HSVA
NEWSWAVE
THE HAMBURG SHIP MODEL BASIN NEWSLETTER 2002/1

INVESTIGATION OF BUBBLE VEIL GENERATION FOR REDUCTION OF PROPELLER INDUCED VIBRATIONS

A DEVELOPMENT IN COOPERATION WITH BLOHM + VOSS

by Christian Johannsen

By the order of the Blohm + Voss GmbH, Hamburg, Germany, a new airation system has been developed in cooperation with HSVA to reduce propeller induced vibration excitations.

The propeller is well known as one of the main exciters of ship vibrations. The high speed and large power of today's passenger, container or navy ships requires carefully designed propeller geometries working in a perfectly optimized wake field to keep this excitation as low as possible. Nevertheless, even the optimum propeller is always a compromise between different design targets. Often various constrains must be respected, i.e. exclusive concentration on lowest vibration excitation is impossible during the design process. To achieve highest comfort in spite of these difficulties, additional measures beside a well designed propeller may be necessary.

Several airation systems are known as useful measures to reduce propeller induced vibrations. Some of them suppress particular hydrodynamic effects that may be responsible for the vibration excitation. Other measures just damp the excitation independent of its hydrodynamic origin. However, these measures often suffer from an extensive air requirement, which is necessary to build up a sufficiently damping layer.

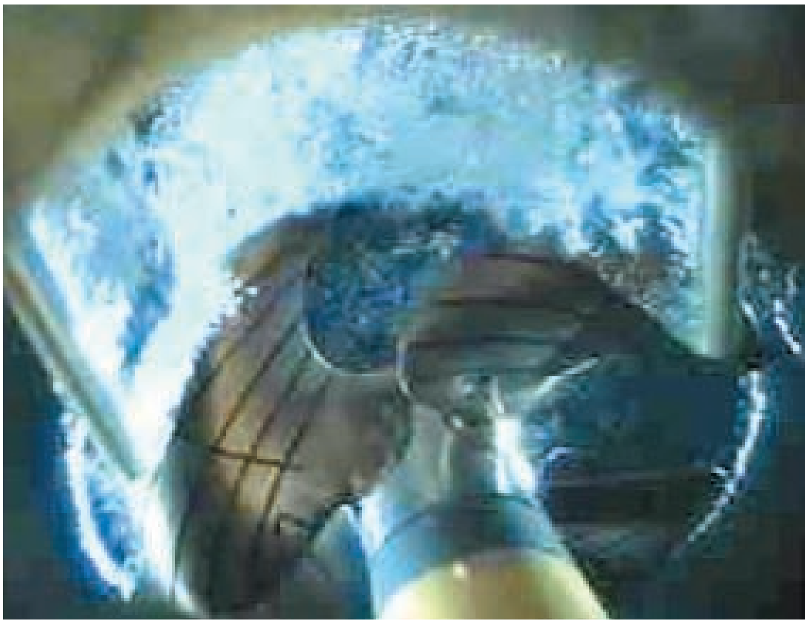


Fig. 1
The Bubble Veil in Model Scale

The airation system described here provides a bubble veil, i.e. a mixture of water and air, working as a damping layer between propeller and hull with a minimum of air requirement. It consists

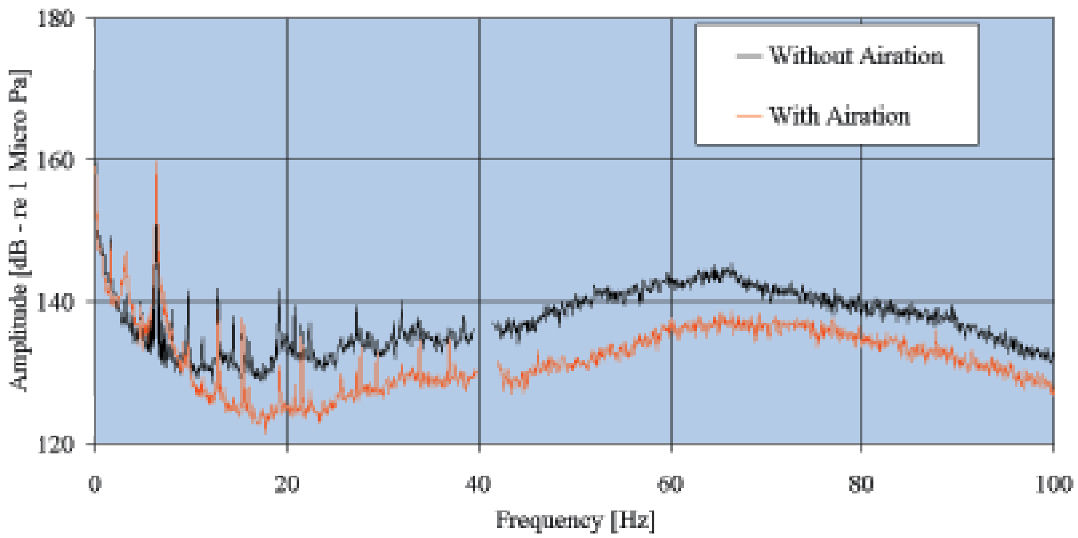


Fig. 2
Influence on the Frequency Spectrum

of a number of ventilation tubes installed in front of the propeller plane. Extensive optimization tests have been performed with a complete 1 : 22.5 ship model in HSVA's large Hydrodynamics and Cavitation Tunnel HYKAT to find the best location and penetration width of these tubes into the water. Fig. 1 shows the system in action during the test in HYKAT. Two tubes can be seen on the left and right side of the picture blowing air into the water between propeller and hull. The air spreads into a voluminous veil of bubble water mixture. As could be concluded from the simultaneous hull pressure measurement in HYKAT, this veil has a very effective damping characteristic. Fig. 2 shows the influence of the airation on the hull pressure frequency spectrum above the propeller. From a full scale frequency of 10 Hz up to the end of the measuring range a reduction of the hull pressure variation between 4 and 9 dB could be obtained. The amount of air has been varied during the tests. If the air outlet is well positioned, the required air quantity becomes surprisingly low.

