HSVA Newswave 2015/1

THE HAMBURG SHIP MODEL BASIN NEWSLETTER

HSVA'S supervisory board elected Dr. Janou Hennig as managing director by February 1, 2015. To ensure a smooth transition, she shared this position during a period of two months with the previous managing director Jürgen Friesch who retired by April 1.

IN THIS ISSUE:

www.hsva.de relaunched!

MARINTEC CHINA 2015

1st–4th December

Dear reader,

HSVA bids farewell to retiring managing director Dipl.-Ing. Jürgen Friesch.

After many successful years as HSVA's managing director, Jürgen Friesch retired on April 1, 2015. During the last ten years, he established HSVA as a modern, financially healthy and technically innovative company in an international market.

HSVA is indebted to Jürgen Friesch for his dedicated technical and management work. He gave HSVA strength for new challenges and created a thorough basis for the company's future development. He is leaving a healthy, modernized company settled well in the international maritime industry.

Personally, I would like to express my deepest thanks for giving HSVA and myself the opportunity for a good transfer of responsibilities, also by postponing the date of his retirement, and last but not least for his humour and continuous support. We wish you a very enjoyable future and a healthy and inspiring retirement!

Janou Hennig

Jürgen Friesch and his Achievements

As a German navy officer, Jürgen Friesch served on board of fast boats and studied naval architecture in Hanover and Hamburg. In 1979, he joined HSVA, working in the fields of propeller design and development, cavitation prediction and the development of model test facilities for the investigation of propeller cavitation. His work used to be accompanied by full scale trials on large ships resulting in the validation of his research work on propeller cavitation.

In 1989, HSVA's cavitation tunnel HYKAT was opened, and Jürgen Friesch was elected as head of Propeller, Cavitation and hydro-acoustics. This worldwide new and unique model test facility enabled HSVA to offer new types of services for the improvement of propellers and ships for her international clients.

In 2004, Jürgen Friesch was elected as managing director, facing him with many technical and financial challenges in dynamic times. During this period,

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HSVA became a modern service provider for the worldwide maritime industry. The many challenges included the maintenance and modernisation of HSVA's model test facilities, workshops and buildings. The efforts resulted in building a first side wave maker in the Large Towing Tank to generate long- and short-crested waves. Furthermore, the propeller milling machine and the propeller measurement machine were renewed. The ice facilities were renovated and the Large Ice Tank was upgraded with a wave maker which gives HSVA a couple of further unique possibilities for advanced model testing. During this productive period of time, HSVA increased her number of employees from 80 to 100.

For many years, Jürgen Friesch represented HSVA at the International Towing Tank Conference (ITTC), first as technical specialist, then as chairman for cavitation and propellers in different committees, and finally in the Advisory Council and Executive Committee, among others as representative for all model test facilities in central Europe. Jürgen Friesch is member of many scientific and technical advisory boards such as the Maritime Cluster Germany. For 10 years, he shared his expertise as visiting lecturer at Technical University Berlin.

Dr. Janou Hennig Started as New Managing Director of HSVA

Janou Hennig has a background in applied mathematics from Technical University Berlin in Germany. Already during her studies she got involved in the world of model testing and large scale wave generation which drove her to further specialize in ocean engineering during her research within several joint industry projects. This brought her to HSVA for the first time in 1999 where she was in charge of the deterministic wave generation for an exciting cooperation on computer controlled capsizing tests. In 2005, she received a doctor's degree from Technical University Berlin and was subsequently awarded the Georg Weinblum Award and became a Werner-von-Siemens "Young Academic" for her dissertation on "Generation and Analysis of Harsh Wave Environments".

In 2005, she joined MARIN, where she was in charge of projects on scale model testing and computer simulations for the international maritime industry. Her specialization on the modelling of environmental conditions led to her involvement in and management of large industry research initiatives. She was senior project manager at MARIN's Offshore department until she moved on as team leader of the R&D department.

Janou Hennig is also visiting lecturer at the Universities of Duisburg-Essen and Berlin in Germany, teaching offshore hydrodynamics and wave theory.

New Wave Generator for HSVA's Large Ice Model Basin

Fig. 1: Ice floes in sea waves, Barents Sea 2014

✎ *by Nils Reimer*

The rapidly changing ice cover in the Arctic Ocean attracts more and more shipping companies to prepare their fleets for operation in this area. Additionally, the interest in hydrocarbon exploration and exploitation and related transportation in arctic areas is moving forward. As the permanent ice cover is diminishing, most of the activities are now taking place in an area known as the marginal ice zone (MIZ) characterized by dynamic processes in which the ice cover is broken up by waves and resulting ice floes are driven by wind, waves and current.

In order to investigate the efficiency and risk of marine activities in above mentioned conditions, physical modeling can be used to provide results on wave propagation in ice as well as wave–ice interaction. The attenuation of waves in ice is currently observed by remote sensing but can hardly be measured in nature. Model testing can provide valuable knowledge on the actual energy dissipation and fracture process, the relation between wave parameters and broken floe size and the simultaneous impact of waves and ice on ships and offshore structures. Furthermore, the formation of ice under wave influence can be studied.

HSVA has therefore decided to enhance its testing portfolio in the Large Ice Model Basin with a wave generator. The system was successfully installed in December 2014. The generator consists of four flap type wave making modules covering the total 10 m width of the basin. The flaps of 1.3 m height can be attached to a basement structure such that the hinge position is set 1.2 m above bottom. All four modules can be installed and removed from the basin within two hours while the basin is filled up with water.

