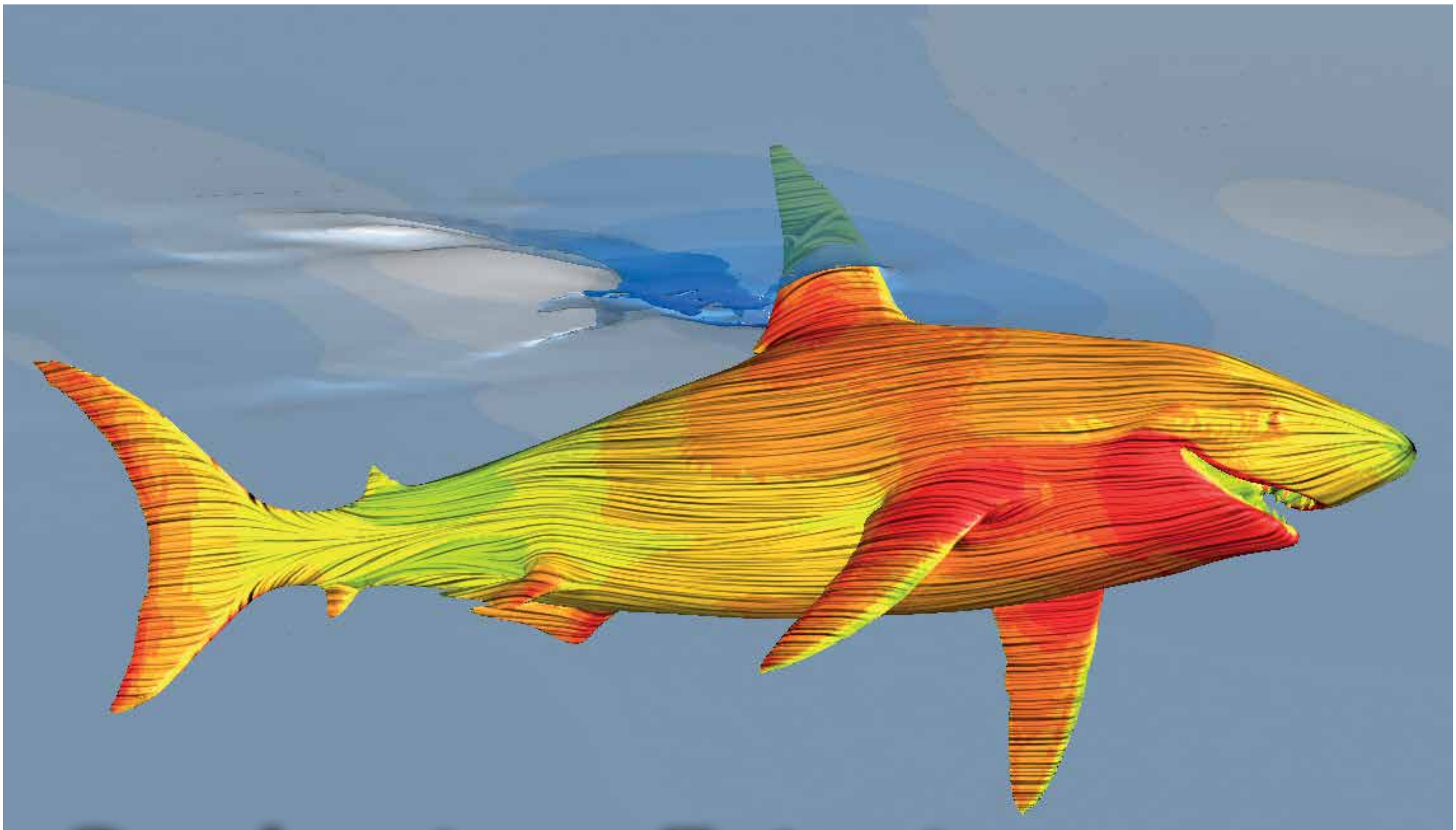
issue 1-16

newswave

The Hamburg Ship Model Basin Newsletter



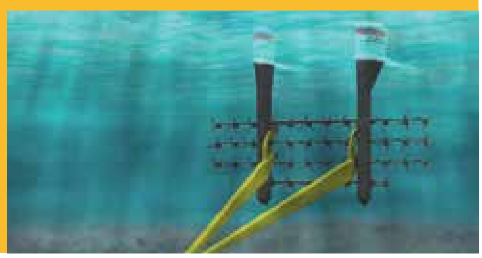
Reducing Friction

What can be done to make ship hulls more slippery and reduce friction?

Inspired by dolphins – new ways of reducing frictional ship resistance

How we help THW to make their rescue work safer

"TidalPower"– renewable energy from tidal currents



editorial

Dear reader,

when I was drawn into the world of model testing I was extremely excited about the new, rather intuitive insights the observation of the behaviour of scale models in real water waves revealed to me. Finally, in contrast to developing numerical models and studying their results, I could get a much quicker idea what the underlying mechanisms of a physical process could be and whether a mathematical model would be appropriate. I decided to stay with model testing leaving to some extend behind the rather "dry" business of mathematics!

My enthusiasm was even quickly damped when shortly after my discovery I heard from the experts in this field that model tests would be replaced by numerical methods sooner or later. What a disappointment in view of the fun model testing can be!

However, while delving more into the depth of hydrodynamic model testing and staying in touch with numerical modelling I realized that this did not prove true; the more we were able to model complex systems the more questions arose concerning their applicability and whether all relevant aspects were realistically covered. To improve our models we needed more insight into the physical processes – by model testing. Nowadays, not only due to a significantly larger computing capacity, we have many excellent models available, and we see that they are consequently used during the various design processes. A sort of standard method is to limit the number of model tests in favour of a numerical model tuned by particular data points gained by a few model tests of the full system. And this gives us even more challenges in developing further our model test techniques!

Some advanced methods in modelling complex physical processes numerically and experimentally are presented in this issue of our Newswave. I hope you enjoy reading about this well balanced complementarity as much as I did! I am looking forward to developing further and applying all this together with you.

Yours sincerely

Dr. Janou Hennig

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Hull fouling – organisms like barnacles, mussels, sponges, algae and sea squirts attach themselves to the hulls of ships

Reducing Friction

In many areas of life friction is considered a handicap. Unless you sit in your Formula I car and negotiate a bend at the Monaco Grand Prix where you need to rely on the proper "grip" of the car's tyres – friction will be a negative force hindering advancement. Ships are no exception.

by Jochen Marzi

Ship resistance is the main source of energy consumption for most cargo vessels. The resistance is mainly made up from two components: viscosity-related friction forces and pressure-related forces. The latter are a function of form and model basins have been working for a long time to improve this part. It was especially in recent years that advanced CFD techniques reached a level which allows reliable application to hull form optimisation and attain new levels of (pressure) resistance reductions to the extent that, for the calm water case, today's best hull-forms have less than 20% share of form-related resistance. In turn, the viscosity-dominated friction parts of the resistance become more and more important.

This evolution is further emphasised by the present trend towards lower speeds – "slow steaming"– which pronounces viscous resistance even more. Fig. 1 indicates the relation of viscous resistance to pressure resistance for a container vessel over a speed range from 18 kts to 24 kts. The ratio is increased by a factor of 1.85 when sailing at the lower end of the speed range indicated here and will be further accentuated for even smaller speeds. The universally adopted lower transportation speeds hence lead to an even further increased effect of frictional resistance and an amplified interest of the shipping industry to look into means to reduce or, at least, limit the viscous effects on ship resistance.

But what can be done to make ship hulls more slippery and reduce friction? The first answer in all cases is: the coating. Since the ban of former TBT paints, producers seek more environmentally friendly replacements with similar properties to reduce hull fouling and the accompanying increase of surface friction. A variety of coating concepts has been developed; including silicone based foul release paints (FRC), self-polishing copolymers (SPC), and controlled depletion paints (CDP), some of these still being subject to new environmental concern. Today many products on the market claim benefits, however, it must be noted that despite the work started in the EU project TARGETS in 2012 there is still no formal, comprehensive overview comparing the quality of the different product concepts available.

From a hydrodynamic point of view the function of hull coatings is to guarantee a smooth surface. But are there not other ways to positively influence the resistance? Digging deeper into technology options reveals the concept of air lubrication which received a lot of interest in recent times. Feeding air under the ship's bottom is meant to avoid the direct contact between water and the surface so that only a shear layer between water and air is generated. This apparently leads to reduced skin friction on the hull and promises substantial resistance gains. The drawback is that air lubrication requires active feeding of air into the boundary layer of the hull, a process which in itself requires energy. A number of systems have been proposed over the past years but experience made in full scale sea trials indicates that not all of them attain a net gain in energy consumption. Positive effects can be obtained from systems which use rather small "micro bubbles" which are expected to influence also the structure of the turbulent boundary layer. Damping turbulent fluctuations appears to be a very promising concept to positively influence viscous resistance.

A second way of influencing a turbulent boundary layer is the application of riblets. Small grooves in the surface of the coating prevent energy-intensive exchanges between small scale vortex structures and help to reduce losses in a turbulent boundary layer. At present, HSVA is involved in the development of such patterned surfaces in the context of the eShark project which is presented on page 9 in this issue of Newswave.

A novel concept is addressed in the FLIPPER project which is also presented in more detail on the pages 6 to 8. Here so-called compliant coatings are used to dampen boundary layer instabilities which inevitably lead to laminar-turbulent transition very early on a ship hull. If this transition process can be delayed and shifted towards higher Reynolds Numbers, a part of the "turbulent peak" can be cut and, hence, friction forces can be reduced. Our simulations show that if the right material is used, a noticeable gain can be obtained.

