UNIVERSITÄT DUISBURG ESSEN

Open-Minded

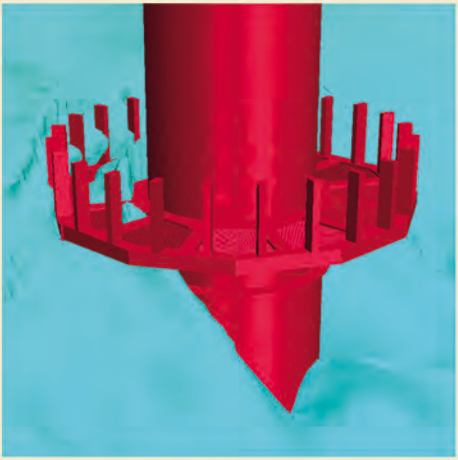
ISMT

Institut für Schiffstechnik, Meerestechnik und Transportsysteme

Universität Duisburg-Essen

ANNUAL REVIEW 2018

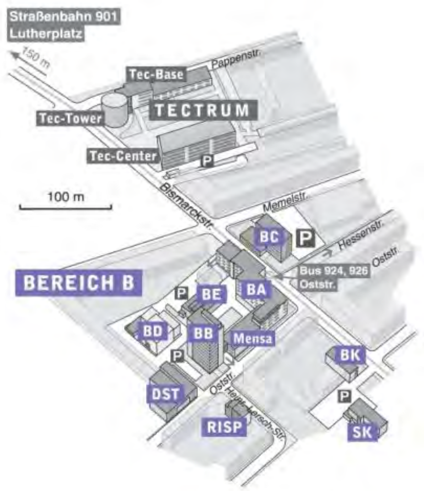
Institute of Ship Technology, Ocean Engineering and Transport Systems (ISMT)



Faculty of Engineering/Department of Mechanical Engineering
Institute of Ship Technology, Ocean Engineering and Transport Systems (ISMT)

Editor: Claudia O'Donoghue
Contact: Institute of Ship Technology, Ocean Engineering and Transport Systems (ISMT)
Bismarckstr. 69
D-47057 Duisburg

Phone: +49 (0)203 379-4596
Fax: +49 (0)203 379-2779
E-Mail: ISMT@uni-due.de
Internet: www.uni-duisburg-essen.de/ismt



Publication: April 2019

Table of contents

Preface

Dear Reader,

The year 2018 has been a successful year for us, with a view to the extension of our research activities on cavitation, sloshing and wave-induced loads on ship and offshore structures. Various research projects have been completed and new ones have been acquired. National and international PhD students are working on different subjects related to the above research activities.

In total, at our institute 16 students graduated (bachelor and master). Some bachelor graduates will continue their studies at our institute.

Our international co-operation in research and teaching has been intensified by a framework co-operation contract with the Dalian University of Technology (DUT), China, pursuant to the original cooperative education program agreement between the two universities concluded in 2015.

I hope that our institute’s activities will find your interest and that you enjoy reading our annual review.

Prof. Dr.-Ing. Bettar Ould el Moctar

1. The institute – an overview

Professors

Prof. Dr.-Ing. Bettar Ould el Moctar (Managing Director)
Prof. Dr.-Ing. Milovan Perić

Secretariat

Martina van Lück
Claudia O’Donoghue

Research staff and doctoral students

Senior engineers

Dr.-Ing. Jens Neugebauer
Dr.-Ing. Udo Lantermann
Dr. rer. nat. Fabian Reuter

Simon Burmester, M.Sc.
Hassan El Sheshtawy, M.Sc.
Yanxin Feng, M.Eng.
Dirk Hünniger, Dipl.-Phys.
Changqing Jiang, M.Eng.
Ebrahim Kadivar, M.Sc.
Wenjing Lyu, M.Eng.
Dipl.-Ing. Thomas Myland
Andreas Peters, M.Sc.
Robert Potthoff, M.Sc.
Malte Riesner, M.Eng.
Grusche Seithe, M.Sc.
Simon Tödter, M.Sc.
Chiara Wielgosz, M.Sc.

Youjun Yang, M.Sc.
Mohamed Youssef, M.Sc.
Lahbib Zentari, M.Eng.

Technical staff
Ralf Thomzik

Student assistants
Andreas Baloghy
Lisa Bosmann
Hannes Dierksmeier
Rafael Golf
Michael Kollek
Alessandro La Ferlita
Yan Qi
Lars Reckers
Nathalie Reinach
Tom Schickel
Björn Wierczoch

2. Current research projects

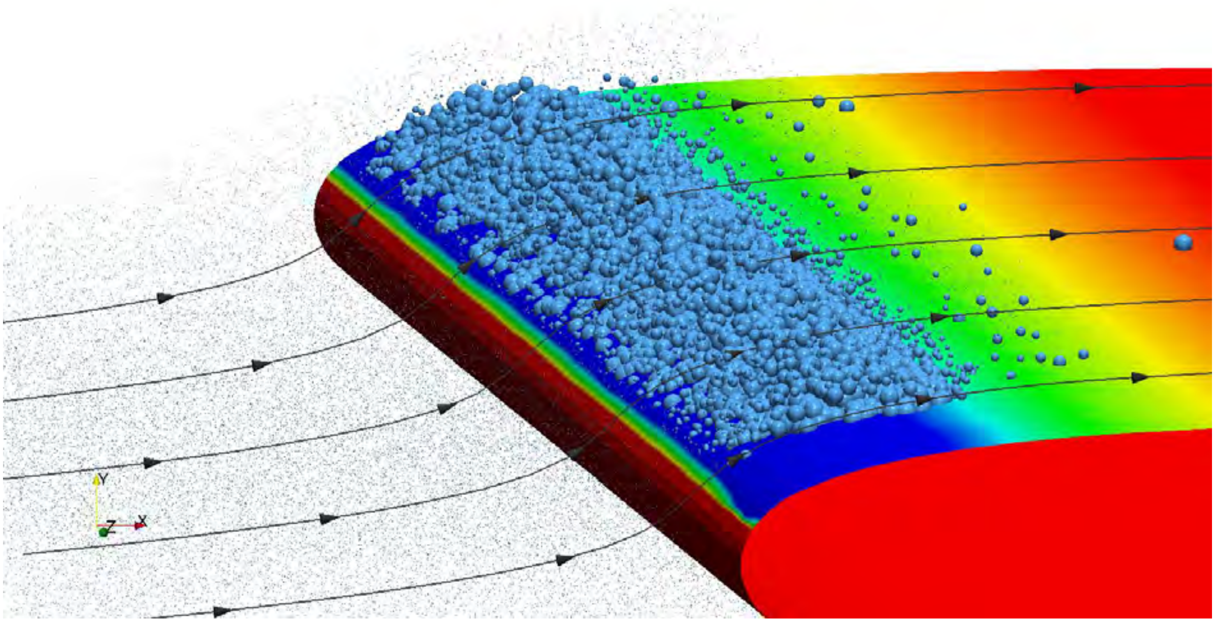
In research, the main focus of attention is on the fields of hydrodynamics and fluid-structure-interaction as well as the design of marine power plants. Moreover, investigations are made in the field of ocean engineering (e.g. wave energy).

Our research projects:

Project	**Project research**	**Page**
Development of a Numerical Method to Predict Hydrodynamic Cavitation Induced Erosion	Andreas Peters, M.Sc. Youjun Yang, M.Sc.	13
Investigation of Sloshing in Partially Filled Tanks Considering Density Ratio and Phase Transition Effects	Robert Potthoff, M.Sc.	14
Development of an Efficient Method to Calculate Springing-Induced Higher Order Loads	Malte Riesner, M.Eng.	16
Development of an Innovative Multipurpose Ship for Maintenance and Repair of Offshore Wind Turbines	Dipl.-Ing. Jens Ley Dipl.-Ing. Thomas Myland Guillermo Chillcce, M.Sc. Youjun Yang, M.Sc.	18

Development of a Numerical Method to Predict Hydrodynamic Cavitation Induced Erosion

The aim of this project is the development of a reliable numerical method for the assessment of hydrodynamic cavitation induced erosion. An Euler-Euler method, as well as an Euler-Lagrange method will be extended by additional terms and equations for bubble dynamics. These methods will be strongly coupled. Figure 1 shows the simulation of cavitation on a hydrofoil using the Euler-Lagrange method. To reduce the computational effort, the coupling algorithm will be applied to a limited part of the computational domain considered as relevant for cavitation induced erosion. An approach to qualitatively predict cavitation erosion has been developed by the scientists. The extended erosion model will be improved based on additional flow details, bubble dynamics, and bubble transport to better predict the erosion sensitive areas and to estimate erosion rates for different materials. The developed numerical method will be validated based on experimental data from former research projects and from literature. The coupled method will be applied to predict cavitation induced erosion in the maritime field.



The project is funded by Deutsche Forschungs-gemeinschaft (DFG) and the scientists in charge are Andreas Peters, M.Sc. and Dr.-Ing. Udo Lantermann

Investigation of Sloshing in Partially Filled Tanks Considering Density Ratio and Phase Transition Effects (SLOSHING)

The main objective of this project is to carry out a dedicated experimental investigation of the influence of phase transition and density ratio between gas and liquid phases on sloshing and sloshing induced loads. For this purpose, a test tank will be designed and an experimental procedure will be developed which allows the use of water as the liquid phase at ambient temperature with air or a gas mixture of high density as the gas phase.

Figure 1 exemplarily shows a test set-up from a previous test campaign. Further on, boiling liquids under reduced pressure will be used to investigate phase transition effects.

The experimental setup will allow the measurement of the free surface behaviour by means of high-speed video recordings as well as the flow velocities in the tank using Particle Image Velocimetry. Pressures on the tank walls are measured by flush-fitting miniature pressure sensors. For the different model fluids, several experiments with various tank motions and impact scenarios will be performed. A broad base of test results to deeply analyse the influence of density ratio and phase transition will be generated. Understanding the effects will lead to a long-term improvement of the prediction of sloshing loads in full scale.

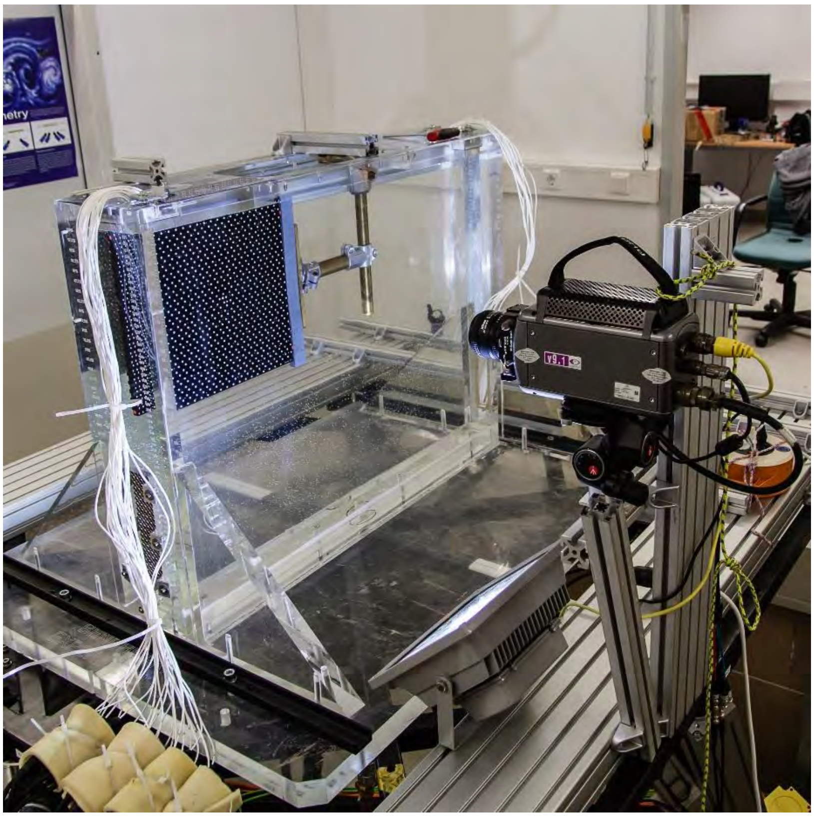


Figure 1: 2D Tank with pressure sensors and high-speed camera

The project is funded by Deutsche Forschungsgemeinschaft (DFG) and the scientists in charge are Robert Potthoff, M.Sc., and Dr.-Ing. Jens Neugebauer.

