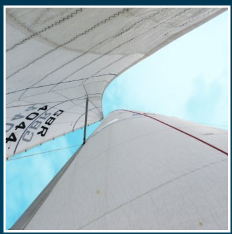
Lloyd's Register

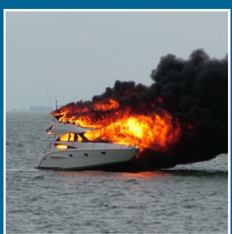
UNIVERSITY OF Southampton

# UK Marine Technology

# Postgraduate Conference

# UK MTPC 2011





# Welcome Note

"It gives me great pleasure to welcome postgraduate students from the leading academic groups in the UK in marine technology and maritime engineering sciences to the Second UK Marine Technology Postgraduate Conference in Southampton. This event builds on a successful first meeting held in June 2010 in Newcastle and seeks to emphasise the continued importance of the subject to societal and industrial well being.

The UK maritime sector directly employs over 410,000 people (and at least that many indirectly). It is a £56 billion turnover sector, bigger than automotive and more than double the size of aerospace and agriculture combined – it is the largest maritime sector in Europe. It also represents a high added value component to the UK economy. This high added value is attributed to the technological advances that are engendered in the country's industrial establishments, many of which are seeded through the various doctoral and related research programmes in the universities.

The city of Southampton has had a long maritime tradition, of over a thousand years, serving both as a port and as a shipbuilding and engineering industry centre. The University of Southampton has played a prominent role in research and education in ship science, nautical studies and maritime engineering sciences for over 50 years. The environment is therefore apt to serve as the host for the many talented and gifted researchers. I wish you an enjoyable, interesting and stimulating MTPC 2011."

Professor Ajit Shenoi

Lloyd's Register / Royal Academy of Engineering Research Professor

School of Engineering Sciences

# Foreword

"The world is changing rapidly. In the bygone days of innovation, large corporations and governments maintained internal laboratories like Bell Labs in the USA and Defence Research Agency in the UK. These labs were essentially research universities embedded in private companies and government departments, and their employees published academic papers, spoke at conferences and even gave away valuable breakthroughs. Bell Labs, for instance, created the world's first transistor after World War II — and never earned a dollar from the innovation. Today almost no corporate labs based on the Bell model remains as a new appreciation that innovations may flow best when scientists and engineers stick to practical problems. The obsession with marrying research and markets, while generally a strength of past innovation path, leaves some needs unmet. To fill them, companies need boots on the ground at universities. Indeed premier marine technology institutions here in the UK possess an unmatched reservoir of intellectual talent and creativity. Postgraduate students, moreover, are still the most cost-effective research labour force anywhere, and with most faculty member salaries typically paid by colleges and universities for instructional services, the costs of adding this intellectual firepower to research projects is relatively small especially if additional financial gearing can be provided by research councils and European Union funding. In addition, UK universities combined have a full spectrum of laboratory assets and expertise that would be prohibitively expensive for most companies to reproduce.

It is my vision and ambition to contribute to the making of Lloyd's Register a global leader in innovation enabled by technology. As part of a challenge-led approach to innovation my task is to 'Connect and Catalyse' with postgraduate students being an integral part of the pool of the requisite catalyst we need to connect.

It is with great pleasure that Lloyd's Register is able to sponsor the second UK Marine Technology Postgraduate Conference at the University of Southampton. I welcome postgraduate students from all the universities engaged in research in new technology and innovative solutions to problem encountered by the marine industry in a rapidly changing and turbulence world in which the society at large demands a sustainable future. Judging from the diversity and quality of papers to be presented at this conference, I am very pleased to witness in the world of UK marine technology research community, we have much talent ready to respond to the challenges.

Last Conference in 2010 sponsored by Lloyd's Register was a great success. Witness the high calibre of the papers, and of the presenters, combined with the many attractions that Southampton City have to offer will, I am sure, make this another memorable event. So once again, welcome to MTPC 2011!"

Dr. Fai Cheng

Head of Strategic Research Group

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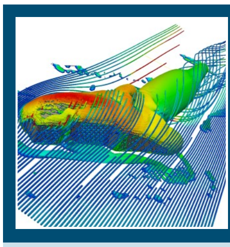


## Conference Sponsors

Since 1760, Lloyd's Register has worked to enhance the safety of life, property and the environment, at sea, on land and in the air, helping its clients to ensure safe, responsible and sustainable supply chains. Through their impartial advice, broader knowledge, deeper experience and closer relationships they have helped ensure a safer and better world for over 250 years.

The Lloyd's Register Group is a global independent risk management and safety assurance organisation. Members of the Group provide services designed to help clients around the world to achieve their business goals, while optimising safety and quality, and protecting, even improving, the environment.

Combining their global reach with in depth local knowledge they deliver bold new solutions in the harshest conditions, facing the toughest problems.

The Royal Institution of Naval Architects

The Royal Institution of Naval Architects is an internationally renowned professional institution whose members are involved at all levels in the design, construction, maintenance and operation of marine vessels and structures. Members of RINA are widely represented in industry, universities and colleges, and maritime organisations in over 90 countries. RINA is a world renowned and highly respected international professional institution and learned society whose members are involved at all levels in the design, construction, maintenance and operation of all marine vessels and structures.

Membership of RINA demonstrates the achievement of internationally recognised standards of professional competence, and the commitment to professional integrity and high standards of practice governed by the Institution's Code of Professional Conduct.

Institute of Marine Engineering, Science & Technology

IMAREST

Established in London in 1889, IMarEST is the leading international membership body and learned society for marine professionals, with over 15,000 members worldwide.

The IMarEST has a strong international presence with an extensive marine network of 50 international branches, affiliations with major marine societies around the world, representation on the key marine technical committees and non-governmental status at the International Maritime Organization (IMO).

# Conference Programme

## Thursday 9th June 2011

9.30 Registration and refreshments

10.30 Welcome speech

10.40 Keynote speech

11.00 Session 1

Bio-inspired Underwater Vehicles

12.25 UK MTPC Delegate photo

12.30 Lunch

13.30 Session 2

Hydrodynamics

15.20 Refreshments

15.50 Session 3

Structural Materials

17.00 Close

19.30 Conference dinner

## Friday 10th June 2011

9.00 Session 4

Marine Engineering Systems

10.30 Refreshments

11.00 Session 5

Fluid Dynamics

12.30 Lunch

13.30 Session 6

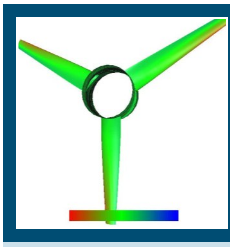
Underwater Acoustics and Vibration

15.00 Refreshments

15.30 Session 7

Marine Structures

16.30 Prize giving and close



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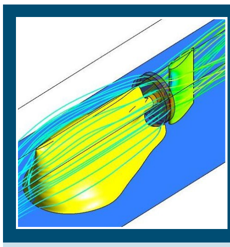

## Contents

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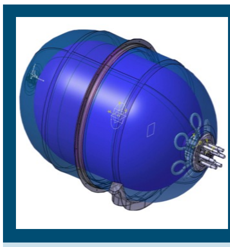


Session 1

# Bio-inspired Underwater Vehicles

# Nature in engineering for monitoring the oceans (NEMO): Bio-inspired propulsion, hydrodynamics and energy expenditure

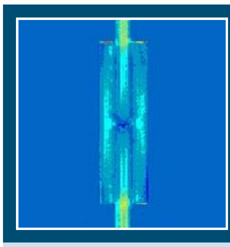
*Maryam Haroutunian, School of Marine Science and Technology, Newcastle University*

Over 750,000 known marine species ranging in size from a few micrometers to dozens meters, have arrived at "successful" solutions for surviving and operating in the ocean space through evolution. Many of these have capabilities and functionality which have much in common with the engineered capabilities required for underwater vehicles e.g. propulsion/locomotion, manoeuvrability/agility and the ability & resilience to operate at depth. Indeed, in many examples, it appears the biological solutions exhibit superior performance compared to the technological alternative, yet by different and diverse means.

This research is part of a collaborative project, "Nature in Engineering for Monitoring the Oceans" (NEMO). An extensive study on the capabilities of marine animals has been conducted in relation to the equivalent functionalities in AUVs. The principal focus is on biological solutions to depth, speed, agility and endurance capabilities while considering the cost in terms of energy expenditure. This includes propulsion analysis and production of propulsor design coefficients & kinematics and form coefficients which leads to design philosophy development, design techniques, implementation methods and application of bio-inspired systems for improving the performance of AUVs.

NEMO project includes the National Oceanography Centre and the University of Southampton and is funded by the Engineering and Physical Sciences Research Council (EPSRC).

maryam.haroutunian@newcastle.ac.uk



## The numerical study of robotic fish hydrodynamics

*Wei Jin, University of Strathclyde*

The main objective of the project is to design and develop fully functional robotic fish with chemical sensor and communication infrastructure. The mission of the fish is to gather information on pollutants and hazardous substances within a port environment. This is a public service domain with requirements for monitoring and reporting pollution regularly from EC directive 2005/35.

The individual components integrated on the robotic fishes need to be functionally tested in the laboratory before finally assembled. One of the components is fluid dynamics, which should effectively control the motion of robotic fish (to avoid obstacles, to search pollutants).

The Experiments were carried out at the Kelvin Hydrodynamics Lab in April 2011. The model fish was attached to the Planar Motion Mechanism (PMM) via a strain gauged sting. Due to the limit of measuring system and load cells, only linear range of model tests (small yaw angle etc.) can be fulfilled with satisfying accuracy. The whole range of parametric studies needs to be tackled by numerical methods.

The hydrodynamic performance of robotic fish is numerically investigated by solving RANS equations and closing turbulence model (SST K-w). The commercial software FLUENT is chosen to cope with the problem based on our experience on the study of ship hydrodynamics. Second order upwinding interpolation for convection was used. SIMPLE algorithm was applied to solve pressure. The user defined function (UDF) was developed to deal with special manoeuvring motions.

The simulations of manoeuvring motions include steady yaw, oscillatory sway and oscillatory yaw (which can be done at small values of parameters in model test), and steady turning (which is beyond the capability of our facility). The hybrid mesh was generated with special care of quality and resolution. Total cells for the medium sized mesh are around 10M. The calculations were run on a High Performance Computing Cluster (HPCC) with 8*130 (nodes) processors provided by Esteem Systems Ltd. It takes roughly 48 hours for a typical case of calculation using 16 cores.