In model scale just brass pipes of 8 mm diameter were used as airation tubes. Of course in full scale a smooth fairing will be necessary to keep the additional resistance low and to prevent cavitation problems at the tubes. Furthermore investigations had been necessary to ensure that a voluminous bubble veil will develop in full scale as

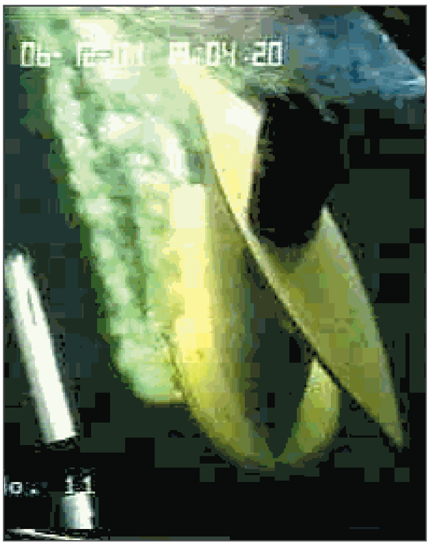


Fig. 3 The Full Scale Bubble Veil

well. Therefore additional tests were performed with an 1 : 1 model of such a ventilation tube in HSVA's large towing tank (Fig. 3). While the interior pipe system of this model was made from steel, the fairing and the air distribution "shoe" at the end of the tube were manufactured from wood. Various speeds, air quantities and air outlet configurations were investigated this way under full scale conditions. Valuable experience about air quantity and supply pressure requirement could be gained from these tests. Fig. 3 shows the development of the bubble veil at quite a low “ship” speed in the towing tank. Fig. 4 shows the final geometry of a steel prototype.

The main advantage of this system is the relatively small air requirement due to the good damping characteristic of the air bubble - water - mixture. This advantage allows relatively easy integration of the system in the stern steel structure.

For further information please contact the author or Mr. G. Schulze at Blohm + Voss, Dep. SKE 1.

Fig. 4 The Real Device

NATIONAL R&D PROJECT "REYNOLDS NUMBER EFFECTS ON POD DRIVES" IS COMPLETED

by Friedrich Mewis

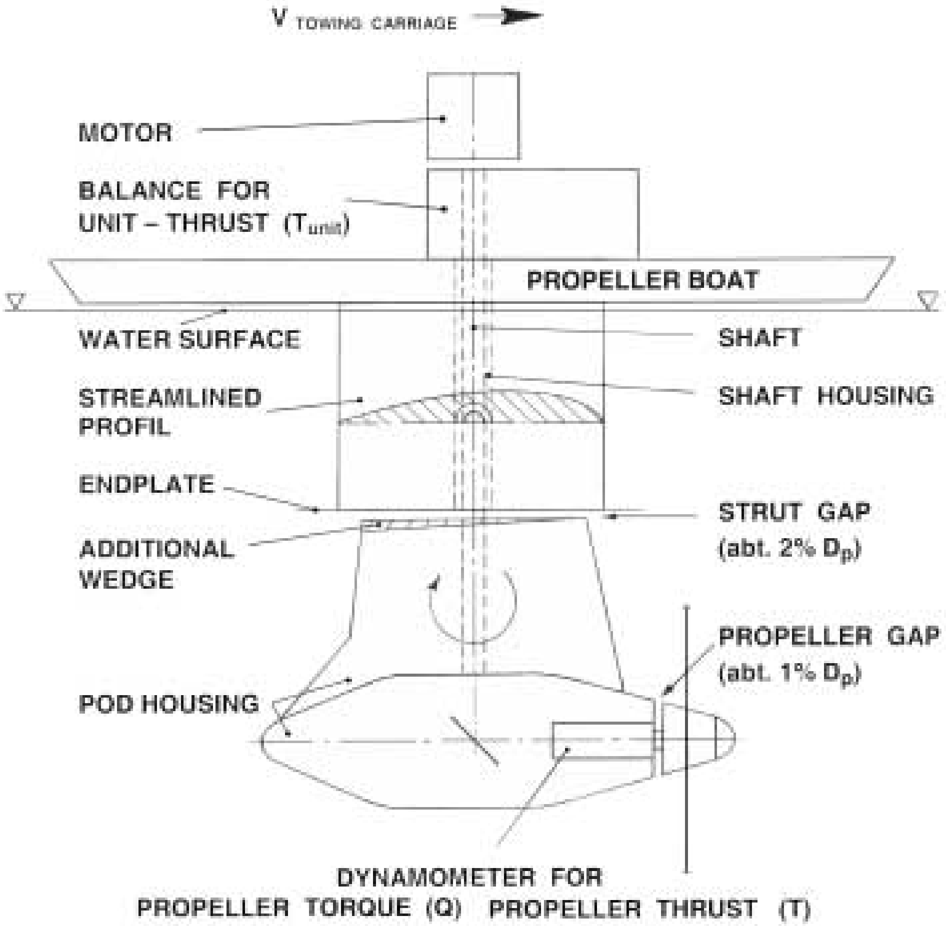


Fig. 1 Pod open water test setup

At the end of 2001 the R&D project "Reynoldszahleffekte an Pod-Antrieben" was completed. The result was a new approach for converting the propulsion and resistance model test results to full scale. Within the project the measuring setup for open water pod unit tests were redesigned and systematical tests with different configurations of pod installations were carried out. One result of the project was the identification of problem areas and the outline of clear installation recommendations for open water tests and self propulsion tests with pod units. Fig. 1 shows the installation for an open water unit test with the so-called propeller boat used at HSVA. Fig. 2 shows the small Reynolds number effect on open water characteristics within the investigated Reynolds Number range. Parts of the results are published in HADMAR 2001, Varna, Bulgaria.