Development of an Efficient Method to Calculate Springing Induced Higher Order Loads

The aim of this project is to further develop a three-dimensional boundary element method based on Rankine sources to predict sectional loads acting on ship structures in waves taking into account springing-induced hydroelasticity effects. Wave-induced forces, leading to resonant ship responses, are subdivided into Froude-Krylov, radiation and diffraction forces. For higher order springing it is important to consider nonlinear effects related to

Froude-Krylov forces. These forces are computed in each time step based on the instantaneous wetted surface. With regard to springing, diffraction and radiation forces can be treated in a linear way. They are computed in the frequency domain and transferred into the time domain using convolution integrals. To account for hydroelasticity effects, the flow equations are coupled with the equations of motion (rigid and elastic). The elastic deformations are computed using a modal decomposition approach to efficiently solve a reduced set of natural modes. A Vlasov beam and three dimensional Finite-Element models will be used. Further, simplified methods for prediction of hydrodynamic damping will be developed and verified. The methods to be developed are extensively validated using results from model tests and field methods based on Reynolds-Averaged-Navier-Stokes-Equations.

The prediction of a valid tug power also requires knowledge of further nautical aspects, such as the available tugs, towing angles, available space and harbour restrictions. The software programme developed will be the basis on which a nautical engineer can estimate the tug power.

The project is funded by Deutsche Forschungs-gemeinschaft (DFG) and the scientist in charge is Malte Riesner, M.Sc.

Development of an Innovative Multipurpose Ship for Maintenance and Repair of Offshore Wind Turbines (INNOSHIP):
Sub-project "Safety and Efficiency of a Multipurpose Ship for Maintenance and Repair of Offshore Wind Turbines in Seaways"

Within this joint research project scientists of the University of Duisburg-Essen are working on the sub-project SiEWin (safety and efficiency of a multipurpose ship for maintenance and repair of offshore wind turbines in seaways). A boundary element method for the calculation of seakeeping and maneuvering is further developed towards typical scenarios of multipurpose service vessels for offshore wind turbines. The method is extended to calculate safety-relevant issues of service vessels (stability, loads, etc.) and to design jack-up leg systems for "semi-jack-up" and full "jack-up" state. Also the multipurpose service vessel, designed within this joint research project, will be optimized with spot on energy efficiency during operation by using the developed numerical method. In addition, structural analyses for the jack-up legs and the ships' structure are performed.

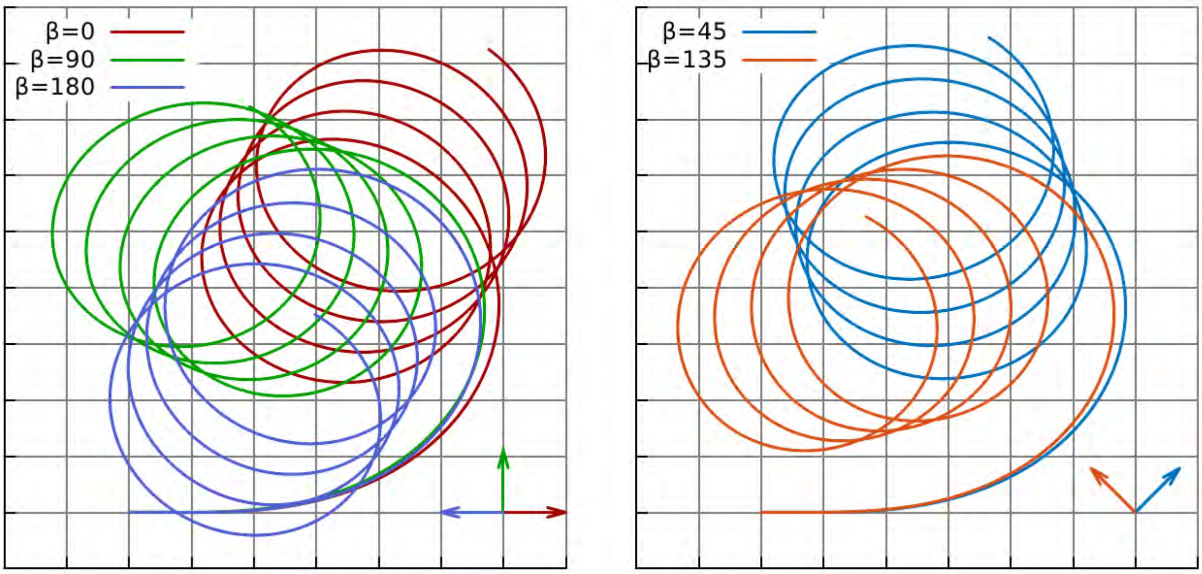


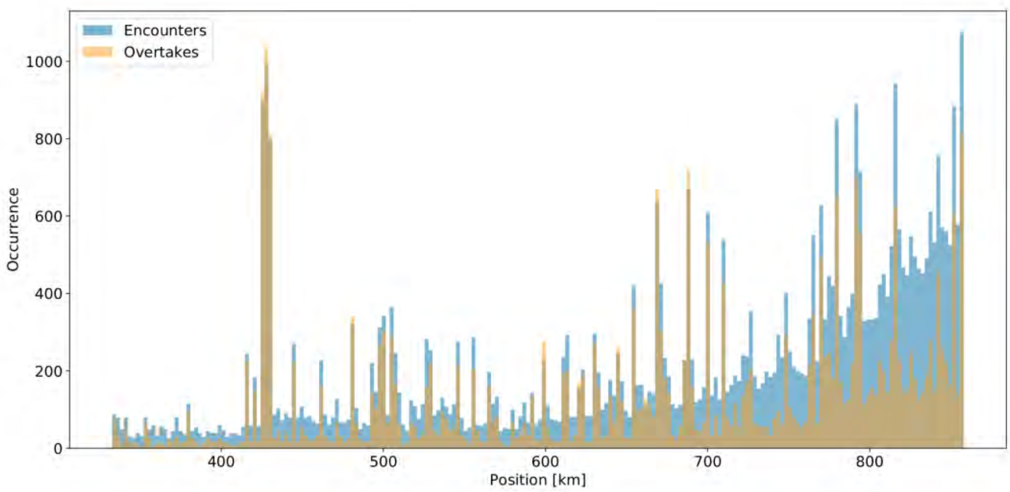
Figure 2: Calculated turning circle for waves of different incident angles

The project is funded by the Federal Ministry for Economic Affairs and Energy (BMWi) and the scientists in charge are Dipl.-Ing. Jens Ley, Dipl.-Ing. Thomas Myland, Youjun Yang, M.Sc., and Guillermo Chillcce, M.Sc.

AIS-based assessment of shipping traffic (AIS)

In inland navigation, the use of decision support systems which assist the shipmaster and make ship operation more cost-efficient, is increasingly gaining in importance. However, in order for a system to be developed which supports the shipmaster in navigational situations by giving decision support, the current traffic situation has to be precisely recognised and assessed. Automatic recognition and assessment of traffic situations – which is an easy task for the human brain – is extremely challenging for a computer system, a fact which can easily be derived from the scope of research carried out in this field of computer science.

The aim of the project is to develop a system which automatically identifies characteristic traffic situations from AIS-data and to assess them with regard to navigation complexity and safety. The project consists of three phases of approximately one year each. Initially, a suitable infrastructure has to be developed for importing and storing the AIS-data which is made available by the Federal Waterways and Shipping Administration (WSV). This is followed by developing a pattern to identify characteristic traffic situations from the available data. These will, on the basis of different parameters, be assessed with regard to navigation complexity and safety for the ship traffic in the third phase.



Encounters and overtakes of ships on the river Rhein on 8 February 2017

The project is funded by the Federal Waterways Engineering and Research Institute (BAW) and the scientist in charge is Dipl.-Phys. Dirk Hünniger

Multi-use affordable standardised floating Space@Sea (SPACE@SEA)

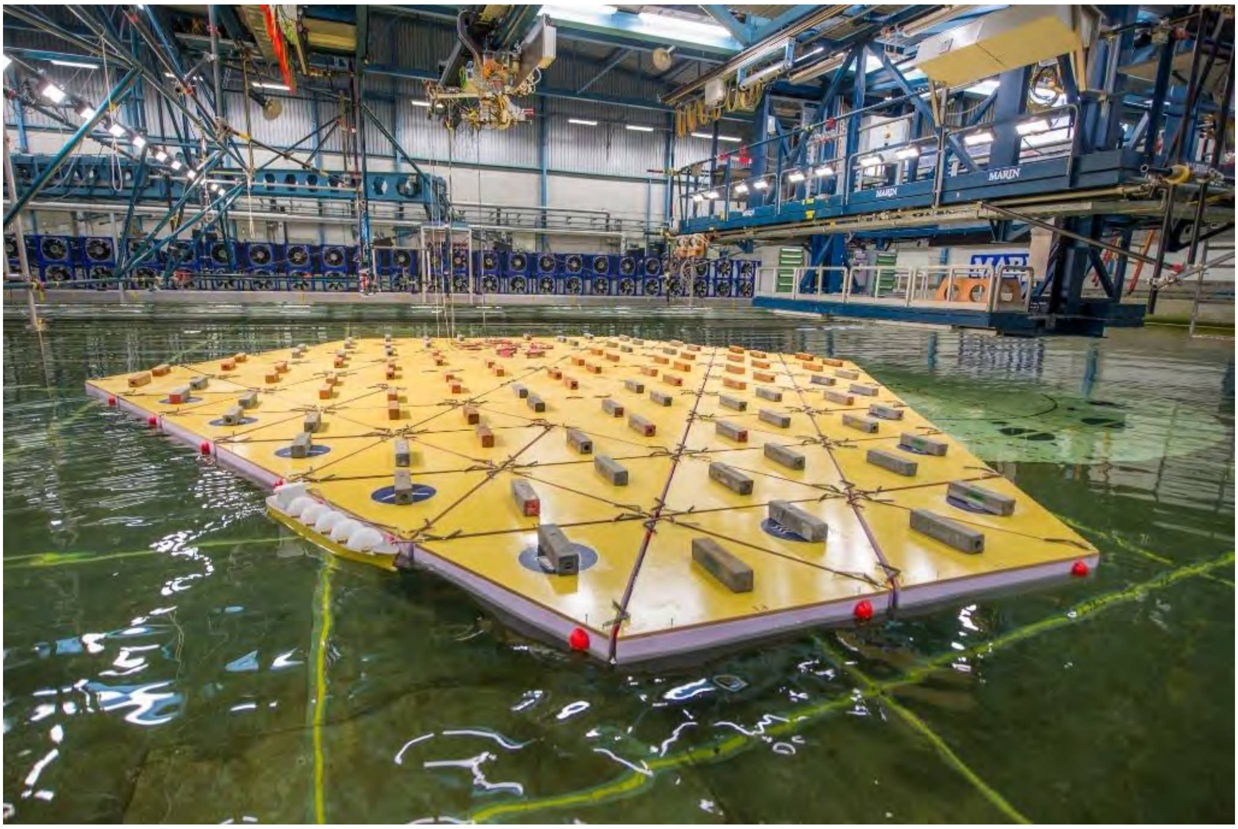
As a result of new developments of ocean usage such as renewable energy, farming and housing, the demand for affordable deck space at sea is increasing. A sustainable and cost-effective platform to operate safely at sea is required. Therefore, the Space@Sea project introduces a floating concept, consisting of multiple coupled floaters, suitable for deeper waters. Further, it can be relocated if needed. The overall goal is the development of a sustainable and affordable workspace at sea by developing a standardised and cost efficient modular island with low ecological impact.

