issue 1-19

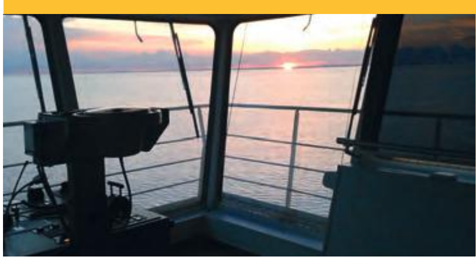
HSVA newswave

The Hamburg Ship Model Basin Newsletter

Rolling News

HSVA greatly improved the HERM method within the research project *HERMes*

Full Scale Measurements – A Valuable Input to Performance Optimisation



TrAM – How to Optimise Battery-Driven High-Speed Marine Vehicles

Flow Generator Development for Cussons' Large Cavitation Tunnel K44

editorial

Dear reader,

these times are all about change – such as changing markets, technologies and legislative conditions. As a research based service provider, reacting to change and pushing change ourselves should be our DNA. We should look for the optimum solution to our clients. This can be hard work as smart solutions are not always the simplest ones, as Einstein is quoted for: *"A ship is always safe at shore but that is not what it's built for."* However, also with respect to change, people are different, some are more reluctant to change than others. Personally, I love the dynamics of change and development, and I enjoy seeing the sparkling eyes of the many in my team when they find or develop something new!

Some of our recent changes are based in our own developments such as optimizing our production for a better service to our customers. Other changes origin in the diversification of the ever changing market we are simply faced with. Our strength is defined by responding appropriately to them.

In this sense, I am pleased to present our new issue of NewsWave full of recent projects. There is an increasing demand for artic technology and we have recently been looking into the behaviour of common hull shapes in ice – a result of a good cooperation with ONR showing again that increasing our expertise means cooperation is the key.

Another good example for a long standing good cooperation together with innovative thinking are outdoor tests performed in a lake in the Hanseatic town of Lübeck. To quote Einstein once more, *"We cannot solve our problems with the same thinking we used when we created them."* We have been working on new solutions and on many more key topics, and I hope you enjoy reading on some of them in this NewsWave!

Best wishes,

Prof. Dr. Janou Hennig

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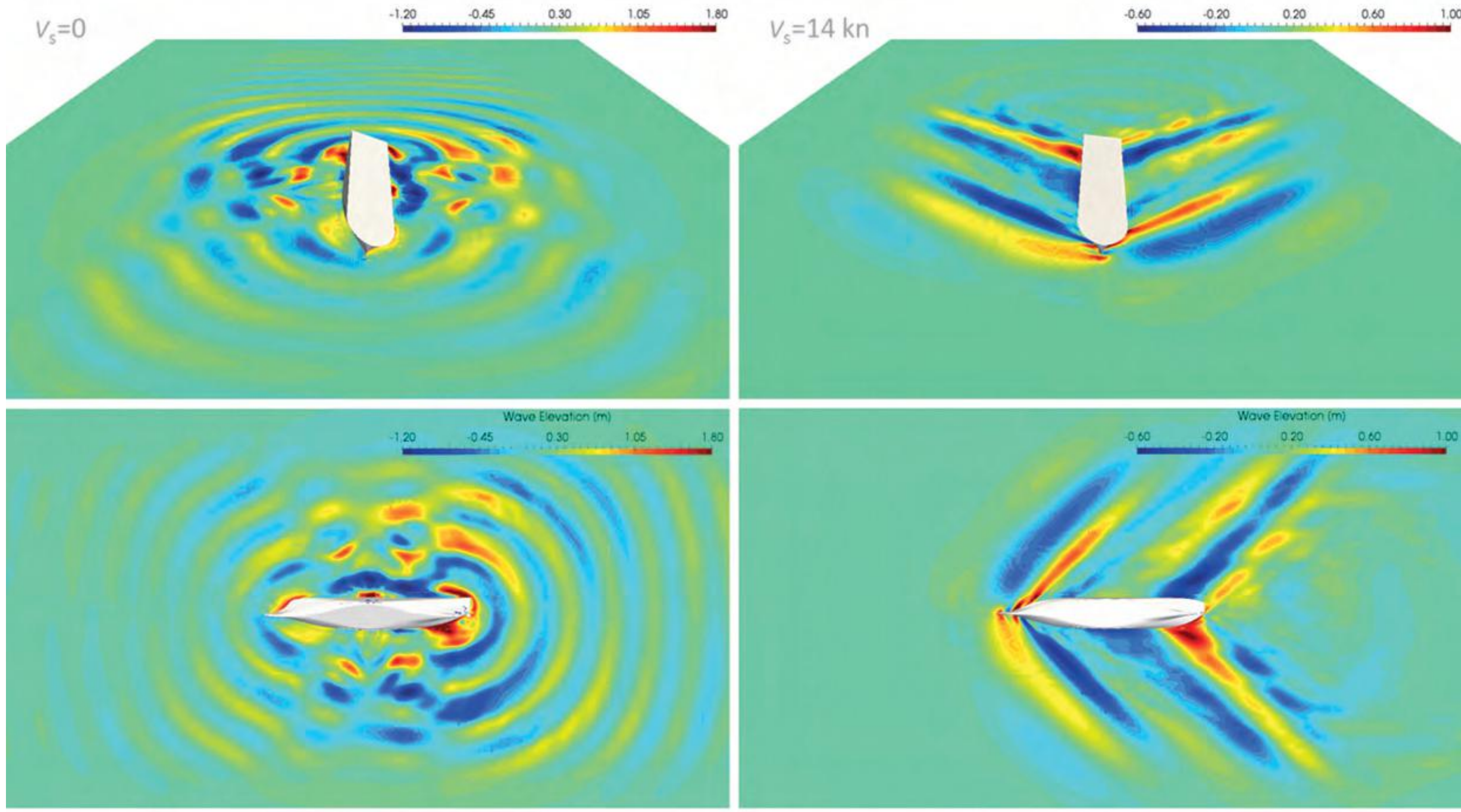

HERMes Brings You Rolling News

HSVA recently enhanced the capabilities of the in-house flow solver *FreSCo+* in order to simulate harmonic excited roll motions of ships.

by Lars-Uve Schrader

In adverse sea conditions ships may be exposed to excessive rolling due to the small rotational inertia, restoring force and damping of the roll motion compared to the other degrees of freedom. Accurate roll predictions are therefore essential to accomplish a safe ship design. Potential theory-based methods for the calculation of motions in waves do not fully capture the physics involved in ship rolling such that they need input in terms of roll damping coefficients. These may be obtained from roll decay tests with sufficient accuracy unless the ship model is subject to extensive roll damping e.g. in the presence of large appendages or anti-roll devices and at forward ship speed. A superior alternative for these cases is to conduct tests with harmonic excitation of the roll motions (HERM). Recently HSVA greatly improved the HERM method within the research project ***HERMes*** introducing a new gyroscopic excitation device along with enhanced test and post-processing procedures [1]. ***HERMes*** also addressed the development of a "virtual HERM test" based on CFD which was implemented into HSVA's RANS equation solver ***FreSCo+***. ►

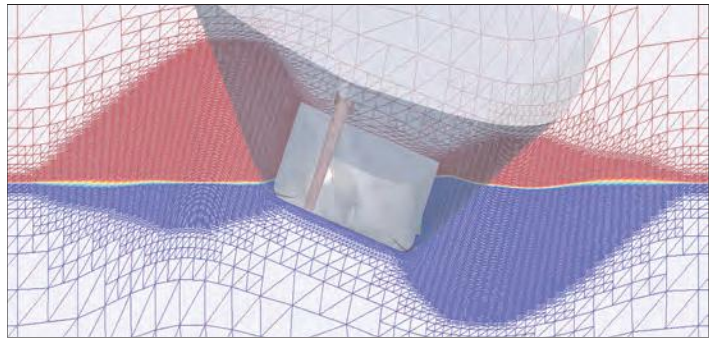

Figure 1: Cross cut through the CFD mesh highlighting the mesh deformation around the rolling ship hull. Colors show the location of the free surface between water (blue) and air (red)

Numerical Setup

FreSCo$^+$ features a body motion solver along with different CFD mesh treatments to track the ship motion response to HERM forcing (or waves). The mesh deformation approach was chosen for the HERM simulations for efficiency reasons. The CFD mesh was designed such that the free surface stayed within the refined region even for the largest occurring roll angles (Figure 1). In the chosen framework the forward speed of the vessel (if any) was realised by moving the fluid while suppressing the surge motion of the hull. The other five degrees of freedom were largely unconstrained; however, the sway and yaw components needed to be limited by individual PID controllers mimicking the rudder action so as to avoid excessive nonphysical drifting and yawing of the rolling vessel.