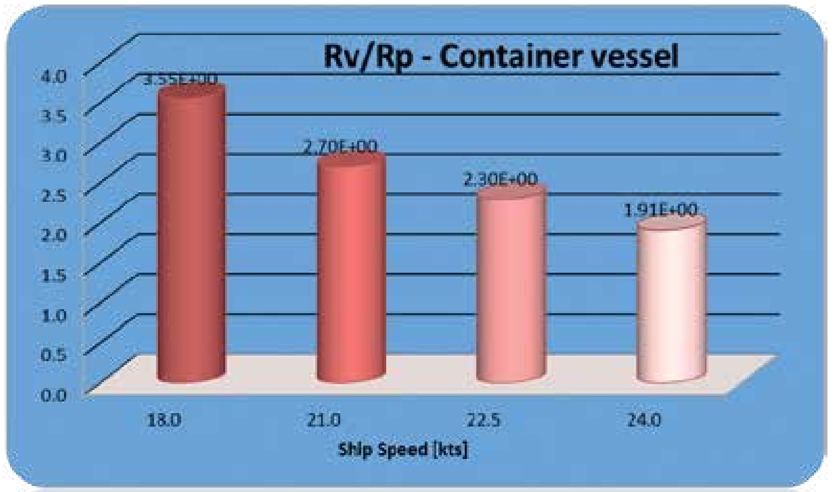
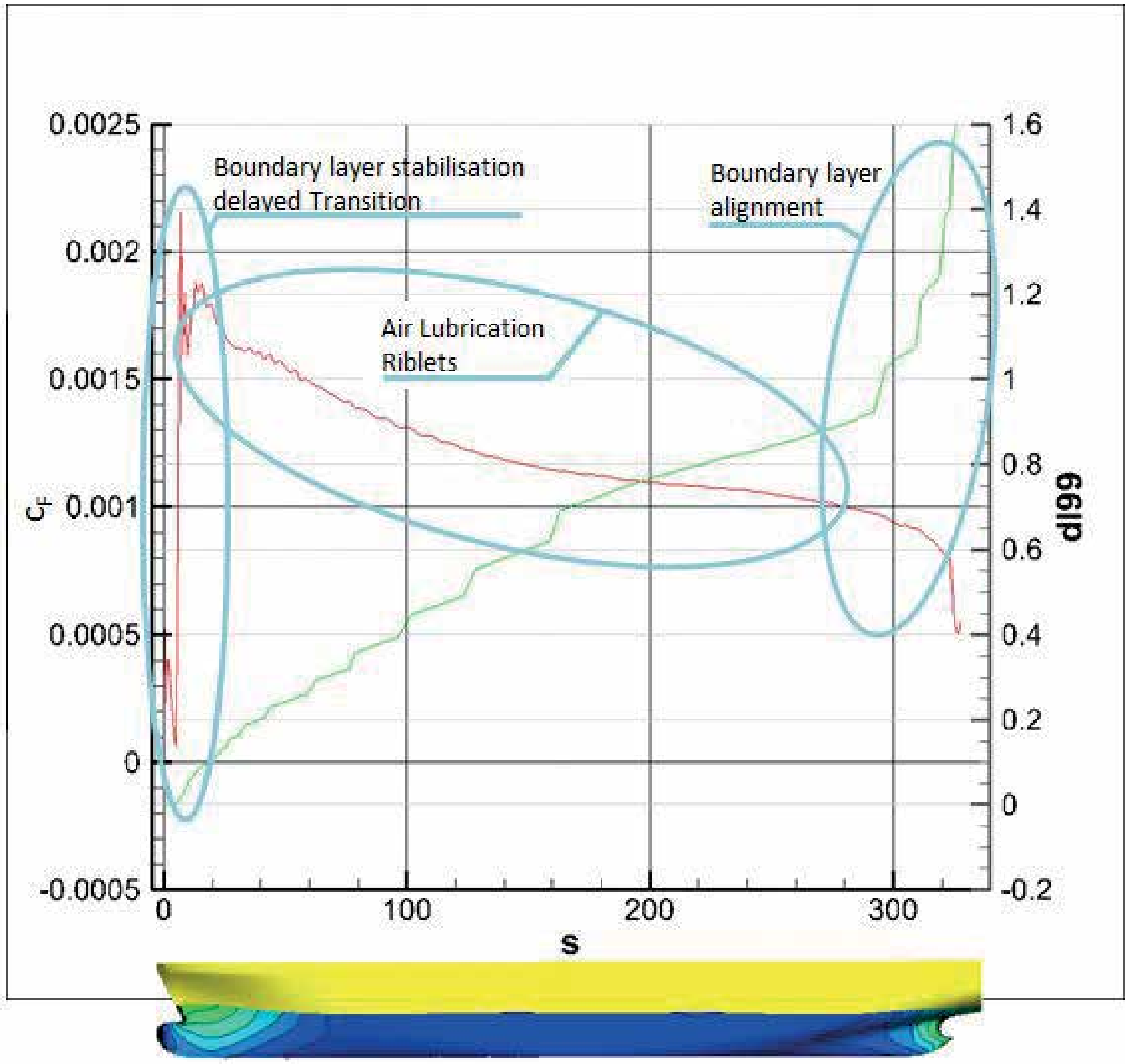


Figure 1: Relation viscous resistance / pressure resistance as a function of speed for a medium sized container ship

Following the flow along the hull, the sudden increase in boundary layer thickness towards the stern in areas of high surface curvature coincides with momentum losses in the boundary layer. In this region further means of boundary layer control promise a stratification and a reduction of energy losses which has been shown in an internal project already.

All the elements and techniques addressed so far promise a positive influence on friction resistance. For several of these there are still considerable obstacles to overcome en route to full "real world" applications, but fundamental work has been done during past and present research and development initiatives. Following a long tradition of friction resistance research at HSVA, we will continue to work on the entire friction reduction complex in a holistic approach, covering a variety of means to influence the various causes of friction losses. Fig. 2 indicates in a simplified way the different areas of interest in friction losses along a typical ship hull. This is exemplified by a local skin friction curve (red) computed along a streamline on the hull and the growth of the boundary layer thickness (green). Following the path of the water along the hull it appears to be most promising to apply different concepts in different sectors of this path. In the future these concepts shall be brought together to provide a full coverage of surface friction treatment. ■

Figure 2: Friction resistance – areas of interest and potential means for reduction



"Dolphin Compliant" Coatings for Drag Reduction

The drag of a ship in operation is often dominated by friction between the hull and the surrounding water. HSVA is exploring possibilities of reducing the frictional ship resistance, drawing inspiration from dolphins.

by Lars-Uve Schrader

Dolphins are able to sustain an underwater speed of about 9 m/s across long distances [1]. This fascinating endurance has led to the hypothesis that the thick, pliable dolphin skin keeps a large portion of the boundary layer flow in a low-friction laminar state through a delay of transition to turbulence. In the research project FLIPPER, HSVA and their partners have investigated possibilities of applying a drag-reducing "synthetic dolphin skin" in the form of a compliant coating to the bow of a small SAR vessel (Figure 1). This ship has been chosen because of its simple bulb-less bow shape, creating a weakly accelerated boundary layer flow.

Polymeric coatings with properties similar to those of dolphin skin have been developed by the project partner Fraunhofer-IFAM. These will soon be tested in HSVA's large water tunnel HYKAT, using a 1:3.2 scale model of the ship (Figure 2). The experiments will be conducted at a high tunnel speed of 10 m/s, yielding a laboratory

Photo: Fassmer.de

Figure 1: SAR vessel of the German Maritime Search and Rescue Association DGzRS, designed by Fassmer

Photo: Fotolia

Reynolds number of about 50 million. This is just by a factor of 2.5 below the Reynolds number of the real SAR vessel such that test results with relevance for field applications will be obtained.

The test model is equipped with interchangeable bow segments to be coated with different polymers and with a standard paint for reference (Figure 3). This setup facilitates a swift test procedure and a straightforward comparison of different compliant coatings. The bow segments will be mounted in an overhung arrangement to the main test body such that the drag force of the coated bow can be measured by a load cell.

Compliant Coating

Apart from conducting the water-tunnel experiments, HSVA's role in FLIPPER consists in computing the mechanical properties of the compliant coating. To this end, a dynamical model of dolphin skin [2] has been implemented into a numerical procedure for the prediction of laminar-turbulent boundary layer transition [3]. The coating model is composed of an array of springs and dampers and a flexible membrane, mimicking the thick blubber and the thin dermis of dolphin skin (Figure 4). The membrane is supported by the springy layer in such a way that it can execute vertical motions and bending. The main parameters are the thickness, the stiffness (E-modulus) and the damping (loss tangent) of the "synthetic blubber" and the "synthetic dermis". E-modulus and loss tangent of various visco-elastic polymers have been measured by Fraunhofer-IFAM through dynamic mechanical analysis (DMA, see Figure 5 for an example).

Delay of Transition to Turbulence

In calm water, laminar-turbulent transition is usually initiated by the excitation and amplification of minute boundary layer disturbances called Tollmien-Schlichting (TS) waves. The role of the compliant coating is to attenuate or even suppress these TS waves so as to slow down the transition process. The coating design requires knowledge

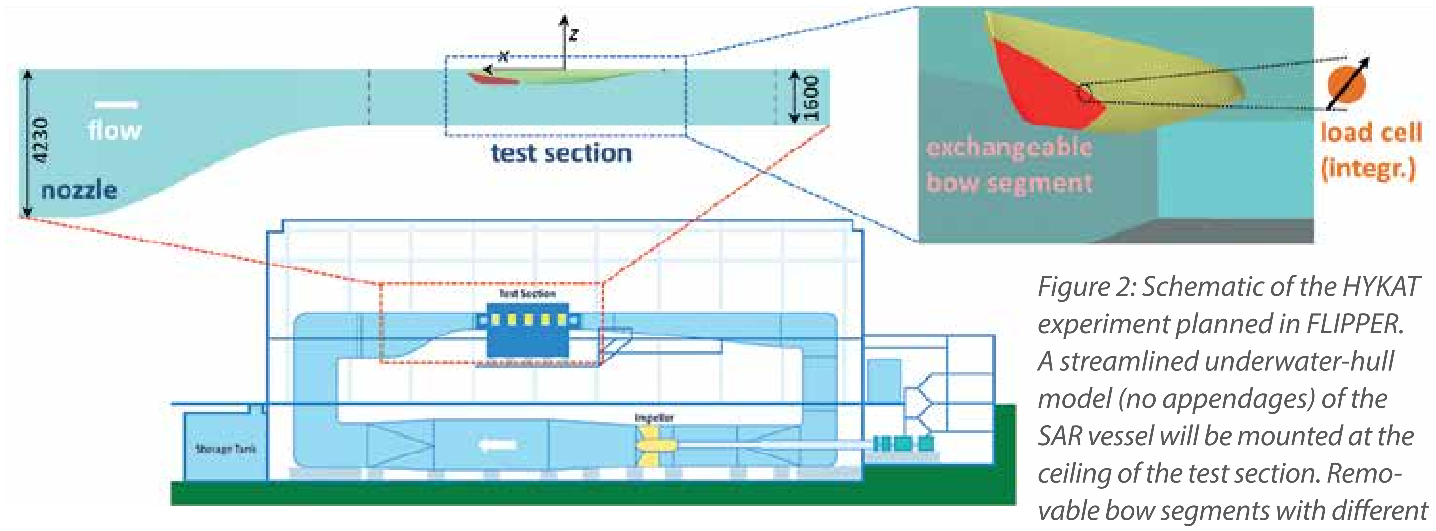


Figure 2: Schematic of the HYKAT experiment planned in FLIPPER. A streamlined underwater-hull model (no appendages) of the SAR vessel will be mounted at the ceiling of the test section. Removable bow segments with different coatings, supported by a load cell, can be inserted into the main body

about the frequencies and growth rates of the TS waves that ultimately trigger the breakdown from laminar to turbulent flow. This knowledge can be gained using boundary layer linear stability theory (LST) in conjunction with the e^N criterion for transition prediction. HSVA adopted an existing LST