Existing knowledge from the maritime industry is considered. However, there are still some novel challenges to be addressed. For example, the multi-body interaction of a large number of floaters needs to be investigated. Smart mooring systems are required for cost efficient and safe station keeping of the structures. The Space@Sea consortium is facing the challenge of designing floating systems that are larger than ever built before.

The University of Duisburg-Essen contributes to this project by developing, validating and applying numerical methods in the following fields:

- Extension of existing numerical methods for the simulation of multibody dynamics in waves.

- Development of complex mooring simulation technologies that are suitable for the introduced floater concept to predict the articulation forces.
- The University of Duisburg-Essen is responsible for identifying and determining the limiting criteria using the numerical methods developed.
- The detailed design will be assessed in terms of structural integrity, motions and relative motions to identify critical sea states.



Source: MARIN

The project is funded by the European Commission and the scientist in charge is Grusche Seithe, M.Sc.

Multibody Systems

As inland vessel size increases while existing waterways stay the same, the prediction of maneuvrability in restricted waters is essential to ensure safe navigation. The German Federal Waterways Institute (Bundesanstalt für Wasserbau) operates a ship handling simulator in order to predict ship motions. This tool encompasses a wide range of instruments and capabilities that allow to simulate realistic navigation in real-time. The realistic representation of the ship's dynamics depends on the hydrodynamic derivatives, which are determined based on full scale tests in open waters.

With the improvement of computational fluid dynamics in recent years, numerical tests for maneuvring prediction present an alternative to experiments. While several methods are available to numerically assess the maneuvring capability of monohull ships, only few research focused on the dynamics of pusher-barge, although they represent a significant part of inland waterways traffic.

The objective of this project is to develop a suitable parameter identification procedure for pusher barge systems. In order to achieve this goal, following tasks are to be completed:

- Design and build a typical pusher and barge system.
- Conduct CPMC tests in deep and shallow water for validation purposes
- Test different RANS-based CFD methods to assess the capabilities for further numerical investigations

- Conduct extensive CFD simulation to replicate numerically the CPMC tests in deep and shallow water
- Conduct a comparative study between experimental and numerical parameter identification to perform maneuvring simulations of different pusher barge configurations.

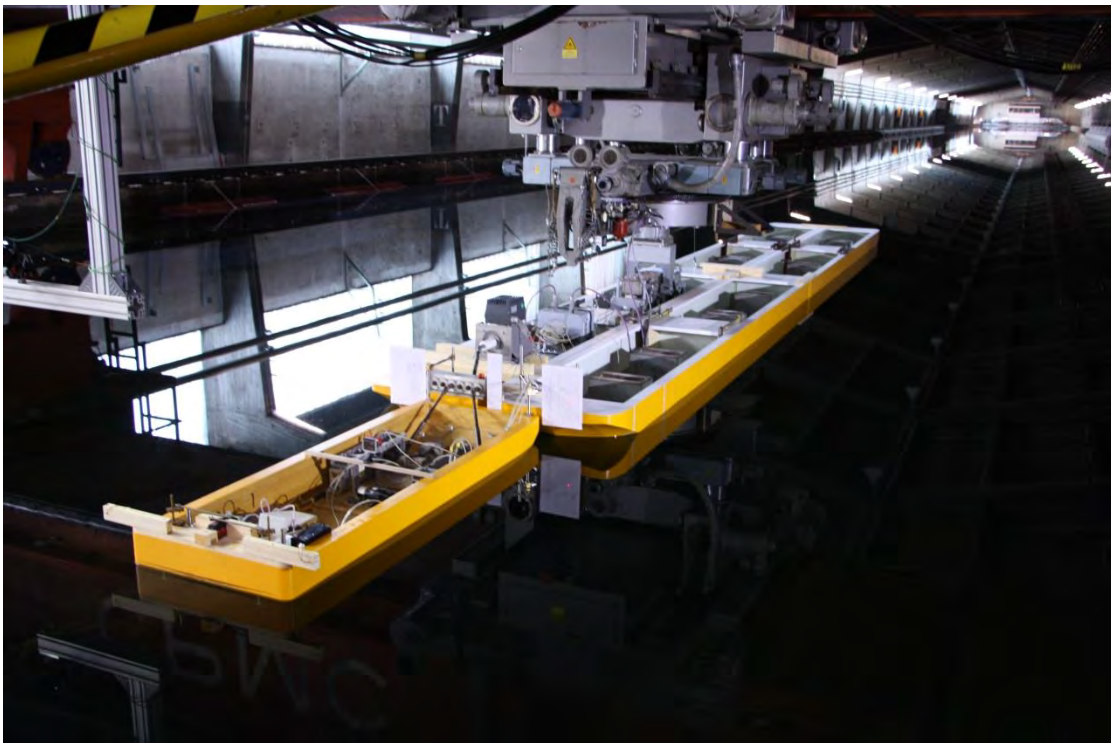


Figure 1: Pusher-Barge configuration being tested at the HSVA in Hamburg (Source: HSVA)

The project is funded by the Federal Waterways Engineering and Research Institute (BAW) and the scientists in charge are Lahbib Zentari, M.Eng., and Dipl.-Ing. Thorsten Dettmann (BAW)

Slamming Loads

In rough seas, ships and offshore structures may be subject to wave-induced impact related loads. These slamming loads, characterised by high pressure peaks, are high and may affect the structure's integrity. Besides, lesser slamming loads may induce vibrations that have a detrimental effect on passenger and crew comfort or cause damage to sensitive cargoes onboard. Ships with a long horizontal stern, such as containerships or cruise ships and mega yachts, or ships with a large bow flare are prone to slamming-induced pressure loads because at these locations' large relative vertical velocities and accelerations occur between structural components and incoming waves.

To predict slamming loads of vessels, the Institute of Ship Technology, Ocean Engineering and Transport Systems (ISMT) of the University Duisburg-Essen (UDE) investigates the impact related forces, pressures and strains related to the deadrise angle and the impact velocity. Furthermore, the influence of hydroelasticity is a central part of the research.

The aim is to get a deeper understanding of impact processes and to validate the different factors affecting forces and pressures on immersing structures.

Figure 1: Slamming Facility

The research of the ISMT consists of the following topics:

- Investigation of impact related loads depending on the velocity and deadrise angle.
- Investigation of the influence of hydroelasticity and characterisation of the fluid structure interaction (FSI) during elastic water impact.
- Effect of aeration and water properties on slamming loads.
- Effect of horizontal flow velocities.

The scientist in charge is Simon Tödter, M.Sc.

Vortex-Induced Vibrations (VIV)

Cylindrical structures, e.g. the pillars of offshore wind energy converters, are prone to vortex-induced vibrations (VIV) as well resulting from wind flow during the transportation from shore to the installation site and in the time interval between the installation on the foundation and the installation of the gondola and rotor. While VIV is suppressed during operation by the design of the structures, the structure is prone to VIV in the aforementioned conditions. Some Offshore structures are even arranged partially in air and water (multi-phase flow) and thus may reveal a different behaviour compared to those in a single-phase flow.

The phenomenon VIV is a well-known topic in the offshore industry. However, there is still a lack of research on the suppression of VIV. Therefore, the Institute of Ship Technology, Ocean Engineering and Transport Systems (ISMT) of the University at Duisburg-Essen (UDE) investigates the flow and structural response in homogeneous and multi-phase arrangements. Here, the long-term aim is to develop a suitable possibility to suppress VIV of offshore wind structures.

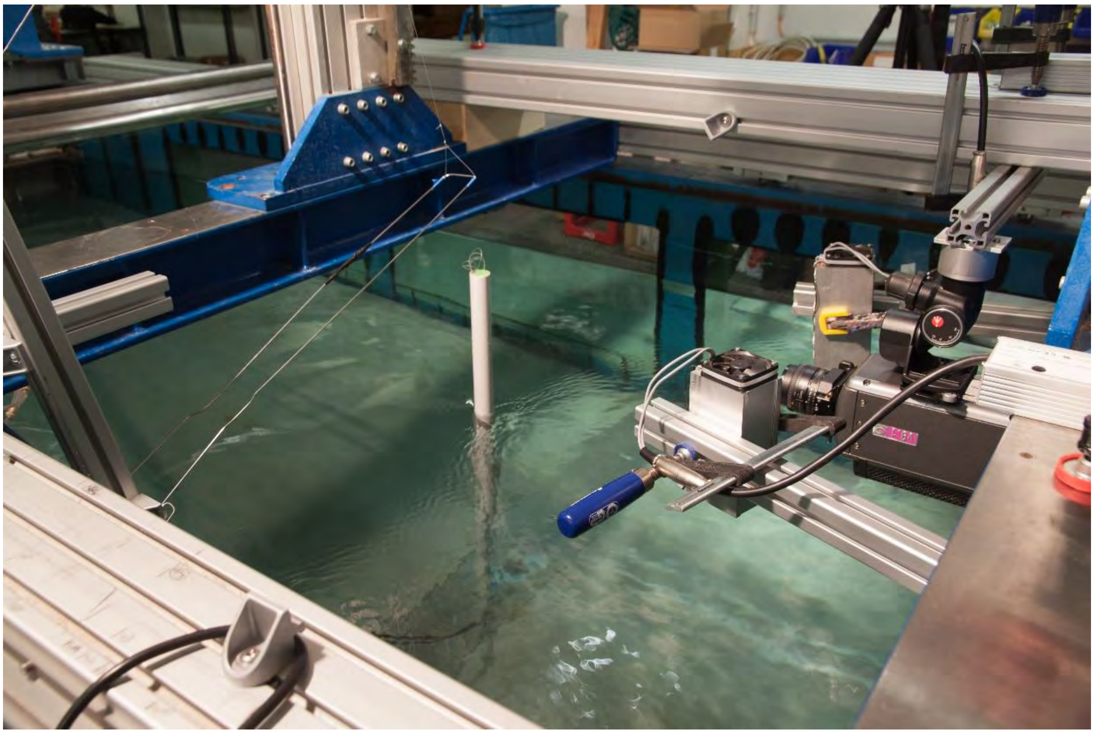


Figure 1: VIV of a surface-piecing pillar

The research of the ISMT consists of the following topics:

- Investigation of the structural response of completely and partially submerged pillar in the circulating water channel.
- Investigation of the structural response of pillars in air flow (in cooperation with institute of hydraulic turbomachines of the Ruhr-University Bochum (RUB)).
- Flow visualisation around structures.
- Test, analysis and development of suppression devices.