The system is able to produce regular and irregular waves while the maximum wave height is limited to 0.25 m and the maximum deep water wave period is 1.8 s with respect to basin depth. The system is further equiped with an active absorption to reduce reflections. The actual wave signal input is calculated by userfriendly software AwaSys, which then transmits the signal to the control software.

First Investigations:
After the system was set up and calibrated in ice free water, first tests were carried out with regular waves in a model ice sheet of about 30 mm thickness and model ice strength of 45 kPa. The wave period was kept constant for most tests, while the wave height was increased stepwise. Table 1 shows the complete test matrix.

The main intention of first tests was to observe the interaction of waves and model ice to obtain practical knowledge on

- parameter relations,
- measuring indication and practicability on similarities to phenomena observed in full scale.

Test ID	Ice Thickness	Wave Period	Wave Length	Wave Height	Exposure Time
2010	29.8 mm	1.27 s	2.52 m	2 cm	10 min
2020	29.8 mm	1.27 s	2.52 m	5 cm	10 min
2030	29.8 mm	1.27 s	2.52 m	7 cm	10 min
2040	29.8 mm	1.27 s	2.52 m	10 cm	10 min
2050	29.8 mm	1.27 s	3.51 m	10 cm	10 min

Table 1: Testing parameters for first series of wave ice tests

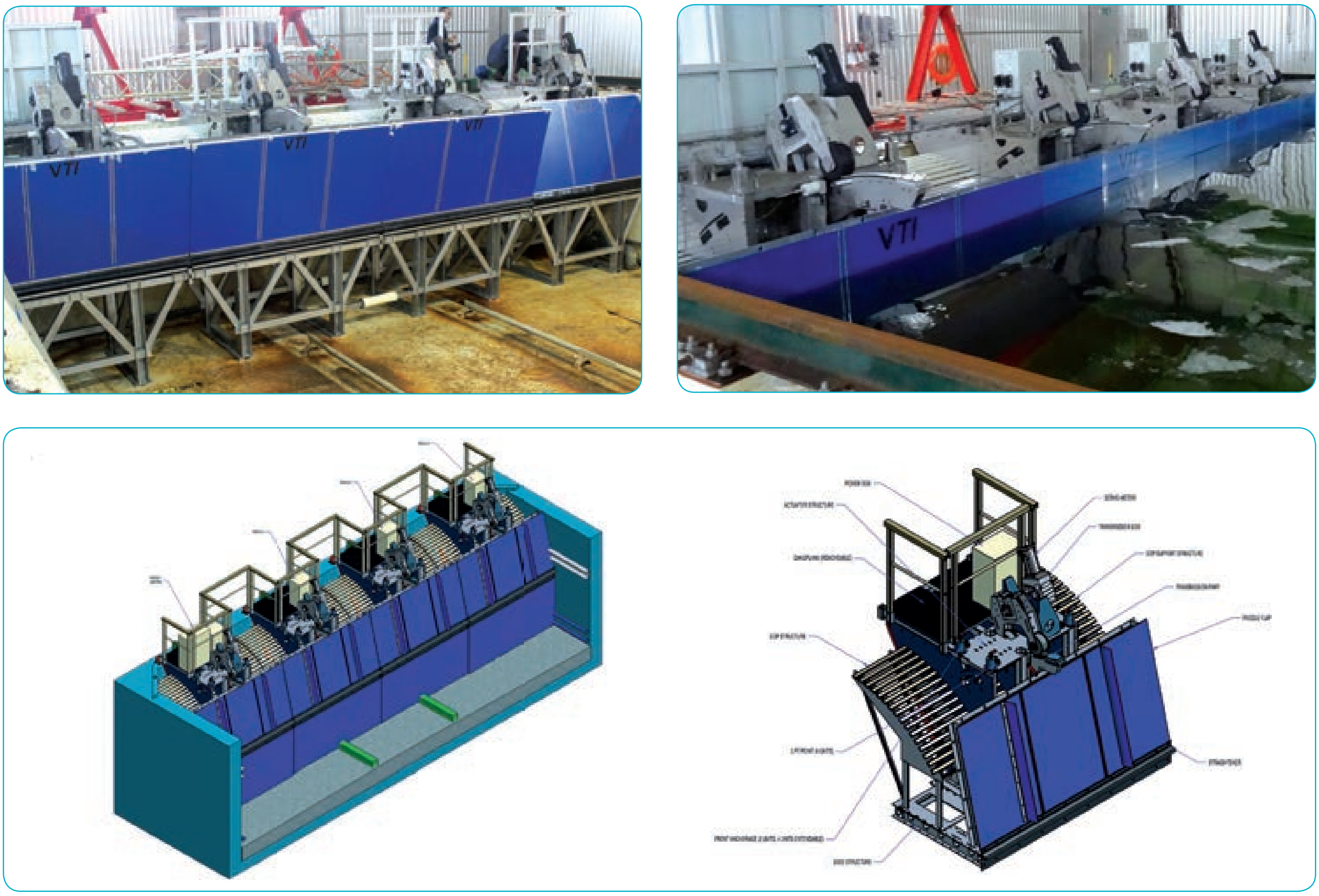

Fig. 2: New flap type wave generator in HSVA's Large Ice Model Basin

To reduce wall effects the ice sheet was cut free on both sides. The distance between the wave maker and the ice edge in the basin was about 10 m.