Figure 3: Water-tunnel test model: Main body (top) and exchangeable bow segment (bottom)

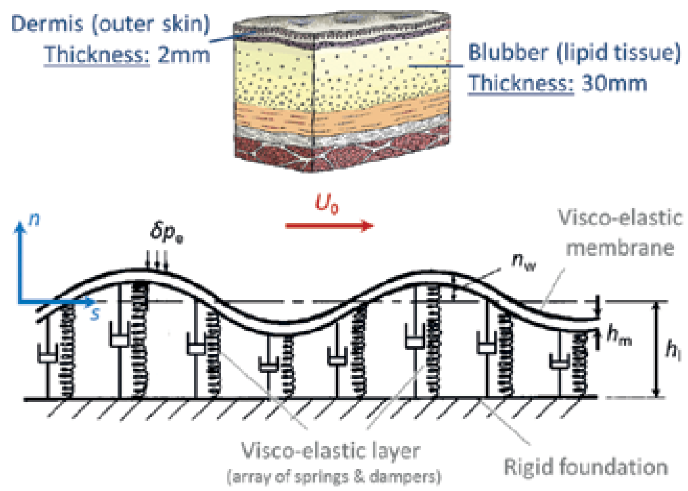


Figure 4: Dolphin skin: Cross section (top) and mechanical model (bottom)

programme (from KTH Stockholm, cf. [3]), and augmented it by the e^N criterion and the compliant-coating model. This resulted in an efficient numerical tool amenable to an extensive parametric study of the mechanical coating properties. The study revealed that a thick synthetic blubber layer of low stiffness and low damping is required for an effective mitigation of the TS waves. The synthetic dermis, on the other hand, should be thin and resistant to bending so as to suppress flow-induced surface instability (FISI) waves borne by the soft coating material. These FISI waves must be avoided because they may lead to self-sustained absolute flow instabilities and rapid transition [4].

Application to the Ship Bow

The laminar boundary layer along the bow of the SAR ship model has been obtained by adapting a Falkner-Skan boundary layer profile [5] to a RANS solution of the outer flow field [6]. This profile has been subject to a LST study in order to calculate the amplifying TS waves, considering an uncoated (rigid) and a coated (compliant) surface. The coating consists of a very soft silicone layer ("blubber") covered by a stiff polyethylene membrane ("dermis"). The outcome of the LST analysis is a stability diagram showing TS wave frequencies versus downstream distance from the stem of the ship model (Figure 6). The area inside the loop-shaped curves corresponds to regions of amplifying (unstable) TS waves. A single unstable region (grey curve) is observed in the case of a rigid wall while this region splits into two much smaller loops (green curves) for the compliant surface, highlighting the ability of the "synthetic dolphin skin" to suppress many of the unstable TS waves. In particular, no unstable waves at all are seen in the range from 210 mm to 280 mm downstream of the stem.

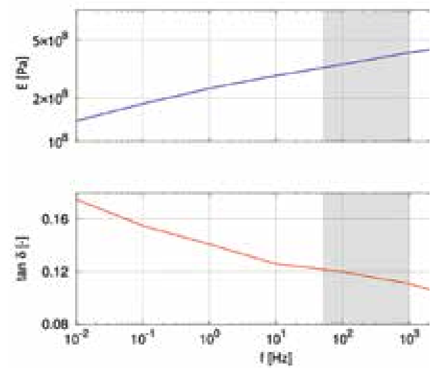


Figure 5: Dynamic mechanical analysis of a thin polyethylene film (data by Fraunhofer-IFAM): Stiffness (E-modulus, top) and damping (loss tangent, bottom) versus excitation frequency. The shaded area marks the frequencies of interest for transition delay

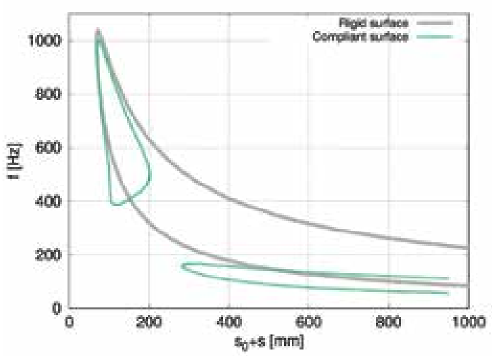


Figure 6: Stability diagram for slightly accelerated Falkner-Skan flow, modelling the laminar boundary layer along the bow of the SAR vessel. The diagram shows regions of amplifying TS waves for a rigid (uncoated) and a compliant (coated) bow surface ("blubber": silicone, "dermis": polyethylene)

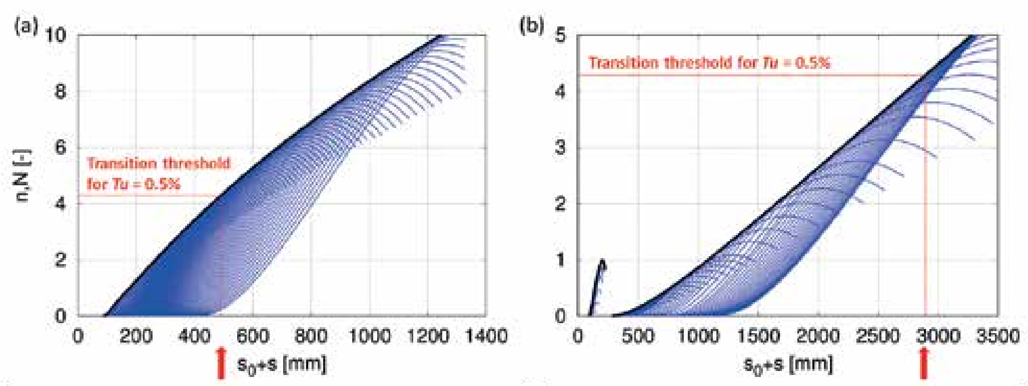


Figure 7: Prediction of the transition point by the e^N criterion after Mack [7], assuming a turbulence intensity of Tu = 0.5% in the test section of the HYKAT water tunnel. (a) Rigid surface: Transition to turbulence occurs approx. 0.5 m downstream of the stem (red arrow). (b) Compliant surface ("blubber": silicone, "dermis": polyethylene): Transition to turbulence occurs approx. 2.9 m downstream of the stem (red arrow)

Next, the e^N transition criterion after Mack [7] has been evaluated in order to compute the location of laminar-turbulent transition, assuming a turbulence intensity of 0.5% inside the HYKAT test section (Figure 7). This requires the calculation of the individual TS wave amplification curves (blue lines) and their envelope (black line). For the rigid surface (Figure 7a), transition to turbulence occurs approx. 0.5 m downstream of the stem of the ship model, while the compliant coating shifts the transition point by almost 2.4 m in the downstream direction (Figure 7b). This remarkable transition delay is mainly due to a substantial mitigation of the growth rates of all TS waves by the compliant coating.

Summary

In the research project FLIPPER, HSVA has developed a numerical procedure for the design of drag-reducing compliant coatings for maritime applications. The ingredients are a classic transition-prediction method widely used in aeronautics and a simple mechanical coating model inspired by dolphin skin. The new tool has been applied to the boundary layer along the bow of a small SAR vessel so as to establish values of the coating thickness, stiffness and damping suited to effective transition delay. Based on these findings, HSVA's partner Fraunhofer-IFAM has designed a "synthetic dolphin skin" made of silicone and polyethylene. According to HSVA's numerical prediction, this compliant coating is able to shift the transition location by almost 2.4 m under idealised conditions, leading to a significantly enlarged region of low-friction laminar flow along the ship hull. HSVA will soon conduct water-tunnel experiments to test the drag-reducing potential of the synthetic dolphin skin in a practical setting and to verify the numerical predictions as well as the suitability of the compliant-coating model. ■

FLIPPER is conducted by the Fraunhofer Institute for Manufacturing Technology and Advanced Materials (IFAM), Hamburg University of Technology (TUHH), ARKEMA and HSVA within the ERA-Net scheme MARTEC II of the European Commission. Funding by the Federal Ministry for Economic Affairs and Energy of Germany (BMWi) is gratefully acknowledged. HSVA thanks the Fassmer Group and DGzRS for their permission to use the hull design of the SAR vessel.

[1] Carpenter PW, Davies C, Lucey AD, Current Science 2000, 79(6): 758-65
[2] Carpenter PW, Garrad AD, J. Fluid Mech. 1985, 155: 465-510
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[6] Schrader L-U, HSVA Newswave 2015, 2015/1: 6-8
[7] Mack LM, in AGARD CP 1977, 224: 1.1-1.22

On Integrated Propulsor Design and Surface Friction Reduction

Research Projects HYKOPS and eSHaRk have got approval.

by Christian Johannsen

HSVA was awarded funding for two new research projects addressing very different, but forward-looking aspects of ship hydrodynamics. Both are joint research projects of three years duration, having been launched in the beginning of 2016.