The scientists in charge are Dr.-Ing. Jens Neugebauer, Simon Tödter, M.Sc., Mohamed Youssef, M.Sc., and Hassan El Sheshtawy, M.Sc.

Sloshing and its effects on ship motion

The seakeeping properties of a LNG carrier at sea with partially filled tanks are influenced by the flow motion inside the tanks. The LNG carrier at relatively calm water could induce large movements of the flow in the tanks and lead to sloshing (breaking waves) inside them. To achieve an accurate prediction of the interaction of sloshing and its effects on ship motions, complex numerical models and the nonlinear ability of coupling are still challenging problems. To deal with these challenges, contributions have been made towards improved numerical techniques as well as mathematical models of key physical phenomena.

This research work has dealt with the development and validation of CFD methodology for simulating sloshing phenomena and ship RAO motions as well as their coupling effects. Field method and hybrid method, which - based on the open source tool libraries of OpenFOAM - have been further developed, validated and utilized. Specifically, the field method for solving incompressible and compressible free surface Newtonian flows using RANS equations has been adopted in sloshing simulations. The compressible VoF method was further extended with the generic wave generation and the absorption method for coupled ship motions with sloshing simulations. The hybrid method follows by coupling a Rankine Source time domain solver for ship motions in waves with the RANS based field method for sloshing in partially filled tanks.

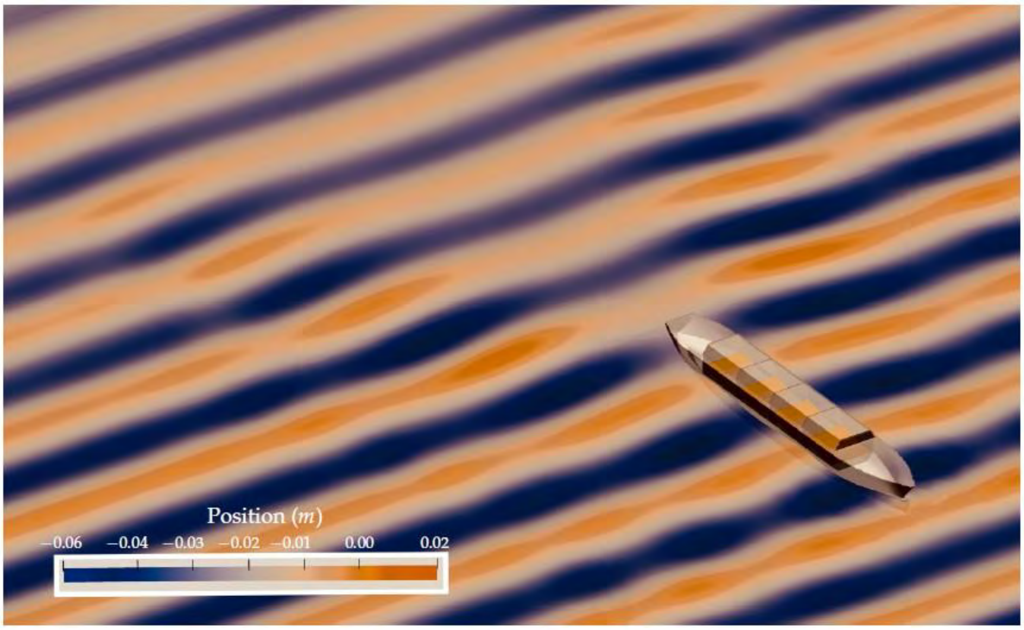


Figure 1: The LNG carrier (zero speed) in head waves at wave length λ to ship length L ratio of λ/L=0.40.

The scientist in charge is Wenjing Lyu, M.Eng.

Motions and Loads on Moored Floating Structures

Moored offshore structures are exposed to time-varying environmental loads, such as wind, waves and currents, which give rise to large dynamic motions. To reliably assess moored floating offshore structures, interdisciplinary knowledge of floating structure hydrodynamics, mooring system dynamics, and their interaction is required. Although potential flow methods are widely used in marine hydrodynamics because of their robustness and computational efficiency, they cannot, however, consider viscous effects, nor extreme wave conditions, a fact limiting their applications on wave-structure interactions.

Contrary to the above method, an unsteady computational fluid dynamics (CFD) approach directly includes all physical effects related to offshore structures. For the open-source CFD library OpenFoam, only the linear spring is available as a mooring model. The aim of this project is to develop advanced mooring models in the CFD-toolbox OpenFOAM. A dynamic mooring model MoorDyn was implemented into the OpenFOAM to conduct a fully coupled analysis of moored offshore structures.

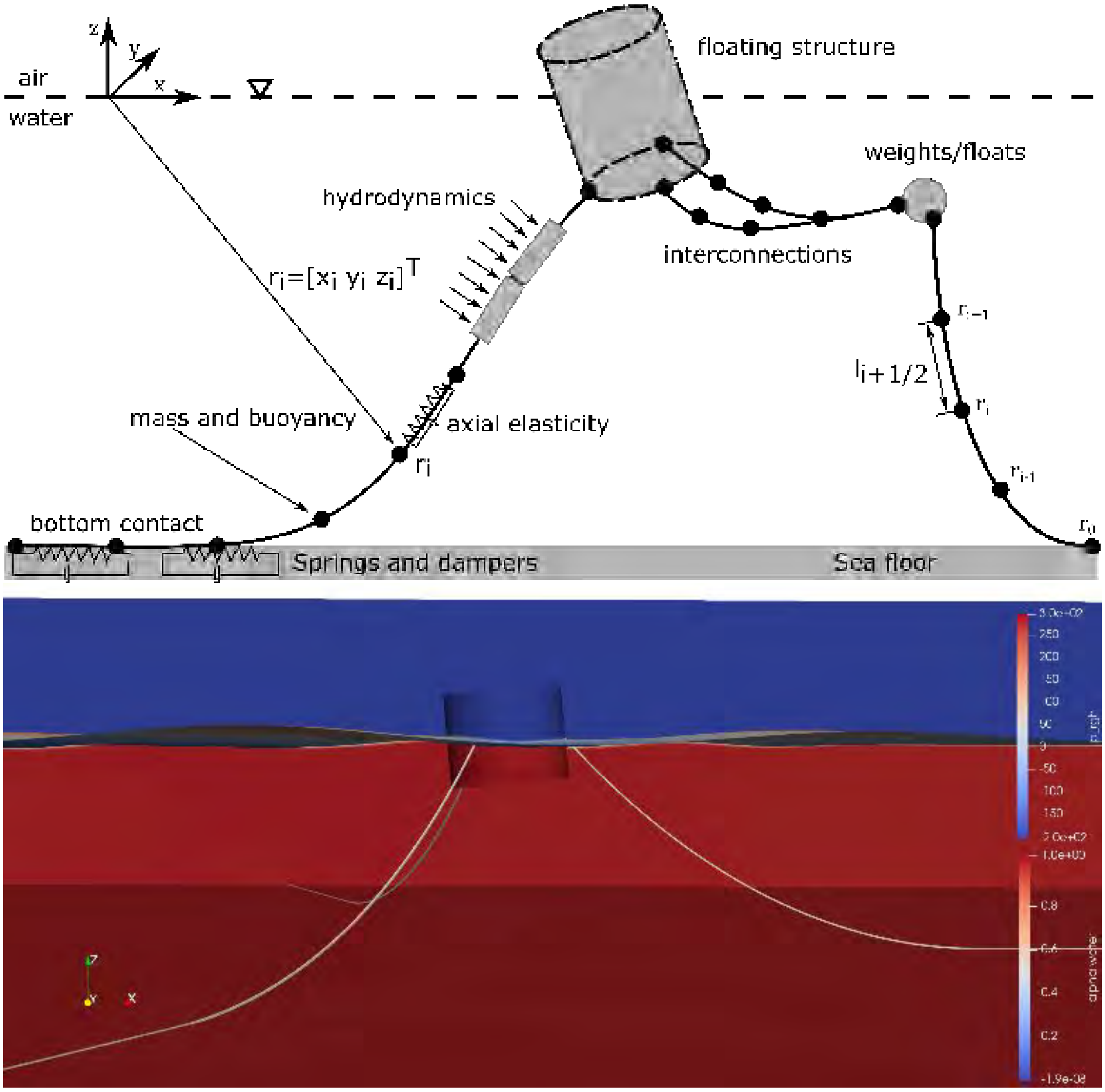


Figure 1: Sketch of the dynamic mooring model (left) and fully coupled analysis of a moored offshore structure(right)

The University of Duisburg-Essen (UDE) contributes to this project by developing, validating and applying numerical methods in the following fields:

- Improvement of the existing mooring model in OpenFOAM by implementing a more advanced dynamic mooring model.
- Verification and validation of the implemented dynamic mooring model coupled with the RANS Solver.
- Comparison with existing mooring models implemented in potential flow solvers and RANS solvers.
- Application of the coupled analysis methods for moored offshore structures in various sea conditions.
- Numerical prediction of motions and loads of moored offshore structures including the effect of structural dynamics and mooring dynamics.
- Extension of the dynamics and loads prediction by including hydroelasticity effects (FSI).

The scientist in charge is Changqing Jiang, M.Eng.

Prediction of Ventilated Cavitating Flows

The focus of this research project is the study of ventilated cavitating flows via numerical simulations.

Ventilation is the physical phenomenon characterized by the entrapment of non-condensable gas, in this study air, in the liquid (water) flow around a fully or partially submerged body due to the presence of a pressure difference.

Cavitation, on the other hand, consists in the formation of vapour cavities in a liquid, water in this study, and it is caused by a sudden fluctuation of the pressure. These phenomena can be present individually or together mutually enhancing themselves.

The marine propeller is an application where both these phenomena can occur causing negative effects such as blade surface erosion, unacceptable levels of noise and vibrations, and unexpected great losses in propeller thrust and torque.

Computational simulations on cavitating propellers are widely present in the maritime (not only) engineering environment while ventilation modelling is a subject undergoing intense research and few studies are present in literature. The aim of this project is to develop a mathematical model able to numerically simulate the presence of sole ventilation and ventilation in conjunction with cavitation on foils and marine propellers. For the numerical simulations, the Computational Fluid Dynamics (CFD) code ReFRESCO, based on the Reynolds-Averaged Navier-Stokes (RANS) equations, is used.

The first step of the project is to simulate the open water characteristics and the cavitation structures of the Duisburg Test Case (DTC) propeller (Fig. 1) tested in the cavitation tunnel of the University of Duisburg-Essen (UDE).