The numerical results are validated against model test data. Overall, good agreements were achieved. Most importantly, the analysis of numerical results is successfully applied to assists the optimisation of fish geometry.

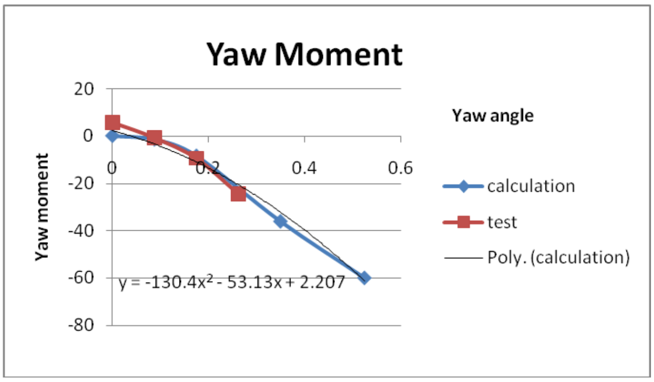



Figure 1 Validation of computational results



wei.jin@strath.ac.uk

# Bio-inspired flapping foil for manoeuvrable underwater vehicle platform

*Sain-Gee Keith Man, Fluid Structure Interactions Group, University of Southampton*

An autonomous underwater vehicle (AUV) is an intelligent robotic submarine that can perform its entire mission autonomously without any human input. This study identified a significant difference between marine animals and AUV manoeuvrability, particularly at moderate speed when compared to aquatic flyers, such as seals, penguins and sea turtles. Conventional AUVs such as the REMUS 100 have very poor manoeuvrability compared to its bio-inspired counterparts. However, even the performance of bio-inspired AUVs is still inferior to many marine animals; especially paired fin propelled aquatic flyers, many of which are capable of turning in less than half of the animal's body length. Aquatic flyers rely solely on the flapping of paired hydrofoils on either side of the body. Lift is produced by oscillating the angle of attack of the foil in relation to the incoming flow, over a complete flap cycle this lift generates a net thrust. Previous attempts (Licht et al., 2004, Kato et al., 2004) to replicate the impressive performance of paired fin propulsion has lead to mixed results, the most successful of which is MIT's sea turtle robot, Finnegan AUV, which achieved a turning circle of 0.77BL at a speed of 0.72BL/s.

| Platform | Turn rate ( °/s) | Turn diameter (Body length)(BL) | Turn speed (BL/s) |
|---|---|---|---|
| REMUS 100 | 5 | 2.9 | 0.5 |
| VCUUV (Tuna inspired) Anderson and Chhabra, 2002 | 75<br>16.9 | 2<br>3.7 | <br>0.5 |
| Finnegan (Sea turtle inspired) | | 0.75 | 0.72 |
| Yellow fin Tuna | | 0.94 | |
| Bottlenose dolphin | 252 | 0.44 | 2 |
| Humboldt Penguin | 550 | 0.24 | |

The NEMO project's Nature Inspired Manoeuvrable Bio-Locomotive Experiment (NIMBLE) (Figure 1) aims to extend the work of Licht et al. on Finnegan. A key innovation in NIMBLE will be its 3-axes actuation to simulate the fin path traced by animal flipper's during each propulsion cycle. Unlike previous 2-axes experiments, which have been restricted to roll and pitch, marine animal flippers are also articulated in yaw. Penguin flippers trace a figure of eight and seal fins trace a horizontal D-shaped path (Massare, 1994). A quasi-2D numerical model provided initial estimates for designing the NIMBLE flapping foil testing platform. The model estimated a 10kg vehicle travelling at a speed of 2.2m/s and at a Strouhal number of 4.5 would require a combined propulsion power of 20.8W. Penguin propulsion system efficiency is between 15-20% (Hui, 1988), so the vehicle would require between 105-139W if the same efficiency was assumed. A 10kg king penguin requires a total power of 105W to swim at 2.2m/s(Culik et al., 1996), so the result is similar to the numerical model.

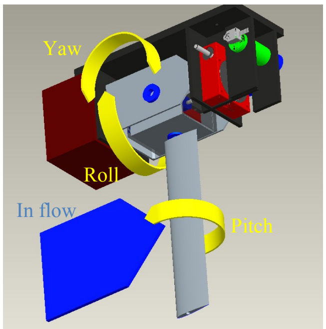



**Figure 1 - NIMBLE flapping foil platform**

The NIMBLE foil platform will perform its investigation in a towing tank environment, to acquire transient force and power measurements for simulated manoeuvres. In addition, flow visualisation techniques will be performed to study the resulting wake from a three axes propulsion cycle and the platform will serve as a test bed for NIMBLE AUV's control systems. The goal of NIMBLE is to help understand the reason behind the yaw action in biological flapping foils and its benefit to propulsion and manoeuvring.

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S.K.Man@soton.ac.uk

## A harmonic energy based gait production strategy for an underactuated robotic fish

*D. T. Roper, School of Marine Science and Engineering, University Of Plymouth*

In recent years there has been a growing interest in the development of biomimetic robotic swimmers or *robotic fish* [1]. Typically constructed as a planar multi body chain, robotic fish emulate the moving body wave employed by their biological counterparts to generate locomotive thrust.

Like terrestrial biomimetic locomotors, there has been a recent trend towards under actuated design of robotic fish such as the three link robotic dolphin outlined in [2] where only one of the joints was actively controlled. Or the compliant swimmers outline in [3], again with only one active actuator. These swimmers take advantage of an affect demonstrated in [4],whereby harmonic stimulation of a passive body can create an effective forward swimming gait.

Unlike with terrestrial biomimetic locomotion where the reaction forces of the solid ground can easily be calculated, with aquatic locomotion the reaction forces created by the fluid are difficult to calculate, and subject to highly chaotic dynamics.

A classical geometric control approach to gait generation, would seek to directly control the geometry of the robot, however *Energy based control*, (EBC) models the system as a harmonic oscillator, then seeks to control the total amount of energy in the system. For simple examples of EBC the reader is directed to [5] [6].

EBC is particularly attractive for gait generation, as it is likely to result in near harmonic motion which is ideal for most locomotive patterns. Furthermore the direct control of energy is likely to result in a good energy efficiency, findings presented in [7] demonstrated that a simple harmonic model of a human walking gait could predict step frequencies for individuals under a variety of load conditions.

For the purposes of this research a three link free floating planer multi body chain with sprung joints will represent the robotic fish. This model is in-keeping with observations made in [8] that fish use springs in parallel with active muscle movement to produce efficient harmonic swimming gaits.

Ignoring Influence of the surrounding fluid and regarding the system in isolation. Every distinct energy level will represent a different harmonic phase cycle. By appropriate selection of spring constants these phase cycles can be shaped into useful forward swimming gaits.


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daniel.roper@plymouth.ac.uk

## Session 2

# Hydrodynamics

# Dynamics analysis of a raising sunken vessel

*Arun Kumar. D. V., Dept. of Naval Architecture & Marine Engineering, University of Strathclyde*

Marine salvage is an act of rescuing a ship, its cargo, or other properties from impending peril. Salvage comprises of rescue towing and refloating a sunken or stranded vessel. The main aim of the salvage operation is twofold: to prevent the pollution to the marine environment and to clear a channel for the navigation. Ships sink or capsize because they lose their buoyancy or stability due to weather damage, collision, battle damage, flooding or other means. Damage makes their salvage more difficult than it would be for an intact ship in the same location [1]. The concept of using buoyancy systems (i.e. air inflated bags) for the salvaging of sunken vessels from ocean depths has been around for centuries. The operation of buoyancy systems is based on Archimedes' principle. In general, the bottom of the inflatable bags (balloons) is attached to the payload to be lifted and inflated using pipes from air compressors. In this paper, the considered lift bag is an open bottom type reinforced flexible bag in the shape of a vertical cylinder. The bags, made of Vectran (the most advanced polymer material) are unique due to their elongated shapes and stability at the bottom end. The main drawback of using the typical inflating bags for marine salvage operations is the uncontrolled vertical acceleration as they ascend the water column. During the ascent of a pay load, this vertical acceleration can create a huge instability when the lift bag reaches extremely high velocities up on reaching the ocean surface. This may cause the lift bag to literally launch in the air forming a potentially hazardous working environment for divers and salvage crews [2]. Accelerated ascent can also cause the lift bag to breach the surface of the water fast such that the air escapes from the bottom. This purge causes the payload to sink back to the bottom which, in turn, results in the loss of time, high operating and maintenance costs, and the damage to divers or crew members [3].

This work is part of the Surfacing System for Ship Recovery (SuSy), a European Commission funded project whose primary objective is to avoid the propagation of spillages by stabilizing the vessel immediately after an accident. As far as the consortium is aware, there is no simulation system currently available for modelling the impact of using buoyancy systems to the salvage of sunken ships. The presentation discusses the development and application of a time domain simulation program for the dynamics analysis of the raising sunken vessels. The coordinate position (trajectory), velocities and angular velocity components of the raising vessels is calculated with respect to the vertical (diving) plane. Numerical simulations are obtained by solving the State Dependent Ricatti Equation (SDRE) in body - fixed coordinate system. A sliding mode- depth controller is designed on the basis of a simplified four- degree- of -freedom vertical plane equation of motion. The system is simulated by using Matlab's Simulink program. For the dynamics control, Matlab's s-function is used. Within that block, the state- space equations are solved by using a Matlab's numerical integration routine with a variable time- step size. The efficacy of the sliding mode controller is investigated for the marine salvage operation.

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arun.d.v@strath.ac.uk

# The effect of flexibility on the design and performance of an inflatable boat and environmental considerations

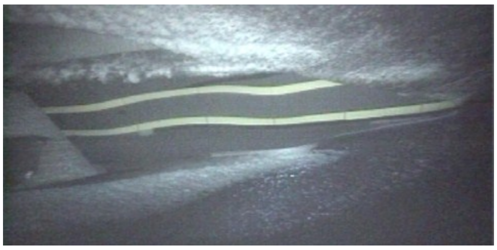
*Peter. K. Halswell, Fluid Structure Interactions Research Group, University of Southampton*

This project is supported by the Royal National Lifeboat Institute (RNLI) and they design, build and maintain the largest fleet of rigid inflatable boats (RIBs) and inflatable boats (IBs) in the UK. Currently, there is relatively little scientific understanding about the performance of RIBs and their design is usually based on the experience of the designer. There is considerably less understanding about the performance of IBs. Experiments into the performance of RIBs includes; [Haiping et al. (2005), Townsend et al (2008a), Townsend et al (2008b)] and of IBs includes; [Dand et al. (2008)]. A computational model of a RIB has been constructed by [Lewis et al. (2006)].