The first important observation during the test series was that the ice sheet of 30 mm was remaining intact at 2 cm wave height, but started to break close to the edge at a wave height of 5 cm. The first cracks were orientated close to 90 degree towards the wave propagation direction and only a few cracks in longitudinal direction were initally observed. At this point also occasional cracks at some distance from the ice edge could be found such that a large floe was formed, which was then broken into smaller fragments.

After the exposure time of 10 min, the average floe size had reached a certain value and was not further decreasing. The break up had not yet reached the rear part of the basin in which the ice was still intact. Therefore, the generation of waves was stopped and the wave height was increased to 7 cm for the next test run. At this wave height the floes

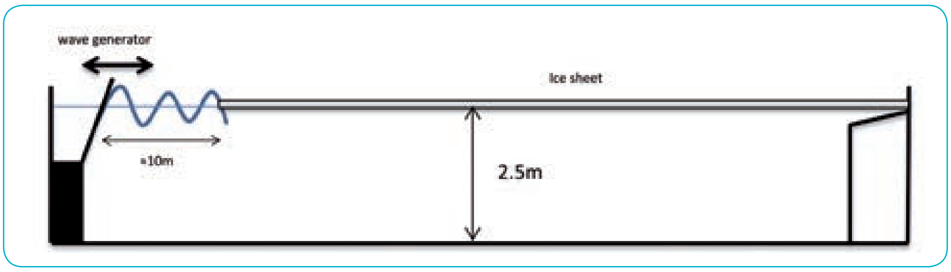

Fig. 3: Schematic diagram of wave test with model ice

Fig. 4: Break up of 30 mm model ice sheet by 5 cm waves with a length of 2.5 m / Waves progressing from the observer‘s opposite side

in the fore part of basin were further broken into smaller pieces. As the fracture zone was not progressing an area of rafted floes (see Figure 5) was forming at the intersection of broken ice and intact ice. In this area several layers of floes were compacted and slush ice was produced by periodically colliding floes.

Finally, the wave height was increased to 10 cm to break up the remaining ice and in one additional test run, the wave length was also increased to propagate further into the intact ice sheet. After 10 min of wave duration, the whole ice sheet was broken up. Photographs were taken to document the final stage of floe sizes. The resulting floe size image is presented in Figure 6. A zone of smaller floes in loose configuration has formed in the forepart close to the former ice edge. This area is followed by the zone of rafted ice with slush. In this area floes have been compacted as waves approached from one side and intact ice or large floes were supporting on the opposite side. In the rear part very large ice floes remain and form a nearly 100 per cent coverage of the basin. The resulting distribution is very typical for the marginal ice zone.

Fig. 5: Impressions of rafted zone with slush ice between level and broken ice

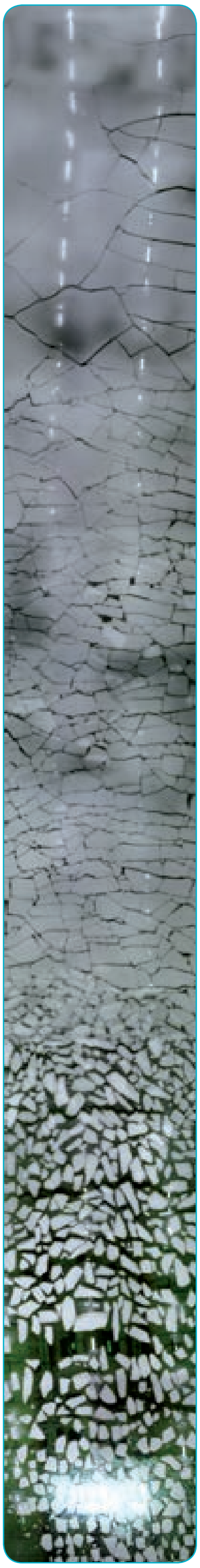

Fig. 6: Floe size distribution in entire basin after last test run

Next Perspectives:
The observations and anlysis made during the first tests are used to prepare concepts for future wave ice testing for floating or fixed offshore structures. A very first impression was obtained during tests of a moored floating structure kept at the same heading in waves with ice.

Future investigations should focus on

- Ship manoeuvring in waves and ice
- Global and local loads by waves and ice
- Ice accumulation around structures in presence of waves
- Station keeping of floating structures in waves.

Fig. 7: Floating structure in ice covered waves of 0.1 m wave height

Drag Reduction Inspired by Dolphins

by Lars-Uve Schrader

Dolphins possess a thick layer of lipid tissue under their skin, the "blubber". Apart from serving as a thermal insulator and energy storage, the blubber is believed to modify the flow past the dolphin's body favourably, leading to diminished drag at swimming speed. It is hypothesised that the dolphin's flexible skin delays the transition from low-friction laminar flow to high-friction turbulent flow [1].

Is it possible to reduce the frictional drag of ships in a similar manner by applying a blubber-like compliant coating on the hull? To find an answer, HSVA recently joined forces with experts in material sciences, chemistry and hydrodynamics within the research project ***FLIPPER****** (Fig. 1).

