- Materials Technology
- Pipeline Technology
- Ocean Space Utilization
- Ocean Engineering
- Polar and Arctic Sciences and Technology
- CFD and VIV Symposium
- Offshore Wind Energy
- Ocean Research Technology
- Douglas Faulkner Special Symposium

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Walter Kuehnlein, Conference Chair

25TH ITTC Membership in Technical Committees

HSVA staff members Christian Johannsen (Head of the Propeller and Cavitation Department) and Jens-Holger Hellmann (Deputy Head of the Ice and Offshore Department) have been assigned members of the specialist committees on Cavitation and on Ice. Jens-Holger Hellmann has been promoted as chair of the ice committee.

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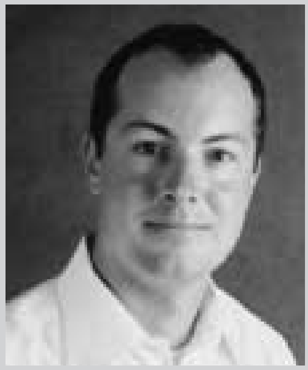

ALEXANDER MRUGOWSKI

Alexander Mrugowski joined HSVA in 2002 as a project manager in the resistance and propulsion department. He is responsible for resistance and propulsion tests for new projects, in particular for motor yachts, navy vessels and fast ships. Furthermore he supervises wind tunnel tests carried out in cooperation with the Technical University of Hamburg-Harburg.

Mr. Mrugowski completed his apprenticeship and worked as a boat builder on Lake Constance before studying naval architecture at the University of Applied Sciences in Kiel. He is an active sailor, and his master thesis was dealing with the CFD analysis of downwind sails for an IACC-Yacht.

Sailing, skiing and mountain biking are his favourite spare time activities.

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