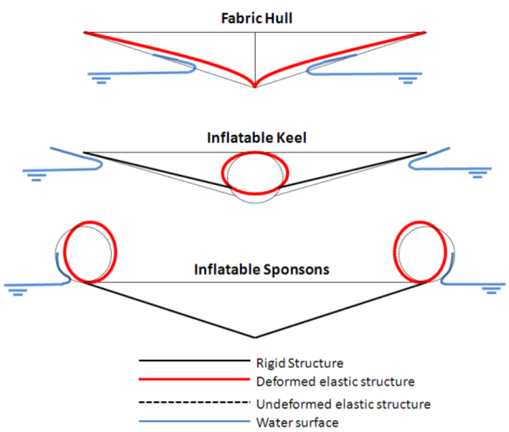
Anecdotal evidence has shown that the flexibility of an IB improves its performance, especially in waves. Therefore the focus of this project is to scientifically prove how and why the flexibility or hydroelasticity enhances performance and to present the results in the form of design guidelines for the RNLI when they come to redesign their inshore lifeboat (IB1). This project is in essence studying hydroelasticity with highly deformable boats.

Inflatable boats can potentially be optimized through hydroelasticity to improve their performance. The improved performance will include; reduced boat motion (and hence human exposure to vibrations), increased forward speed and lower added resistance in waves. So the aim of this paper is to show that hydroelasticity can be used to optimise a vessel, not just study its effects. The project aims to verify this belief.

The hydroelasticity within the IB1 consists of three main areas; global hydroelasticity, hydroelastic planing surface and hydroelastic slamming. The global hydroelasticity is comparable to conventional hydroelastic theories, such as [Bishop and Price (1979)], and it investigates the dynamic response of the vessel to waves. The hydroelastic planing surfaces is a study of the effect of a fabric and flexible planing surface. The hull of the IB1 is fabric and has minimal out-of-plane bending stiffness allowing it to deform and this affects the boat's performance. The hydroelastic slamming relates to the 2D elastic wedges vertically impacting a free surface. The elastic components include the fabric hull, inflatable keel and inflatable sponsons. It has been proposed that sponsons absorb energy during a slamming motion; this can be tested during these experiments [Natzijl (1998)].



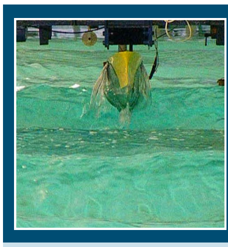
Above – Hull deformation
Below – Elastic wedge impact




The wave and spray generation of a vessel with sponsons in contact with the water are considerably different to a planing craft with hard chines and is not understood. Minimising the wave and spray generation will increase the speed of the craft and lowering the wave energy will reduce the environmental impact from wave wash.

There is an ever increasing concern for the environment so the air and water borne noise produced by this type of craft needs investigating. The air borne noise will be measured using the international standards “Small craft — Airborne sound emitted by powered recreational craft” (ISO 14509) then the results will be analysed and published. The water borne noise will be measured, analysed and published, however, there are no standards for the water borne noise measurements.

ph3e09@soton.ac.uk



# Experimental investigation of transient orifice flow

*Christian Wood, Fluid Structure Interactions Research Group, University of Southampton*

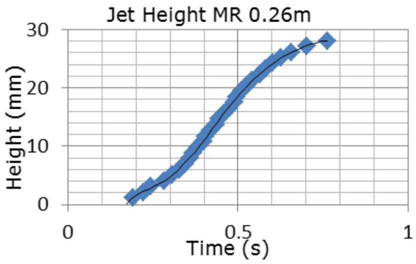
The motions of a damaged ship in a seaway are subject to a number of driving forces, from the excitations from the waves to the constantly changing displacement due to ingress and egress of floodwater and forces induced by floodwater motion. The simulation of a damaged ship is complex due the violent nature of the internal flows and that each of these driving forces are dependent on each other. Using a 2D strip theory coupled with a hydraulic model, it has been shown in [1] that resonant effects can occur with respect to ship-floodwater motions resulting in structural loads that far exceed those in the intact condition. In order to assess this effect in more detail, a greater understanding of the flows critical to this behaviour must be understood. The parameter of interest in this study is the flooding rate and involves taking a brief look into an experimental study of flow through a range of orifice shapes and areas.

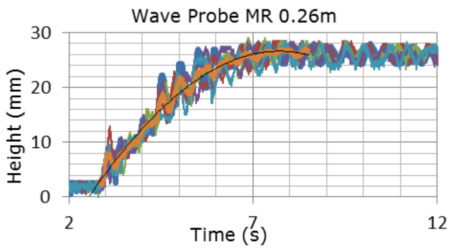
Torricelli was the first to observe a correlation between flow rate and the square root of the pressure head. This was later proved by application of Bernoulli's equation, where a co-efficient of discharge $C_d$ is used to take viscous effects into account.

$$q = C_d A\sqrt{2gh} = C_d A\sqrt{\frac{2\Delta p}{\rho}}.$$

For Reynolds numbers in excess of $O(10^3)$ it has been shown in [2] that $C_d$ scales for specific orifice geometries. Currently, from [2] is it understood that factors affecting the steady flow rate through an orifice include fluid viscosity, surface roughness, thickness of the orifice plate, area ratio of orifice to surrounding geometry. However the CFD study in [3] showed that there is also a flow rate sensitivity on the shape of the orifice and location with respect to the surrounding geometry.

An experimental study has been performed using the geometry from [3] and a small array of orifice shapes and areas. Measurements have been taken using a wave probe for overall tank fill and a high speed camera to capture floodwater jet height. An example of the raw data plotted is shown below.




In order to get a full time to flood picture of the these cases it is necessary to use data from both data sets. $T_0$ can be determined from the jet growth whilst the finished flooding time is better determined from the wave probe data, where the sloshing oscillations can be filtered out. The findings from which will be presented at the conference.

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 C.D.Wood@soton.ac.uk

# Dynamic responses of an integrated coupled mooring line-floating platform interaction system subject to wave loads

*Aichun Feng, Fluid Structure Interactions Research Group, University of Southampton*

Floating offshore platforms are basically maintained in a position by a multipoint mooring system with mooring lines arranged in a radial fashion about the platform. The mooring line integrated with the floating structure to resist sea loads. The unreliability and inaccuracy of the uncoupled method, which assumes the mooring lines as geometrical non-linear mass-less springs with their inertial effects neglected, significantly increase as the water depth increases.

The coupled method used in this paper considers the mooring line-rigid floating platform interactions by simultaneously solving the governing equations describing the coupled dynamics of the integrated system. The dynamic force from the mooing line is added to the platform to calculate its motion which in turn affects the dynamic equilibrium of the mooring line. The dynamic characteristics of mooring line is fully considered based on a three dimensional theory for geometrical non -linear elastic slender rod wherein drag loads on the line are evaluated using a modified Morison's formulation. The deformed state of the rod is described by a space curve which is a function of arc-length and time. Based on finite element method (FEM), the rod is approximated as a numerical model in a global coordinate system.

The dynamic response for moored structure due to large-amplitude slow-drift resonance is of greatly importance. Instead of the traditional Newman's approximation, second-order wave-induced forces are formulated by quadratic transfer function (QTF), which combines with linear diffraction / radiation panel method for the first-order wave forces to improve the accuracy of results.

Our research aims to investigate the dynamic characteristics of various deep-water floating structures using the coupled method based on the Newmark method in time domain. The dynamic response of a semi-submersible system has been simulated according to this method. The system belongs to SEDCO-700 series moored in 295m water while the mooring system is composed of 12 mooring lines. Each mooring line consists of chain-wire-chain-wire. The initials numerical results of the structure motion and mooring tension conform to the experiments quite well.

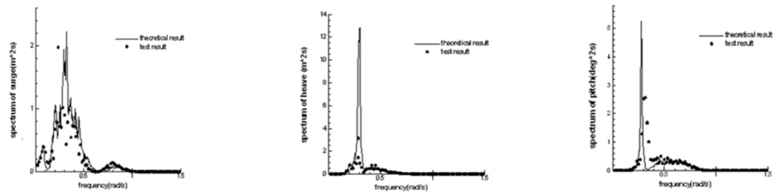


Figure1 Comparison of numerical and experimental results of structure motion

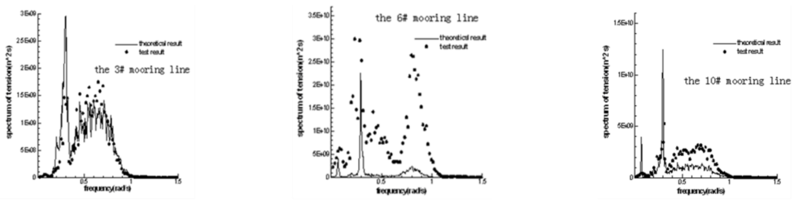
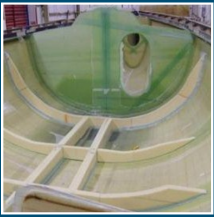



Figure2 Comparison of numerical and experimental results of mooring tension

Obviously, there are two peaks in motion spectrums and tension spectrums. The larger peaks lie in the wave frequency while smaller ones fall in low-wave frequency. They are caused by the first-order and second-order force respectively. Because of the shallow draft of semi-submersible and therefore nature frequency lies in wave frequency. The motions are mainly caused by first-order force.