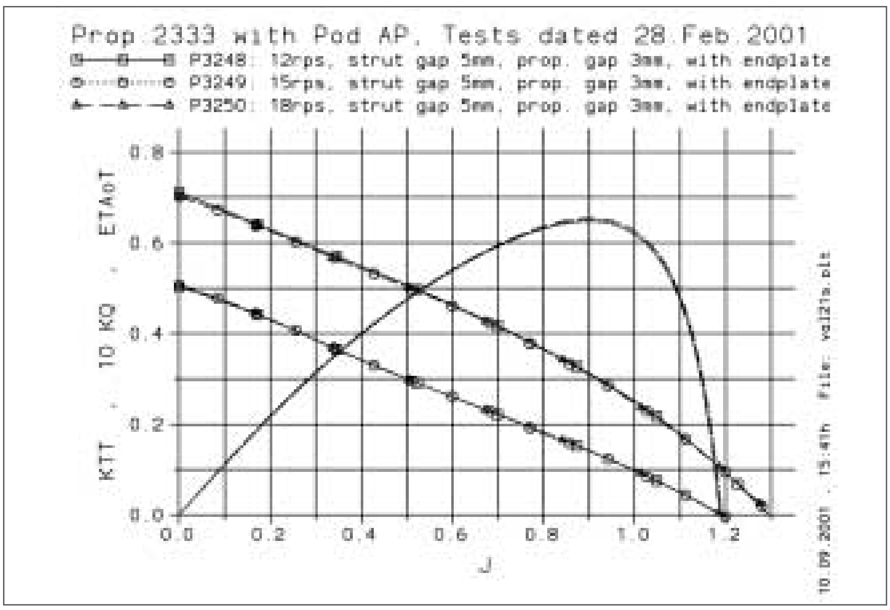
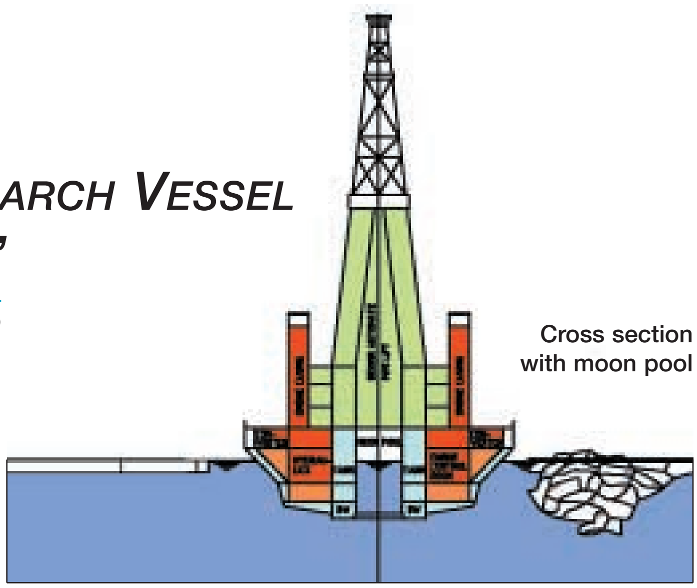


Fig. 2 Open water characteristics of a pod unit for different propeller speeds (based on measured unit thrust)

Sketch of an Arctic Deep Drilling Research Vessel "Aurora Borealis"

by Karl-Heinz Rupp



Cross section with moon pool

The Arctic Ocean remains the only major sub-basin of the world's oceans that has not been sampled by any deep drilling research vessel. The properties of high latitude oceans are currently the subject of intense scientific and environmental debate because they are and have been subject to rapid change and because they react more rapidly and intensely to global changes than other regions of the earth.

A new state-of-the-art research icebreaker with a deep-drilling capability is therefore required to fulfill the needs of European polar research. This new icebreaker would be conceived as an optimized scientific platform and will allow conducting for long periods international and interdisciplinary expeditions into the central Arctic Ocean during all seasons of the year.

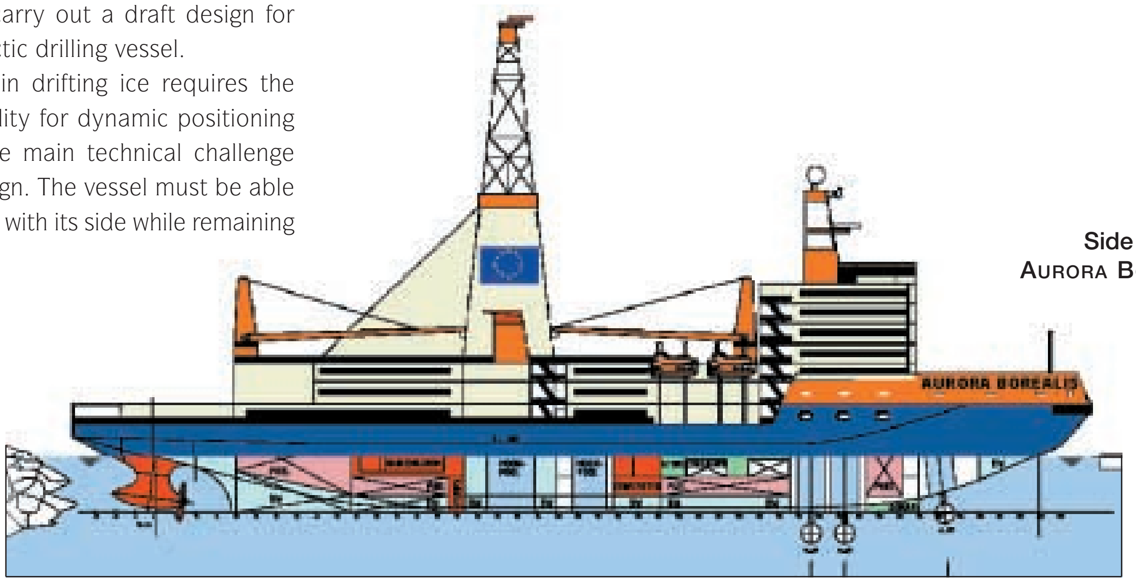
The Alfred-Wegener-Institut (AWI) in Bremerhaven, Germany (www.awi-bremerhaven.de) contracted the Hamburgische Schiffbau-Versuchsanstalt (HSVA) to carry out a draft design for such an Arctic drilling vessel.

Drilling in drifting ice requires the vessel's ability for dynamic positioning which is the main technical challenge for the design. The vessel must be able to break ice with its side while remaining positioned over the drilling pipe. The solution was a strongly sloped side of the vessel (see cross section) and an azimuth propulsion system which allows the vessel to break ice with its stern and rotate around the drilling pipe as necessary.