Hydrodynamic Investigations
HSVA's role in the ***FLIPPER*** consortium is to investigate the near-surface flow (the boundary layer) in the bow section of ships, where the laminar-turbulent transition takes place. CFD computations and experiments in HSVA's Hydrodynamics and Cavitation Tunnel (HYKAT) will be carried out to this end. The focus is on small vessels with simple bow shapes (no bulb) so that the flow field can be approximated by a simplified boundary-layer model. In a first step, a suitable hull geometry of a small SAR vessel has been selected from HSVA's database, designed by the Fassmer

Fig. 1: The research project ***FLIPPER*** *("Flow improvement through compliant hull coating for better ship performance") is conducted by the Fraunhofer Institute for Manufacturing Technology and Advanced Materials (IFAM, coordination), Hamburg University of Technology (TUHH), the French chemicals producer ARKEMA and HSVA*

shipyard for the German Maritime Search and Rescue Association DGzRS (Fig. 2a). A double-body model of this ship hull shall serve as a test bed for the compliant coating (Fig. 2b). Coated and uncoated panels will be inserted into the two half-shells of the double body (Fig. 3a). In this way, the effect of the coating on skin friction (if any) becomes manifest as a force difference between the two half-shells, inducing a yaw moment on the load cell inside the test body.

Boundary-Layer Model

To support the design of the validation experiment, a CFD simulation with the in-house RANSE solver ***FreSCo***$^+$ has been conducted, using a numerical full-scale model of the HYKAT test section and the double-body test probe (Figs. 3b,c). While this simulation reveals the pressure distribution and the streamlines along the hull model (Fig. 4), it does not provide the details of the flow inside the boundary layer, required for a study of laminar-turbulent transition. For this reason, a simplified flow model is used, the Falkner-Skan boundary layer [2]. This model, adjusted to the surface pressure of the CFD simulation, defines a weakly accelerated boundary layer on a wedge. The surface-normal velocity profiles reveal that the laminar boundary layer near the stem of the hull model is initially only half a millimetre thick (Fig. 5).

Transition to Turbulence

In ***FLIPPER***, natural transition is considered. According to this scenario, the transition process is initiated by wave-like flow disturbances, the Tollmien-Schlichting (TS) waves, which are excited in the laminar boundary layer by the environment (e.g. by freestream eddies) [3]. It is believed that the blubber of dolphins is able to damp these TS waves, thereby enlarging the laminar flow regime and delaying the onset of turbulence. This mechanism is referred to as flow control [1]. In order to transfer the dolphin's control strategy to the bow of the present ship model, the amplifying TS waves in the Falkner-Skan boundary layer need to be identified. This can be accomplished by Linear Stability Theory (LST), where HSVA has used the LST code published in Ref. [3]. The outcome of such an analysis is a stability map showing TS-wave frequencies versus downstream distance from the stem of the hull model (Fig. 6). The stability map highlights the region in the boundary layer where unstable TS waves may occur, enclosed by a banana-shaped curve (neutral-stability curve). HSVA's calculations indicate that the present boundary layer is unstable to TS waves with frequencies between 63 Hz and 289 Hz within the first 500 mm from the stem of the ship model, where the coating panel will be located. The compliant material developed by HSVA's partners must feature strong damping

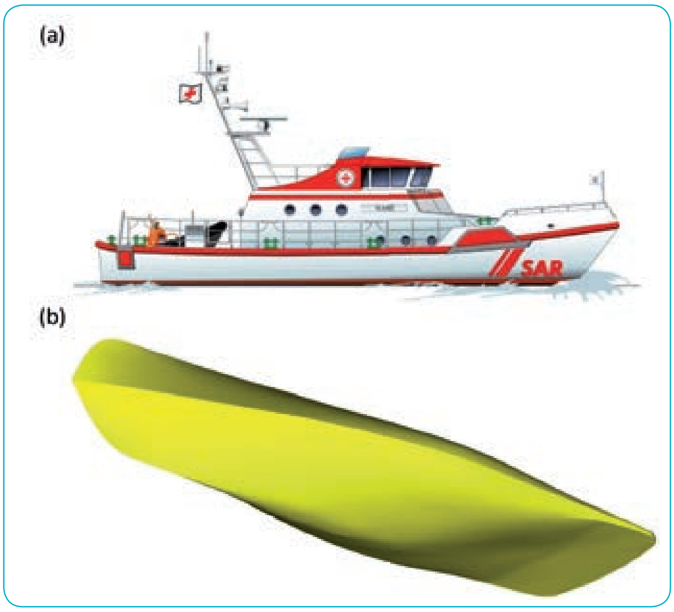

Fig. 2: (a) SAR vessel of the German Maritime Search and Rescue Association DGzRS (20 m class; picture from www.seenotretter.de). (b) Double-body model of the hull in (a) to be used in the validation experiment of **FLIPPER** *(scale $\lambda = 4.5$)*