The virtual HERM methodology was applied to the Hamburg Container Ship (HCS, see [1]) considering bare and appended hulls at different ship speeds. The bare hull at zero speed turned out to be very weakly damped such that long simulation times were needed to obtain convergence of the roll angle amplitude (Figure 2a). To speed up the simulations HSVA implemented the method of Artificial Induced Damping (AID) developed by the Hamburg University of Technology (TUHH) [2]. The idea behind AID is to increase the roll damping of the ship hull artificially so as to accelerate the initial transient simulation phase; simultaneously an auxiliary phase-shifted external forcing moment is imposed to compensate for the extra roll damping.

HSVA slightly modified the original AID implementation of [2] in that the AID action was phased out after a short while (Figure 2b). This approach led to a considerable speed-up of convergence towards the final roll amplitude. In the present example (bare hull at zero speed) the integration time could be reduced from some 80 s to about 20 s thanks to the AID approach (Figure 3), allowing for a substantially shorter simulation time.

Validation and Application

HERM simulations were carried out for different HCS hull configurations at scale 1:52 considering the bare hull and hulls with bilge keels of different heights (0.2 and 0.8 m in full scale). Moreover two different ship speeds (0 and 14 kn) and several excitation moments were investigated. The steady-state roll amplitudes obtained were compared to the corresponding values of the tank experiments

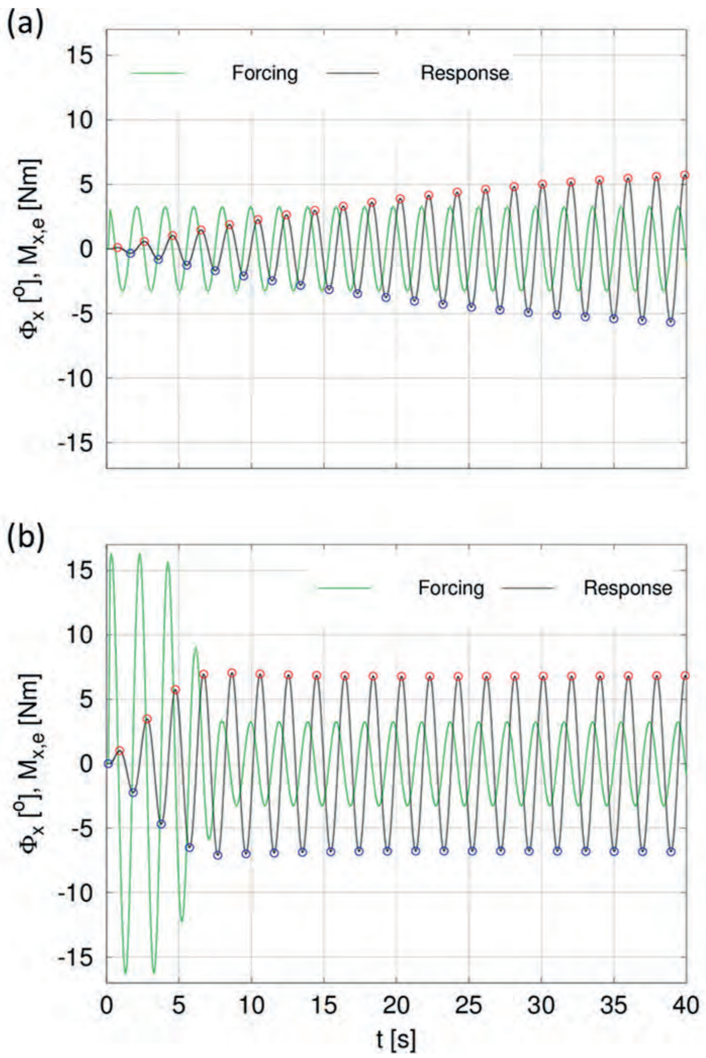

Figure 2: Excitation of roll motion (HERM) of the HCS bare hull (scale 1:52) at zero speed and an excitation moment amplitude of 3.25 Nm (a) without and (b) with the Artificial Induced Damping (AID) technique using an AID moment of 9.75 Nm

(cf. [1]). Although CFD moderately overestimated the roll damping, leading to slightly smaller roll angles (Table 1), the overall agreement with EFD was good. Simulations at zero ship speed turned out to be somewhat more intricate because the boundary layers needed to be resolved (no wall functions) owing to the small flow speed in these cases. The desired roll damping coefficients can then be directly calculated from the roll amplitudes.

The ***HERMes*** project is going on until September 2019: HSVA is currently using the new virtual HERM methodology to investigate the impact of bilge keel size on the roll damping of ships at various forward speeds. CFD simulations are particularly well-suited to this end as they provide detailed data for the analysis and visualisation of

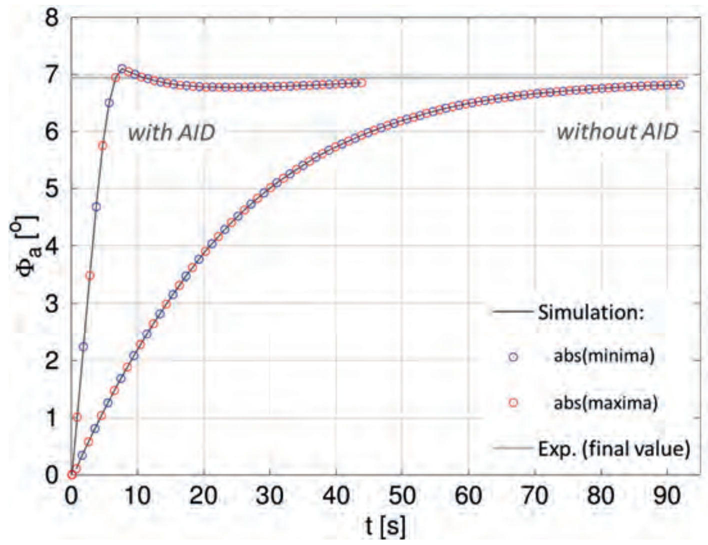

Figure 3: Evolution of the roll amplitude for the HCS bare hull at zero speed under moment excitation without and with the AID technique

V_s [kn]	$M_{x,a}$ [Nm]	T_a [s]	h_{bk} [m]	Φ_a (EFD) [°]	Φ_a (CFD) [°]
0	3.25	1.97	-	6.94	6.82 (-1.7%)
0	34.84	1.93	0.2	19.06	18.47 (-3.1%)
0	92.78	1.94	0.8	22.76	22.26 (-2.2%)
14	16.08	1.92	-	11.10	11.01 (-0.8%)
14	16.08	1.92	0.8	6.99	6.92 (-1.0%)

Table 1: Comparison between steady-state roll amplitudes obtained by physical (EFD) and virtual (CFD) HERM tests of the HCS at model scale 1:52, considering different ship speeds, excitation moments and periods and bilge keel heights

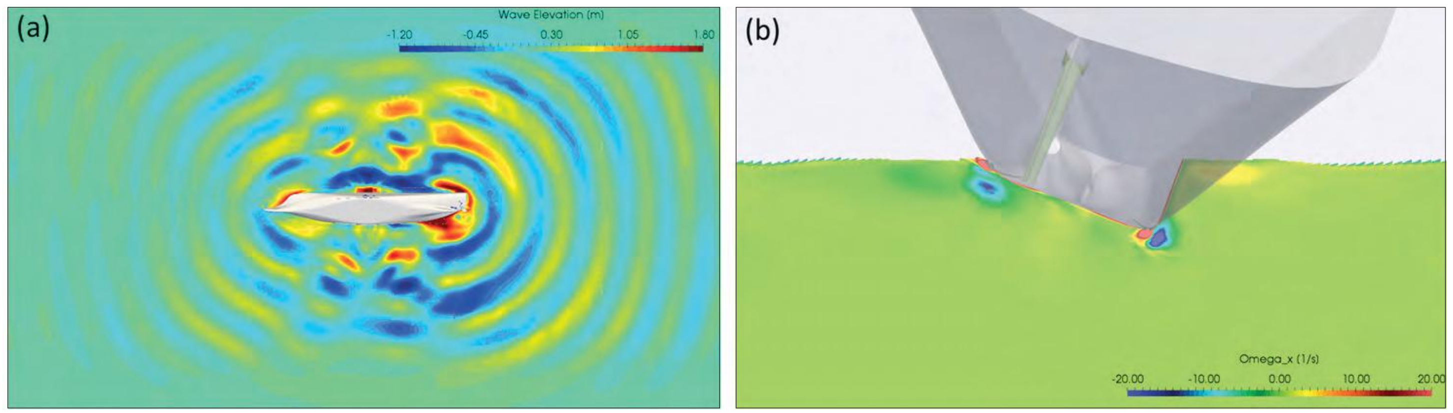

Figure 4: Roll motion of the HCS hull with 0.8-m bilge keels at zero speed.
(a) Wave field looking from below, (b) axial vorticity in the mid-ship cross section

bilge keel effects on wave making (Figure 4a) and vortex generation (Figure 4b). Another scientific aspect in the focus of ***HERMes*** is the scaling of model results to ships for an improved quality of HSVA's seakeeping predictions.