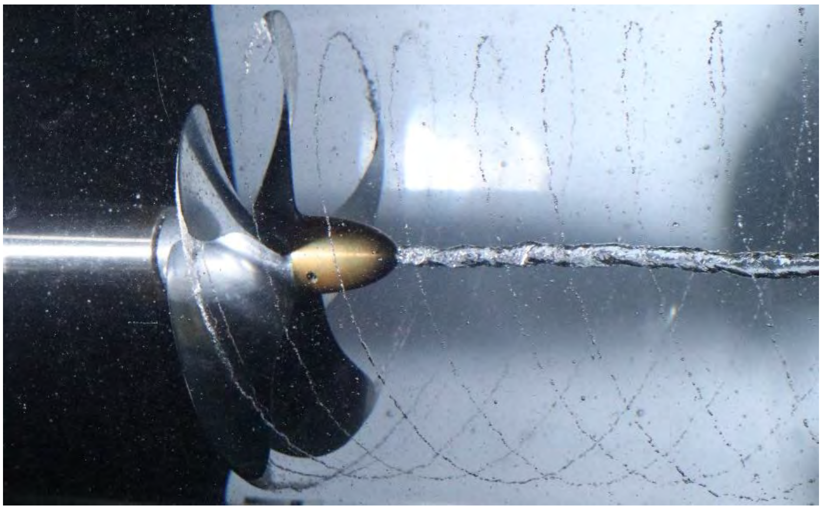


Figure 1: Hub and tip vortex cavitation visualization on the DTC propeller tested in the cavitation tunnel of UDE (Golf, 2018)

The scientist in charge is Chiara Wielgosz, M.Sc.

Damping of Moored Floating Structures

Floating wind turbines (FWTs) become more and more market-ready as can be seen by the first floating wind park in Scotland and the plans for another park in Portugal. Therefore, more sophisticated simulation tools are needed to satisfy the need for better safety and efficiency predictions. For both, safety and efficiency, the hydrodynamic damping is important. The hydrodynamic damping of a floating support structure for wind turbines consists of wave radiation, skin friction, eddy making and mooring line components. Reynolds-Averaged Navier-Stokes (RANS) solvers are needed for skin friction and eddy making damping. Therefore, ReFRESCO was used for the hydrodynamic damping estimation of the DeepCwind semi-submersible floater.

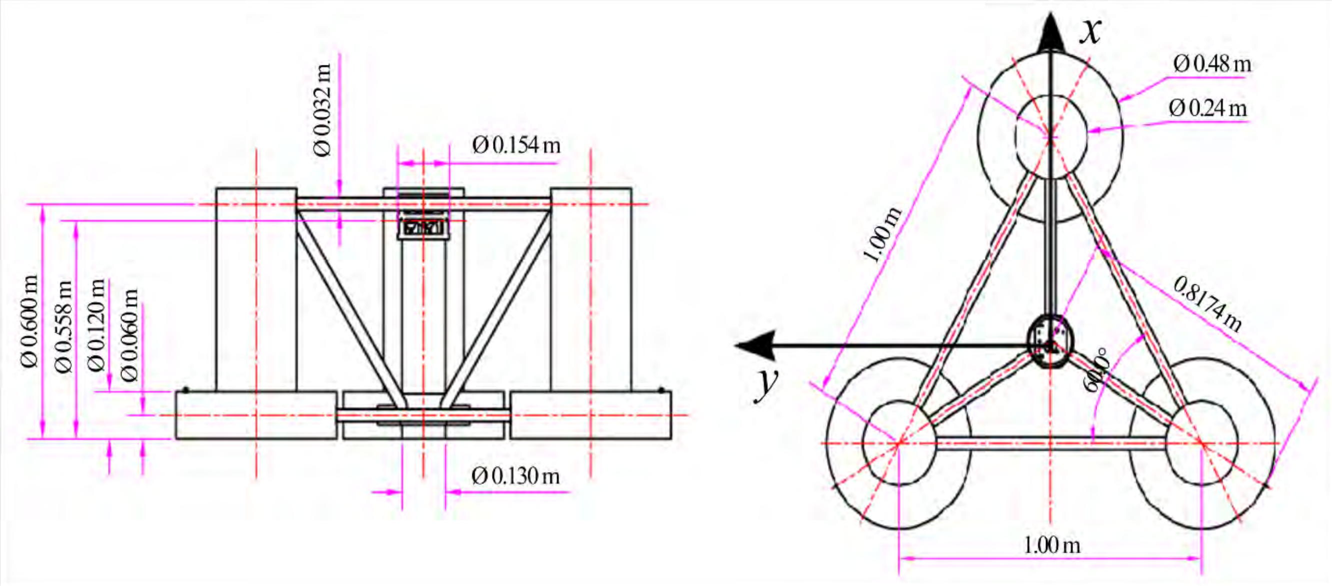
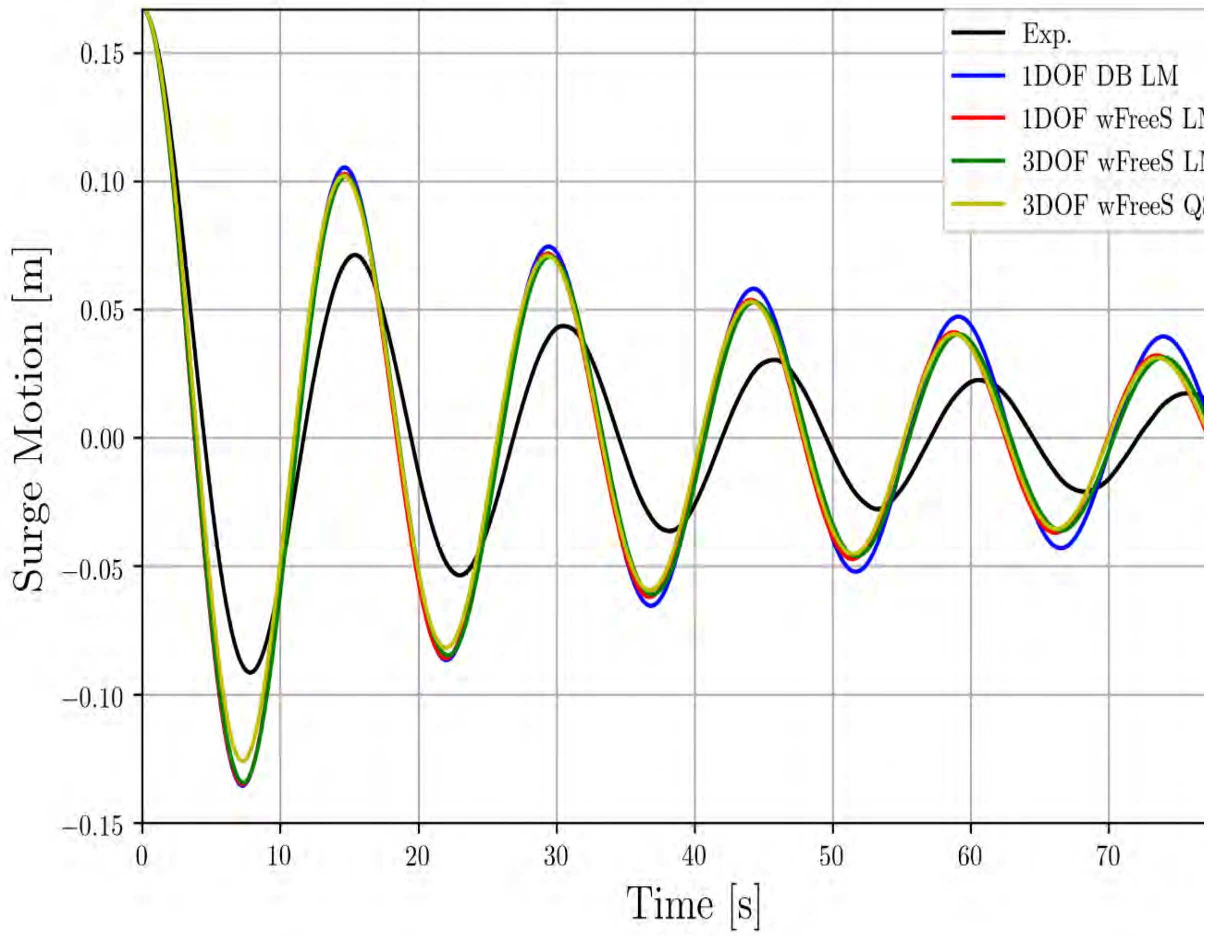


Figure 2: Geometry of the DeepCwind semi-submersible

Several simulations were conducted in the past year to account for all these damping components and to investigate the influence of verification methods. The simulations included and will include the investigation of the following effects on the hydrodynamic damping:

- Free surface (double body and with free surface)
- Viscosity and turbulence models (SST, KSKL, EARSM, laminar, Euler)
- Moorings (linear, quasi-static and dynamic Catenary moorings)
- Coupling of different degrees-of-freedom (single dof surge decay and coupling with other dofs)
- Different spacial and temporal discretization
- Symmetry boundary condition and full domain simulations

Figure 2 shows an example for results of surge decay simulations.



In each case the hydrodynamic damping was investigated using the PQ method of van der Vegt and improved by a least-squares fitting. This method estimates the damping as a combination of linear and quadratic components in which p corresponds to the linear and q to the quadratic damping. Comparing these numerical results to the results of the experiment reveals the following:

- The free surface has the largest contribution to the linear damping.
- The grid resolution has a large influence on the hydrodynamic damping as the numerical damping (diffusion) decreases.

- Turbulence models contribute to linear and quadratic damping.
- Motion coupling and additional quasi-static moorings contribute to the damping on a minor/negligible scale. However, the 3DOF motions (in particular: pitch) are more realistic and match better the experiments.
- Still large differences in terms of quadratic damping remain compared to the model tests.

The scientist in charge is Simon Burmester, M.Sc.

Cavitation

The emergence of cavities in form of voids or gas bubbles in a liquid can affect adjacent solid surfaces when the cavities collapse inertia-dominated. This phenomenon is known as cavitation. It is responsible for a range of effects in many applications, for example for material erosion on ship propellers and turbine blades, and it can be used in ultrasonic cleaning and (sono-)poration of cell membranes. The great range of effects caused by a collapsing bubble is due to the many phenomena that accompany its near-surface collapse. This outlines the conditions for cavitation research – studies must cover temporal scales from nanoseconds to months, and spatial scales from micrometres to centimetres. Phenomena and methods rely on physics, fluid dynamics, acoustics, material science and chemistry.

At the ISMT, we investigate single bubbles with a focus on material interaction. Single bubbles are produced by focusing a laser pulse into liquid, an excellent means to precisely and reproducibly generate micrometre-sized bubbles that violently collapse, an example of a bubble produced in such way is shown in Figure 4. The material erosion on a metal specimen (treated by ultrasonic cavitation) is shown in Figure 5.

The second pillar of cavitation research at the ISMT is the hydro-dynamic cavitation generated in the cavitation tunnel of the Institute. The cavitation tunnel allows the circulation of about 6000 l of water at up to 10 ms^{-1} at ambient pressures of -0.9 bar to +1 bar. In the tunnel's measurement section, the cavitation around objects such as hydrofoils and propellers is studied. Figure 6 shows different cavitation structures at a propeller blade, Figure 7 illustrates the temporal evolution of the surface of a propeller blade exposed to cavitation.

In vivid interplay with experiments, at the ISMT we carry out advanced simulations on cavitation, from the simulations of single bubbles, to the prediction of cavitation and damage in technical flows.