In addition, results show that the effect of the case where one taut mooring line is broken on the dynamic characteristic of the semi-submersible platform in bad sea conditions will be remarkable. The developed coupling approach provides a mean to simulate more complex practical cases with some mooring lines broken due to damage or accidents to predicate dynamic loads changes for the safety of offshore system.

a.feng@soton.ac.uk



## Motion prediction of a deep-vee hull form catamaran in regular waves

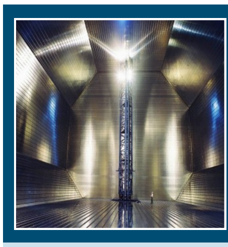
*Musa Bashir, School of Marine Science and Technology, Newcastle University*

This paper presents the results of experiments carried out to determine the motion/Seakeeping behaviour of a deep-vee hull form catamaran in regular sea condition. A deep-vee catamaran model for the Newcastle University's RV Bernicia replacement vessel was used for the motion prediction. The experiments were performed in the university's towing tank. The results obtained were validated using a 3D panel method in frequency domain. A comparison of these results with the motion characteristics of the NPL's (National Physical Laboratory) round bilge catamaran series of similar geometrical properties revealed that the deep-vee hull forms possess significantly better seakeeping capabilities than the NPL's round bilge hull form.



m.b.bashir@ncl.ac.uk

# Structural Materials



## A new tool for identification of defects in adhesively bonded joints

*Rachael C. Waugh, Fluid Structure Interactions Research Group, University of Southampton*

The use of adhesive bonds in engineering and marine structures is currently hindered by a lack of knowledge of joint reliability. Adhesively bonded joints offer many advantages over bolted joints, which includes a more uniform stress distribution eliminating stress concentrations at the edge of the fastener holes. Furthermore, access to only one side of the joint is required for assembly. To enable a better understanding of the efficiency of adhesive joints there is a need for improved non-destructive evaluation (NDE) techniques. As any reduction in joint efficiency can be related to defects in the adhesive joint, inspection techniques must be capable of reliably all defect types.

Current methods of assessment are typically able to identify defects in the joints that have a definite volume such as voids or inclusions. Defects that are of zero or very small volume, known as kissing defects, are much harder to locate. Kissing defects manifest because of improper adhesion between adhesive and adherend. No physical void is present but the bond at this position has a reduced strength than expected. As a result of this the overall strength of the joint will be reduced which could have potentially catastrophic results. The exact cause of this reduced adhesion is unknown, but possible causes may be contamination, abnormality in the adhesive chemistry or curing process, moisture ingress, residual stresses or a combination of these factors. Kissing defects are presently undetectable using current techniques of inspection.

**Figure 1** Experimental set up for PPT showing square wave pulse application and thermal decay data collection.

Pulsed phase thermography (PPT) (Fig. 1) is an active thermographic method. It combines the application of a heat pulse as used in pulsed thermography and the processing technique of a Fast Fourier Transform to find phase values, as in lock-in thermography. PPT has shown promise as an effective near surface non-destructive evaluation (NDE) technique in a range of applications. To date there has been limited work carried out studying the suitability of PPT to assess the integrity of adhesively bonded joints and less still on the potential detection of the improper adhesion in kissing defects.

The current work aims to develop a thermographic method using PPT that is suitable for the complete inspection of adhesive joints, particularly in composite materials. So far, an increased understanding of the nature and potential causes of kissing defects has been obtained and the thermographic method of PPT has been studied. Initial experimental work is presented that focuses on the implementation of PPT on solid materials with artificial defects. Methods for manufacturing kissing defects in the laboratory are proposed to produce defects in a realistic and reproducible way. This was performed in two ways: either by creating a dry contact bond or by using a contaminant. Full-field stress analysis techniques have been applied to assess the effect of the defect and ensure there is a representative loss in structural performance of the bond in the neighbourhood of the defect. It is shown that the PPT approach requires modification to detect such defects. In the presentation results from PPT are compared to other NDE methods such as water coupled ultrasound to ensure the PPT could produce results that are comparable to a more established technique.


rcw1n09@soton.ac.uk

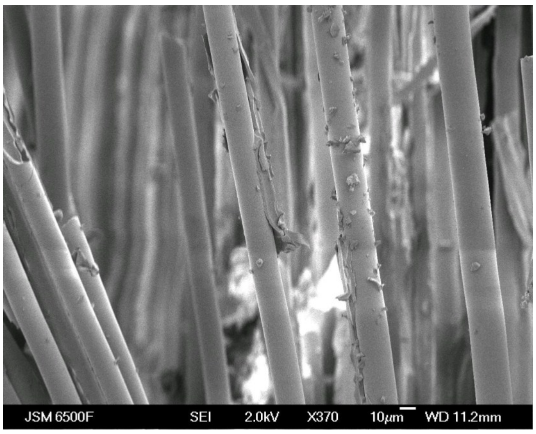
# Hygrothermal ageing and the implications on the mechanical properties of sustainable composite materials for structural marine applications

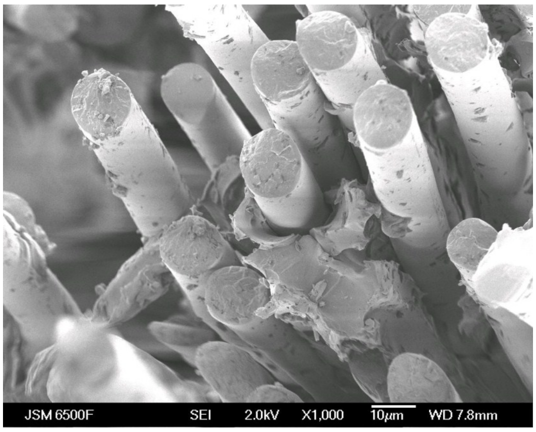
*Mari Malmstein, Fluid Structure Interactions Research Group, University of Southampton*

Exposing composite materials to the marine environment leads to complex internal processes, including osmosis, which tend to degrade the material's mechanical properties. Although these processes are not fully understood yet, the conventional marine composites, like glass reinforced epoxy, are still considered to perform well under varying environmental conditions. Composite systems currently used in marine applications are generally relying on petroleum based synthetic materials that are energy intensive to produce, expensive, and difficult to recycle. Recently, new biodegradable materials have been introduced due to environmental concern and societal awareness. Whilst the automotive and civil construction industry have made advances in the use of sustainable composite materials, the high structural performance end of the market seen in the marine industry has little confidence in the performance of these emerging materials. One of the reasons is the variability of natural constituent materials that leads to varying performance and compatibility issues between fibres and resin. Therefore, it has been decided to define the properties of one constituent material at a time. As resin has been reported as having a bigger environmental impact and little data exists on resin performance, this research seeks to determine the viability of using glass fibre reinforcements with two candidate natural-based resins, linseed oil and castor oil resins, for marine structures.

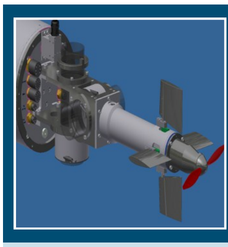
A materials test programme has been undertaken which encompasses the issues of environmental degradation and durability of composite materials in humid environment. The effect of water diffusion on the durability of glass reinforced castor oil and linseed oil resins in comparison to epoxy resin has been investigated. Epoxy/glass and castor oil/glass specimens were prepared by resin infusion using 10 layers of 0°/90° plain weave glass fibre fabric as reinforcement. Linseed oil/glass specimens were prepared by hand lay-up and UV-cure. The specimens have been immersed in water at 40 °C (hygrothermal ageing) to accelerate the ageing process. Tensile, flexural and interlaminar shear strength and moduli of the immersed materials are being tested with 2 week intervals. Scanning Electron Microscope (SEM) is being used for detecting the differences in failure modes of the specimens. For the first time, this research is employing Computed Tomography (CT) to detect the presence of water in a composite and investigate its effects on the structure of the material.

Preliminary findings show that before ageing the mechanical properties of castor oil/glass specimens compare better to epoxy/glass than linseed oil/glass specimens. The strength of castor oil/glass is approximately 70 % and linseed oil/glass 35% of epoxy/glass specimens. Flexural and interlaminar shear strength show very similar behaviour. Moisture absorption tests with epoxy/glass specimens show that moisture uptake at 40 °C follows Fick's diffusion. Remarkable reduction in tensile, flexural and interlaminar properties was noticed after 2 weeks of immersion for all three materials.



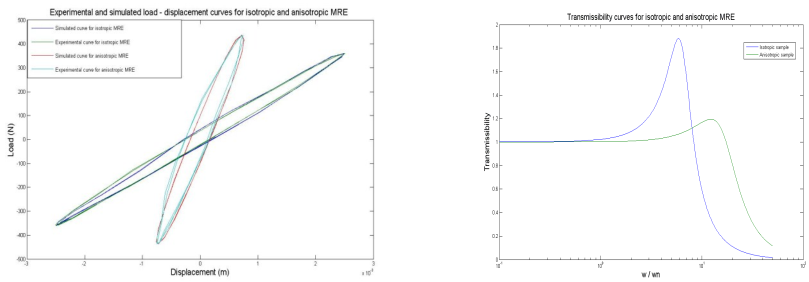

m.malmstein@soton.ac.uk



## Dynamic modelling of magnetorheological elastomers and applications in vibration isolators

*Kyriaki Sapouna, Fluid Structure Interactions Research Group, University of Southampton*

Magnetorheological elastomers (MRE) are a category of smart materials that can adjust their mechanical properties according to the intensity of an external magnetic field. MR elastomers consist of ferromagnetic particles suspended in a low permeability elastomer matrix. When an external magnetic field is applied during curing, the particles align in the direction of the field and form an anisotropic material while in any other case the material is considered isotropic. MR elastomers, like most elastomers, are governed by a nonlinear stress-strain relationship with a complex modulus of elasticity that in addition depends on the magnetic field. However the majority of researches assume a linear behaviour when it comes to mathematical modelling for simplicity reasons. The aim of this project is to develop a mathematical model capable of predicting the dynamic mechanical behaviour of MR elastomers in order to simulate and finally design a vibration isolation device for marine applications. The first step was to examine the mechanical characteristics of the two types of MRE in static and dynamic loading conditions. Isotropic and anisotropic samples were manufactured in the laboratory using silicon rubber and carbonyl iron particles. Static loading tests were performed while varying the magnetic field from 0T to 190 mTesla. Both samples increased their stiffness when the magnetic field increased while anisotropic samples showed greater nonlinearity. It was observed that the MR effect was more pronounced in isotropic samples while anisotropic samples were much harder.




a) b)

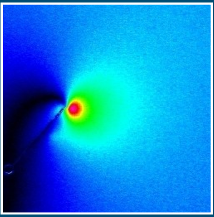
Figure 1: a) Experimental and simulated dynamic loading hysteresis curves b) Transmissibility curves for isotropic and anisotropic MRE.