Summary

In the project ***HERMes*** HSVA substantially improved the experimental execution of HERM-based roll damping studies (see [1]) and added the "virtual HERM test" to the service portfolio. The former approach ideally complements HSVA's experimental seakeeping services while the latter method is useful during the vessels' design phase. Both approaches are ready for application to industrial projects on ship stability in waves – please contact us for a tender. ■

Supported by: Federal Ministry for Economic Affairs and Energy, on the basis of a decision by the German Bundestag

The project ***HERMes*** is funded by the Federal Ministry for Economic Affairs and Energy, Germany.

[1] A. Schumacher, Enhanced Experimental Technique for the Effective Determination of Ship Roll Damping, HSVA newswave 1-18, pp. 6-8, 2018

[2] S. Wassermann, P. Sumislawski, M. Abdel-Maksoud, Accelerated HERM Technique by Induced Artificial Damping for Efficient Ship Roll Damping Estimation, Proc. 13th Int. Conf. on the Stability of Ships and Ocean Vehicles (STAB), Kobe, Japan, pp. 627-634, 2018

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5th Seminar for Shipowners

On 20th of March 2019 HSVA invited shipowners from Northern Germany to Hamburg for the 5th Seminar for Shipowners. Our guests in the welloccupied venue have been welcomed by Prof. Dr. Janou Hennig and her team in the quite unique atmosphere of a cosy private cinema.

by Hilmar Klug

Dr. Jochen Marzi, Dr. Petri Valanto and Dr. Florian Kluwe delivered three presentations about different topics under the umbrella of the seminar title "Reduction of Emissions in Shipping – The Contribution of Design and Hydrodynamics":

The design of efficient ships – the role of the shipbuilding research institute in a holistic process; Jochen Marzi (Head of the CFD Department)

Today, ship design is a holistic process in which a multitude of different design disciplines play a decisive role. Besides stability, strength and many others, hydrodynamic performance is an indispensable prerequisite for fulfilling the transport task of a ship. Efficiency and legal environmental requirements demand particularly efficient and low-emission ships today and in the future. At the design stage, essential steps are taken to ensure safe, economical and environmentally friendly operation and it is here that shipowners, operators and charterers can influence the future ship and its economic success which often hinges on its hydrodynamic performance. The role of the model basin is evolving into a central service provider in the design process, contributing to product development with special knowledge and investigations, also taking into account life cycle aspects. The presentation highlights HSVA's current developments in the areas of ship resistance, propulsion and energy management in the context of ship design. Using modern methods, the components of resistance, from friction to aerodynamics, are investigated and optimisation possibilities are demonstrated.

Hydrodynamic boundary conditions for the safe and efficient operation of ships in seaway and in ice; Petri Valanto (Head of Seakeeping and Manoeuvring Department)

Traditionally the optimisation of the propulsion power in calm water is the main focus in the ship design process with the obvious goal to keep the fuel consumption and consequently the operating costs as low as possible. The EEDI regulations intensify this effort under the consideration of the CO^2- output per transport work done. As the design condition in calm water is hardly ever met after the ship delivery, the total resistance of the ship hull in real conditions in wind and waves is a worthy secondary objective of the hydrodynamic optimisation of the hull form. This approach to optimise the propulsion power is frequently accompanied by safety regulations or concerns. Thus the evident question arises: How much power is necessary also in adverse weather conditions still to be able to navigate safely. How can the Safe Return to Port or the Minimum Safe Powering requirements be satisfied without installing unnecessary additional power on board. Further new challenges unfold along the opening of potential arctic shipping routes. The presentation seizes these questions and gives detailed insights on how information from numerical calculations and model tests can be used for the advantage of the clients, for a better ship design satisfying all necessary rules and requirements.

Verification of the required propulsion power in full scale – challenges and solutions; Dr. Florian Kluwe (Head of Resistance & Propulsion Department)

Determining the required propulsion power of a real ship in full scale is an important parameter for demonstrating the performance of a ship's design. It is linked to numerous contractual and legal obligations. This includes the building contract, which usually sets the objectives for performance and speed. Furthermore, the achieved Energy Efficiency Design Index (EEDI) is of paramount importance. (For details on this topic please read the corresponding article.)

The presentations were followed by a lively and much longer than anticipated discussion involving all speakers plus Mr. Christian Johannsen (Head of the Propellers & Cavitation Department) on the stage and our guests in the audience. The discussion was hosted by Mr. Nils Reimer (Head of the Arctic Technology Department) and covered many of the topics that are on the shipping businesses' agenda today.

The day ended with further talks and discussions during the final reception with drinks and fingerfood.

The very positive feedback from the attending representatives from shipowners, supplying industry, class, university and the German Society for Maritime Technology made the decision easy to continue our series of seminars for shipowners.

The next seminar will be held in spring 2021 and we are happy to invite you already today and look forward to welcome you in Hamburg for the 6th Seminar for Shipowners.

In order to serve you with information and our thoughts about the most interesting topics please send us your proposals to **seminar@hsva.de**

Evaluating Full Scale Performance

The power demand and the related speed-power performance are important factors for the competitiveness of ships and thus are settled in contractual clauses and assigned with significant penalties. With the introduction of the Energy Efficiency Design Index (EEDI) the importance of speed trials increased even further.

by Florian Kluwe and Jan Richter

Full scale measurements are valuable input to the optimisation of in-service performance and basis for the development of correlation procedures between prognosis-models (model tests, CFD) and the real ship. For these reasons an accurate determination of the power demand during sea trials is crucial and needs to be performed reliably and accurately.

Even if the measurements are made with highest precision and state-of-the-art tools the resulting figures may not be directly comparable with contractual figures as the latter are associated with reference conditions while the trial is conducted under limited but uncontrolled environmental conditions. The raw data need to be processed and converted to the reference conditions by applying various corrections.

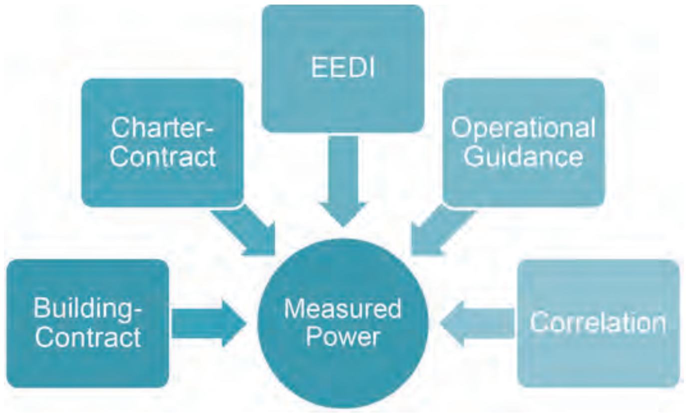

Figure 1: Motivation: Stakeholders in Full Scale Performance Data

A set of input data is needed to perform this data processing which includes environmental conditions (wind, waves, water depth, etc.) and ship and propulsion related data (such as torque, rpm and speeds) – see Figure 2 for an overview.