HYKOPS, Development of a Framework for the Design of Innovative Manoeuvering and Propulsion Devices, is a national research project coordinated by the Flensburger Schiffbau-Gesellschaft with ten partners and funded by the German Ministry for Economic Affairs and Energy (BMWi).

Whoever has been asked to perform numerical calculations for a multi-part manoeuvering and/or propulsion device can certainly tell never-ending stories about the incompatibility of the geometry descriptions, especially when the parts were submitted by different providers. The first time consuming and error-prone challenge is to struggle with different numerical formats and coordinate systems to arrive at one consistent numerical model. Fine-tuning of individual parts of the arrangement often requires repeating this torture again and again. This is what HYKOPS is about. The aim is to build up a frame work that allows quick combination of various parts of a manoeuvering and/or propulsion concept to one consistent description. Shaft bracket arms or shaft bossings, semi-spade or full spade rudders, rudders with bulb or without, with flaps or with fins, ducts or stators behind or in front of the propeller, propellers with fins on the blade tip or on the boss cap – the list is almost unlimited. Interfaces to various calculation tools will be included in the frame work and tailor-made output formats for subsequent purposes will be provided.

The aim of HYKOPS is to make propulsor design more efficient and fail-save in future. HSVA will – among others – enhance the functionality of the in-house propeller analysis tool QCM. The analysis of ordinary and unconventional propellers shall finally show the same quality and reliability.

eSHaRk, Eco-Friendly Ship Hull Film System with Fouling Release and Fuel Saving Properties, is an European innovation action under the Horizon 2020 programme. The project is coordinated by PPG Coatings Europe BV and has five partners.

Even if the oil price is down these days, ships still sail slowly because of the tonnage over capacity, especially in the container transport market. The lower the ship speed, however, the more one can gain with a hull surface made for least frictional resistance, rather than a hull form made for least wave resistance. Consequently hull cleaning or silicone based paint are well known keywords in this respect, but eSHaRK covers a new approach to this. The project aims on friction reduction by means of a structured hull surface copied from fast swimming sea animals. In opposite to other approaches in the past this structured surface will be realized by a foil with foul release properties, being applied by a robotized laminator.

The aim of eSHaRk is to make shipping more cost effective and eco-friendly. HSVA will be responsible for the surface morphology as well as for the experimental evaluation of its effectiveness.

As different as the project targets of HYKOPS and eSHaRk are, HSVA's participation will help to improve our expertise towards our customer's needs. ■

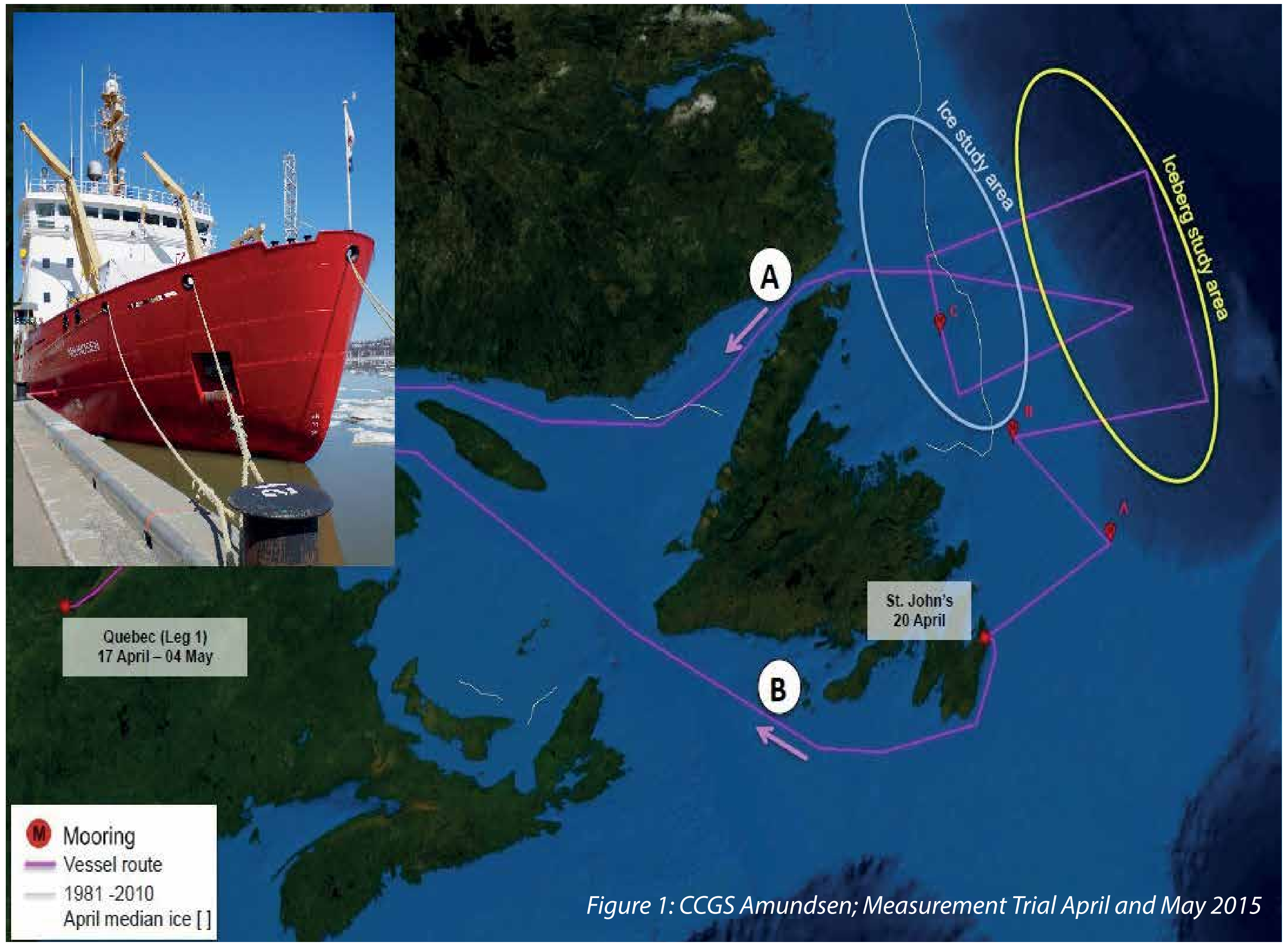


Figure 1: CCGS Amundsen; Measurement Trial April and May 2015

Conceptual Design and Testing of an Ice Force Measurement System

To investigate the development and characteristics of ice in the area of Newfoundland "Statoil" and "ArticNet" formed a joint research project. The intention was to band together a working group of scientists and crew members in order to conduct a safe and successful measurement trail on board the Canadian Coast Guard Ship "(CCGS) Amundsen".

by Philipp Hinse

HSVA participated in the Amundsen Trail Leg 1 in April and May 2015. The objective of HSVA was to design and test a new kind of ice force measurement system. Sensors on the outer ship shell at the ship side shall give information about the interaction between ice and structure for lower ice drift velocities. Processes as they can be found in drifting and compressive sea ice. The melting process was already in a late stage, but the Labrador Stream still brought a lot of ice down from Baffin Bay along the Labrador Coast to the waters of Newfoundland which was further apparent by icebergs and multi-year floes. The ice itself was subject to harsh weather and wave conditions during the winter.

The new Ice-Pressure Panel System is based on an Internal Ice Force Measurement system. The flexible magnetic fixing system was constructed to connect the sensor to the outer ship shell in a short time. Two sensor panels were lowered by a winch system, placed at the fender position,

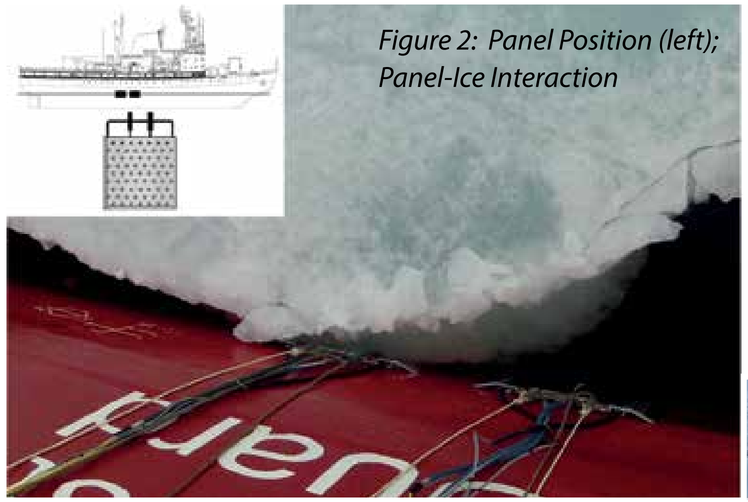
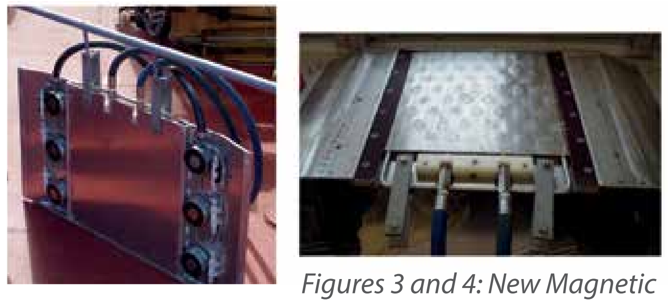


Figure 2: Panel Position (left); Panel-Ice Interaction


Figures 3 and 4: New Magnetic Ice Force Panel Sensor

to the waterline and saved by ropes to the ship in case of a disconnection. After bringing the sensors to the target position the magnets were switched on and the ship was manoeuvered against ice floes.


Figure 5: Ice Conditions, Ice Study Area, April 2015

The measurement system during expedition trial on board the CCGS Amundsen showed that it is possible to measure ice forces directly on the ship shell and by this provide a closer look to the interaction behaviour of ice and ship. Hereby a step from investigating local ice loads on vessels by back-calculation of measured strains on frames has been made to direct load determination by using ice force panels and hereby reducing the influence of the global structure. But this step implies an extreme change of sensor requirements and this especially in view of the installation. In this kind of ice force measurements the sensor system itself has to withstand harsh ice and weather forces. Through the ice force panel tests during the expedition in spring of 2015 on the CCGS Amundsen many new experiences were gained. These experiences will help to improve the sensor system, enhance new sensors, and the results will help to validate model tests as well as numerical models in many ways.