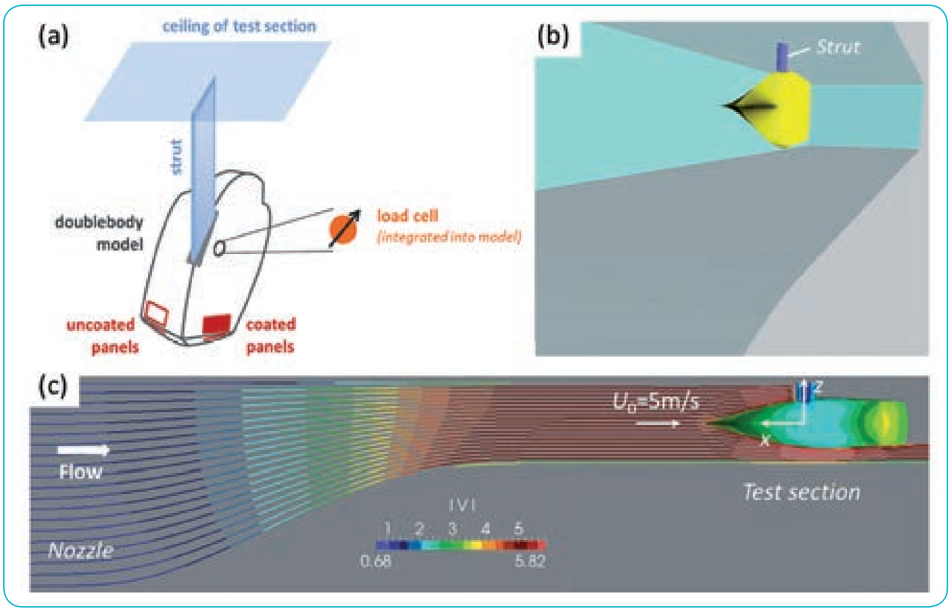

Fig. 3: **FLIPPER** *validation experiment to be conducted in HSVA's test facility HYKAT. (a) Sketch of the experimental set-up and the double-body test probe. (b) Full-scale CFD model of the validation experiment covering the inflow nozzle and the test section of the HYKAT including the test body. (c) Flow speed and streamlines in the test section and pressure distribution on the double-body ship model*

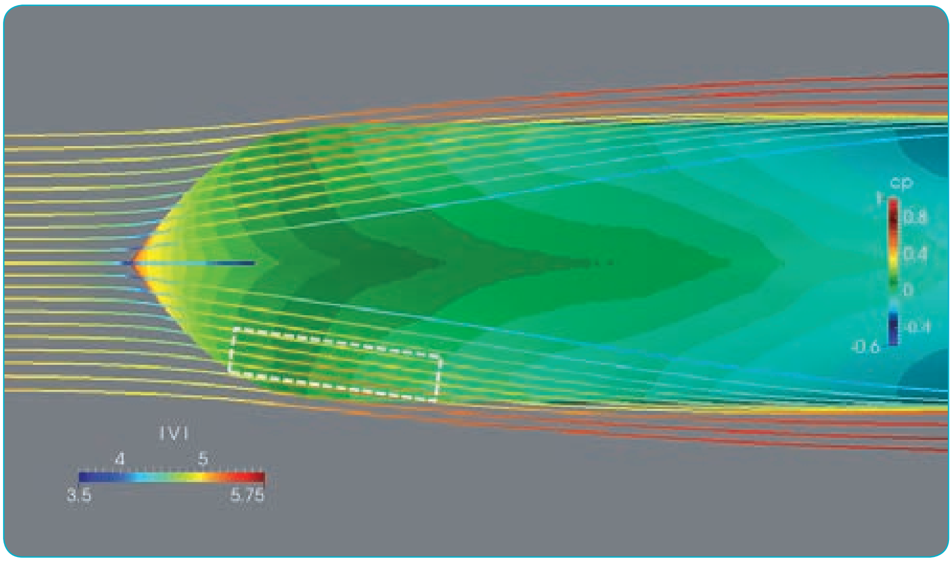

Fig. 4: Pressure distribution and streamlines in the bow region of the double-body test probe. The white box indicates the prospective location of the compliant-coating panel

capabilities for waves in this frequency band in order to function as a flow-control device. If well-designed, the compliant surface coating will shift the "unstable banana" and thus the onset of turbulence towards larger distances from the vessel's stem, leading to extended laminar flow.

Summary

Friction between the ship hull and the surrounding water plays a dominant role for the resistance of many ship types at transit speed. The frictional losses can be reduced by maintaining a low-dissipation laminar flow state over a longer stretch of the hull surface. This requires a flow-control mechanism such that the transition to turbulence is delayed. The coating-based control strategy pursued in ***FLIPPER*** is passive as no energy input into the boundary layer is necessary. For this reason, passive control mechanisms are often more efficient, more robust and cheaper than active flow-control devices (e.g. "air lubrication").

FLIPPER is conducted 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 in the project* **FLIPPER.

[1] Gad-el-Hak, M. 1996 Compliant Coatings: A Decade of Progress. Applied Mech. Reviews 49, 147-157
[2] Schlichting, H. 1968 Boundary-Layer Theory. McGraw-Hill
[3] Schmid, P. J., Henningson, D. S. 2001 Stability and Transition in Shear Flows. Springer