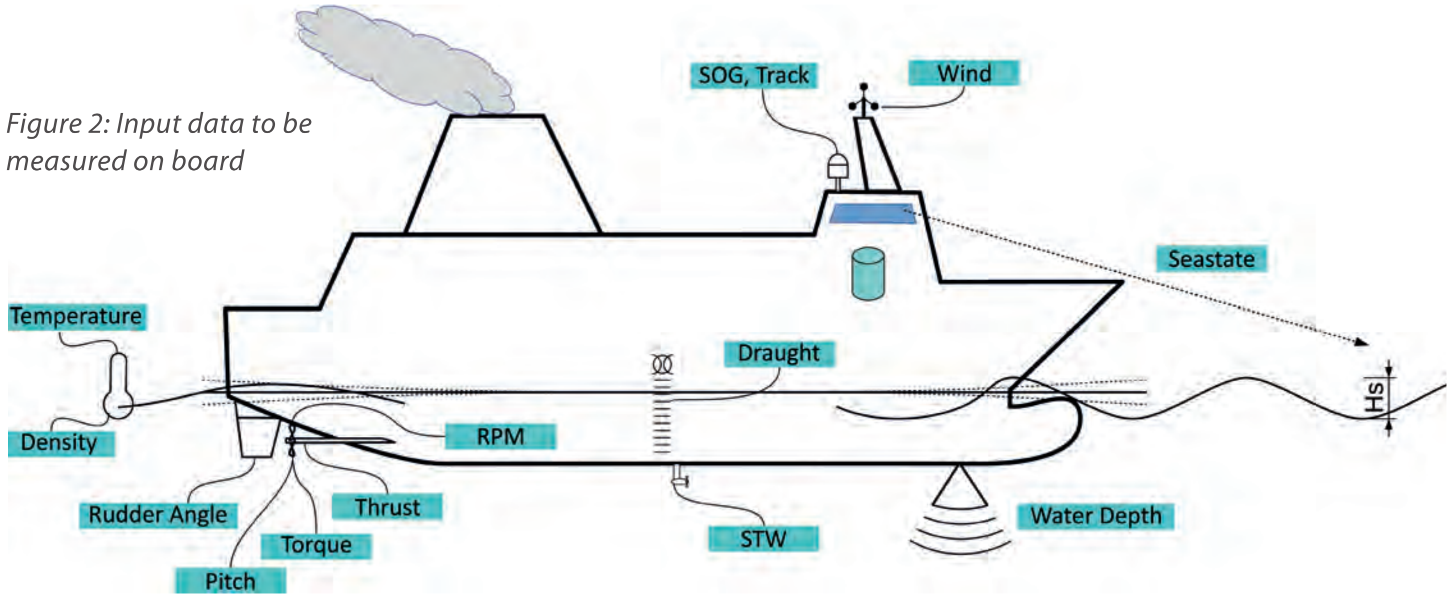

Figure 2: Input data to be measured on board

For the conversion to reference conditions various semi-empirical procedures have been developed over the years by model basins, shipyards and standardisation organisations. While individual yard-standards were the prevailing procedures in the past this has fundamentally changed with the establishment of the EEDI, which requires corrections following either the ITTC or the ISO standard. Prior to entering into force of the EEDI, efforts were made to harmonise both approaches, aiming at a unified procedure for assessing speed trial recordings. Nowadays the technical contents is mainly developed by ITTC and adopted by ISO after review. Therefore the standards ISO 15016:2015 and ITTC 7.5-04-01-01.1 (2014) are equal apart from minor differences. Apart from a new shallow water correction method ITTC's latest revision 7 (2017) mainly contains smaller corrections and clarifications compared to the previous revision which are expected to be adopted in the next revision of the ISO standard as well.

For speed trial analyses, HSVA usually reverts to one of the following:

- **HSVA standard**
- **ISO 15016:2015**
- **ITTC 7.5-04-01-01.1 (2017)**

The HSVA standard is considered the preferred procedure as it provides enhanced options for correction of current, wind, rudder angle and drift which are not covered by the latest ISO and ITTC standards.

All corrections are based on simplified, semi-empirical fluid dynamics and thus have limited accuracy and scopes of validity. The environmental influences have different levels of impact on the added resistance of ships with the dominating disturbance usually being caused by wind, waves or current.

ITTC states a target accuracy of seatrials that are performed within the limits of the standard of 2% in power. The accuracy achieved under realistic conditions shows a significantly larger scatter. Figures 3 and 4 present an example of 5 identical container ships, one of the five being considered an outlier due to non-compliance with the standard.

Figure 3 shows the relative CP (quotient of corrected power derived from the speed trials in function of predicted

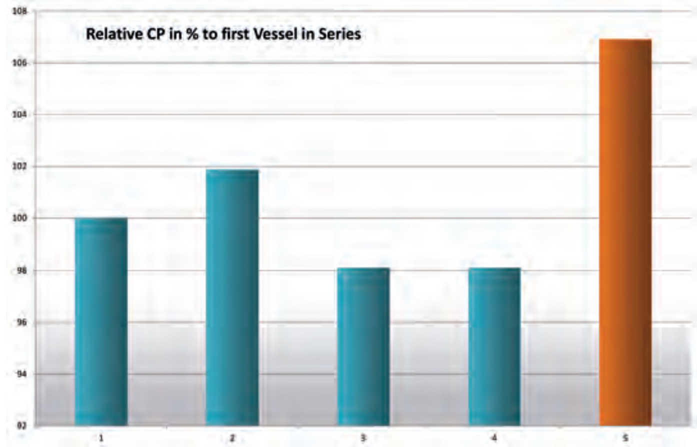

Figure 3: Relative deviation of power demand amongst 5 identical container vessels

power) values for the five container vessels. From this example a variability of results of approximately 6% (+/- 3%) can be derived. From our experience this is a typical value observed for sister vessels.

Dangers and pitfalls

The fewer corrections required, the better the quality of the trial results. Therefore the effect of wind and waves should be small, the water should be deep and little frequented (to prevent ship-ship interactions). Drift and rudder action should be logged to better assess the quality of the trial. The tidal current of the area should be moderate, well known and lacking any arbitrary currents, such as estuary inflows etc. All draught marks, water temperature and density should be taken in the trial area and immediately before carrying out the speed trial. Air pressure and temperature are required for determining the air density. The draughts need to match an existing prediction to a sufficient degree. Each power setting should be consecutively tested by at least one double-run with and against the primary wave (or wind) direction. Speed trials in which the double-runs of a power setting are separated tend to results with higher uncertainties.

ISO and ITTC standard average the corrected wind speed and wind direction of a double run. Although the approach is a practical means of correction, cases with large differences in wind direction may result in wrong conclusions. The data set of wind force coefficients, especially the ones approved by ISO 15016:2015, is limited. To ascertain realistic corrections wind tunnel tests are recommended, especially for vessels with unconventional superstructures.

The current speed usually needs to be determined from the data provided by the log sheet. If current buoys are close to the trial area, the information may be used to verify the calculated current speed and direction. According to experience averaging gives acceptable estimates for slow currents. The Iterative Method gives better results but assumes a semi-diurnal tidal current which may be insufficient for some areas. The HSVA standard procedure determines the current based on the propeller load. It provides a sufficiently smooth propagation of current speed over time unless suspicious runs have been logged.

The effect of shallow water ranges from insignificant to strongly over-corrected, depending on the prevailing water depth and ship speed. All established correction methods are based on rather small and specialised empirical data sets, sometimes backed and extended by numerical computations. Another common source for inaccuracies is estimating the sea state, especially since more recent methods propose accounting for both wind sea and swell which, if wrongly estimated, may result in significant over-corrections.