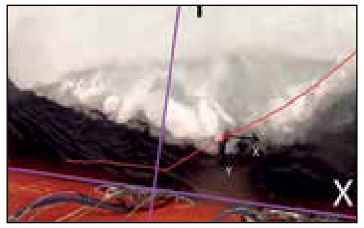


Figure 6: Motion analysis of an Ice Floe


Figures 7 & 8: Stitched Pictures of an Ice Floe (left); Area Analyses of Floe Shape (right)

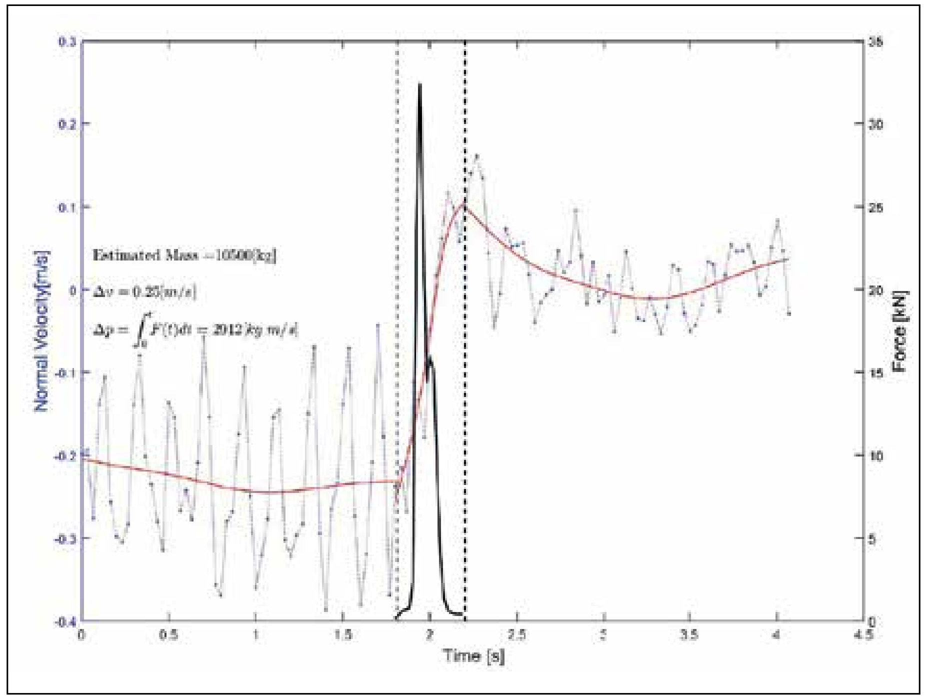


Figure 9: Momentum Analysis of Ice Ship Interaction

Photo: Bundesanstalt Technisches Hilfswerk, Ortsverband Bendorf

HSVA Investigation Helps to Improve Workboat Safety in the Federal Agency for Technical Relief

The behaviour of the multipurpose workboat MzAB of the Federal Agency for Technical Relief (THW) was investigated with respect to the general safety of the boat and especially with respect to an accident that took place on the Elbe River in Magdeburg in November 2013. The results of the investigation improve the safety of future workboat operations.

by Petri Valanto

The investigated multipurpose workboat MzAB of the THW is a 7.5 m long catamaran made of marine aluminium. With two outboard motors the boat is highly manoeuvrable and reaches the speed of about 33 to 35 kn. The boat has a very practical 1.3 m wide bow hatch. This allows an easy rescue of persons or floating objects, transport of bulky goods on wheels and facilitates easy operations with divers. These properties enable very versatile boat operations, which makes this workboat an interesting alternative to many help and rescue organizations.

On behalf of the Procurement Office of the German Federal Ministry of Interior (BMI) the behaviour and safety of the multipurpose workboat MzAB were investigated in various deployment scenarios and hazards in calm water and in waves, first with numerical computations, and subsequently with model tests in the most critical cases chosen. Circumstances, which can lead to hazardous situations or even to capsize of the boat, could be identified.

After the reconstruction of the accident circumstances on the Elbe River in Magdeburg on 23 November 2013, the potentially most hazardous situations were identified with various hydrostatic and hydrodynamic computations with the programmes SEDOS and HSVA Rolls. On the basis of the simulations of the full load case with these potential codes the combinations of speed, wave direction and wave length and height were chosen for the model tests.

Figure 1: The HSVA Model of the multipurpose workboat MzAB with an IBC-container on deck

As a final step the numerically predicted behaviour of the MzAB was verified and further investigated in the model tests for the general safety of the boat. With a free-running model of the MzAB tests in regular waves of various directions and speeds were carried out. Furthermore the accident scenario, as it took place on 23 November 2013 on the Elbe River at Magdeburg, was re-enacted twice in the model tests. The successful repetition closed out any boat behaviour by change in the tests. Further, special situations like engine failure, behaviour with an open bow-ramp in waves, and the course-stability and porpoising at high speeds in calm water and in waves were investigated.

Altogether the MzAB showed a very good behaviour in waves and could cope with extreme situations well. Critical situations did not occur, except in one range of speed and wave conditions, which also includes the accident scenario on the Elbe in November 2013. With the help of the numerical simulations and the re-enactment of the accident in model tests also the cause of the accident could to a large extent be clarified.

Figure 2 shows the MzAB in steep, 10 m long head waves at speed of about 8.5 kn. The relative speed between the MzAB and the waves is high enough to cause sufficient dynamic lift forces to heave the bow causing a somewhat rough ride, but providing also a safe passage of the boat.

Figure 3 shows the MzAB in steep, 10 m long following waves at speed of about 8.5 kn. The relative speed between the MzAB overtaking the waves and the waves themselves is low enough not to cause significant dynamic lift forces on the bow and is sufficiently high to let the bow to penetrate the wave crest, which in certain conditions can lead to very rapid flooding of the boat over the bow ramp. This mechanism was also the root cause for the mentioned accident on the Elbe River.

With the help of the gained knowledge on the behaviour of this boat type at different speeds in waves of various directions the ascertained risks or hazards can be pointed out at the training of the persons handling the boats.

This should considerably improve the operational safety of this widely used workboat type in the THW and other organizations using the boat in Germany and other European countries. The investigation report, HSVA Bericht Nr. 1684, in German can be downloaded at **www.hsva.de**.

The investigation was carried out in cooperation with the Hamburg University of Technology, Institute of Ship Design and Ship Safety. ■

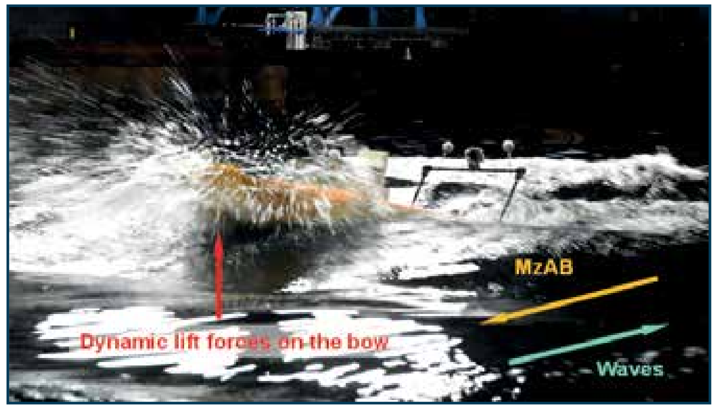


Figure 2: MzAB in head waves (180°), boat speed 8.5 kn, wave length 10 m, wave height 1.0 m

Figure 3: MzAB overtaking following waves (0°), boat speed 8.5 kn, wave length 10 m, wave height 0.6 m. At waves higher than 0.5 - 0.6 m instant flooding can occur

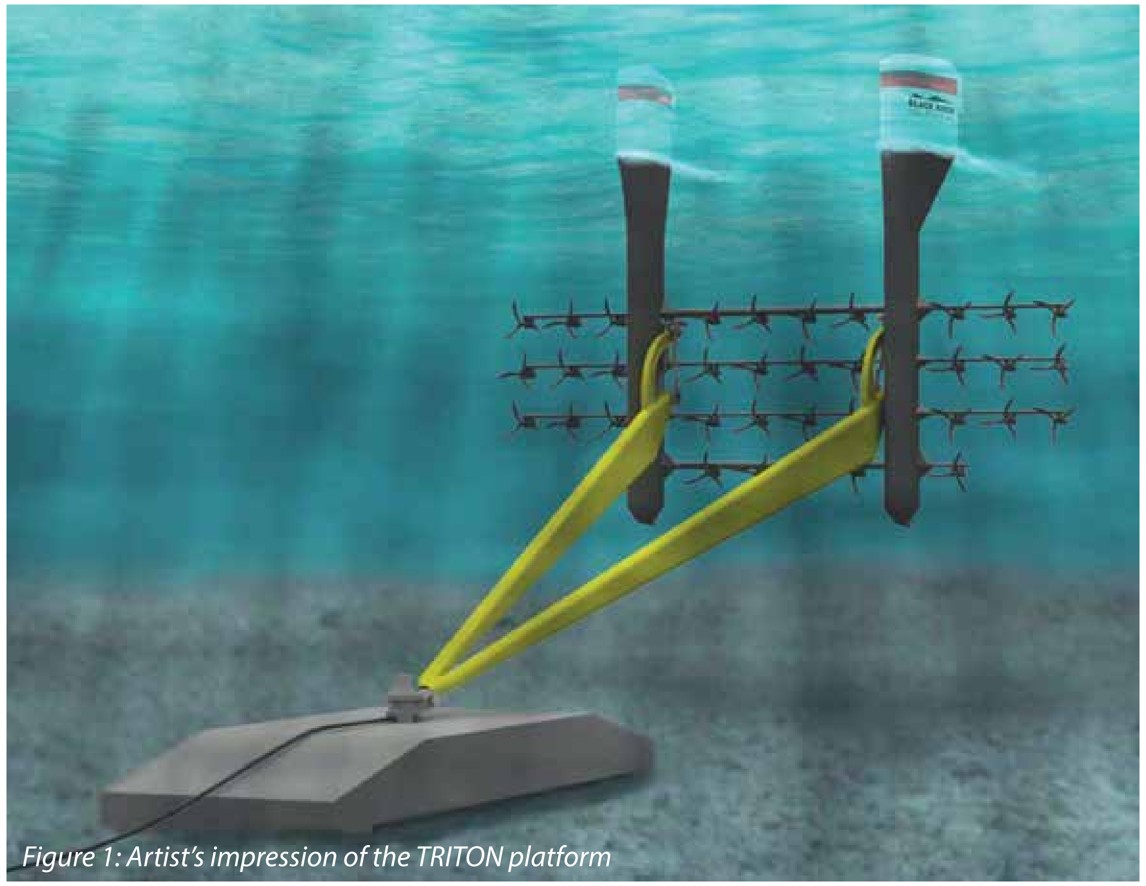


Figure 1: Artist's impression of the TRITON platform

Renewable Energy from Tidal Currents – the Research Project "TidalPower"