The dynamic behaviour was examined using the standard linear viscoelastic model consisting of stiffness $k_1$ in series with a Kelvin Voigt chain of stiffness $k_2$ and damper c that depend on the external magnetic field. To validate the model, harmonic compression loading tests were performed and a parameter extraction method using MATLAB curve fitting algorithms was developed based on the BS ISO 4664 standard. When increasing the external magnetic field by only 50 mTesla the dynamic stiffness for isotropic samples increased by 100 % while the damping factor decreased by 17%. Anisotropic samples showed higher damping factor and dynamic stiffness under the same magnetic field. The transmissibility of a single degree of freedom mass isolator system for both samples was simulated using the proposed model. Isotropic MRE showed a much smaller transmissibility value in the isolation region and natural frequency than anisotropic samples while a 50 mTesla increase in the magnetic field resulted to a shift in the natural frequency by 22%.

MRE can therefore, be used in active isolation systems that can adjust the natural frequency and value of transmissibility according to the level of generated vibrations. For the marine industry where unpredictable dynamic loading conditions are the case, MRE isolators could greatly decrease the level of vibrations transmitted from the machines to the shell of the ship and the opposite, resulting to smaller fatigue loads and a much more comfortable journey.


ks9g09@soton.ac.uk

# Marine Engineering Systems



## Development of an index for maritime transport costs and connectivity for the UK

*Stavros Karamperidis, School of Marine Science and Technology, Newcastle University*

The purpose of this research is to develop an index of maritime transport costs and connectivity for the UK. Such a tool will be of considerable use not only within the maritime sector, but also more generally in economic policy. The proposed index will allow various factors such as distance, vessel designs and new intercontinental routings, to be modelled and ''weighted'' based on the perceptions which various practitioners and academics have for the impact of those factors in the UK. The comparison with other economic indicators, such as GDP, will be the ultimate outcome of the present research.

**Research approach:**

A mixed-method approach will be applied to the research. In the first instance, a review of commercial and academic literature was undertaken. The literature review highlighted factors affecting and the maritime transport sector has been conducted; a variety of indices for predicting change in the sector were also identified. A qualitative phase involving interviews with key stakeholders will follow. This combination of research methods will provide tacit knowledge about changes in the UK maritime transport industry. This will compliment the quantitative phase of the research that will involve analysis of disparate datasets to develop the proposed index. The index will subsequently be tested for validity with the key stakeholders identified in the first phase of the research.

**Findings and Originality:**

Forty seven factors affecting the maritime costs and connectivity have been identified from the literature review. Some of those factors are: transhipment routings, vessel designs, new and emerging intercontinental routings, and access channels. It is envisaged that consideration of various dimensions of risk will also be a central part of the research project.

To better understand how the indices work, the present research will deal with the various indices found from the academic and commercial literature review. A content analysis and a literature review of the indices that are relevant to the maritime sector have been conducted. A total of 99 indices were found and studied. The conclusion of this exercise was that the most frequently mentioned index was the Baltic Dry Index (BDI).

The key to the development of the proposed index is the collation and analysis of reliable data on services and costs. This is how the proposed index will contribute to promoting economic efficiency in the UK maritime transport sector.

**Research impact and Practical impact:**

The creation of an index, similar to prominent indices such as the Dry Baltic Index, the Logistics Performance Index and the Liner Shipping Connectivity Index, is the ultimate outcome of this research. The proposed index will be unique as it will incorporate industry-specific factors sourced from a combination of qualitative data and knowledge from the broader literature. The index will assist all of those involved in the maritime transport chain to better understand the impact of changes in services and costs on their operations.



stavros.kakmperidis@newcastle.ac.uk

# The selection of economically viable carbon dioxide emission reducing technologies in ship design

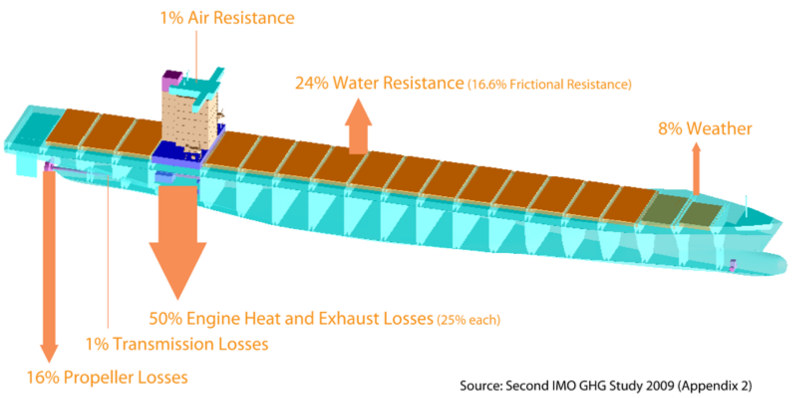
*J. Calleya, Marine Research Group, Department of Mechanical Engineering, University College London*

Background

According to the Second IMO Greenhouse Gas Study, 2009, shipping accounts for 3.3% of global carbon dioxide emissions, while aviation accounts for 1.9% of global carbon dioxide emissions. Figure 1 shows the distribution of fuel energy and hence $CO_2$ emissions for a conventional ship.

The substitution of non-renewable oil-based fuels for alternative fuels is the single biggest obstacle that the maritime industry will have to overcome in the near future. Most of the alternatives to oil-based fuels are undeveloped when you consider that oil-based fuels have been used extensively as a means of propulsion over the past century, making these alternatives less cost -effective. A number of carbon reducing alternatives and supplements to heavy fuel oil have been studied in recent years. What has not been looked at so thoroughly is how the application of these carbon reducing technologies influence the design of the ship and the technologies themselves.

Figure 1 Distribution of Fuel Energy for a Conventional Merchant Ship



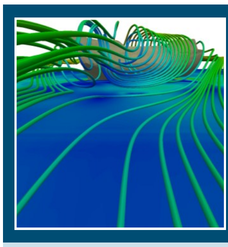

There are three main technological ways to reduce carbon dioxide emissions. These are; improving energy efficiency, using fuels with less emissions per work done (e.g. LNG) or using emission reduction technologies. Operational measures (such as weather routing and speed optimisation) have an advantage in that they do not require any technological changes and can be implemented short-term.

Approach

This work contributes to the wider Low Carbon Shipping project between five universities crossing different areas of expertise, briefly, the purpose of this project is to examine the potential of different carbon dioxide emissions reducing measures available between the present day and 2050.

From the ship design perspective, the focus is modelling the effect of carbon emission reducing technologies on ship design and examining, which technology or combination of technologies provide the best carbon dioxide emissions reduction and/or best financial incentive given a emission reduction requirement. A parametric ship design model is being used to model the impact of carbon dioxide reducing technologies on merchant ship design, cost and overall carbon dioxide emissions (this is depicted in Figure 1 with the energy losses superimposed). Both the retrofit of current ship designs with carbon emission reducing technology and future newly built low carbon dioxide emission ship designs are being examined over a timeframe to 2050.

j.calleya@ucl.ac.uk



# Integration of solid oxide fuel cell technology and thermal reformers with the ship auxiliary power plant

*Gonzalo Azqueta-Gavaldon, Marine Engineering, Strathclyde University*

Fuel Cell technology is considered as an effective alternative to the traditional combustion engine to achieve the mitigation of air pollution.

The possibility to operate high temperature Fuel Cells with high-hydrocarbon chemical reformers makes this technology capable of operating with a wide range of fuels, in addition to pure hydrogen, which is necessary to avoid the problems that hydrogen operation entails, production and storage.

This fact together with their low carbon footprint compared to the diesel engine, makes high temperature Fuel Cells a very promising solution for reducing carbon emissions on board ships; via installation as part of the ship's auxiliary power plant.

At the present time, several land-based systems have utilised Fuel Cells for power generation. In order to effectively implement Fuel Cells for marine onboard power generation, a study of how a marine based Fuel Cell system differs from a land-based system has been carried out.

One of the largest challenge that arises when trying to install a Fuel Cell system onboard a ship is the minimisation of the volume and weight of the system due to the low volumetric power density of Fuel Cell Systems, and the space constraints that are present on the ship's main engine room. This can be directly achieved by integrating the Fuel Cell's auxiliary systems with the existing systems within the ship's power plant.

In this paper a theoretical study concerning the use of tubular Solid Oxide Fuel Cells (tSOFC) operating together with thermal hydrocarbon reformers for a range of different fuels, is presented as a substitute of the conventional marine diesel generators for the ship auxiliary power plant.

First the ship total energy demand is established by an empirical method based on statistical analysis, and the necessary propulsive power is calculated using power prediction methods. By combining the statistical method with the power prediction method is possible to estimate the ship auxiliary power demand for a range of general cargo ships using a regression technique. The different systems associated with the ship auxiliary power plant are determined and sized by statistical analysis of the three different power demands and an external ship database.

The Fuel Cell operational parameters, namely pressure, voltage and current density, are determined with a theoretical study and correlated with manufacturer data

The Fuel Cell design parameters and the reformer system are determined for a range of power requirements via a simulation model. The dimensions, weight and energy demand of the Fuel Cell Stack, Fuel Cell auxiliary systems and reforming systems are estimated and scaled for the power range. Then a study of the individual systems integration with the ship's existing auxiliary power plant is undertaken.

A study showing possible SOFC topologies with the different Fuel Cell and reforming Systems for marine use is presented.

Potential carbon emissions reduction by the use of Fuel Cells for a range of ships and the use of different fuels is finally estimated.


gonzalo.azqueta-gavaldon@strath.ac.uk

# Nonlinear energy harvesting using a flapping foil

*Jian Yang, Fluid Structure Interactions Research Group, University of Southampton*

Although the design of energy harvesting using the flutter phenomenon of foil has been used in some studies, the actual power generation unit was always neglected by researchers. Moreover, linear springs were considered in both heave and pitch degrees of freedom in their work, which would introduce divergence when the flow velocity exceeds the critical flutter speed. To overcome these limitations, the system under current investigation is a nonlinear energy harvesting system which consists of a flapping foil with coupled heave and pitch motions and an electro-magnetic generator excited by incompressible quasi-steady air flows (Fig.1). As indicated by the theory of aero-elasticity, the system is able to exhibit a stable limit cycle oscillation when the flow velocity is above the critical speed. The mechanical energy imported from the air flow can be converted into electricity by the generator.