The basis of the ship design is the research work of the last decade carried out in HSVA's ice department for improving icebreaking vessels. The "Aurora Borealis" (project name) is one of the results of this work, but further, more detailed technical research is necessary for this project. At present the preliminary study calls for the following vessel dimensions and capabilities:

- Overall Length about 140 m
- Displacement 23.000 tons
- Ability to support research of different polar science disciplines
- Ability to endure winter and spring expeditions in the Central Arctic Ocean
- Ice breaking performance of more than 2 m of ice thickness and dynamic positioning in drifting ice
- Deep drilling capability

A detailed plan for scientific Arctic marine research for the next one to two decades will be established by a working group of the European Polar Board by the spring of 2002. This plan will define the need for a large research icebreaker that can operate year round in ice covered waters. One of the next steps will be a feasibility study carried out by representatives from different European polar research institutes and engineers experienced in the design of ships and drilling facilities.



Side view of Aurora Borealis

A GUI Driven Panel Program presents a New Way of Analysing and Optimising Ship Propellers

by Heinrich Streckwall and Dieke Hafermann

HSVA's propeller panel program PPB is now released for the use by our customers. The program was developed to predict the performance of the propeller in its natural environment behind the ship. Special features of the method used are:

- Transient flows are solved in the frequency domain
- Time history of forces and moments for one blade are obtained
- Cavitation is predicted 3D unsteady
- 4 corner panels of insufficient quality are triangulated automatically
- Any hub type is possible, especially a Pod shaped one
- The calculated propeller hull pressures include the rigid hull and the free surface influence

Fig. 1

Providing a hull surface description, PPB determines, how the flow around the hull is influenced by the moving propeller which may for instance show cavitation in some blade positions (a sample for a predicted cavity is given in Figure 1). This approach leads to the propeller hull pressures.

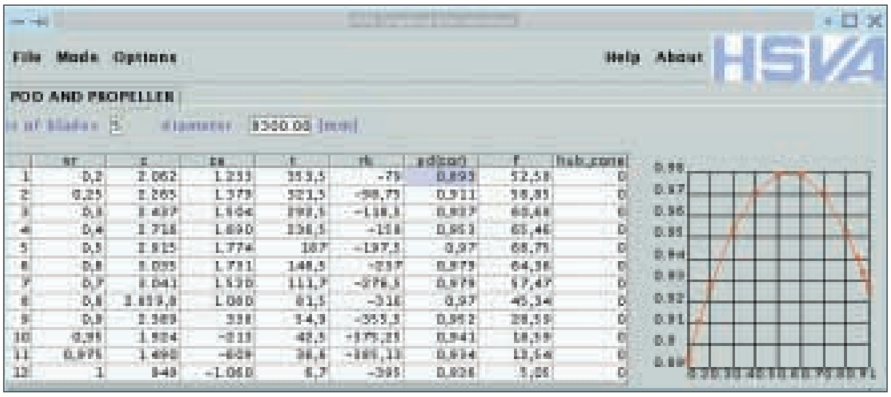
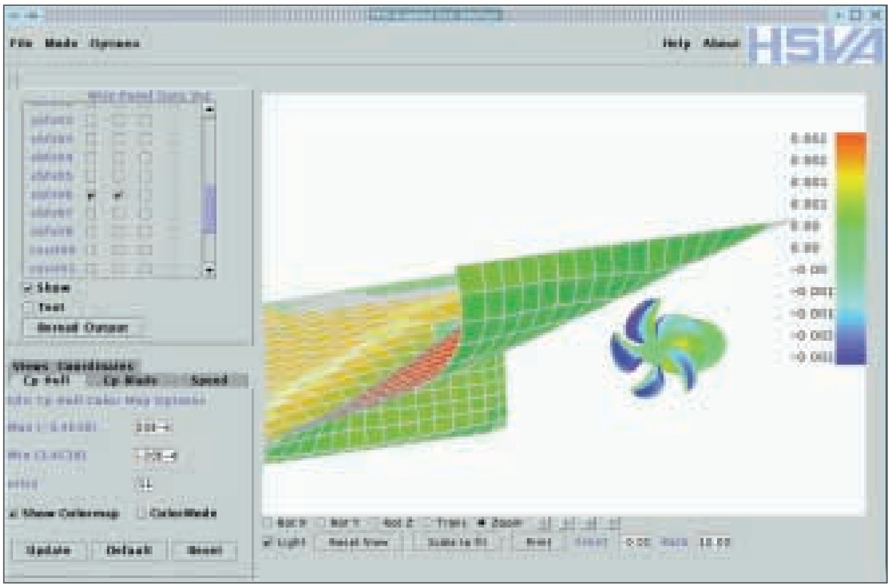


Fig. 2

A big improvement concerning the handling of such a complex numerical approach was achieved by preparing, starting and controlling every computational step from a 'graphical user interface' (GUI). Working with pull down menus and check buttons the Java based GUI assists in preparing and viewing input data, such as propeller main data (Figure 2) and wake files. Moreover the GUI serves as a visualisation tool and thus substitutes commercial tools for contour and vector plots (Figure 3). The GUI version of the panel program works under MS WINDOWS NT and Nx and under LINUX. HSVA will continuously work on the maintenance and improvement of this propeller panel program and will add new features, such as ducted propeller performance prediction.