Improving the quality

Improving the accuracy of speed trials primarily means to either reduce the influence of environmental factors or to improve the accuracy of measurements and environment corrections. Some of the ideas listed below should be considered:

- **measurements of directional sea states by buoys or similar devices**
- **determination of ship specific wind resistance coefficients by DES-Simulation or wind tunnel tests**
- **determination of additional hydrodynamics (drift, rudder effect, seakeeping …) by model tests or CFD**
- **directional calibration of wind anemometers including the ship-influence**
- **avoidance of non-parallel currents to the vessel's course**

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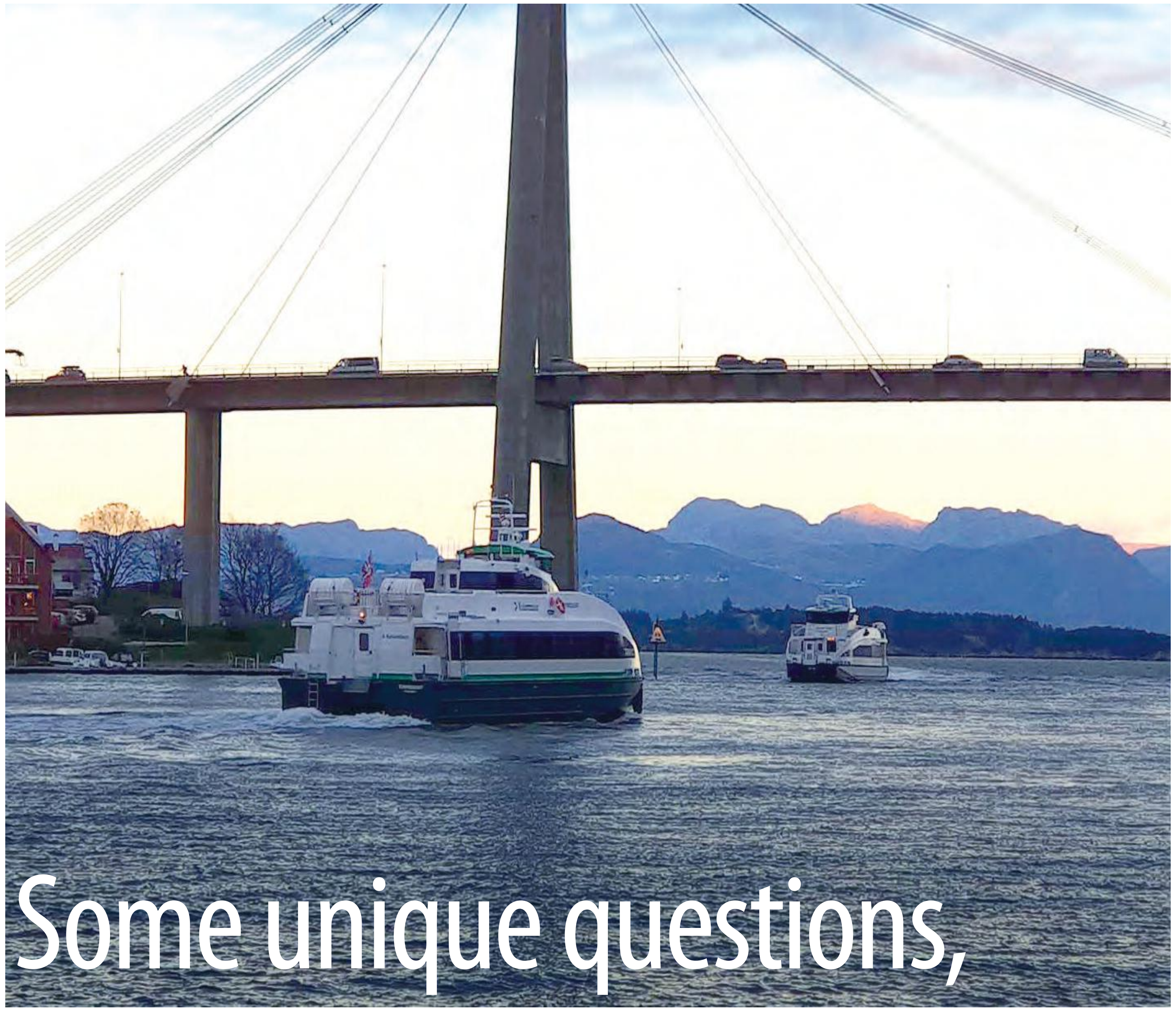
HSVA Services for Speed Trials

- **witnessing and consultancy**
- **speed and track recording (DGPS)**
- **shaft power and revolutions measurement**
- **recording of board data via NMEA/pilot plug**
- **analysis acc. to ISO, ITTC or HSVA standards**



Some unique questions,

when optimising battery-driven high-speed marine vehicles

The recently launched TrAM (Transport, Advanced and Modular) project (https://tramproject.eu/) was introduced in HSVA/newswave/1-18. In TrAM HSVA is in charge of the hydrodynamic optimisation and model testing of the planned prototype of all electric zero emission fast passenger vessels which will be constructed using an advanced modular production.

by Apostolos Papanikolaou and Yan Xing-Kaeding

New manufacturing methods are anticipated to contribute to 25 percent lower production costs and 70 percent lower engineering costs. The project is in the fore-front of recent developments by the maritime industry, namely in terms of the implemented zero emission technology and manufacturing methods, but also because it enables electric-powered high-speed vessels to be competitive in terms of offered services, comfort, costs and the environmental footprint. ▶

The optimisation of battery-driven (zero-emission) ships (here for fast passenger transport) in coastal (short distance) services introduces some new aspects in ship design optimisation, which affect both the hydrodynamics of the vessel as well as its overall design. These aspects are:

Technology issues:

- Battery capacity [kwh]
- Battery weight and space requirements
- Battery life
- Recharging technology

Operational issues:

- Time schedule and associated speeds (keeping a fixed overall travelling plan, while calling at a number of closely located spots with specified arrival/departing time: like a bus service)
- Recharging frequency/recharging spots/ recharging time

For keeping a fixed time schedule the vessel needs to attain continuously varying speeds, reaching and keeping the maximum operational speed for short time, while accelerating and decelerating most of the time. Depending on the maximum achievable operational speed, the times for acceleration and deceleration change, with an immediate effect on the magnitude of the required acceleration/deceleration (Fig. 1). The following diagrams show for a hypothetical operational scenario and varying maximum speed the speed timeline and associated accelerations, which are partly very high (Fig. 2).

This complex operational scenario has an impact on ship design by way of the specification of the required transport capacity that determines the size of the ship and the maximum operational speed, which is determined in relation to the achievable accelerations by the employed propulsion system. The maximum speed and acceleration will jointly lead to the estimation of the magnitude of required powering [kW] and propulsive performance. The resulting required battery capacity [kWh], however, will be determined by taking into account the time for the next battery recharging. Noting that the life of batteries strongly depends on the frequency of recharging and the loading level (state-of-charge) of the batteries, clearly batteries of larger capacity will have a longer lifetime than smaller ones. However, as the battery capacity is directly related to the batteries' weight and space requirements, this has an immediate effect on ship's design, sizing and displacement and thus also on the installed power and maximum speed. These requirements call for some iteration of the estimated data (loops in the design spiral), or better today for the use of a holistic, synthetic, multi-objective optimisation approach, like that advanced in the HOLISHIP project (www.holiship.eu, coordinated by HSVA).

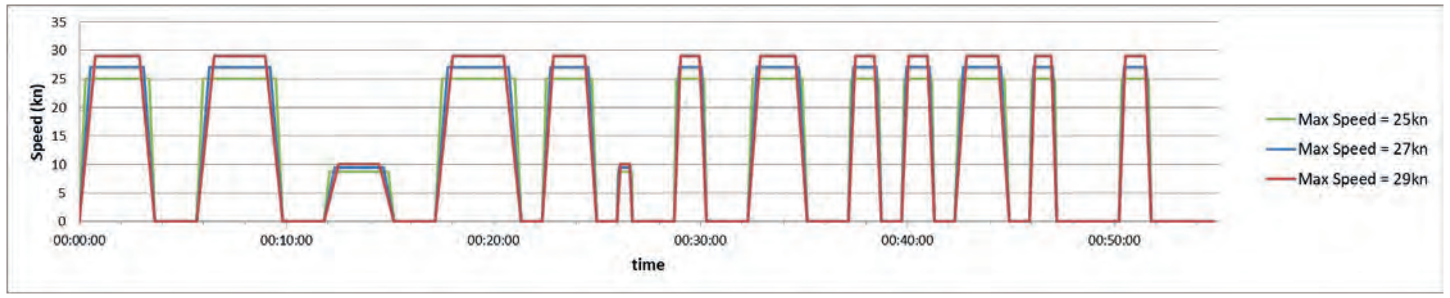


Figure 1: Typical operational speed profile for pre-specified number of port calls and travel plan