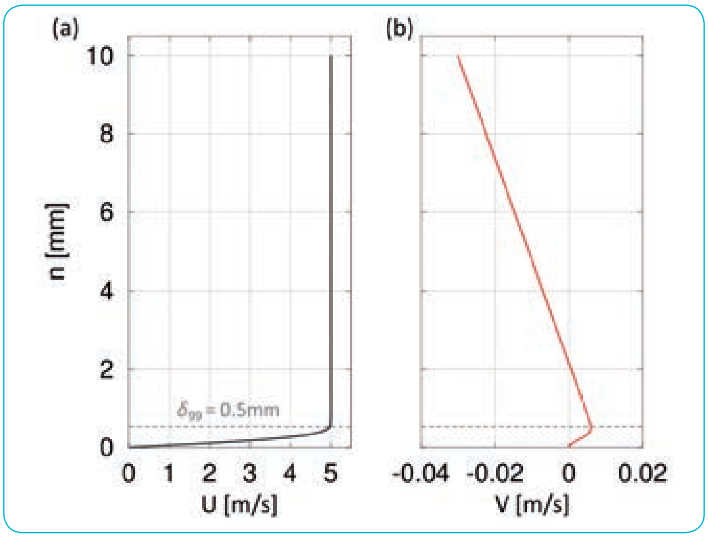

Fig. 5: Flow profiles along the surface-normal coordinate for a weakly accelerated Falkner-Skan boundary layer. (a) Streamwise velocity. (b) Surface-normal velocity. The profiles pertain to the upstream edge of the compliant-coating panel (cf. Fig. 4), where the boundary layer is still very thin (0.5 mm in thickness)

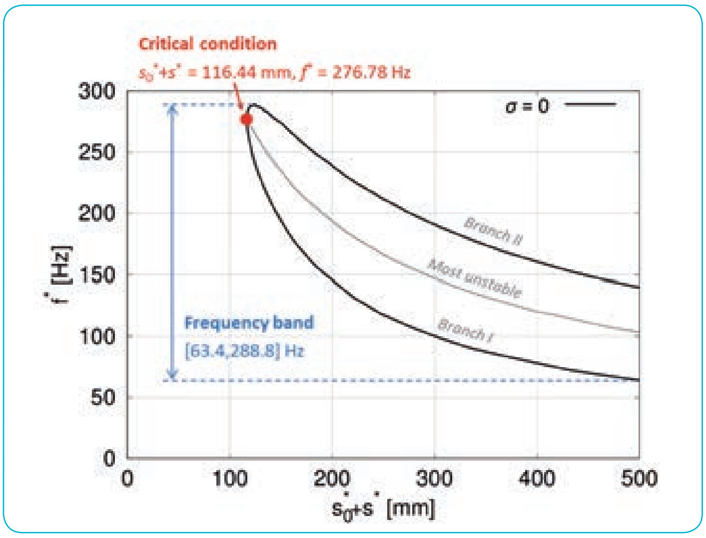

Fig. 6: Stability map for a weakly accelerated Falkner-Skan boundary layer, serving as a model for flow over a ship bow. The region inside the black curve indicates the presence of unstable TS waves (triggers of turbulence). The present boundary layer becomes unstable approx. 116 mm downstream of the stem of the ship model. Unstable waves with frequencies between 63 Hz and 289 Hz may occur in the flow field within the first 500 mm from the stem.

Tip Vortex Cavitation – an Invisible Source of Noise?

by Christian Johannsen

Together with Andritz Hydro, Ravensburg, visual and acoustic cavitation inception tests were carried out in HYKAT, HSVA's large Hydrodynamics and Cavitation Tunnel, with an 1.8 m long full scale propeller tip. Purpose was to investigate the audibility of vortex cavitation prior to its visual detectability.

Besides vibrations excited in the structure of ships as well as erosion damages in the material of ship propellers, propeller cavitation can have a third disadvantageous effect: Cavitation makes noise. For navy propellers, but not only for navy propellers, the ship speed up to which the propeller operates free of cavitation is therefore an important quality feature. It is often reported that cavitation on a ship propeller can be acoustically detected at lower ship speeds than those, where the cavitation becomes visible. This is a nasty phenomenon because cavitation inception predictions – as they are a standard investigation before a navy propeller is built in full scale – are normally based on model tests. Here cavitation inception is determined visually. The detectability of a navy vessel due to propeller cavitation noise may start earlier than would be derived simply from such a visual cavitation inception test. The same holds for the acoustic annoyance of the sensitive owner of a luxurious mega yacht.

State-of-the art cavitation testing facilities, such as HYKAT, allow precise determination of visual and acoustic cavitation inception at model scale with the propeller acting behind the complete ship model. Visual and acoustic cavitation tests are straight forward in this facility, as long as they can be performed under the common assumption of cavitation number identity between model and full scale. This assumption, however, fails in case of tip vortex cavitation inception. This phenomenon is considerably delayed at model scale due to the – relatively speaking – too high viscosity. As a consequence of that, the weak noise of a beginning tip vortex cavitation is sometimes drowned at model scale by developed root or sheet cavitation, which in full scale does not occur at this propeller operation point.

To overcome the problem Andritz Hydro, the home of the well-known "Escher Wyss Propellers" for navy and mega yacht applications, and the HSVA performed an experimental study. Aim was to determine the gap between acoustic and visual tip vortex cavitation inception for a full scale propeller blade tip of 1.8 m characteristic chord length in HSVA's HYKAT. The idea behind that was to enable continuation with visual tip vortex cavitation tests at model scale in future, and to deduce the acoustic inception point from these tests by application of the gap between visual and acoustic vortex cavitation inception as found in the present study. Vague estimates of a two knots gap have been mentioned here and there in the past, but are based on doubtful comparisons between full scale acoustic measurements on one hand and model test based visual inception predictions on the other.

The cooperative tests were carried out in HYKAT. The propeller blade tip and the very rigid device for its angular adjustment were designed and delivered by Andritz Hydro. The blade tip made of brass represented the radial range from 0.8 R to 1.0 R of a roughly 4 meters diameter controllable pitch navy propeller at scale 1. The chord length of the tip at 0.8 R was 1.8 m and it penetrated roughly 0.4 m into the test section (Figs. 1 and 2).