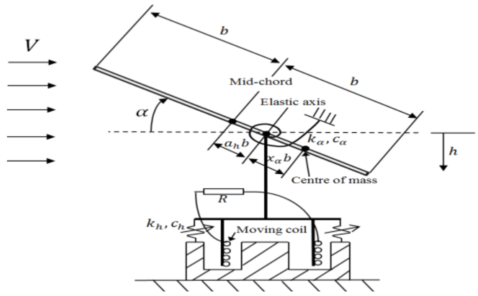



Fig. 1. Schematic map of the energy harvester

## Coupling system model

Considering a flat foil of a unit span, the equations of motion and equation for electric circuit are written as

$$m\ddot{h} + S\ddot{\alpha} + c_h\dot{h} + k_{h1}h + k_{h2}h^3 = F - iBl, \quad (1)$$

$$S\ddot{h} + I_\alpha\ddot{\alpha} + c_\alpha\dot{\alpha} + k_{\alpha1}\alpha + k_{\alpha2}\alpha^3 = M, \quad (2)$$

$$L\frac{di}{dt} + Ri - Bl\dot{h} = 0 \quad (3)$$

where $F$ and $M$ are aerodynamic lift and moment and can be expressed analytically using quasi-steady aerodynamic theory; $B$, $R$ and $L$ are magnetic intensity, resistance and electric conductance.

## Equation of energy balance

By assigning $T = \frac{1}{2}m\dot{h}^2 + \frac{1}{2}I_\alpha\dot{\alpha}^2 + S\dot{\alpha}\dot{h}$, $D = \int(c_h\dot{h}^2 + c_\alpha\dot{\alpha}^2)\mathrm{d}t$, $U = \frac{1}{2}h^2\left(k_{h1} + \frac{1}{2}k_{h2}h^2\right) + \frac{1}{2}\alpha^2\left(k_{\alpha1} + \frac{1}{2}k_{\alpha2}\alpha^2\right)$, $P_c = \frac{1}{2}Li^2$, $P_g = \int Ri^2\mathrm{d}t$, $p_{in} = \int(F\dot{h} + M\dot{\alpha})\,\mathrm{d}t$, the equation of energy balance is obtained as

$$T + D + U + P_c + P_g = P_{in}, \quad (4)$$

where $T$, $D$, $U$, $P_c$, $P_g$ and $P_{in}$ stand for total kinetic energy, total dissipated energy, total potential energy, energy stored in electric conductance, energy generation and total input energy, respectively. Equations (1)-(3) may be transformed to a set of first order differential equations. Then by using the fourth-order Runge-Kutta method, the response and energy variables may be obtained.

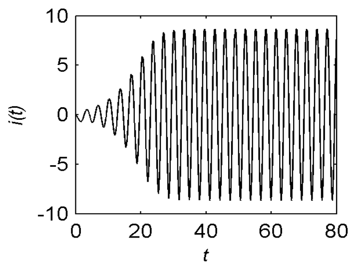



Fig. 2. Dynamic current ($m = 406.20kg, S = 101.55kg\cdot m, c_h = 4.8745kg/s, c_\alpha = 4.8745kg\cdot m^2/s, k_{h1} = 146.23N/m, k_{h2} = 146.23N/m^3$, $k_{\alpha1} = 913.97N\cdot m, k_{\alpha2} = 1371N\cdot m, V = 19.5\,m/s$, $I_\alpha = 101.55\,kg\cdot m^2$, $x_\alpha = 0.25, r_\alpha = 0.5,\ a_h = -0.5$, $B = 0.5\,T, l = 20m, R = 1\Omega,\ \ L = 0.05H, b = 1m$, $\rho = 1.293\,kg/m^3$).

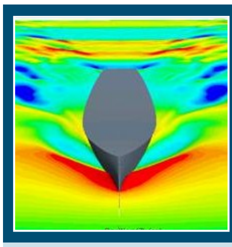
## Results and discussions

Table 1. Energy exchanges (J) (parameter the same as in Fig.2)

| Energies | $\Delta P_{in}$ | $\Delta T$ | $\Delta D$ | $\Delta U$ | $\Delta P_c$ | $\Delta P_g$ |
|---|---|---|---|---|---|---|
| Without generator | 893.0 | 141.1 | 779.4 | -27.6 | NA | NA |
| With generator | 5970.3 | -68.31 | 435.1 | 11.21 | -0.5 | 5592.8 |

The simulation results are shown in Fig.2 and Table 1. Fig. 2 shows that the amplitude of the steady state dynamic current is approximately 8.63A. Correspondingly, maximum instantaneous power generation is 75.58W. In Table 1, the change in energy variables in the time span (50,200) for the system with generator is compared with that without generator. It is shown that the input energy is much larger for the former case than that for the latter. It is also found that for the case with generator, the input energy is largely converted into electricity with only a small portion being dissipated by damping. It can be concluded that the stable limit cycle oscillation of flapping foil supported by nonlinear springs can used to extract energy from the air flow. This study also demonstrates the necessity of considering the coupling effects of the foil and generator. Future work will focus on optimising system parameters to improve the energy harvesting efficiency.

jy1g09@soton.ac.uk



Session 5

# Fluid Dynamics

# Smoothed particle hydrodynamics method in fluid-structural interaction of marine engineering

*Fanfan Sun, Fluid Structure Interactions Research Group, Southampton University*

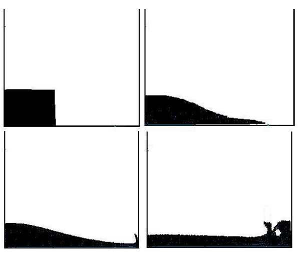
Many fluid-structure interaction problems often involve violent fluid motions in marine engineering field, such as slamming and green water. It is important to understand fluid-structure interaction for a safe use of structures in marine environment. Since these problems are nonlinear with complex boundary conditions, an efficient numerical method is required. Smoothed Particle Hydrodynamics (SPH) method as a mesh less method can easily deal with free surface variation of the fluid as well as large deformations. It therefore has potential to solve the fluid–structure interaction problems happened in the violent sea. The objective is to apply and improve SPH method to simulate violent fluid-structure interactions.

The SPH theory is based on the theory of integral interplant that uses kernel function to approximate delta function. A physical property is obtained by the interpolation between a set of points inside a certain area:

$$A(\mathbf{r}_a) = \sum_b m_b \frac{A_b}{\rho_b} W(|\mathbf{r}_a - \mathbf{r}_b|, h)$$

The governing equations for incompressible continuum include the conservation of mass and momentum in Navier-Stokes equations: $\frac{1}{\rho}\frac{D\rho}{Dt} + \nabla \cdot \mathbf{v} = 0$ and $\frac{D\mathbf{v}}{Dt} = \mathbf{g} + \frac{1}{\rho}\nabla \cdot \tau - \frac{1}{\rho}\nabla P$

Where t is the time, ρ is the density, g is the gravitational acceleration, P is pressure, v is velocity, $\tau$ is viscous stress tensor and D/Dt refers to the material derivative. To satisfy the incompressibility, the mass density of each particle is kept as a constant during the simulation and the velocity divergence will be zero automatically [1]. The dam-breaking case was used to demonstrate the performance of the incompressible SPH as shown in Fig. 1. To obtain an efficient model different boundary treatments were investigated, the pressure values obtained from these methods are compared with experimental data produced by [2] shown in Fig. 2.



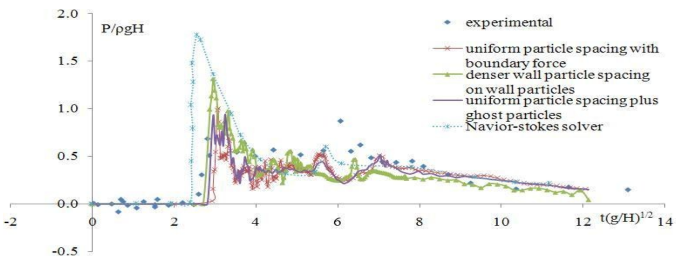



Fig. 1 Dam-breaking simulation with ICSPH Fig. 2 Pressure obtained from different methods comparison

All these three boundary treatments find the first pressure peak around the right time compared with experimental data. The first peak values obtained from numerical method are slightly larger than observed in the experiment. Boundary treatments with repulsive force and ghost particles gave similar results, denser wall particle boundary treatment give slightly higher peak value than the other two treatments. Except the second peak value, the overall curves agree with experimental data well. There is no obvious second peak pressure in the simulations. This is perhaps because of entrained air effects which are not predicted during the simulation. But compared with other numerical method such as Navier-Stokes Solver, SPH gives closer values to the experimental ones.

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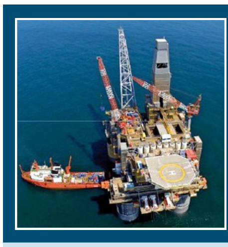
[2] Z. Q. Zhou, J.O. DeKat, and B. Bunchner, " A nonlinear 3-d approach to simulate green water dynamics on deck," Proceedings of the 7th international conference on numerical ship hydrodynamics, Nantes, July 1999.

ffs1g09@soton.ac.uk



## Experimental and numerical study on bubble split

*Baoyu Ni, Computational Fluid Dynamics Group, University College London, Harbin Engineering University*

Bubble split is a very common but complex phenomenon in the nature. Unsteady bubble dynamics in the splitting process is always a hot subject for two-phase (gas/liquid) flow mechanics. The reason for bubble split is usually complex, and some main reasons are listed here. Firstly, a bubble in a vortex field may splits into small sub-bubbles because vortex core radius, circulation and pressure distribution vary along the length of the vortex (Choi J K, Chahine G L,2002), which is found through the interaction between the bubble and vortex induced by propeller; secondly, if the volume of a bubble is so large that the surface tension can't sustain its shape, collapse or splitting will break out (Bird J C, et al. 2010); thirdly, a steady bubble will be separated by the disturbance of other objects, and Kim et al.(1990) simulated the split of a steady bubble when meeting different floating bubble breakers; fourthly, a bubble near rigid wall would split into two small sub-bubbles when the Bjerknes force equals to the reverse buoyancy (Zhang A M et al. 2009).

In this paper, we mainly study the bubble split phenomena in a narrow flow field, which is formed by several close rigid walls. Study is undertaken in both experiment and numerical simulation.