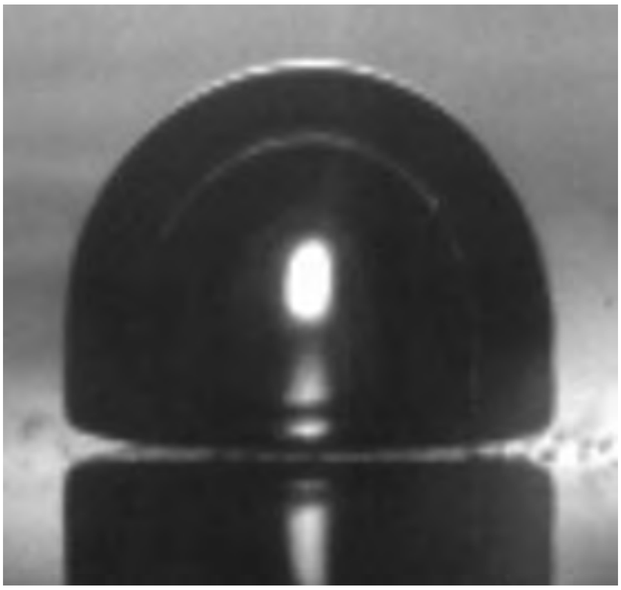


Figure 4: A single, laser-induced cavitation bubble collapses at a solid (on the solid surface in the bottom of the image a mirror image of the bubble is visible). The bubble diameter is about 800 µm, it collapses after only 80 µs – consequently high-speed imaging, microscopy and short time exposure techniques are necessary. During collapse the bubble strikes the solid surface and generates surface damages such as cavitation erosion.

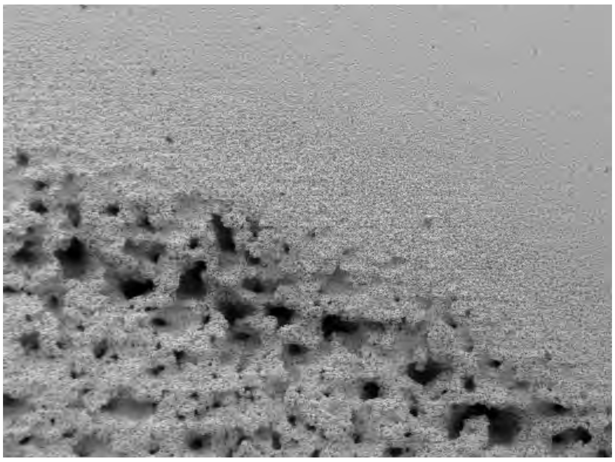


Figure 5: Scanning electron microscopy of cavitation damages on a metallic surface. The material is strongly eroded in the lower left corner: the surface roughness is increased and holes are formed.

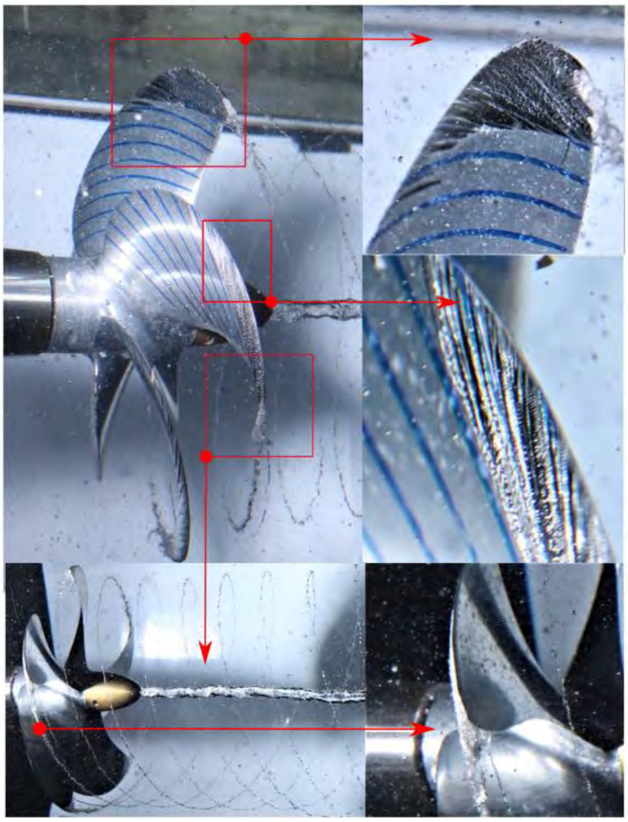


Figure 6: Overview of some cavitation structures at a Duisburg-Test-Case propeller in the cavitation tunnel.

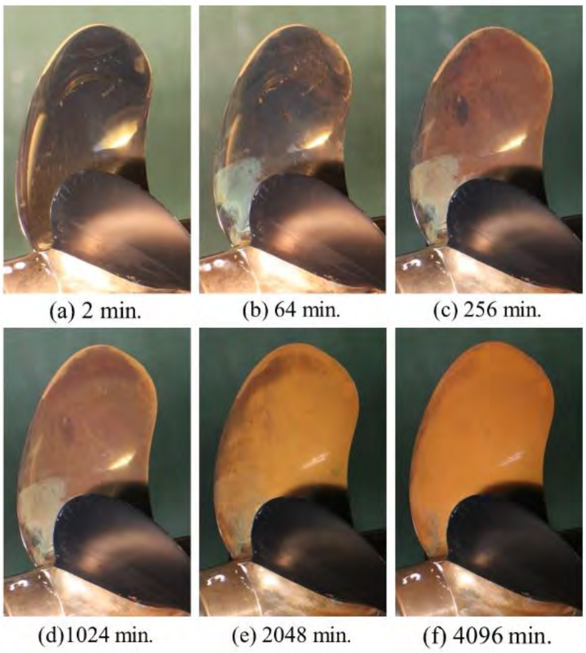


Figure 7: Temporal evolution of a propeller blade exposed to cavitation in the cavitation tunnel. Different color shadings indicate the different material damage.

The scientist in charge is Dr. rer. nat. Fabian Reuter.

Experimental and Numerical Investigations of the Passive Control of Unsteady Cloud Cavitation Using Cavitating-Bubble Generators (CGs)

The research is aimed at the study of a passive control method to control unsteady cloud cavitation that is characterized by regular shedding of large vapour structures from the solid surface of a cavitating immersible body. Unsteady cloud cavitation is an important subject of research because of its destructive impacts on various industrial applications, including ship propellers and rudders, pumping and hydraulic machinery systems. For this, we placed miniature vortex generators, so-called cavitating-bubble generators (CGs), on the surface of a benchmark CAV2003 hydrofoil and investigated the effects of these CGs on the structure of a sheet cavity and also on the dynamics of unsteady cloud cavitation. For the numerical part of the work, we modelled firstly the unsteady cavitating flow around the hydrofoil without passive control using a hybrid URANS model which was implemented in an open source code. Next, we studied the effect of CGs on the mechanism of the sheet and unsteady cloud cavitations. For the experimental part of the work, we analysed the temporal and spatial cavity characteristics in comparison with those for the original hydrofoil (without CGs) by means of high-speed imaging.

In addition, we used an acoustic measurement to register the signal of local pressure variations in time and thereby derive power spectra of the pressure pulsations induced by the collapse of the large-cavity structures at the trailing edge of the hydrofoil. The results showed that the implemented cavitation control method is an effective tool to manage the unsteady behaviour of cloud cavitation and to mitigate the amplitude of pressure pulsations for the sheet and cloud cavitation regimes. It was revealed that, with this control approach, the large-scale cavitation clouds appear to be broken and only small-scale cavity structures are shed away from the hydrofoil surface. Moreover, a notable reduction in the cavitation-induced vibrations of the solid surface may be expected.

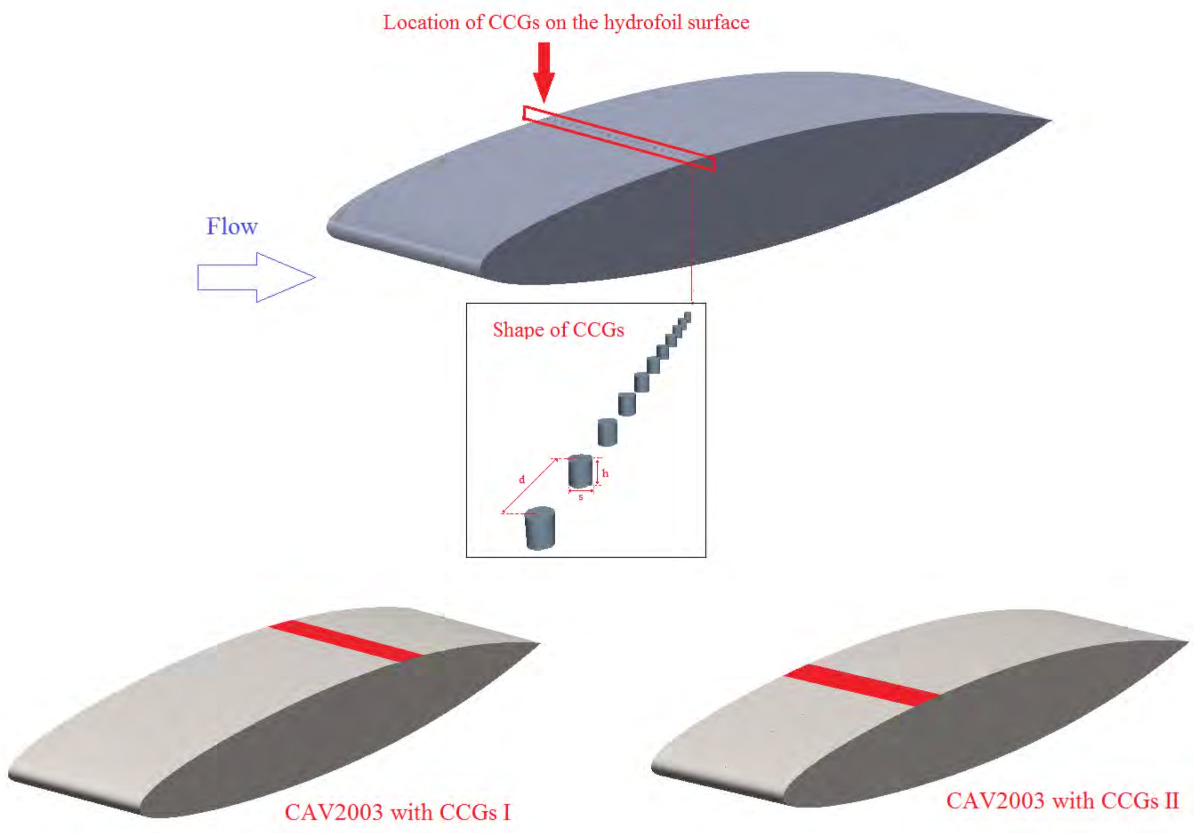


Figure 1: 3D view of Cylindrical Cavitating-bubble Generators (CCGs) mounted on the suction side of the hydrofoil. Symbols D = d/l ref , H = h/lref and S = s/l ref designate the dimensionless parameters of the CCGs with regard to the chord length of hydrofoil, where s, h are d are diameter of the CCGs, height of the CCGs and distance between the cylindrical obstacles, respectively. l ref is the chord length of the hydrofoil and x is the location of the CCGs to the leading edge. The left and the right images at the bottom show the position of the CCGs at the downstram and upstream of the hydrofoil suction surface, respectively.

The scientist in charge is Ebrahim Kadivar, M.Sc.

Experimental Investigation on the Naturally Ventilated Cavitation

Cavitation is a physical phenomenon of water evaporation. It occurs when the pressure in water drops lower than the vapor pressure, while the temperature of water remains nearly the same. When the vapour cavities generated in low-pressure regions are transported by the flow to a higher pressure region, the cavities will violently collapse and cause cavitation erosion by removing the material surface of the solid walls (e.g. propeller).