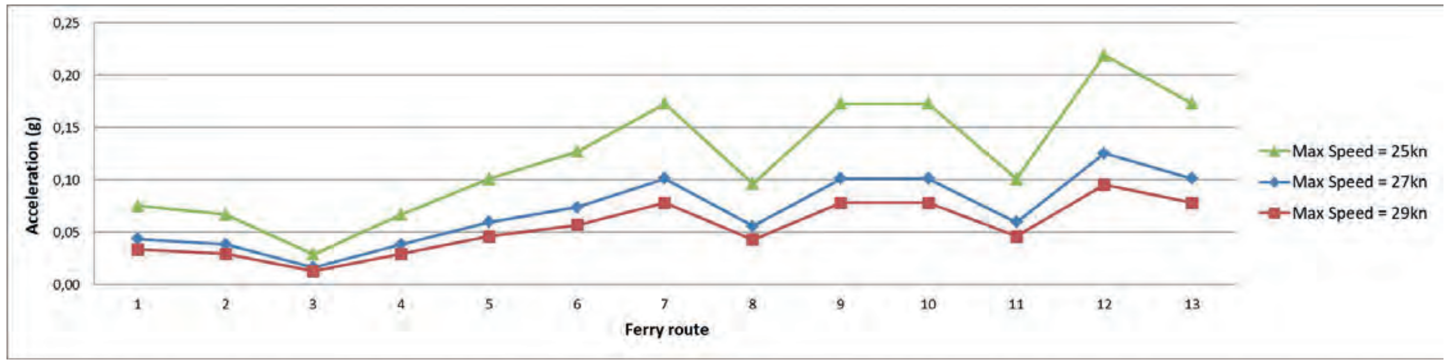


Figure 2: Required acceleration profile for different maximum speeds and pre-specified travel plan

Assuming now a maximum required speed, minimum required acceleration and the battery capacity specified by the operator (in line with his planned time schedule and recharging plan), the hydrodynamic optimisation of ship's hull and propulsion system needs to address in parallel three issues:

- What is the required average and maximum speed to meet the schedule including intermediate stops and recharging?
- What is the minimum required propulsion power for the vessel to achieve the required maximum speed?!
- What is the minimum required propulsion power, torque moment and thrust to achieve the required minimum acceleration?!

Objective 1 may be optimised independently for alternative routes, number of stops and recharging schedules (in terms of time and location). Objective 2 corresponds to the classical "speed-resistance-propulsion" power optimisation problem in naval architecture, and a minimisation of the power will lead to smaller batteries or to extended recharging schedules. Objective 3 is related to the operational profile laid down in objective 1, it may be considered as an additional constraint to obj. 2, or may be optimised in parallel, if a proper modelling of the unsteady forward speed problem is available.

An interesting issue, when conducting model tests for verifying the numerical predictions for the "speed-resistance-powering" relationships, is the measuring/testing of ship's acceleration process, namely quantifying the effect of unsteadiness in forward speed and of the associated hull-propeller interaction and efficiency. This presumes proper modelling of the propulsion/electro-engine's rpm-torque profile and propeller's unsteady performance. This is a challenging issue both for the physical and the numerical simulations by CFD.

Closing, it should be noted that marine batteries' technology is rapidly improving towards the development of more compact, higher efficiency and longer life products. The implementation of an energy management system is for battery driven vehicles imperative. Similar systems are widely employed by the automotive industry in fully electrical or hybrid cars and are driving developments in the maritime industry now and in the years to come.

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Figure 3: Typical route for TrAM demonstrator (Stavanger-Hommersåk-Stavanger)

Flow Generator Development for Cussons' Large Cavitation Tunnel K44

Cussons Technology Ltd, the well-known provider of all kinds of model basin equipment in Manchester, England, and HSVA have joined forces to develop a flow generator or axial pump for the latest and largest K44 cavitation tunnel in Cussons' portfolio. The flow generator consists of an impeller as well as a pre-swirl stator.

Figure 4: Flow generator and casing installed in HSVA's large high-speed cavitation tunnel

by Tom Lücke and Eva Göricke

The whole development has been performed parallel in close cooperation between Cussons, dealing with the structural and hydrodynamic design of the cavitation tunnel, and HSVA, developing the flow generator based upon the predicted flow characteristic by means of CFD. These characteristics did not only consist of the recirculating flow history of the tunnel hull structure, but also included all internal flow improving devices, like turning vanes in the four elbows as well as honeycombs upstream of the test section. Since both the cavitation tunnel and its flow generator are intended to allow the end-user high-level scientific investigations in the field of cavitation and acoustic, the high inflow quality into the test section and the silent operation of the tunnel will be crucial for successful operation of the facility.

Besides the design the project included cavitation tests in the large high-speed cavitation tunnel of HSVA to prove the flow generator's performance as it had been done years ago before HSVA's well-known HYKAT cavitation tunnel was built.

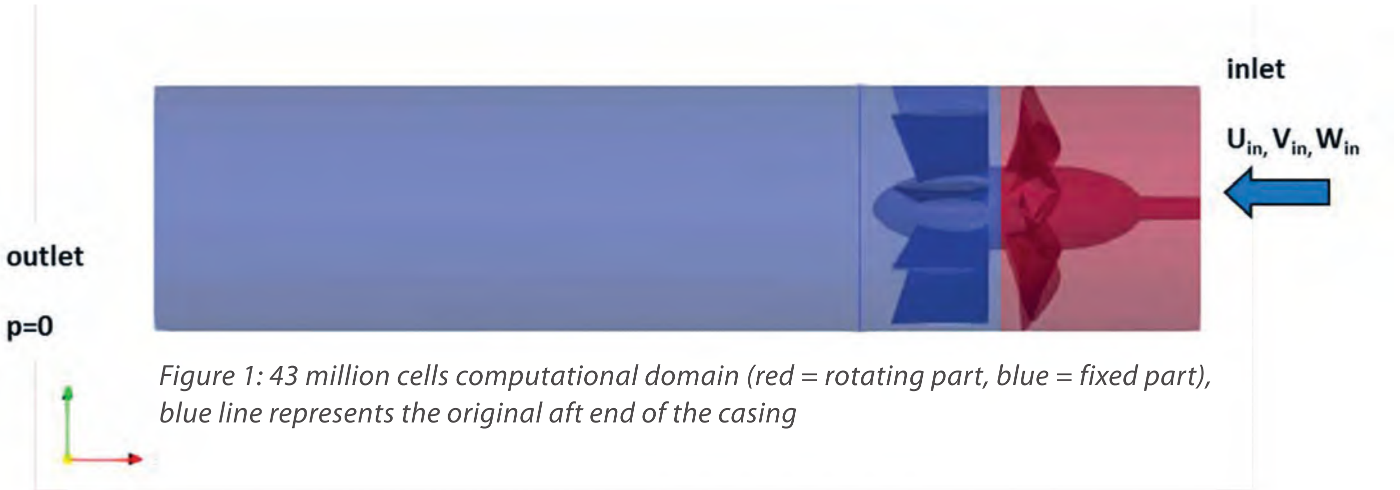

Figure 1: 43 million cells computational domain (red = rotating part, blue = fixed part), blue line represents the original aft end of the casing

Development Process

High efficiency, cavitation prevention and the counter balance of the impeller swirl by the post swirl stator describe the main and challenging targets of the flow generator design.

After the design had reached a sufficient progress level by means of a non-viscous panel code, the whole flow generator was optimised in more detail using the HSVA in-house flow solver ***FreSCo+***, the latter being a viscous flow solver (RANS solver) especially developed for marine applications [1-3]. All calculations have been performed in full scale, where the k-ω-SST turbulence closure model has been applied. The flow domain was discretized by about 43 million cells with the focus on high grid density in the gaps and around the blades to be able to capture the relevant flow structures. The corresponding grid domain (Fig. 1) was decomposed into a fixed aft domain containing the stator, and a rotating fore domain containing the rotating impeller. Both domains communicated by sliding interface technique.