For further information please contact ppbgui@hsva.de

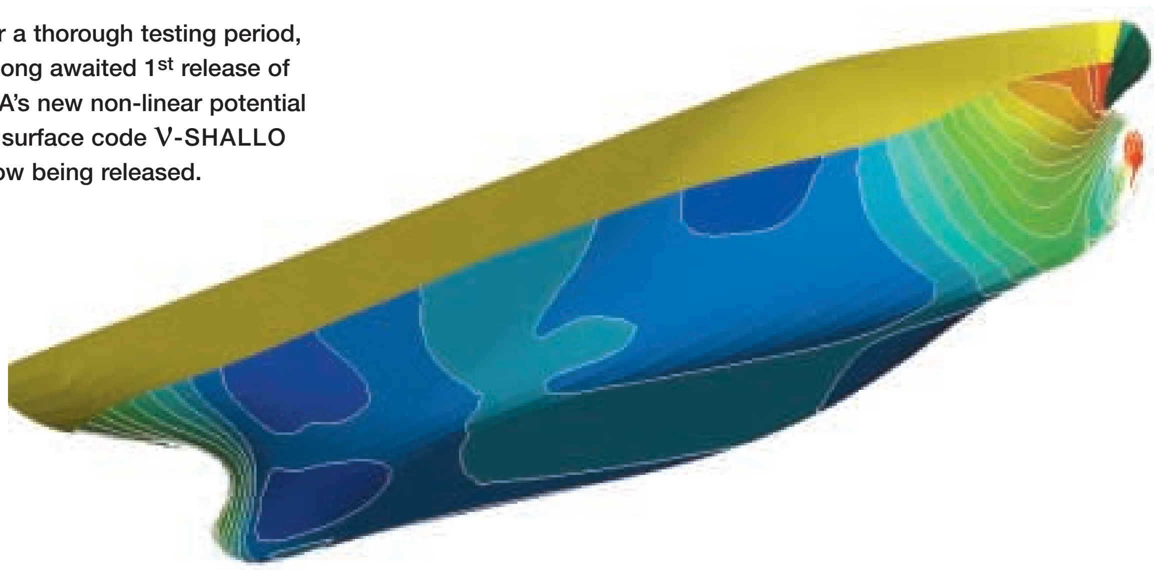
Fig. 3



V-SHALLO – HSVA'S NEW WAVE RESISTANCE CODE

by Jochen Marzi

After a thorough testing period, the long awaited 1st release of HSVA's new non-linear potential free surface code V-SHALLO is now being released.



This all new CFD code will boost performance during design analysis and optimisation. The programme has been developed using latest singularity as well as numerical techniques. Advanced programming concepts make it an "easy to use" window oriented application that will integrate smoothly into a variety of design environments.

V-SHALLO is capable of computing a large number of different flow cases such as:

- (unlimited) deep water condition
- shallow water
- monohulls (conventional ships)
- multi hulls (catamarans, SWATH, trimarans)
- asymmetric ships (monohulls as well as catamarans)
- submarines
- fixed models as well as free to trim and sink conditions

V-SHALLO has been written in FORTRAN 90 making use of a number of advanced concepts. Executable versions are available for MS-Windows 9x and NT operating systems as well as for LINUX.

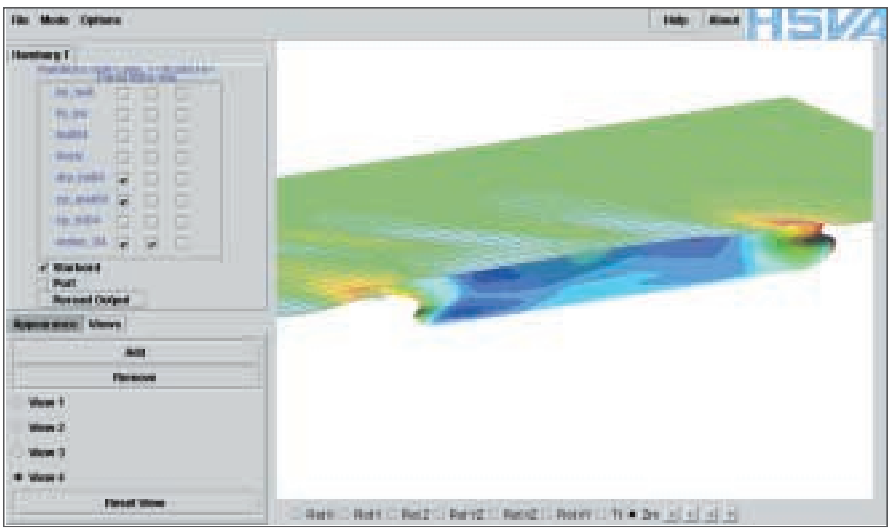
A completely new Graphical User Interface (GUI) for V-SHALLO has been developed using JAVA© and is available for all platforms. This GUI substantially facilitates user input and control of computations. It supports

- Input generation
- Import of panel models from different formats
- Control and modification of panel models
- Visualisation and Control of computational results.

V-SHALLO presently supports panel input from different sources such as NAPA/npn© and GiD© and ICEM/CFD.

For further information please contact nushallo@hsva.de

Please visit HSVA's web site for further details: www.hsva.de



Research is the Root of our Success

by Jürgen Friesch

Customer orientated research has always been a solid foundation for HSVA's business activities. Research for improving our facilities, for the development of new methods, new procedures and software is essential to meet future challenges and answer the questions of our clients. HSVA is a central point for applied research in all areas related to transport systems and ship technologies in open water and in ice.

Research in the fields of ship manoeuvring, sea keeping, resistance, propulsion and cavitation has always been important at HSVA. Today, theory, model testing, and CFD predictions are the elements of an integrated approach to perform both, commercial and research projects. As a model basin, we act as a link between basic research carried out at the universities and the demands of our industrial partners by adapting research results to new problems, new challenges and to solve the daily troubles of the shipbuilding industry.

HSVA is currently engaged in 12 projects and thematic networks within the EC Framework Programme. HSVA is co-coordinating two of them, **EROCAV** and **STRICE**.

All aspects of pod propulsion of ships are studied in the project **OPTI-POD**, mainly to develop guidelines for the design of ships with pod propulsion and optimization from a hydrodynamic point of view with respect to efficiency, safety and environmental impact. HSVA's role is related to hydrodynamic interactions and for carrying out model tests regarding resistance, propulsion, cavitation and maneuvrability and to develop guidelines for the design of ships with pod propulsion.

VRSHIPS-ROPAX 2000 is an EC Technological Platform for integration of advanced simulation tools in order to maximise interoperability in waterborne transport.