In marine applications, the ship or propeller mostly operate with the free water surface. When for instance the propeller operates at high loadings and close to the free water surface, it can suck the air into the low pressure region in water through the vortex generated by propeller rotating (Califano 2011). This phenomenon of air drawing into water is called ventilation. The appearance of ventilation can change the cavitation considerably. In order to investigate the influence of ventilation on cavitation, three experimental tests are planned to be conducted, namely the ventilation test without cavitation, the cavitation test without ventilation and the test with both cavitation and ventilation.

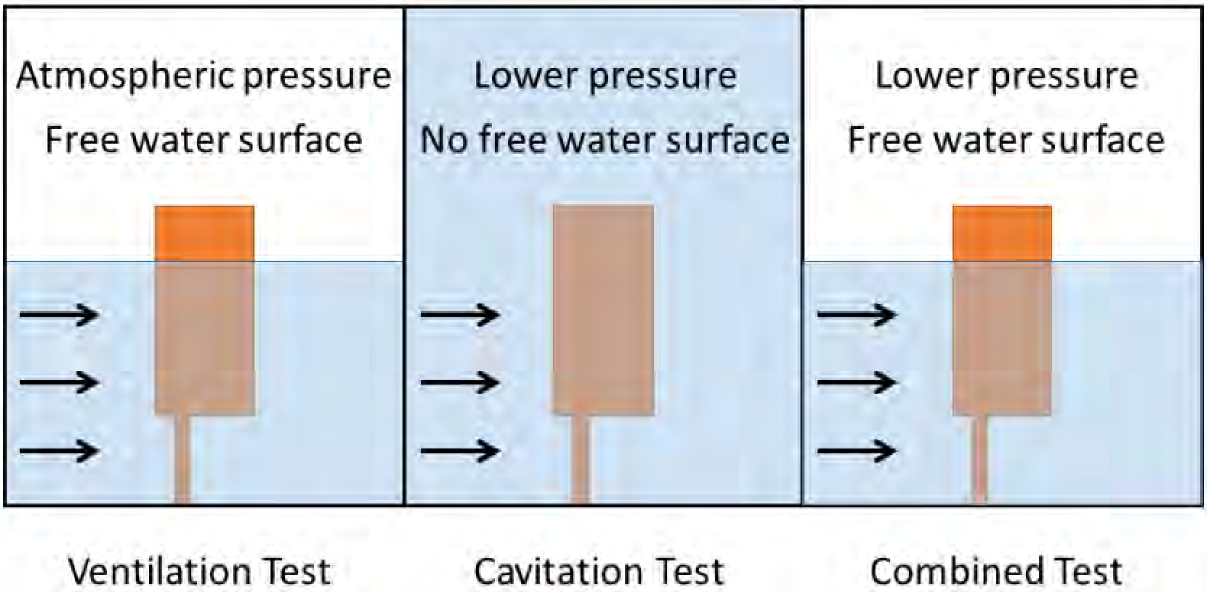


Figure 3: Schematic representation of the designed tests

The scientist in charge is Youjun Yang, M.Sc.

3. Learning & teaching

3.1 Bachelor theses

Lukas Wolfertz

Processing bathymetric data of the Rhine in Duisburg to generate numerical grids and numerical calculations of the flow velocities in a defined part under high water conditions

Prof. Dr.-Ing. Bettar Ould el Moctar

Dr.Ing. Udo Lantermann

Benjamin Kossmann

Determination of favourable operating conditions for the circulating water tank at the ISMT

Prof. Dr.-Ing. Bettar Ould el Moctar

Dr.-Ing. Jens Neugebauer

Johannes Mersmann

Development of a design concept for efficient and low-maintenance controllable pitch propellers

Prof. Dr.-Ing. Bettar Ould el Moctar

Dr.-Ing. Jens Neugebauer

Dipl.-Ing. Yannick Eberhard

Rafael Golf

Investigation of cavitation on a DTC propeller

Prof. Dr.-Ing. Bettar Ould el Moctar

Dr. rer. nat. Fabian Reuter

Katharina Wennemar

Conception, planning and evaluation of an electric drive train for an inland vessel

Prof. Dr.-Ing. Gerhard Krost

Dr.-Ing. Jens Neugebauer

Lars Reckers

Concept design of a human powered boat with hydrofoils

Prof. Dr.-Ing. Bettar Ould el Moctar

Dr.-Ing. Jens Neugebauer

Jens Stephan

Prediction of fin stabilizer forces induced by ship motions in waves

Prof. Dr.-Ing. Bettar Ould el Moctar

Dr.-Ing. Jens Neugebauer

Dr. Sven Wassermann, SKF Marine GmbH

Holger Spardel, SKF Marine GmbH

Emmanuel Anagho

Design and dimensioning of a copper-free, stainless axial pump

Prof. Dr.-Ing. Bettar Ould el Moctar

Dr.-Ing. Jens Neugebauer

Markus Kizler, Robert Bosch GmbH

Domenic Predel

Development of a measurement concept and set-up for sloshing-induced loads on LNG pump towers

Prof. Dr.-Ing. Bettar Ould el Moctar

Dr.-Ing. Jens Neugebauer

3.2 Master theses

Alexander Funk

Design Optimisation of Hoistable Masts for Submarines

Prof. Dr.-Ing. Bettar Ould el Moctar

Dr.-Ing. Jens Neugebauer

Dandan Dong

Numerical Prediction of Wave-Induced Hydrodynamic and Sectional Loads Acting on an Ultra-Large Offshore-Platform

Prof. Dr.-Ing. Bettar Ould el Moctar

PD Dr.-Ing. Tao Jiang

Yuxing Lin

Numerical Analysis of Vortex-Induced Vibrations of Closely Arranged Tower Structures for Offshore Wind Turbines during Transport

Prof. Dr.-Ing. Bettar Ould el Moctar

Dipl.-Ing. Jens Ley

Kalyan Chakravarthy Bodapati

CFD Simulations of Cavitating Flows in Injection Components

Prof. Dr.-Ing. Bettar Ould el Moctar

Dr.-Ing. Udo Lantermann

Dr. Michael von Dirke, L'Orange GmbH

Gerard Mouokue, M. Sc., L'Orange GmbH

Satish Natarajan

Design and Optimisation of a Tidal Stream Turbine

Prof. Dr.-Ing. Bettar Ould el Moctar

Dr.-Ing. Udo Lantermann

Nico Majcen

Optimization of the seakeeping behaviour of an offshore supply vessel for transit and dynamic positioning

Prof. Dr.-Ing. Bettar Ould el Moctar

Dr.-Ing. Jens Neugebauer

Malte Riesner, M. Eng.

Christian Plauk

Numerical Analysis of Current and Wave Loads Acting on a HEXABASE-Foundation and Comparison with Equivalent Loads on a Monopile Structure

Prof. Dr.-Ing. Bettar Ould el Moctar

Dr. Galal Galal

Dipl.-Ing. Jens Ley

Michael Thome

Hydrodynamic Loads on LNG Pump Towers - A Comparison of Methodologies

Prof. Dr.-Ing. Bettar Ould el Moctar

Dr.-Ing. Jens Neugebauer

David Böttcher

Experimental Feasibility Studies for a Novel Design Concept of a Wave Energy Converter

Dr.-Ing. Jens Neugebauer

Dr. rer. nat. Falko Mahlendorf, Lehrstuhl Energietechnik

Dr.-Ing. Alexander Martha, NEMOS GmbH

Hannes Dierksmeier

Numerical Simulation of the Flow Around a Sphere

Prof. Dr. Milovan Perić

Prof. Dr.-Ing. Bettar Ould el Moctar

3.3 Doctoral theses

Sebastian Sigmund

Performance of Ships in Waves

Prof. Dr.-Ing. Bettar Ould el Moctar

Hemant Sagar

Numerical and Experimental Investigation of Laser-Induced Cavitation Bubbles and Induced Damage

Prof. Dr.-Ing. Bettar Ould el Moctar

Mahdi Ghesmi

Assessment of Wave Induced Responses on Articulated Ships (submitted)