Tidal currents offer a highly reliable energy source since they are, in contrast to the wind or solar energy, very predictable and can thus contribute to the stabilization of future power supply systems.

by Katja Jacobsen

The idea of energy generation from tidal currents itself is not new, but new is the present concept developed by SCHOTTEL HYDRO GmbH (Figure 1). Contrary to the existing concepts, which have large turbines with diameters of up to 20 m mounted at the sea bottom, the innovative concept is based on the principle of a semisubmersible structure. Two floating spar buoys carry four cross arms, each equipped with ten SCHOTTEL turbines SIT250, resulting in an array of 40 turbines with the total capacity of 2 MW. The tether arm connects the floating TRITON platform to the fundament on the sea bottom. The swivel joint on the fundament enables the structure to follow the flow direction as well as to keep an optimal position, even for extreme tidal ranges, in the upper water layers with the highest flow speed.

The platform also allows an easy access for maintenance purposes, which is an important advantage compared to existing, completely submerged concepts: In the operating mode the top of the spar buoys, hosting the power and utility equipment, can be entered from service vessels. The turbines themselves can be accessed above the water surface in the maintenance mode of the platform, which is the platform rotated 90 degrees around the joints between tether arm and the spar buoys (Figure 2). The transition to the maintenance position and back to the operating position is enabled by deballasting or flooding the ballast tanks in the bottom of the spar buoys.

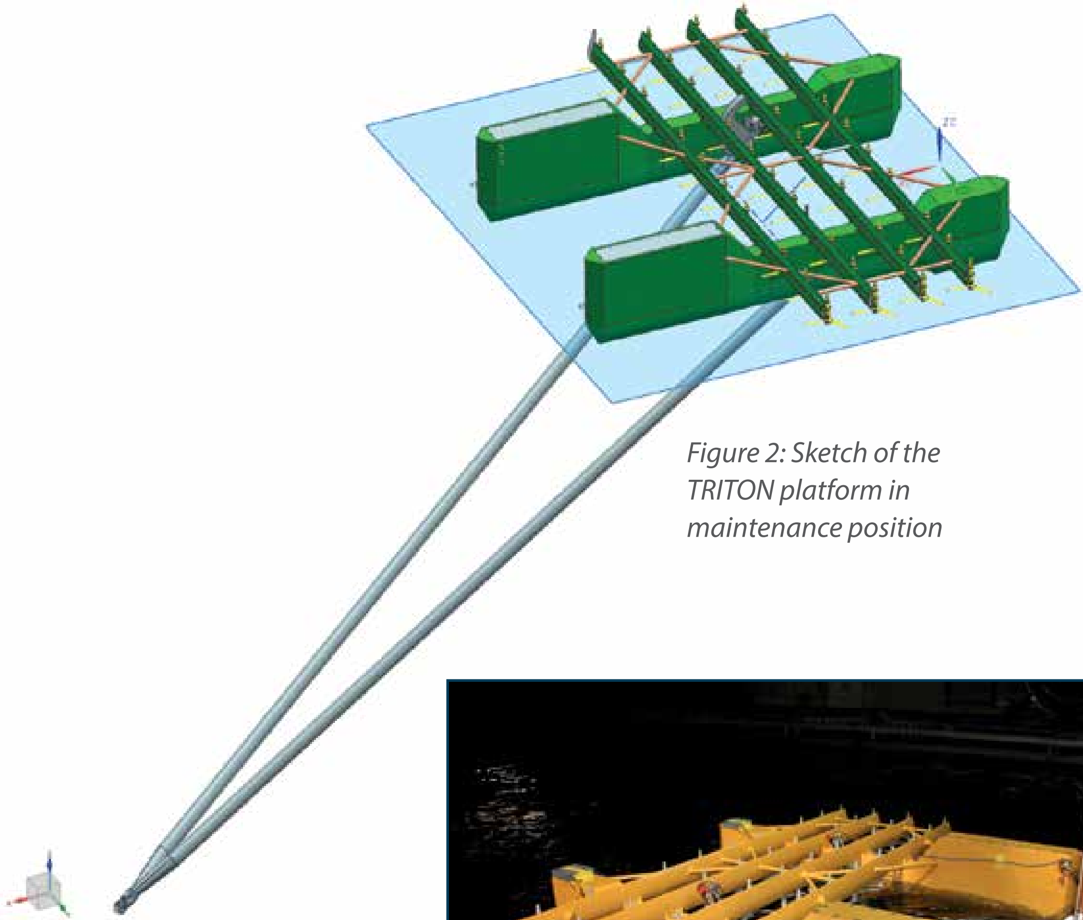


Figure 2: Sketch of the TRITON platform in maintenance position

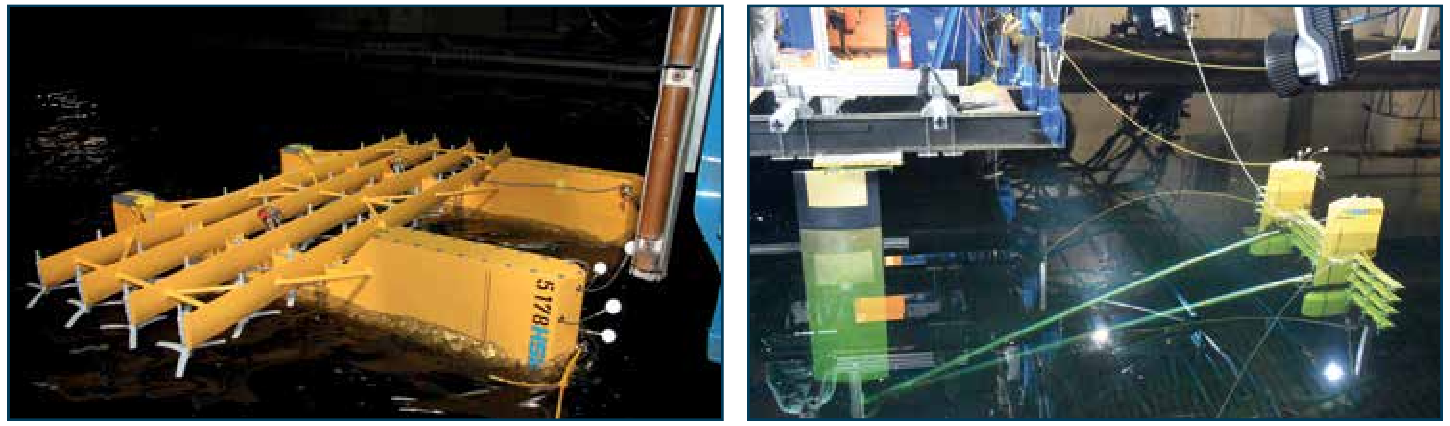


Figure 3: Fully equipped TRITON model in the maintenance mode (left) and test setup with the platform in operating position (right)

For reliably capturing tidal energy, the platform needs to have sufficient stability and survivability. Within the framework of the research project "TidalPower", partially funded by the German Federal Ministry for Economic Affairs and Energy (BMWi) and coordinated by SCHOTTEL HYDRO GmbH, the five project partners develop optimal solutions regarding design of the platform and its installation, the loads in the structure, the turbines and the control of the overall system. At HSVA the model of the TRITON platform, built at the scale of 1/17, is tested in various environmental conditions for operating and maintenance modes, as well as for the transition between these. Therefore the model is equipped with ballast tanks and a pump system.

In order to simulate the current flow on the model, the tether arm was connected at the depth of 3.3 m to the streamlined profile (sword) used for towing (Figure 3). The platform was tested in current and waves from all sides to determine the loads acting on the foundation and at the connections between the tether arm and the spars buoys as well as the motions of the platform in its 6 DoF. With the tests it was possible to confirm the favorable behaviour of the platform in waves regarding floatability and stability. Under the influence of multidirectional current and waves the platform reached a stable equilibrium very quickly. In waves the platform executes, as expected, only very small heave motions. The influence of a sudden asymmetric failure of a turbine on the platform orientation was simulated with decay tests. These tests proved that the platform recovers rapidly back to a stable swim position.