Design Results

The design study resulted in a seven-bladed impeller and a nine-bladed post-swirl stator. Focus of the impeller design lay on the right balance between face and backside cavitation in order to delay cavitation inception as much as possible. In this process, cavitation was assumed to occur whenever the CFD-derived local pressure coefficient c_p underruns the cavitation number σ_n. This was a conservative assumption, as it requires always sufficient nuclei in the tunnel water to stimulate the cavitation inception.

$$c_p = \frac{p - p_{ref}}{0.5\rho\,(\pi \cdot n \cdot D)^2}$$

$$\sigma_n = \frac{p - p_v}{0.5\rho\,(\pi \cdot n \cdot D)^2}$$

As a typical result, the wall-bounded flow is characterised by the surface pressure coefficient c_p together with the

Figure 2: Surface pressure coefficient c_p and trace of limiting streamlines revealed from CFD

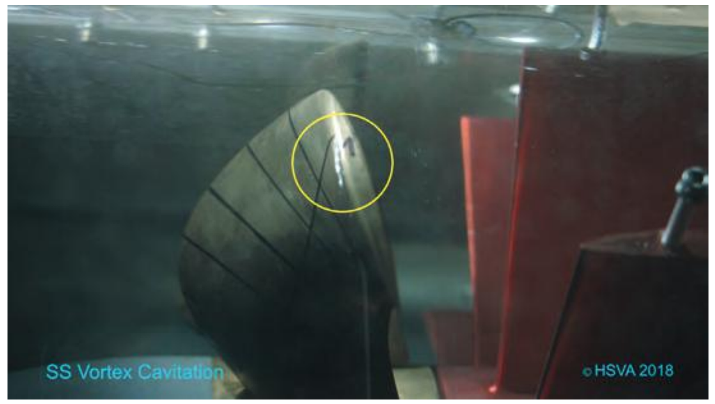

Figure 5: Back tip vortex cavitation occurring just under extreme overload conditions

traces of the limiting streamlines as shown in Fig. 2. A minimum c_p-value is visible near the blade's leading edge (depicted by the circle) in the upward passing blade position, reflecting the highest periodical blade loading within the wake field. At this position also the first onset of back cavitation in overload conditions was observed during the cavitation inception tests, see Fig. 5.

Figure 3: Milling process of the D = 410 mm stator model

Model Tests

Models of impeller and stator of 410 mm diameter had been manufactured from brass and aluminium respectively (see Fig. 3 showing the stator during milling process), whereas the casing had been manufactured from Perspex to allow cavitation observation through the casing. The cavitation tests have been performed in the large high-speed cavitation tunnel of HSVA, see the spectacular upstream view of the flow generator in the test section in Fig. 4.

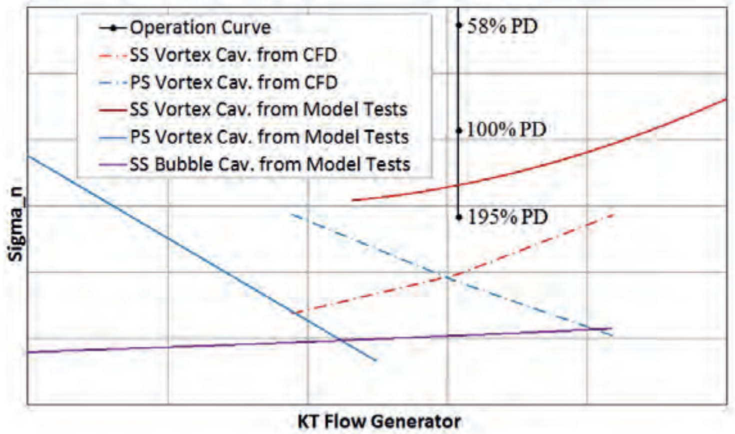

Figure 6: Cavitation diagram indicates absence of cavitation far beyond maximum power

The non-uniformity of the flow generator inflow (representing the complete recirculating flow history of the whole K44 tunnel) was modelled iteratively via wake screens installed upstream of the test section.

The cavitation inception diagram (Fig. 6) shows the cavitation inception curves $\sigma_{i\,(KT)}$ of the impeller blades and the design operating curve, the latter being determined numerically as well as by means of the model tests. Here the operating curve represents a vertical line at constant K_T, reflecting a constant relation between impeller and tunnel water speed. The intersection between the operating curve and the cavitation inception curve indicates the operating point at which the respective cavitation phenomenon will occur in full scale.

Within the whole operation range of the tunnel (up to 100% PD) the flow generator will be free of cavitation. While the CFD-derived cavitation bucket is balanced around the operating curve, the cavitation bucket derived from the cavitation tests reveals a certain shift towards earlier back than face vortex cavitation. Nevertheless, only if the head loss of the tunnel would change significantly, cavitation is expected to occur, but even than at much higher speeds than the design speed of the tunnel.

This extremely encouraging flow generator performance was the result of highly sophisticated viscous flow calculations, very experienced model testing procedures, and a close cooperation between HSVA and Cussons Technology. ■

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Investigations on the Level Ice Resistance of Ships with Non Typical Icebreaking Bow Shapes

For typical icebreaker shaped vessels with an inclined bow and low flare angles the major components of the hull-ice interaction process are quite well understood. Analytical methods exist to predict the average resistance based on few inputs for the hull shape characteristic and ice properties. For non typical icebreaking ships the interaction process includes many unknown phenomena like cracking, splitting and crushing, which are difficult to be described by straightforward approaches. Furthermore, the accumulation and clearing of the broken ice floes are completely different. Finally, the database (e.g. from model tests) of performance records for such vessels in solid ice is very limited.

by Daniela Myland and Quentin Hisette

The demand for a more profound understanding of ice interaction with non-icebreaker shaped vessels results from an increasing number of those ships accessing Arctic and Antarctic waters. Examples are cruise expedition vessels and government vessels with multiple missions (coast guard, rescue and salvage). Even if the sailing time of those vessels in ice is limited to few weeks in a year, a detailed assessment of their capabilities in ice is required to optimise their design and operational profile.

A study to investigate and understand the basic process of sea-ice interaction with ships of open-water or moderate icebreaking shape is currently ongoing at HSVA. The objective is to identify the major process phenomena and to find correlations between parameters, especially those between the hull geometry, ice properties and motion characteristics of a vessel. The study is supported by the Office of Naval Research (ONR) and includes theoretic investigation and physical model tests conducted in the large ice model basin of HSVA. The aims are as follows:

- **improve principal understanding of the hull-ice interaction process, ice failure and the components contributing to the ice resistance**
- **find methods to evaluate the ice performance (ice resistance, attainable speed) as well as the factors of major influence**
- **enhance quantity and quality of ship-ice interaction observations**
- **provide a database of results obtained under controlled conditions**

The reference ship DTMB 5415 is considered for the study. The geometry of this navy vessel concept, precursor of the DDG 51 Arleigh Burke destroyer class, has been used by numerous research institutions focusing on open-water resistance, seakeeping and propulsion. To date, investigations on its performance in ice have not been carried out. Ship particulars are given in Table 1 and hull lines are presented in Figure 1. The clearly non-icebreaking bow and the large range of hull angles measured at various draughts make it suitable for the purpose of the present study. ▶

Figure 1: Schematic drawing of ship model with instrumentation

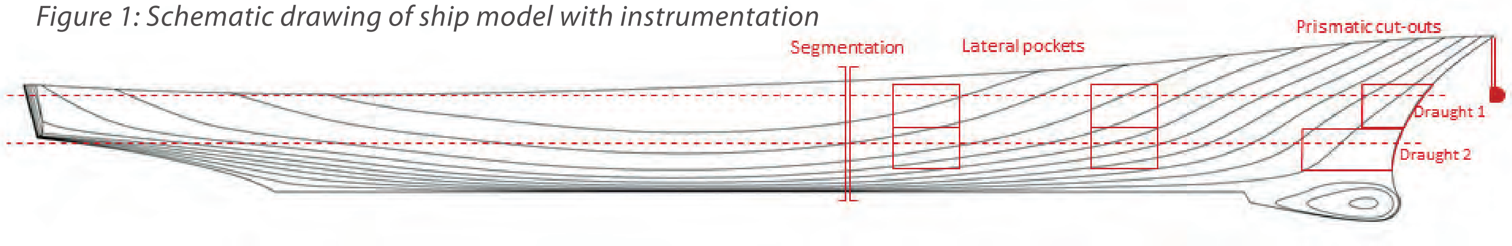

Table 1 – Ship particulars of DTMB 5415

DTMB 5415 – Main particulars					
Lpp	[m]	142.00	Displacement	[m³]	8424
Lwl	[m]	142.18	WSA	[m²]	2973
Bwl	[m]	19.06	CB	[–]	0.507
T_{Design}	[m]	6.15	Propulsion		2x FP 6.15m