Erosion on ship propellers and rudders is being studied in the **EROCAV** project, using full scale investigations and the related model tests in different cavitation tunnels. One of the main aims is to minimize the risk of cavitation induced erosion by improving the prediction methods, and thus reduce maintenance costs and increase operational lifetime. For further information visit the EROCAV web page http://www.erocav.com

In the **KAPRICCIO** project, a new type of propeller, the KAPPEL Propeller is investigated in model and full scale. This propeller offers an increase in propulsive efficiency with lower vibration excitation compared to a conventional one. For further information visit the KAPRICCIO web page http://www.kapriccio.dk/

FANTASTIC has been launched in 2000 and brings together 14 European Partners having significant expertise in geometry modelling, CFD and experimental hydrodynamics as well as optimisation strategies. The project aims at providing a framework for an automated hullform optimisation strategy based on parametric hull form descriptions and integrated CFD methods. HSVA is involved in CFD adaptation for the optimisation environment. The potential flow code ν-SHALLO has been successfully tested in an integrated environment together with a parametric NAPA model. Further work will include also viscous flow simulations.

MARNET - CFD is the Maritime Industries Network dealing with CFD computations for shipbuilding / marine applications. Lead by WS-Atkins (UK) it brings together about 40 interested parties from EU Maritime Industry and Research. The network has 4 Thematic areas focussing on steady state problems, e.g. resistance, transient flow simulations incl. ship motions, propeller flows and offshore applications.

A successful project proposal based on one of the "Grand Challenge" problems identified in Marnet – CFD is the **EFFORT** proposal dealing with full scale measurements and the validation of full scale CFD computations. EFFORT was successful in the last round of the 5th framework programme GROWTH and is likely to start in spring 2002.

Transnational Access to Research Infrastructures is a project providing essential services to Europe's research community in industry and academia. In **ARCTECLAB** the access for users from European countries and associated states to the infrastructure is financially supported by the EC. The EC's principle means of support is to buy time on an infrastructure, anything from a world-class or rare assembly of equipment, know-how or techniques. For further information visit the ARCTECLAB web page http://www.arcteclab.de/

HYDRALAB II is a concerted action focussing on the hydraulics, geophysical fluid dynamics, ship dynamics and ice engineering facilities. The aim is to clarify the integrated role of experimental research, including field tests and mathematical modelling in these fields in terms of European society needs and in doing so, to coordinate European research in large scale hydraulic facilities to facilitate the access of researchers and enhance the supporting role of these facilities for other European research projects in the 5th Framework programme. For further information visit the HYDRALAB-II web page http://www.wldelft.nl/hydralab/

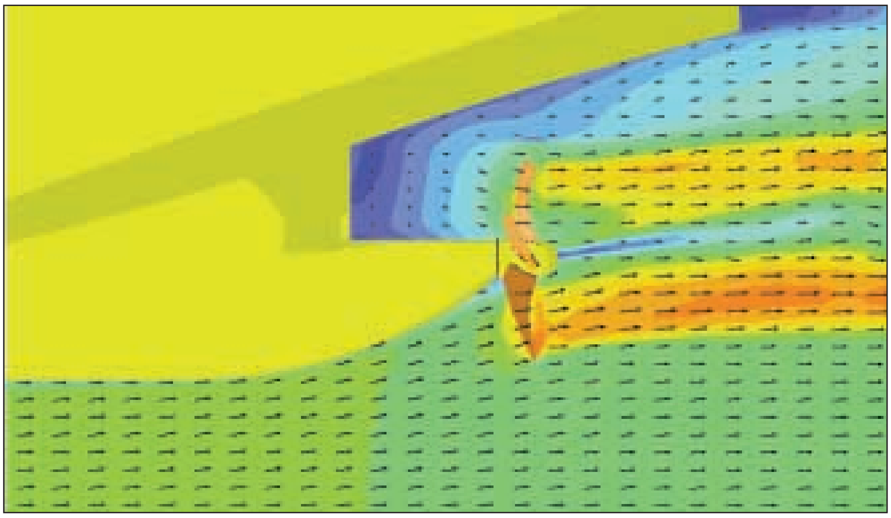
LOLEIF was a RTD Project, under the leadership of HSVA, within the Marine, Science and Technology Program, MAST III, and has been finished in October 2000. Coastal structures in ice covered waters as well as offshore structures have to be designed to withstand the forces of moving ice. The magnitude of these forces are under heavy dispute because the forces predicted by various methods scatter by the factor of 10 and more. This situation as well as indications that the forces are indeed smaller than predicted have stipulated the LOLEIF group to prove the validity of lower ice forces, by this research program. For further information visit the LOLEIF web page http://www.hydromod.de/loleif

STRICE is a RTD Project, under the leadership of HSVA, within the 5th Framework Program Part A, "Energy, Environment and Sustainable Development" continuing the LOLEIF project. Beside the full scale measurements of ice forces acting on the lighthouse Norströmsgrund, located in the northern part of the Gulf of Bothnia, Sweden, the main objectives are numerical approaches, comparison of full scale data with numerical results and recommendations of new design criteria for marine structures in ice covered waters as input for the establishment of an EU - Code. For further information please visit also the LOLEIF web page http://www.hydromod.de/loleif

NEST is a Thematic Network Project within the 5th Framework Program. Partners are ten Universities and Research Institutes from 5 European countries and the Peoples Republic of China, PRC. The NEST project is clustered with the STRICE project. The main objective is to get a better understanding on the physical mechanisms that are responsible for the study state ice-induced vibrations on marine structures. The results of the project will be used as input for recommendations for future design codes for marine structures in ice covered waters.