Prof. Dr.-Ing. Bettar Ould el Moctar

3.4 Taught courses summer semester 2018

Bachelor

Offshore engineering

Prof. Dr. rer. nat. Janou Hennig

Structural analysis of ships and offshore structures 1

Prof. Dr.-Ing. Bettar Ould el Moctar/Dr.-Ing. Galal Galal

Marine power plants 1

Dr.-Ing. Jens Neugebauer

NAPA – Computer-based ship design

Dipl.-Ing. Thomas Guesnet

Control technique

Prof.-Dr.-Ing. Dirk Söffker

Electrical machines

Dr.-Ing. Jörg Stammen

Production technology

Prof. Dr.-Ing. Gerd Witt

Thermal power machines

Prof. Dr.-Ing. Dieter Brillert, Dr.-Ing. Ralf Starke,

Prof. Dr. rer. nat. habil. Christof Schulz

Master

Manoeuvring of ships

Dr.-Ing. Jens Neugebauer

Structural analysis of ships and offshore structures 2

Dipl.-Ing. Jens Ley / Dr.-Ing. Galal Galal

Computational fluid dynamics for incompressible flows 1

Prof. Dr.-Ing. Bettar Ould el Moctar

Ship vibrations

Prof. Dr.-Ing. Joachim Bluhm / Dr.-Ing. Udo Lantermann

Finite Element Method I

Prof. Dr.-Ing. Wojciech Kowalczyk

Shallow water hydrodynamics

Prof. Dr.-Ing. habil. Tao Jiang

Renewable energy technology 2

Prof. Dr. rer. nat. Angelika Heinzel

Fuel cell in decentralised energy supply

Prof. Dr. rer. nat. Angelika Heinzel

Internal combustion engines

Prof. Sebastian Kaiser / Prof. Dr. rer. nat. Christoph Schulz

3.5 Taught courses winter semester 2018/2019

Bachelor

Hydrodynamics 1

Prof. Dr.-Ing. Bettar Ould el Moctar

Ship safety

Prof. Dr.-Ing. Bettar Ould el Moctar

Design of ships and offshore structures 1

Dr.-Ing. Jens Neugebauer / Dr.-Ing. Galal Galal

Structural design of ships and offshore structures

Dr.-Ing. Jens Neugebauer / Dr.-Ing. Galal Galal

NAPA – Computer-based ship design

Dipl.-Ing. Thomas Guesnet

System dynamics

Prof. Dr.-Ing. Dirk Söffker

Economics

Dr. Alexander Goudz

Measurement science and technology

Prof. Dr. rer. nat. Markus Winterer

Project management

Prof. Frank Lobeck

Writing of papers and lecture techniques

Dr.-Ing. Udo Lantermann

Master

Hydrodynamics 2

Dr.-Ing. Jens Neugebauer

Computational fluid dynamics for incompressible flows 2

Dr. ir. Guilherme Vaz

Seakeeping and hydrodynamic loads of ships and offshore structures

Prof. Dr.-Ing. Bettar Ould el Moctar

Safety and risk analysis of ships and offshore structures

Dr.-Ing. Udo Lantermann

Design of ships and offshore structures 2

Dr.-Ing. Jens Neugebauer / Dr.-Ing. Galal Galal

Port management and logistics

Dipl.-Ing. Thomas Schlipköther

Design of submarines

Dipl.-Ing. Hendrik Goesmann

Wave theory and wave loads

Prof. Dr. rer. nat. Janou Hennig

Turbulent flows

Prof. Dr.-Ing. Andreas Kempf

Fluid machines

Prof. Dr.-Ing. Dieter Brillert

Quantitative imaging in flows

Prof. Sebastian Kaiser

Computer Aided Engineering

Prof. Dr.-Ing. Arun Nagarajah

Finite Element Method 2

Prof. Dr.-Ing. Wojciech Kowalczyk

Manufacturing technology

Prof. Dr.-Ing. Gerd Witt

Electrical devices on board of ships

Prof. Dr.-Ing. Gerhard Krost

Port management and logistics

Prof. Grad Engineer Thomas Schlipköther

Failure Analysis

Prof. Dr.-Ing. Alfons Fischer

Applied computational fluid dynamics

Prof. Dr.-Ing. Milovan Perić

Two and three dimensional supporting structures

Prof. Dr.-Ing. habil. Joachim Bluhm

Welding technical manufacturing method

SLV Duisburg

3.6 External lecturers

Dr. Galal Galal, ESOS Wind GmbH

Structural analysis of ships and offshore structures

Design of ships and offshore structures

Dipl.-Ing. Hendrik Goesmann, Gabler Maschinenbau GmbH

Design of submarines

Dipl.-Ing. Thomas Guesnet, DST

NAPA – Computer-based ship design

Prof. Dr. rer. nat. Janou Hennig, MARIN

Offshore engineering / Wave theory and wave loads

Dipl.-Ing. Michael Hesse, DNV GL SE

Structural design of ships and offshore structures

Prof. Dr-Ing. habil. Tao Jiang, D&C TechTrade GmbH

Shallow water hydrodynamics

Dr. Thomas Schellin

Mooring of floating offshore structures

Prof. Grad Engineer Thomas Schlipköther,

Duisburger Hafen AG

Port management and logistics

Dr. ir. Guilherme Vaz, MARIN

Computational Fluid Dynamics for Incompressible Flows 1 + 2

3.7 Excursions

26 – 29 March 2018	Excursion to Eckernförde/Lübeck/Kiel (Gabler Maschinenbau GmbH, Submarine at U-Bootgeschwader, Helmholtz-Zentrum für Ozeanforschung, thyssenkrupp Marine Systems GmbH)
9 July 2018	Day excursion to Schiffer-Berufskolleg Rhein, Duisburg
16 July 2018	Day excursion to MTU Friedrichshafen GmbH, Repair Center, Duisburg

3.8 International collaboration

- Agreement on Cooperation with Dalian University of Technology (DUT)/China, pursuant to the cooperative education program agreement of 2015
- International Academic Agreement with Universidade de São Paulo, Brazil
- Erasmus+ Inter-institutional agreement 2014 – 2021 with Yildiz Technical University, Turkey
- Erasmus+ Inter-institutional agreement 2014 – 2021 with University of Rijeka, Croatia

4. Publications & conference participation

4.1 Journal Papers

Chillcce, G., el Moctar, O. (2018): A Numerical Method for Manoeuvring Simulation in Regular Waves. Ocean Engineering

Mucha P., el Moctar, O., Dettmann T., Ferrari V. (2018): Experimental Investigation of Free-Running Ship Manoeuvers Under Extreme Shallow Water Conditions. Applied Ocean Research

Peters, A., Lantermann, U., el Moctar, Ould (2018): Numerical Prediction of Cavitation Erosion on a Ship Propeller in Model- and Full-Scale", Wear, vol. 408–409, pp 1-12, ISSN 0043-1648

Kadivar E., el Moctar O., Javadi K. (2018): Investigation of the Effect of Cavitation Passive Control on the Dynamics of Unsteady Cloud Cavitation. Journal of Applied Mathematical Modelling (IF: 2.61)

Kadivar E., el Moctar O. (2018): Boundary Layer Instability Control in the Unsteady Cloud Cavitating Flow. Journal of IOP Conference Series Earth and Environmental Science IF:0.3

Riesner M., Chillcce G., el Moctar O., Schellin T.E (2018): Rankine Source Time Domain Method for Nonlinear Ship Motions in Steep Oblique Waves. Ship and Offshore Structures

Riesner, Malte, el Moctar, Ould (2018): A Time Domain Boundary Element Method for Wave Added Resistance of Ships Taking into Account Viscous Effects. Ocean Engineering

Sigmund, S., el Moctar O. (2018): Numerical and Experimental Investigation of Propulsion in Waves. Ocean Engineering, vol. 144, 659–673, pp 35-49

Sigmund, S., el Moctar O. (2018): Numerical and Experimental Investigation of Added Resistance of Different Ship Types in Short and Long Waves. Ocean Engineering, vol. 147, pp 51-67

Shigunov V., el Moctar O., Papanikolaou A., Potthoff R., Liu, S. (2018): International Benchmark Study on Numerical Simulation Methods for Prediction of Manoeuvrability of Ships in Waves Ocean Engineering

Sagar, H., Hanke, S., Underberg, M., Feng, C, el Moctar, O., Kaiser, S (2018): Experimental and Numerical Investigation of Damage on an Aluminum Surface by Single-Bubble Cavitation. J. Materials Performance and Characterization

Sagar, H., el Moctar, O. (2018): Numerical Simulation of a Laser-Induced Cavitation Bubble Near a Solid Boundary Considering Phase Change. Ship Technology Research

Ghesmi, M., von Graefe, A., Shigunov, V., Friedhoff, B., el Moctar, O. (2018): Comparison and Validation of Numerical Methods to Assess Hydrodynamic Loads on Mechanical Coupling of Multiple Bodies. Sip Technology Research

4.2 Conference papers

Toedter, S., el Moctar, O., Neugebauer, J., Schellin, T.E. (2018): Experimental Investigations of Hydroelastic Effects on Loads during Flat Water Entry. Proc. 35th ASME International Conference on Ocean, Offshore and Arctic Engineering, Madrid, Spain, Paper No. OMAE2018-78692

Peters, A., Lantermann U., el Moctar O. (2018): Simulation of an Internal Nozzle Flow Using an Euler-Lagrange Method. Proceedings of the 10th International Symposium on Cavitation (CAV2018), Baltimore, USA.

Reuter F., Sagar H., el Moctar O., Mettin R. (2018): Wall shear rates induced by a single cavitation bubble collapse. Proceedings of the 10th International Symposium on Cavitation (CAV2018), Baltimore, USA.

Kadivar E., el Moctar O. The Investigation of Cloud Cavitation Passive Control around a Hydrofoil Using Cavitating-bubble Generators (CGs). Proceedings of the 10th International Symposium on Cavitation (CAV2018), Baltimore, USA.

el Moctar O., Tödter S., Neugebauer J., Schellin T.E., (2018) Investigation of Hydroleasticity and Air Compressibility on Impact Loads. Proc. of 8th International Conference on HYDROELASTICITY in Marine Technology, Seoul, Korea.

Sigmund S. el Moctar O., Schellin T.E (2018): RANS Predicted Propulsion Characteristics of a Twin Screw Cruise Ship in Regular Head Waves. Proc. of the 32nd Symposium on Naval Hydrodynamics, Hamburg, Germany

Riesner, M., el Moctar, O. and Schellin, T.E., 2018, "Design Related Speed Loss and Fuel Consumption of Ships in Seaways", Progress in Maritime Technology and Engineering (MARTECH 2018), CRC Press - Taylor & Francis Group, London, ISBN 978-1-138-58539-3, pp. 147-155.

5. Events

5.1 Colloquia

7 – 8 June 2018

39th Duisburg Colloquium on Ship Technology/Ocean Engineering (Duisburg) in collaboration with the Federal Waterways Engineering and Research Centre (BAW)
"Ships in the Tension between Sustainability and Efficiency"

The colloquium was jointly organised by the Federal Waterways Engineering and Research Centre (BAW), the Development Centre for Ship Technology and Transport Systems and the Institute of Ship Technology, Ocean Engineering and Transport Systems and focused on how environmental standards affect inland navigation, how harmful emissions can be identified and systems for exhaust gas after-treatment can be developed. Further topics included battery-operated ferries as well as new technical requirements for inland waterway vessels.

6 – 7 November 2018

3rd Cavitation Colloquium (Bochum)

Cavitation has been the subject of research in various different disciplines for many decades, amongst them e.g. physics, chemistry, mathematics, medicine and engineering. For the third time the University of Duisburg-Essen and the Competence Centre Hydraulic

Fluid Machinery (KHS) of Ruhr-Universität Bochum have jointly hosted the colloquium on cavitation and cavitation erosion, addressing many different disciplines. Issues concerning fluid mechanics and material science were discussed.

5.2 Other Events

28 – 29 June 2018

Status of Maritime Research in Germany (Hamburg)

The conference was organised by Schiffbautechnische Gesellschaft – STG - (German Society for Maritime Technology), on behalf of the University of Duisburg-Essen, Hamburg University of Technology, Technische Universität Berlin and the University of Rostock.
This annual conference on a national basis is a platform for the exchange of the results of current research in the maritime field, in combination with a special edition of the journal Ship Technology Research/Schiffstechnik (STR). The topics discussed included cavitation, sloshing, wave-induced loads on ship and offshore structures, design, structure and fluid-structure-interaction.

6. Prizes and awards

Curt-Bartsch-Prize (STG)

On the occasion of the Annual Meeting of the Schiffbau-technische Gesellschaft, Dr.-Ing. Jens Neugebauer was awarded the Curt-Bartsch-Prize for the presentation of his doctoral thesis on the subject “Conception and Validation of a Sloshing Test Facility Including an Assistance Approach for Sloshing Impact Loads“.

In November 2017, the Curt-Bartsch-Prize was awarded to Dr.-Ing. Jan Oberhagemann for the presentation of his doctoral thesis on the subject “On Prediction of Wave-Induced Loads and Vibration of Ship Structures with Finite Volume Fluid Dynamic Methods”.

Best-paper award (ISOPE)

On 13 June 2018, Dr.-Ing. Jens Neugebauer was granted the “Best Paper Award” of the International Society of Offshore and Polar Engineers, in recognition of outstanding originality and significance of the paper “Investigation of the Motion Accuracy Influence on Sloshing Model Test Results”. The paper was presented at the 27th International Ocean and Polar Engineering Conference, San Francisco, USA, 25 – 30 June 2017.

The Wietasch-Prize

The Wietasch-Prize was awarded to the following students for graduating prematurely and very successfully:

Alexander Funk

Kristin Pleines

Simon Tödter

Youjun Yang

7. National/international committee work

- Editor: Journal of Ship Technology Research, Publisher: Taylor & Francis, UK
- Associate Editor: Journal of Offshore Mechanics and Arctic Engineering, Publisher: The American Society of Mechanical Engineers (ASME), USA
- Associate Editor: Journal of Ship Research, Publisher: Society of Naval Architects and Marine Engineers (SNAME), USA
- Associate Editor: American Journal of Civil Engineering, USA
- Associate Editor: Journal of Marine Science and Application, Publisher: Springer
- Associate Editor: Journal of Naval Sciences and Engineering (JNSE), Turkey
- Member of the Council of Science of the Federal Waterways Engineering and Research Institute (BAW), Germany
- Member of the Advisory Council of the International Towing Tank C. ITTC, Denmark
- Member of various international Scientific Committees (e.g. joint ISSC-ITTC committee, ISSC)
- Deputy Head of the Ship Technology Committee of the Association of German Engineers (VDI), Germany

- Member of the Advisory Board of the German Association for Marine Technology (GMT), Germany