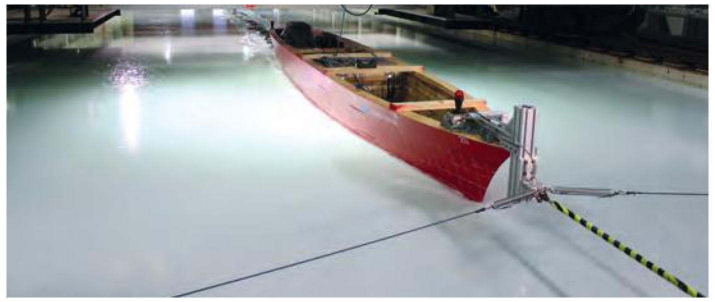

Figure 2: Resistance test in modelled level ice

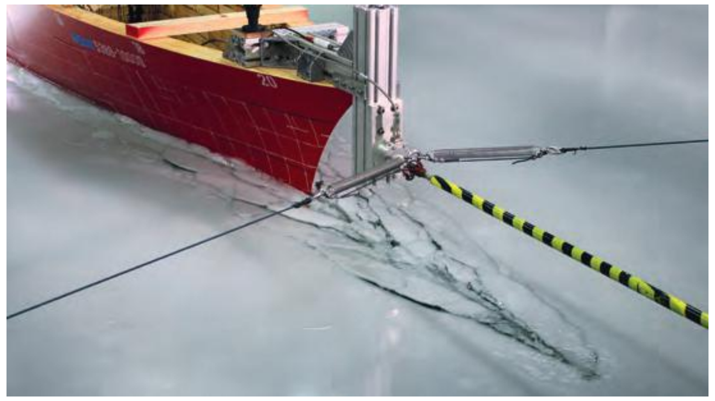

Figure 3: Breaking pattern of ship models bow taken at the end of the test run

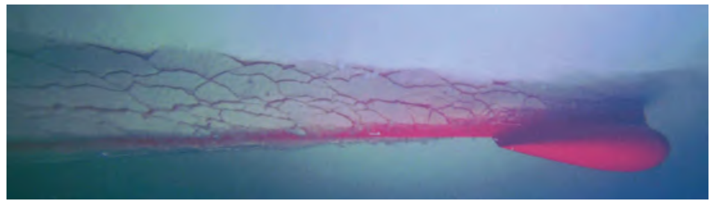

Figure 4: Underwater view of ship model being towed through level ice

In order to gain knowledge about the ice resistance of such hull shapes, the following instrumentation will be used (see Figure 1):

1) Segmentation of the model between the bow and the remaining part of the ship and measurement of the loads between both parts with a multi-component scale.

2) Prismatic-like cut-out at the stem with measurement of the loads with a multi-component load sensor.

3) Two lateral instrumented pockets on one side of the bow, fitted with multi-component load sensors.

4) One uniaxial load cell at the bow, connecting the model to a towing carriage with a double-hinged coupling rod.

Additionally, the stem cut-out and the lateral pockets are repeated at another draught, so that local loads can be measured in six different locations: for two values of the stem angle and in four combinations of the buttock and waterline angles.

Performing resistance model tests in several ice thicknesses and at multiple speed values (see Figure 2 to Figure 4) allow to obtain relevant information to meet the goals of the study. The instrumented prismatic cut-outs allow improving the modelling of the crushing loads at the stem, while the four lateral pockets permit improvement of the estimation of the breaking loads as a function of the hull angles. Additionally, above and underwater video observations serve evaluating the occurrence of crushing at high values of the normal angle. The multi-component scale between bow and stern can help validate the load model made out of the sum of the local lateral loads. Moreover, through comparison with open-water model test measurements, the hull-ice friction forces can be estimated. ■

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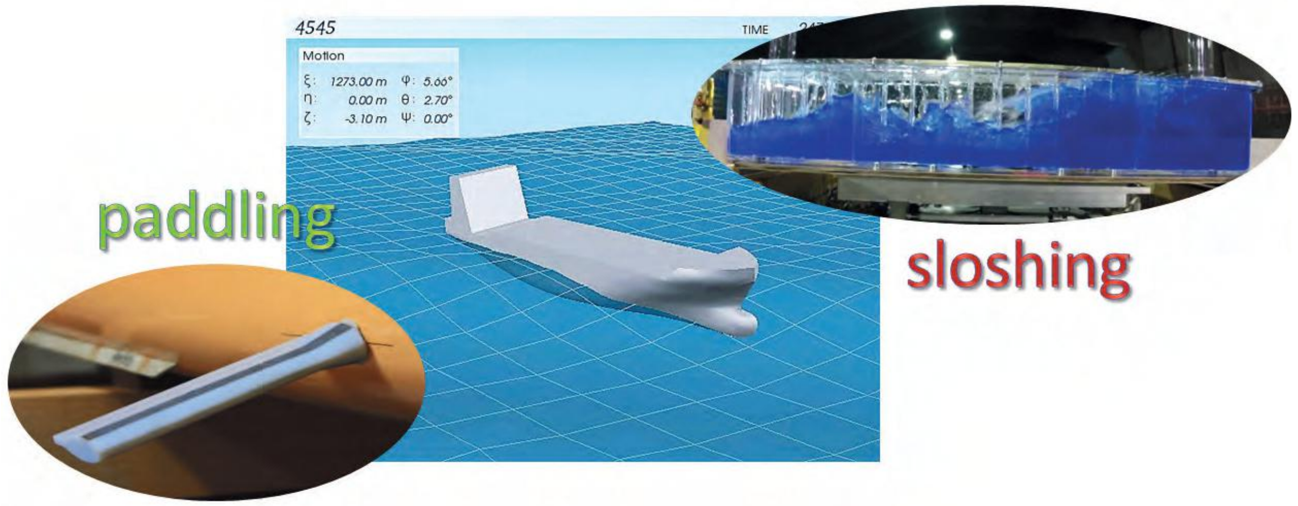

ROLF learns Paddling and Sloshing

by Arndt Schumacher

ROLF is a seakeeping code for simulating large ship roll motions in time domain. The numerical algorithm treats roll motions in a non-linear way, whereas the remaining degrees of freedom are computed with a linear strip method, rendering the computation extremely fast and reliably at the same time. Since many years ROLF is being successfully used by HSVA to determine the risk of ship parametric rolling and capsizing in seaways.

The code was recently extended to include the non-linear roll damping effects of actively controlled fin stabilizers and passive anti-roll tanks in the ship motion simulation. These new features allow HSVA to perform accurate motion simulations yielding valuable and realistic information on the performance of various roll damping devices, like bilge keels, fin stabilizers, and anti-roll tanks, in the early state of customer's ship design projects greatly helping in finding optimal solutions. ■

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by Jan Lassen

HSVA performed manoeuvring tests outdoors with a freely moving ship model in December 2018. In this exceptional case it was important to be able to see the whole manoeuvres being executed. The HSVA used this unique opportunity also to perform standard indoor zigzag tests and to compare the turning circles based on these performed directly outdoors. These results show a very good correlation, even though the outdoor tests had to be carried out in typical northern German winter weather conditions on the target test day.

For best reliability the model track was measured using the differential GNSS with a rover unit on the model and a base unit ashore, allowing high precision measurements with an accuracy of a few centimetres, more than sufficient for the purpose.

The test campaign showed that very good results can be obtained with outdoor tests, which also provide an excellent opportunity to demonstrate and visualise ship rudder manoeuvres being executed, from straightforward turning circles to complicated harbour manoeuvres. ■

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Uwe Schiffner has been working in HSVA's mechanical workshop since 1996.

He is a business economist and master craftsman of precision mechanics. Uwe Schiffner has been head of the mechanical workshop since 2000. Since then he has modernised the production by introducing CNC technology. In addition to his diverse work as a master craftsman, Uwe Schiffner is also responsible for the energy management and for supervising building repairs.

Uwe Schiffner spends his free time with his wife and two children. He likes to work in his garden and loves to repair old cars.

David Kitschaikin started his work at HSVA's model workshop in 2007.

Together with his team he prepares the models for the towing tank tests. Since May 2015 David Kitschaikin has been in charge of the model workshop. He achieved the level of master carpenter in 2017.

In his spare time David Kitschaikin likes to be together with his family. He enjoys fishing, likes to go on holiday and is active in sports. ■

in brief

Photo: Dr. Jens Neugebauer, Universität Duisburg-Essen

HSVA's managing director Dr. Janou Hennig was awarded an honorary professorship by University of Duisburg-Essen. For a couple of years she has been teaching courses on wave theory, wave-induced loads and offshore constructions. On the occasion of her inaugural lecture the university valued in particular her longstanding experience in these areas and her dedication for both research and education which take profit from her practical experience in the maritime industry. Prof. Dr. rer. nat. Hennig is looking forward to an intensified exchange between university and industrial research at HSVA. She calls it a classical win-win situation in which HSVA is supervising numerous master theses every year and shapes a close relationship with potential future employees, customers and partners of HSVA. ■