HSVA is a participant in the following EC Framework Programme projects and networks:

FANTASTIC:	Functional design and optimisation of ship hull forms
VRSHIPS-ROPAX 2000:	Life-Cycle Virtual Reality Ship System(s)
MARNET-CFD:	The Maritime Industries CFD-Network
OPTIPOD:	OPTImal design and implementation of azimuthing PODs for the safe and efficient propulsion of ships
EROCAV:	Erosion on ship propellers and rudders – the influence of cavitation on material damages
KAPRICCIO:	The KAPPEL ship Propulsion Concept Improving Energy Efficiency and Reducing the Environmental Impact.
ARCTECLAB:	ARCtic TEChnology LABoratories for Testing Engineering and Environmental Projects
LOLEIF:	Validation of Low Level Ice Forces on Coastal Structures
HYDRALAB-II:	Infrastructure Network HYDRALAB-II
STRICE:	Measurements on Structures in Ice
NEST:	Networking Studies on Ice and Compliant Structures
EFFORT:	Validation of Full Scale CFD



Towards a Complete Numerical Simulation of Propulsion Tests

by Heinrich Streckwall

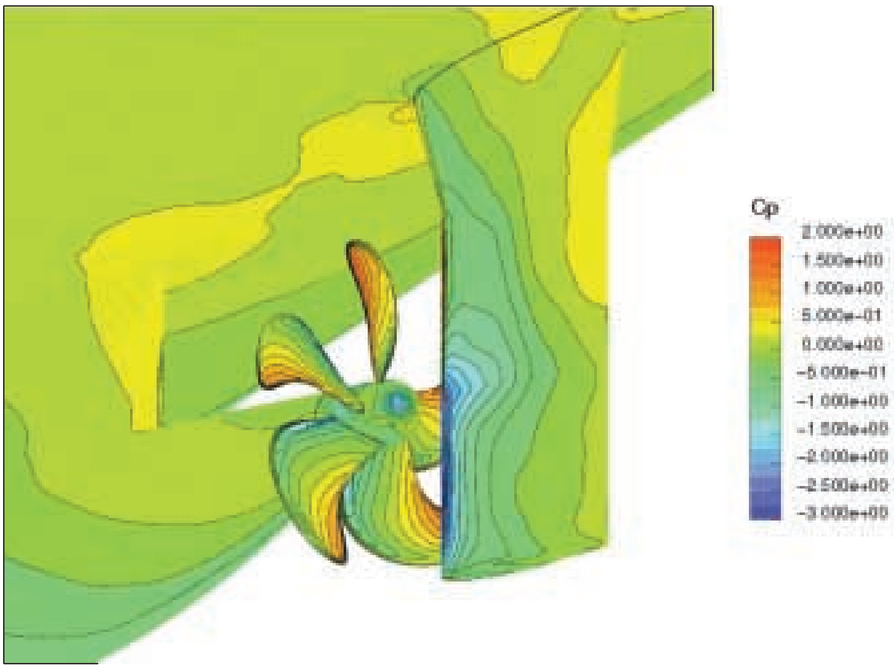
There are various numerical approaches to account for the interaction of the propeller and the ship with its appendages. The effect of the propeller on the rudder, the hull pressure fluctuations and the thrust deduction cannot be obtained with isolated models of either ship or propeller. Within a project sponsored by the German AiF foundation we used the RANSE solver 'Comet' to establish a numerical model which matches 1 to 1 with the propulsion test conditions, which in particular means that...

- the propeller is modelled geometrically correct
- the propeller is turning while the ship is fixed
- the RANSE solver has to be run in the transient mode

Special effort is required to generate the grid for such a problem. The solvers technique to obtain a running propeller within an non-rotating environment is the 'sliding mesh' technique. The propeller is to be situated in a cylindrical block with all cells of this block following the rotation of the blades. The propeller block and the ship block are connected via sliding interfaces, where the connectivity of cells has to be re-processed after every time step. Since time steps have to be quite small, we perform our calculations on an in house PC cluster, which was established just for this purpose.

The results of this 'real numerical propulsion test' are promising. We derived a technique to overstep the start up phase of the system, which helps to calculate the thrust deduction right at the beginning of the time stepping procedure. A good correlation between calculated and measured mean values of the propeller forces was found. The flow around a rudder located in the slipstream was also calculated and the free surface will be included in our analysis soon.

The two figures show the pronounced slipstream (above) and the momentary pressure on a rudder located in that slipstream (below).



Ice Formation Processes in a "Twin Wave Tank" and Freeze-up Ice Run in Rivers Experiments

by Karl-Ulrich Evers

An international group of researchers from Elforsk AB / Luleå University of Technology (Sweden), Institute of Hydroengineering of the Polish Academy of Sciences, Gdansk (Poland), Clarkson University, Potsdam NY (USA) and Scott Polar Research Institute, Cambridge University (UK) recently got access to the European Major Research Infrastructure ARCTECLAB at HSVA. The project was financially supported by the European Commission.

Fig. 1 Twin wave tank and two separetely operated paddles

Fig. 2 Propeller arrangement in the recirculating flume

Experiments were carried out in the Environmental Test Basin at HSVA to investigate the formation processes of different types of river and sea ice. This unique facility was equipped with two distinct "wave tanks" in the same cold room. Two wave makers operated independently in two identical flumes (Fig.1) of about 35 ‰ water salinity. The purpose of this study was to separate the dynamic effect in pancake ice growth from the thermodynamic effect. As the temperature history in both wave tanks was identical, the difference of the resulting ice growth could solely be due to the different wave conditions.

In addition to the two "wave tank" tests, ice was grown in the same room under calm water conditions using a compartment with insulated walls and bottom. Data on the following parameters were sampled hourly: wave number and amplitude, ice surface temperature, ice thickness and pancake size, ice crystal structure, air and water temperature; and water salinity. These data were collected by means of pressure transducer sensors, infrared camera, universal stage, PT 100 strings, and conductivity meter. At the end of each test, ice thickness was profiled and water salinity was measured. Ice samples were drained to estimate ice porosity as well as the salinity which remained in the ice.

Based on these data: porosity, ice cover thickness and salinity, the quantity of ice production was estimated.

In a second phase the wave makers were removed from the tank and the test set-up was modified. For these tests, freshwater was used in a 0.6 m wide recirculating flume having a racetrack form (Fig.2) that had been designed and built especially for this experiment. The water depth was varied in the range $400 < d < 600$ mm in the 22 m long testing section. Four propellers generated the flow in the flume. They had been installed on the opposite side of the testing section. Within the flume we were able to generate flow conditions for the formation of all types of freeze up ice runs, including the flow conditions for the formation of skim ice, pancake ice, and stratified or well-mixed frazil slush runs. The study focused on the determination of the transitional flow conditions for the formation of these ice runs. The level of the cut off turbulence for the formation of static skim ice and for skim ice run was obtained. The experiments also reproduced the beginning of the process of pancake ice formation in rivers. The turbulence criterion, where surface ice runs no longer exist and pancake ice starts forming itself, has been established as well as the level for high turbulence flows.