Fig. 1: Installation of the 1.8 m long full scale propeller tip at the side wall of HYKAT

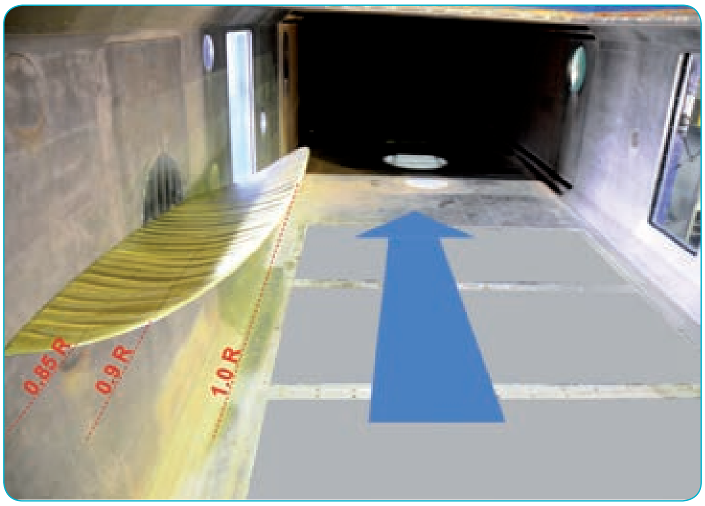

Fig. 2: Blade tip ready for testing

The radial pitch of the original tip had been modified to meet in the uniform flow conditions in HYKAT the same angle of attack, as occurs in average over one revolution in behind conditions under the ship. Mechanically, this pitch setting could be varied in a range of ±22° by means of the angular adjustment device in order to change the blade load. Hydro-acoustic noise measurements were performed by means of a hydrophone located in the anechoic chamber below the test section.

Inception points and noise levels were measured in 67 different combinations of pitch and inflow speed. At zero pitch setting the blade tip was free of cavitation at any tunnel pressure, but at pitch settings above ±5° it was possible to determine visual and acoustic cavitation inception separately. Results are shown in Fig. 3.

The cavitation numbers of desinent tip vortex cavitation are given here versus the pitch setting of the blade tip. A gap between visual and acoustic cavitation inception can be recognized in Fig. 3 indeed, which seems to slightly increase with larger pitch settings. The cavitation numbers for acoustic cavitation inception are higher than those for visual inception. Simply speaking, cavitation could be heard before it could be seen. The cavitation numbers obtained at cavitation inception were than transformed into ship speeds, using the operating data of the vessel that the propeller tip was taken from. A ΔV gap between visual and acoustic cavitation inception was found, which is significantly different than the two knots often reported.

These findings will be used for a conservative estimate of acoustic cavitation inception from a visual cavitation inception test carried out at model scale. This overcomes the deficiencies of purely acoustic tip vortex inception tests described above.

Coming back to the headline of the article it can be confirmed: Yes, there is a range of ship speeds, where tip vortex cavitation can be an invisible source of noise.

Coming back to the headline of the article it can be confirmed: Yes, there is a range of ship speeds, where tip vortex cavitation can be an invisible source of noise.

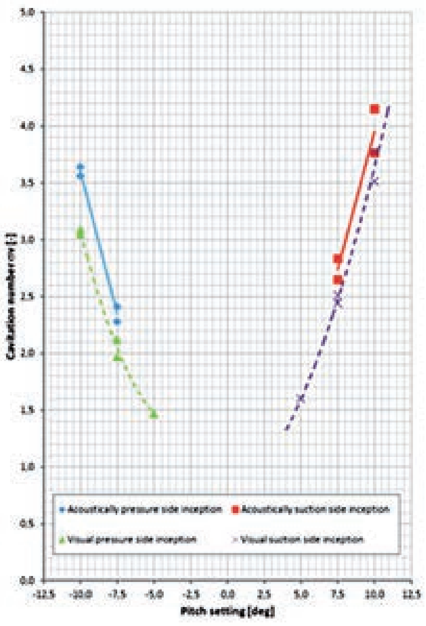

Fig. 3: Cavitation inception diagram

Managing Cargo LiquefAction

by Marco Schneider

Within a recent period of 5 years at least 10 vessels carrying nickel ore were lost due to cargo liquefaction. Besides nickel ore also other soils and materials with high moisture contents are prone to this process.

This was a strong motivation to start the LiquefAction project in which several partners from industry and research joined forces to address this hazard.

In brief, Liquefaction is the process in which an initially solid material changes its physical condition to a liquid state. This process is triggered by external excitation which on land can be earthquakes or at sea ship motions in sea state.

The LiquefAction project tries to look at the problem in a holistic approach, considering all aspects like cargo property, the design of the vessel and the sea condition, that contribute to liquefaction.

The goal of LiquefAction is to identify critical combinations of these aspects which can cause hazards and should be avoided. Guidelines for the safe transport of nickel and iron ores shall be issued and advice shall be given for counter measures after liquefaction occurred. In addition, on-board testing of cargo prone to liquefy shall be improved.

The research performed in the LiquefAction project is partly funded by the "Bundesministerium für Wirtschaft und Technologie" in Germany and the "Ministère de l'écologie, du développement durable et de l'énergie" in France.