Experimentally, following the experiment of Ishida et al. in 2001, we did similar one to simulate the expansion, necking, splitting and rebound of a bubble between two horizontal walls in a water tank. The experimental parameters were as follows briefly: two parallel round coppers which could move up and down were placed in the water tank and the bubble was produced by the electrical discharge at the axis centre of the two circular plates. Bubble behaviours were photographed by the high-speed movie camera.

Numerically, based on potential flow theory, the bubble splitting model in the narrow flow field of multi-boundaries is erected with boundary integral method and corresponding computing program is developed to simulate symmetrical and unsymmetrical bubble split. The calculated results are compared with the experimental data and agree with them very well, which indicates the numerical model is valid. Starting with the basic behaviour of bubble in the narrow flow field, the symmetrical and unsymmetrical bubble split is studied with the program developed in this paper, and feasible rule of 3D bubble split is presented. Besides, the dynamics of sub-bubbles after splitting is researched, and the influences of characteristic parameters on the bubble split and sub-bubbles dynamics are analyzed.

Either symmetrical or unsymmetrical split will induce a pressure discontinuity in the flow field at the moment of bubble splitting. This pressure disturbance will decay and disappear rapidly after the formation of sub-bubbles. Besides, jet formed in the sub-bubble is a typical "narrow jet" and presents a teardrop-shape in the tip. Jet velocity is usually very large, making it quite short from the bubble splitting to jet impact, which is difficult to capture in experiment. Moreover, jet velocity of the sub-bubble reaches its summit sharply after split before it decays to a stable value gradually until the jet impact. Other regularities on volumes, jet breadth, energy and Kelvin pulse of flow field are got through abundant simulations, as well as the effect curves of different strength parameters and buoyant parameters. This paper aims to provide reference for the relevant researches on the dynamics of bubble split, especially in the interaction of bubbles and propeller.

Key words: bubble, split, narrow flow field, sub-bubbles, narrow jet

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ucembni@ucl.ac.uk

# Vortex shedding at the orifice of a damaged compartment in unbounded flow

*G.D. Xu, Damaged Ship Group, Department of Mechanical Engineering, University College London*

### Introduction

A ship compartment would be flooded after its hull structure fails (cracker, damaged hole). The stability of the ship and her sea-keeping performance would be adversely affected. The understanding of the reliability and performance of a damaged ship is highly important. The water inside/outside the ship-hull is linked. There is direct coupling of internal and external liquid through the flow passing the damaged orifice. Flow separation is created at the sharp edge of the orifice, as observed in the experiment carried out by Smith (2009). Many previous works (Massey,1968; Turan, 1992, Palazzi & de Kat, 2002) have adopted hydraulic models to calculate the load on a damaged ship. Although hydraulic models have widely used, it is recognised that they are not always accurate and reliable. The fluid flow in two domains (internal and external) has to be solved as a whole. Present research focuses on the effect of vortex shedding at the orifice.

### Description of the numerical method

It has been assumed that the effect of boundary layer is negligible to the main flow, and the flow separation can be approximated by the vortex shedding. Combining with the irrotational potential theory, we can simulate this procedure by using vortex element method. The introduced velocity potential in the fluid domain satisfies the Laplace equation and non-penetration body surface condition. The compartment starts to move from the rest, the total vortex within the fluid should be zero based on Kelvin condition. The Kutta condition has been applied at the edge of the orifice, where the velocity at the edge is finite and the pressure is continuous. The motion of the compartment is assumed to be small, thus the force can be obtained using the linear the Bernoulli equation. The motion and the force act on the hull are assumed to be periodical. Similar to the linear ship motion theory, added mass and damping force are introduced, which is proportional to the acceleration and velocity. Here the linear least squares fitting has been used to calculate the value of these coefficients. The numerical results show that the vortex shedding has important effect on both added mass and damping coefficient. Further results would be presented in the conference.

### Acknowledgement

The work is supported by the damaged ship research project, sponsored by MoD and Lloyds Register.

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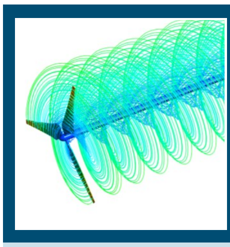
guodong.xu@ucl.ac.uk

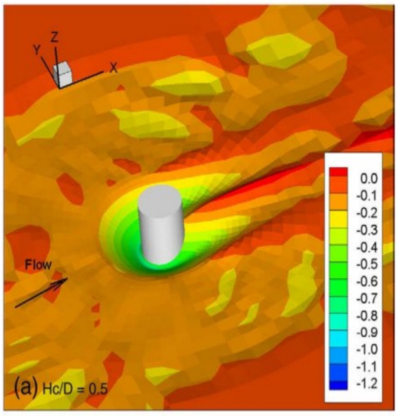


# Numerical modelling of scour around 3D structures

*Greg Melling, Geology/Geophysics and Fluid Structure Interactions Research Group, University of Southampton*

Marine local scour is understood as the removal of sediment from around the base of an object on the seabed caused by the modification of flow conditions due to the presence of a flow obstruction. The introduction of a structure to the seafloor can have a significant impact on the local hydrodynamics, causing flow acceleration, redirection and increased turbulence especially in the locality of the object. Where an object is located on non-cohesive mobile sediment, the alteration of flow patterns can cause erosion of sediment around the structure. While interesting as a phenomenon in its own right, scour, left unchecked, can cause structural damage, major economic losses and (catastrophic) failures. It is also of importance from environmental and archaeological perspectives.

At present, engineering practice is mainly concerned with forecasting the maximum scour depth around marine structures using empirical equations, which are based to a large extent on physical experiments with some corroboration from field data (Whitehouse, 1998). The applicability of these equations is largely confined to geometrically simple structures such as monopiles, piers and pipelines and little guidance is available for complex three-dimensional structures, where expensive physical model tests are required. CFD-based methods are suitable tools for scour prediction, since to accurately predict sediment transport, the flow field, associated turbulent and vortical structures and resulting bed shear stress distributions must be resolved in sufficient detail. CFD methods also offer the benefit of being a spatially and temporally resolved allowing the time-development of scour to be studied.




Several approaches have been employed to date. The simpler "static bed" models involve hydrodynamic simulation on a non-changing bed where the resulting scour pattern is inferred purely by the proxy of the bed shear stress distributions (e.g. Whitehouse et al. 2010). More advanced "morphological scour models" link the flow simulation with a morphological description which allows the bed contours to change during the simulation in response to impinging flows; the actual scour depression is modelled (e.g. Zhao et al. 2010). The prediction of bed change has in most studies been based on sediment transport theory, incorporated into the model to a varying degree of complexity. Most recently two-phase approaches to scour modelling have been introduced. Results suggest that while promising success has been achieved with a variety of approaches there is still room for improvement.

This study aims using OpenFOAM CFD to simulate the maximum vertical and lateral extents of scour around fully-submerged three-dimensional objects under uni-directional and bi-directional flow drawing on physical model and newly-gained industrial field data for validation and performance evaluation.

**Figure 1 - Morphological prediction of scour around a short cylinder (Zhao et al. 2010)**

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UNIVERSITY OF Southampton
School of Ocean and Earth Science
School of Engineering Sciences

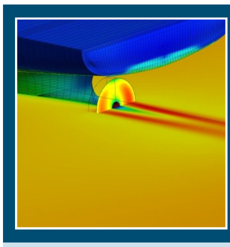
HR Wallingford
Working with water



gim1v07@noc.soton.ac.uk

## Session 6

# Underwater Acoustics and Vibration



## Hydroacoustics of marine propulsors and renewable energy devices

*Thomas P. Lloyd, Fluid Structure Interactions Research Group, University of Southampton*

Background

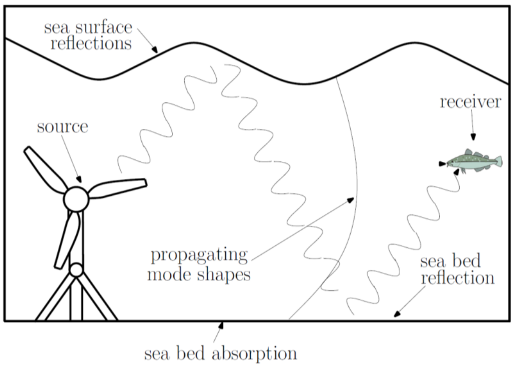
Underwater noise from marine propulsors and renewable energy devices is of considerable interest. Particular examples include: lowering noise signature of military submarines for reduced detectability; low noise AUV or research submarine thrusters to minimise disturbance when studying marine life; and environmental impact assessment of merchant ships, recreational craft (e.g. jet skis), and tidal turbines. Thus far the project has focussed on developing two main methodologies.

Part I: 'hybrid' CFD - acoustics simulations of ducted marine propulsors

All appropriate noise sources are modelled in an incompressible unsteady CFD simulation. Due to the low Mach number of the flow, the noise sources consist largely of fluctuating forces on the rotor and stator blades. These forces provide input to an analytical or numerical acoustic propagation model to estimate the far-field sound, modelling propagation both inside and outside the duct. Work is the simulations is on-going although a clear methodology has been identified.

Part II: environmental impact assessment of tidal turbine noise

A three-stage modelling process has been developed: semi-empirical source modelling; shallow water acoustics propagation modelling; and application of impact assessment criteria. This work has resulted in the submission of two conference papers [1,2], including the application of the methodology to a proposed tidal turbine array site. Preliminary results suggest that the dominant noise is low frequency, affecting fish such as cod, but only in close proximity to the device.

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Acknowledgements

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T.P.Lloyd@soton.ac.uk

# Integrated prediction and optimisation of underwater noise and hydrodynamic performance of an LNG carrier

*Paula Kellett, Department of Naval Architecture and Marine Engineering, University of Strathclyde*

Underwater noise has long been known about, but has always been disregarded as an inevitable side-effect of the marine industry, and except for military and fisheries research applications, it has largely been ignored. However recently, the potential effects of underwater noise on wildlife and the marine environment has in recent years become a prominent area of concern for both government bodies and conservation groups. There are many potentially harmful effects which underwater noise can have on marine wildlife, from changes to key life behaviours such as foraging and diving, avoidance of important areas and reductions in effective communication distances, through to more immediate effects such as hearing damage, and in some extreme cases, stranding and death. While some of the more immediate effects can be clearly seen, it is not yet clear how other more long-terms effects could influence species not only on an individual scale but also on a population-wide scale.