For further information please contact: evers@hsva.de

Spectacular attack of a large ice jam on the Elbe river

Break-up of Ice Jams

by Jens-Holger Hellmann

In cold winters ice is growing on most of the major German rivers. Particularly on the rivers in the eastern part of Germany the ice often reaches a thickness of more than 20 cm. In the case that the freezing period lasts for several weeks the ice cover usually becomes stationary. At the end of the freezing period or during intermediate warming up phases the river ice breaks up and a huge amount of ice drifts down-stream. This ice mass tends to jam for instance in river bends and at bridges and barrages, thereby forming ice dams and pile-ups. Such ice jams impede the water flow and in many cases lead to a rapid increase of the up-stream water level. This bears the danger that river dikes break and that the lowlands are flooded. The endangering of human live, evacuation, biological and structural damages as well as significant economical losses are the potential consequences.

The occurrence of jams can be minimized by a controlled ice break up whereby the stationary ice sheet is broken up by icebreakers before the natural break up happens. The early and effective combating of ice jams reduces or even eliminates the dangerous consequences.

Fortunately, no catastrophe caused by ice jams has happened in Germany within the past 5 decades. This was at least partially due to the effort of the river icebreakers which the German government keeps in readiness mainly for this purpose. The German river icebreaker fleet consists of more than 50 relatively small vessels, most of them less than 30 m in length with a propulsion power between 300 kW and 800 kW. Occasionally their icebreaking capability is also used to facilitate the winter traffic on the inshore waterways.

The main problem when operating these icebreakers is the low water depth in many of our rivers. When combating ice jams this situation is worsened by the fact that ice jams further reduce the water level on the downstream side, from where the ice jams have to be attacked.

Most of the German river icebreakers are more than 30 years old. Thus, although the vessels are constantly being modernized, there is an increasing need to replace the aged units.

In 2001 the German government (represented by the Wasser- und Schiffahrtsamt Eberswalde) signed a contract with the Hitzlerwerft, Lauenburg/Elbe to build a new icebreaker for the river Oder. The commissioning of the vessel is planned for the 2nd quarter of 2002. When the new icebreaker was designed, particular attention was paid to the draft limitation. With a design draft of only 1.45 m the vessel will be able to operate in less water depth than any of the existing Oder icebreakers. The operation requirement for the newbuilding was that her icebreaking performance must not be less than that of the best existing icebreaker operated on the river Oder.

The new icebreaker was model tested in HSVA's ice model basin in the summer of 2001 together with an existing icebreaker which was known for its effectiveness when breaking ice jams. In addition to the standard model test program, which included the assessment of the icebreaking performance in level ice and in ice floes, the ability to break up ice jams was also investigated.

Testing the new Oder-icebreaker in a model ice jam

For this test a special test arrangement was set up in the ice basin: The water depth in the test section was adjusted to only 2 m (full scale) by means of HSVA's shallow water bottom. The bottom was installed in the tank in a complete water-tight manner so as to form a simplified river bed. In order to simulate the residual water flow through the ice jam the "up-stream" water level was raised by means of 4 pumps with 100 m^3/h pump capacity. The total ice mass of a model ice sheet was used to model a grounded ice jam of 50 m length and 1.5 m freeboard (both values full scale).

The model of the new icebreaker broke up the ice jam within 11 rams. This was 6 rams less than the model of the existing icebreaker needed for the same task. Even if the test results are interpreted in a conservative manner it can be stated that the new icebreaker fullfills the requirements.

Inspired by these tests as well as by previous work, HSVA has developed new ideas to further increase the efficiency of river icebreakers when attacking ice jams. We believe that with a totally different ice breaking concept ice jams can be broken up five times faster without increasing the number of icebreakers. To prove these ideas HSVA has applied for funding from the Federal German Ministry of Education and Research and is presently looking for industrial partners for this project.

notes

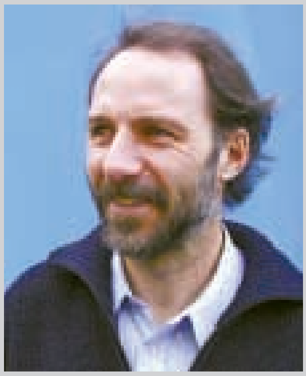
1st Announcement

HSVA will be holding their 4th Customer Seminar on "CFD in ship design" on September 23rd. The seminar will cover up to date topics of CFD applications in design analysis and optimisation of ship hulls and marine structures. For further details please contact our web site at **www.hsva.de**.

Publications 2001

In 2001 researchers and scientists of HSVA contributed with papers in more than 12 international conferences, symposia and workshops. Additionally two customer orientated seminars were hold here in Hamburg. The full list of all papers and publications presented can be found on our web site **www.hsva.de**

MEMBER OF STAFF



JOHN RICHARDS

John Richards joined HSVA in 1990 as a project manager within the Resistance and Propulsion Department. His main activities involve model testing and consulting work for commercial projects, as well as software development. In the recent past he has been actively involved in most of the projects involving pod propulsion, including OPTIPOD sponsored by the EU. Prior to coming to HSVA he was at Petersen Schiffstechnik GmbH, Germany, where for 2 years he coordinated the installation and commissioning of an azimuth thruster system for a series of 5 service ships. Mr. Richards studied mechanical engineering at the University of Southern California in Los Angeles and at the University of California, San Diego. He received his degree in naval architecture, Dipl.-Ing. Schiffbau, from the University of Hamburg, Germany. He has been deputy head of the Resistance and Propulsion Department at HSVA since 1998.

HSVA The Hamburg Ship Model Basin | Bramfelder Straße 164 | D-22305 Hamburg
Phone + 49 – 40 – 69 203 – 0 | Fax + 49 – 40 – 69 203 345 | E-mail info@hsva.de | Internet http://www.hsva.de