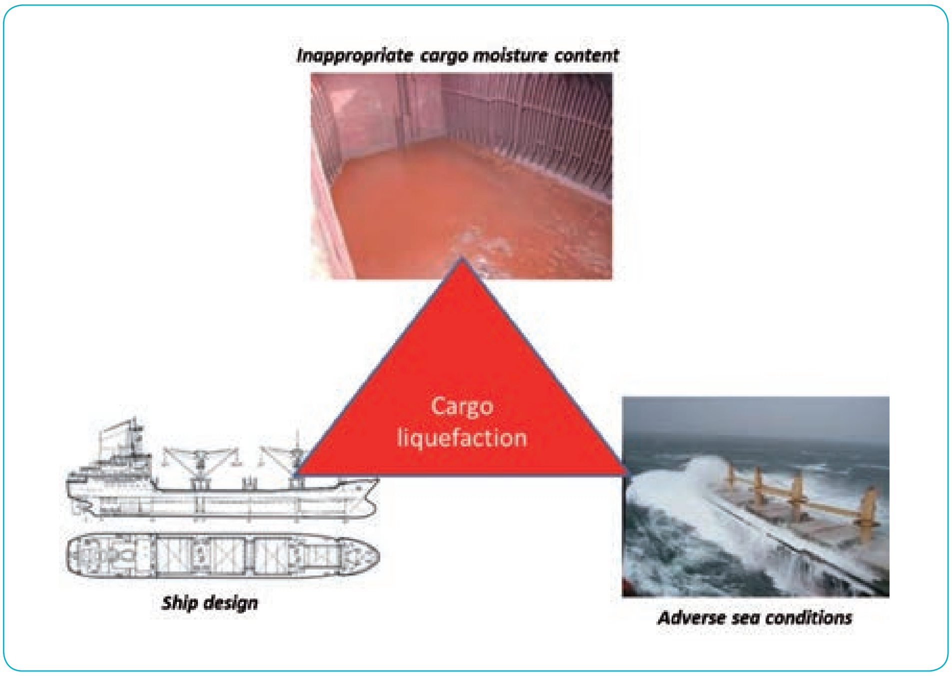

Fig. 1: Holistic approach to cargo liquefaction

Senator Horch Visits HSVA

On February 6, 2015, Senator Frank Horch paid a visit to HSVA. The Senator is responsible for economy, transport and innovation in the Free and Hanseatic City of Hamburg. He bid farewell to retiring managing director Jürgen Friesch and welcomed Dr. Janou Hennig as new managing director. In the light of HSVA being considered a nucleus for the regional as well as international maritime industry, HSVA's present and future situation in relation with current economic developments was discussed together with the current and former chairmen of HSVA's supervisory board, Dr. Herbert Aly and Mr. Gerhard Kempf.

Senator Horch, Janou Hennig and Jürgen Friesch

Member of Staff

Sören Claußen joined the HSVA in January 2014. His main field of activity is the improvement of health and safety as well as fire protection processes. In addition to this, he is responsible for building services and quality management.

Sören studied "Hazard Control" at the Hamburg University of Applied Sciences and finished his bachelor thesis on the "Storage of hazardous substances at Olympus Surgical Technologies Europe" in Hamburg. Hazard Control is a study field about hazard prevention, disaster management, fire prevention and risk management and is realized in cooperation with external specialists such as the fire service Hamburg and the Federal Office of Civil Protection and Disaster Assistance.

Furthermore Sören is currently attending an additional training as "Health and Safety Officer" in order to deepen his skills corresponding to the legal requirements. In his free time, Sören spends much time as a volunteer firefighter. He also likes various kinds of sports like climbing as well as diving in the summer and snowboarding in winter.

Health and Safety at the HSVA

A safe work environment represents one of the most important conditions for the operating ability of a company. It ensures the ongoing performance and efficiency of staff and facilities. That is why at HSVA safety is of highest priority. Due to increasing legal standards and the continuous growth of our company, we intensified our safety efforts and created a new position dedicated solely to that purpose. Since 2014, a safety engineer is taking care of the implementation of all safety and health related requirements. These include the compliance with legal standards as well as the improvement of working conditions beyond the mandatory level. HSVA provides individual solutions for every customer – that is why our safety ambitions need to be adapted to the various changing working processes. Thereby we consider different kinds of safety issues. These range from operational safety, such as the supply of protective equipment, to the skilled usage of hazardous substances as well as fire security and the prevention from psychological stresses caused by noise, the intensity of light or climatic conditions.

In addition to that, our safety engineer is responsible for the maintenance and modernization of the test facility's installations. This will guarantee that safety standards and regulations are already considered during the planning of construction projects.

The combination of all those fields of activities result in an integrated safety system that incorporates health protection, hazard prevention as well as the preparation of convenient work conditions – in a physical and a psychological way. By doing so, we managed to keep accidents, technical disturbances and other damages on a low level. Nevertheless, we know that safety requirements will further increase and new solutions have to be developed in the future. Thus we continuously improve our safety standards and are aiming to optimize our work processes as well as technical installations and implement measures to ensure the constant quality of our services and products.

MARINTEC CHINA 2015

Vistit us at MARINTEC CHINA, International Maritime Conference & Exhibition,
1st–4th December 2015, Shanghai, China.
You can find us in the German Pavilion, hall no. N2 at our stand no. N2F21-04.