The tests in the maintenance mode covered tests at different current velocities and wave conditions. Also in this position the platform is floating in very stable manner, even in waves corresponding to the maximum expected 1-year wave. ■

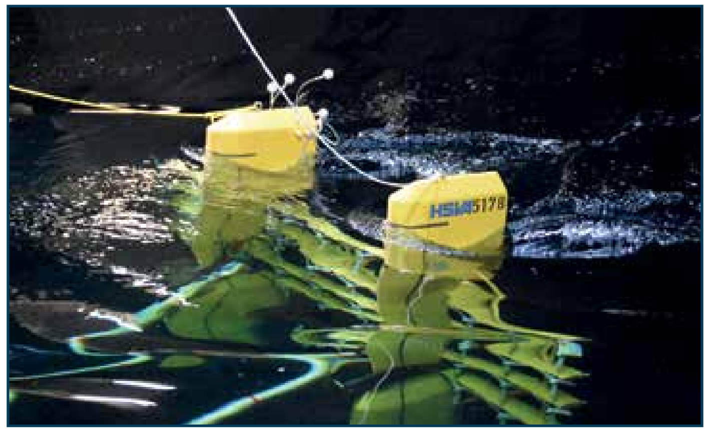


Figure 4: TRITON platform in waves and current

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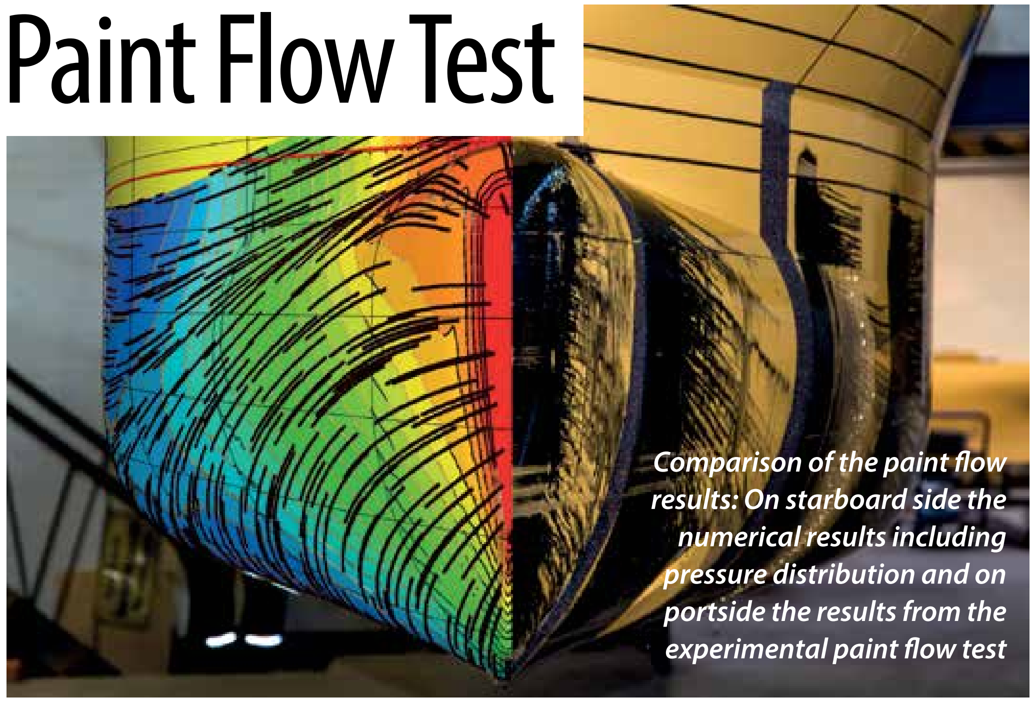
Numerical Paint Flow Test



Comparison of the paint flow results: On starboard side the numerical results including pressure distribution and on portside the results from the experimental paint flow test

An important task for towing tanks is the visualization of the flow on the hull surface. Usually, at HSVA a paint flow test is performed in the large towing tank for this purpose.

by Peter Horn

Viscous paint is applied at several stations on the hull and due to the shear forces acting on the hull surface at forward speed, the paint propagates into the direction of flow. After lifting the model out of the water, the paint visualizes the flow around the hull which can be investigated further. For example such information is important for the streamlined alignment of structures on the hull, like bilge keels or bow thruster grids.

At the same time, this type of test shows some drawbacks in terms of work effort, tank pollution and flow line assessment in areas with low flow velocities.

Progress in numerical modeling has been tremendous over the last years: The accuracy is increasing while the experience of using these methods is rising fast. The numerical approach allows a much more detailed assessment of the flow along the hull, even in areas where flow speed becomes very low.

Having reached the level of production readiness, HSVA therefore now offers the numerical paint flow method as a reliable alternative to the physical test.

Prior to offering this technology as a product, extensive validation has been carried out in order to demonstrate that the new procedure reaches the same level of accuracy as the established testing procedure. A selection of typical, high-quality experimental paint flow tests have been chosen to compare the results of both methods. Different setups and calculation settings for the RANS calculations have been checked within this study. As a quantitative comparison, resulting bilge keel flow lines and alignment angles of the bow thruster grids have been checked.

Overall, the numerical methods show a good compliance with the results from the experimental methods. In the range of measuring tolerance, the deviation of the bilge keel flow line is in the range of single-digit number of millimeters in model scale and few degrees for the bow thruster flow angle. The study showed that dynamic trim and sinkage of the model in numerical calculations have to be taken into account. Furthermore it can be derived from the results of the study that in many cases of large vessels with large draughts and low speeds, the free surface can be neglected, allowing a time-saving simplification to the calculations. However, this simplification cannot be applied for fast vessels which show more pronounced dynamic trim and sinkage characteristics.

The benefit of numerical paint flow test is a much more detailed view into the flow. After performing the calculation once, post processing opens a wide range of different analyses, e.g. pressure distribution and the three dimensional flow far from the hull surface, while the experimental paint flow test shows only the flow on the hull surface. Complex phenomena such as vortices and flow separations can be much easier visualized and analyzed.

This new product is offered as a reasonable and cost effective complement to the common scope of hydrodynamic investigations at HSVA. ■

AP Photo/Fiona Stewart, Garett McIntosh

Alternative Assessment of the Weather Criterion

In the last year HSVA experienced an increased interest in model tests regarding the Alternative Assessment of the Weather Criterion according to the IMO Interim Guidelines MSC.1/Circ.1200. In line with this trend extensive model tests to determine the roll angle φ_1 for a module carrier at several load conditions was performed for a European customer at the end of 2015. These facts prompt us to describe the associated model tests to alternatively assess the Weather Criterion for a ship design and to explain which benefits can be achieved.

by Arndt Schumacher

The conventional Weather Criterion was developed to guarantee the safety of a disabled ship against capsizing in severe weather conditions assuming a free-drifting vessel in beam wind and irregular beam seas. The minimum metacentric height of the ship fulfilling the criterion is determined. The following scenario is considered in the criterion (Fig. 1):

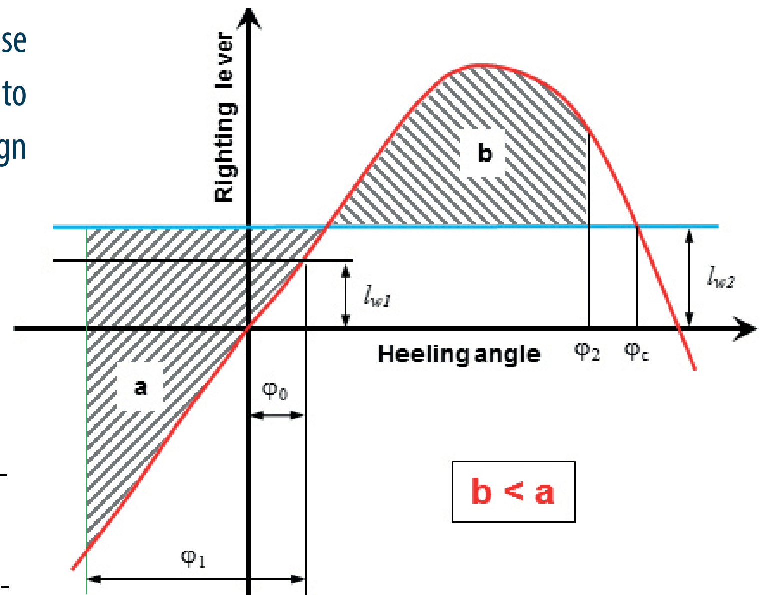


Figure 1: Conventional Weather Criterion

- **The ship is subjected to a steady beam wind, which results in a steady wind heeling lever l_{w1} at the resultant heel angle φ_0.**
- **Then the ship is assumed to roll owing to wave action triggering resonant roll motion to a roll angle φ_1 windward.**
- **In the moment the ship reaches the roll angle φ_1 a wind gust grasps the ship producing a wind gust heeling lever l_{w2}, being 50% larger than the steady wind heeling lever l_{w1}.**
- **Under these circumstances the IMO criterion requires that the area b shall be equal to or greater than area a. The idea behind this requirement is the ability of the ship to absorb the total kinetic energy of the roll back action to leeward as potential energy and hence to stop the dynamic motion without capsizing. In Fig. 1 the criterion is not fulfilled.**
- **The angle φ_2 is the smallest of the following angles respectively: 50°, the largest angle of heel at which no watertight openings immerse or the angle of second interception between wind heeling lever l_{w2} and curve of static stability φ_c.**

In the conventional IMO Weather Criterion (Resolution MSC.267(85), Part A) the steady wind heeling lever l_{w1} is determined by a simple approach not considering its dependency on the ship's heeling angle (constant value for the whole heeling angle range). Further the angle of roll φ_1 is calculated by an empirical formula, composed by a number of coefficients related to different ship characteristics such as the block coefficient, beam, draught and the effect of bilge keels.

Nowadays the Weather Criterion has a limited applicability for ship designs having larger dimensional ranges than originally planned for the criterion, i.e. large passenger RoRo, RoPax, container and heavy lift vessels. Consequently, it has become economically attractive to consider alternative approaches, which better deal with dynamic effects. Another reason for the implementation of alternative methods is that the Weather Criterion requirements are often more stringent and quite frequently restraining design dimensions when other stability criteria indicate a satisfactory safety margin. As a result, IMO allows the use of model tests (wind tunnel and tank tests) to substitute the empirical estimations for the wind heeling lever arm and the angle of roll as described in the Interim Guidelines for Alternative Assessment of the Weather Criterion. All these alternative determinations must be approved by the Administration before the model tests.

In the Weather Criterion it is explicitly recommended to determine the angle of roll φ_1 by model tests according to the guidelines MSC.1/Circ.1200, if at least one of the ship parameters is outside of the following limits:

- **Ship's breadth / Mean draught ≥ 3.5**
- **- 0.3 ≥ ((KG / Mean draught) - 1) ≥ 0.5**
- **Natural roll period ≥ 20 s**

The alternative standard procedure is the direct measurement of the "regular wave roll-back angle" φ_{1r} from which the roll angle φ_1 is determined ($\varphi_1 = 0.7 \cdot \varphi_{1r}$). Model tests in regular beam waves with a required steepness, which depends on the vessel's natural roll period, are performed for a number of wave frequencies. In some cases this procedure is not feasible due to the generation of very steep waves and the wave maker capacity, especially if the vessel has a long natural roll period and a ship model with relatively small scale factor is used. In such cases two different alternative procedures (the three-step procedure and the Parameter Identification Technique, PIT), which allow model tests in less steep regular waves can be applied. But the three-step procedure is sensitive to the quality of the required roll decay tests and the PIT to the quality of the analytical model applied and the numerical solver. In Fig. 2 the benefit of a smaller roll angle φ_1 is shown.

If the vessel features an uncommon large lateral plane area above waterline, it is recommended to perform model tests for the alternative determination of the wind heeling lever l_{w1}. One of the benefits of this approach is the dependency of l_{w1} on the heeling angle (see Fig. 3). The recommended standard model test procedure consists of two different tests: Wind tunnel tests for the determination of the heeling moment $M_{wind}()$ due to steady beam wind and transverse towing tests for the determination of the heeling moment $M_{water}()$ due to steady drift. The wind heeling lever l_{w1} is obtained with the equation:

$$l_{w1}() = (M_{wind}() + M_{water}()) \, / \, displacement.$$

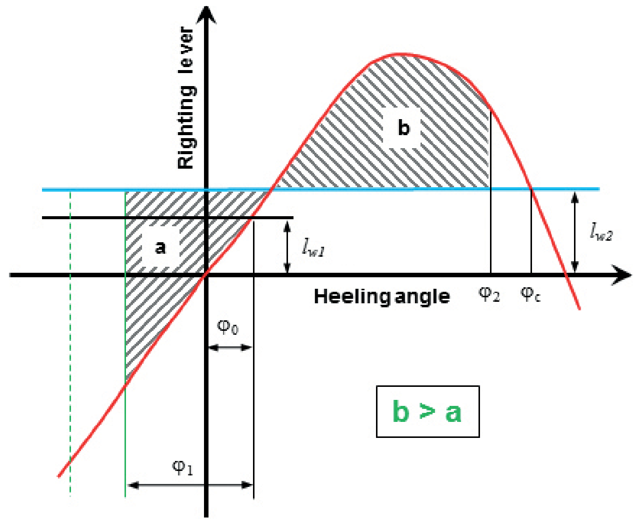


Figure 2: Weather Criterion with decreased angle of roll φ_1

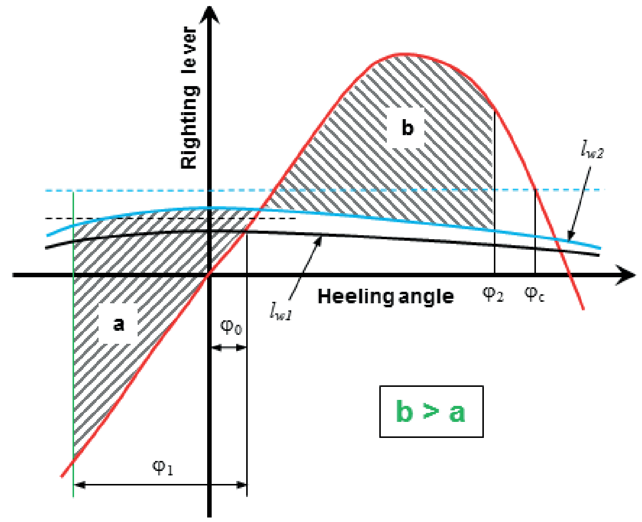


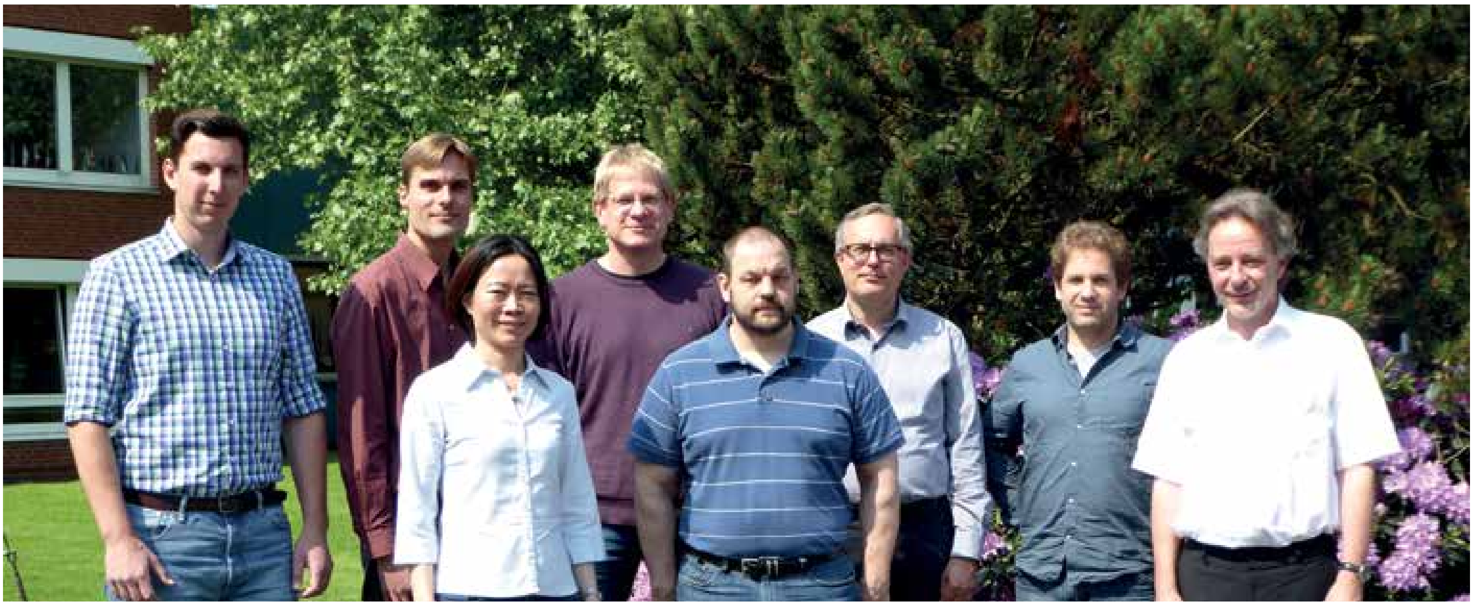
Figure 3: Weather Criterion when the wind heeling lever is reduced and dependent on the heeling angle

As an alternative simplified procedure wind tunnel tests are conducted for the upright condition only. Furthermore, the drifting tests can be skipped and as simplified approach the drift heeling moment $M_{water}()$ can be considered as given by a force equal and opposite to $M_{wind}()$ acting at the hull at half draught. But it is recommended to perform the transverse towing tests if the vessel has a relatively large breadth to draught ratio since the transverse force acting position is often higher resulting in a significantly decreased drift heeling moment.

Prior to carrying out the model tests, it should be carefully checked, which approach is most suitable to yield the minimum allowed metacentric height: the alternative determination of the steady wind heeling lever l_{w1}, the roll angle φ_1 or both. Table 1 gives an overview of the different recommended test procedures according to the MSC.1/Circ.1200 guidelines. Using model tests to determine the required metacentric height according to the Weather Criterion can lead to considerable benefits in the ship design. ■

Table 1: Overview of the different recommended test procedures according to the MSC.1/Circ.1200 guidelines

Alternative Determination of	Recommended if	Procedures acc. MSC.1/Circ.1200	Needed Model Tests and Calculations	Remarks
Angle of Roll φ_1	$B/d \geq 3.5$ $-0.3 \geq KG/d-1 \geq 0.5$ $T_{roll} \geq 20$ s	Standard procedure: Direct measurement	For each Load Case (GM, draught): - 1 test series in regular beam waves with constant steepness at a number of wave frequencies	- in general a ship model with relativ large scale factor is needed
		Alternative 1: Three-step procedure	For each Load Case (GM, draught): - Some roll decay tests in calm water - Some tests in regular beam waves with smaller steepness	- in general the cheapest procedure - in general ship model with smaller scale factor can also be used - procedure is sensitive to the quality of the roll decay tests
		Alternative 2: Parameter identification technique	For each Load Case (GM, draught): - 2 test series in regular beam waves with different steepness at a number of wave frequencies - Numerical parameter identification	- is the costliest procedure of the three - in general ship model with smaller scale factor can also be used - procedure is sensitive to the used analytical model and the numerical solver - high knowledge in the theoretical backround is needed
Wind Heeling Lever l_{w1} $l_{w1} = \frac{M_{wind}(\varphi) + M_{water}(\varphi)}{\Delta}$	*Wind Tunnel Tests:* Large above-waterline lateral plane area	Complete test procedure Determination of M_{wind}	For each Draught: - 1 crosswind test at upright condition and a suffient number of heeling conditions to lee and wind side	- a wind tunnel model for different heeling angles have to be built
		Simplified test procedure Determination of M_{wind}	For each Draught: - 1 test series in crosswind at upright condition (M_{wind} is assumed to be constant independent by heeling angle)	- a cheaper wind tunnel model for the upright position have to be built only - the possible benefit of the decreasing wind moment with increasing heeling angle is not taken
	Drifting Tests: $B/d \geq 3.5$	Complete test procedure Determination of M_{water}	For each Draught: - 1 series of transverse towing tests at upright condition and a suffient number of heeling conditions to lee and wind side	- in general relative large ship models can be also used - relative cheap and easy model tests
		Simplified procedure Determination of M_{water}	For each Draught: - Assumption that M_{water} is the determined wind force Fwind acting at d/2 on the hull	- only wind tunnel test are needed - the possible benefit of the drifting tests is not taken



Members (from left to right): Jan-Patrick Voß, Lars-Uve Schrader, Yan Xing-Kaeding, Jörg Brunswig, Scott Gatchell, Dieke Hafermann, Marco Schneider, Jochen Marzi (head of department)

HSVA's Computational Fluid Dynamics Team

Computational Fluid Dynamics (CFD) is arguably the most important technology for modern hydrodynamic analysis. In recognition of this fact HSVA formed a dedicated CFD team already many years ago.

With a varying crew this unit has established a proven record of achievements with code developments as well as successfully run complex customer projects. Today, the CFD department at HSVA has a strong team of eight members, participating in advanced national and international research projects as well as a wide variety of industry projects. With the help from our in-house developed tools, potential flow code ν-SHALLO and the RANS code *FreSCo+*, the CFD team can perform a large range of complex CFD investigations covering marine flow problems from classic resistance and propulsion predictions to detailed investigations, such as energy saving devices, seakeeping, bubble sweep down analyses and aerodynamic flow.