This project focuses on ship radiated underwater noise during normal operation, rather than other sources of noise such as sonar or air-gun arrays for seismic survey. The project aims to investigate principal shipboard noise sources from full scale measurement data, model the hydrodynamic noise pressure distribution about an existing LNG vessel and then use numerical hydroacoustic modelling to assess the noise spectra and levels at given receiver distances in the far field. These spectra and levels will then be assessed against known threshold values for marine animal physical damage, behavioural changes and other adverse effects, both on an individual and population level. These separate sections will then be combined into a modular numerical model capable of predicting noise underwater radiated noise spectra and levels from any commercial vessel, in any given area of operation.

There are three main types of ship radiated underwater noise sources: machinery noise, propulsion noise and hydrodynamic noise. It is widely accepted that above cavitation inception speed (CIS), by far the most dominant source of underwater noise is the propeller and cavitation noise. Below CIS, machinery noise becomes dominant, with the main engines typically being the most significant sources.

Most existing underwater noise models are heavily empirically-based, however recent work has seen a rise in numerical methods such as the application of the Ffowcs-Williams Hawkings Acoustic Analogy, originally developed for aeroacoustic application, to hydroacoustic problems. This method is typically coupled with hydrodynamic analysis in CFD software, and can produce extremely accurate and reliable results. This approach will also form a significant part of the final numerical modular ship noise prediction model.

The project is currently in its first year. Initial work is based on trying to recreate full scale measured underwater noise data for an existing LNG Carrier using commercially available CFD software. Once this can be reliably achieved at speeds near or below cavitation inception speeds, further modelling work will be carried out for more realistic prediction of propulsion noise and key onboard noise sources. These models will eventually form modules in the final numerical model.

paula.kellett@strath.ac.uk

## The effect of vortex-induced vibration (VIV) on marine steel catenary risers (SCR) fatigue

*Ali Vatandoust, School of Marine Science and Technology, Newcastle University*

Vortex induced vibration is one of the most challenging phenomena in offshore industry which can affect every slender cylindrical body subjected by Current profile. In this project, the effect of Vortex induced Vibration on the deepwater Steel Catenary Risers (SCR) fatigue is going to be investigated. Two wake oscillator models (Milan and Iwan & Blevins) and two Vortex tracking models were chosen to predict VIV of the SCR in different condition such as different current profiles, directions, different top-side vessel motions, and etc. Orcaflex software, form Orcina ltd., has provided these models as a VIV toolbox which is used in the project. Some mesh and time sensitivity tests have been accomplished to get the best segment sizes and time steps for future analysis. In future, I am going to start my analysis with main project data and some diffraction analyses are needed to get hydrodynamic data for Spar and FPSO as top vessels.



a.r.vatandoust@newcastle.ac.uk

## Optimal propeller design philosophies for ships in real operating conditions

*David Trodden, School of Marine Science and Technology, Newcastle University*

With agency's such as the IMO imposing strict limits on Greenhouse Gas emissions from ships, new designs and technologies need to be developed that meet these demands. One way of reducing emissions is to increase propulsive efficiency.

In order to highlight potential areas for improved propulsive efficiency, it is necessary to assimilate the integrated flow characteristics of a ship in service. Propellers are usually designed and analysed for flow arriving from directly in front of it; which in reality is not the case. This research, funded by the Engineering and Physical Sciences Research Council (EPSRC), aims to analyse propeller performance for a ship in a seaway, that is, examining the propeller for flow at varying inflow angles. The intent being, to determine whether a propeller can be designed for a particular shipping route that has an overall greater efficiency than one that has been designed for the dead ahead case.

A voyage simulation methodology is being developed that includes the combined influences of the hull, rudder and propeller over varying flow regimes. This mathematical model will then be utilised to study propeller performance over differing, real world, operating conditions.

d.g.trodden@newcastle.ac.uk

Session 7

# Marine Structures

# Simulation of an actual collision incident between a tanker and a bulk carrier

*Anuar Abu Bakar, School of Marine Science and Technology, Newcastle University*

The simulation uses the Finite Element ABAQUS explicit code to investigate the effect of the collision between the bow of the striking ship and the full beam of the struck ship. Simulations are carried out to investigate the effect of both a lateral collision and also to simulate the actual collision conditions. The progressive failure of the side shell is investigated considering both, the effect of damage due to plastic deformation during collision, and damage evolution including material rupture. The results presented include the crushing force as a function of time; the energies involved in plastic deformation and a comparison between the predicted resultant damage levels and the actual damage caused during the incident.

a.b.abu-bakar@newcastle.ac.uk

# Topological optimization of power flow problems in marine structures

*X.G. Xue, National University of Defence Technology, China; FSI Group, University of Southampton*

**Introduction**

A power flow analysis (PFA) provides a technique to model the high frequency dynamic responses of structural dynamical systems of high modal density. The optimization of the geometry and topology of structural lay out has great impact on the dynamic performance of marine structures. In this research we use the method of topology optimization to design the structure lay out for suppressing the energy response and controlling the transport of vibration energy in plate structures.

**Overview of Power flow Problems**

Consider a structural body occupying an open domain $\Omega$ bounded by a closed surface $\Gamma$ as show in Fig.1. The energy flow balance equation for the steady state structural problem can be obtained through the energy conservation relation and the time- and space- averaging process as

$$-\frac{c_g^2}{\eta\omega}\nabla^2 e+\eta\omega e=\pi; \quad e=e_0 \quad on \quad \Gamma^e \quad and \quad q=q_0 \quad on \quad \Gamma^q \tag{1}$$

where $e$ is the time- and space-averaged energy density function, $\nabla^2$ is the Laplace differential operator, $\eta$ is the hysteresis-damping factor, $\omega$ is the excitation frequency, $\pi$ is the input power density, and $c_g$ is the group speed. The weak formulation of Eq. 1 can be obtained by multiplying the virtual energy density $e'$ with it. We obtain

$$a(e,e')=l(e) \text{ for all } e'\in\Omega \;; a(e,e')=\int_\Omega\left(-\frac{c_g^2}{\eta\omega}\nabla e\cdot\nabla e'+\eta\omega e e'\right)d\Omega \quad \text{and} \quad l(e)=\int_\Omega \pi e' d\Omega-\int_\Gamma q e' d\Gamma \tag{2}$$

**Level set method based Topological optimization**

We consider an optimization problem to maximization of energy dissipation. So that the problem can be formulated as

$$\text{Minimize } \Pi=\int_\Omega \eta\omega e d\Omega$$

$$\text{Subject to: } a(e,e')=l(e); \quad \int_\Omega d\Omega\le V_{\max} \tag{3}$$

Level set is a method to represent and tracking moving boundary and is transparent to topological changes. Let's define the embedding function as illustrated in Fig. 2.

$$\Phi(X,t)>0 \quad \forall x\in\Omega\setminus\partial\Omega; \quad \Phi(X,t)=0 \quad \forall x\in\partial\Omega; \quad \Phi(X,t)<0 \quad \forall x\in\bar{\Omega}\setminus\Omega \tag{4}$$

Propagation of the boundary of a structure during the course of optimization is described by the Hamilton-Jacobi equation:

$$\frac{\partial\Phi(X,t)}{\partial t}+\nabla\Phi\frac{dx}{dt}=0 \tag{5}$$

**Initial Results**

The optimal design problem of a short cantilever beam is show in Fig.3.

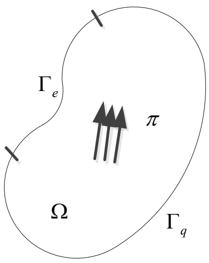



Fig.1 A structure body

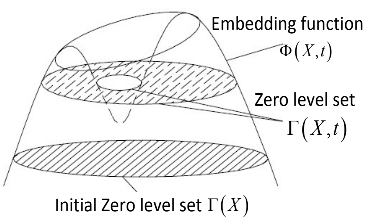



Fig.2 Level set model

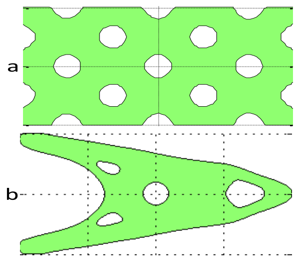



Fig.3 Initial optimization Results



xx4g10@soton.ac.uk

# Strength and reliability of stiffened cylinders using analytical and numerical

*Pretheesh Paul C, P.K. Das, NA-ME Department, University of Strathclyde*

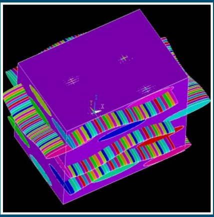
The modern design approaches consider structural reliability as one of the essential criteria to be satisfied for structural integrity. The partial safety factor approach has been proved superior to conventional factor of safety approach as it provides a rational estimate of the component level structural requirements. The reliability based design optimisation need a tool to predict the structural capacity as accurately as possible. Hence the strength analysis of structures with a higher degree of accuracy is quite important and crucial in the overall design process. Either a robust analytical model for the structural response or a calibrated numerical analysis tool with reasonable model uncertainty factor is the most suitable options for this purpose.

A huge number of precise structural capacity assessments are necessary for the evaluation of structural reliability depending on the statistical parameters of design variables. Although the numerical methods can be used for reliability analysis, the time and expense involved is quite high. It further demands great effort and expertise for acceptable results. Considering the above facts, an analytical approach in terms of basic structural design parameters to predict the structural capacity is easier for the reliability analysis. Moreover, a component level reliability assessment for a huge structure with number of local structural parts at a preliminary design stage cannot afford much time and expense. The necessity of a good analytical strength model for initial design process is hence become very important at this instance.

Cylindrical shells are one of the major structural components in offshore engineering world. Researchers from the last century (Thimoshenko, P. and Gere, J. (1961), Windenburg D F, Trilling C. (1934), Von Mises R (1929) etc.) rigorously investigated the underlying mechanisms of this category of structures and predicted the structural behaviour under various loading conditions. Many of these closed form relations in terms of the basic geometrical and material design parameters predicts the behaviour reasonably accurate. Rule based design codes like DNV; API etc are also available for the assessment of structural capacity for the stiffened cylindrical structures under different loading conditions. This paper establishes a modified version of a strength model which was proposed earlier for ring, stringer and orthogonally stiffened cylindrical shells. A large population of experimental data are used to compare the accuracy of the proposed strength model and other major practicing codes. The mean and COV of model uncertainty factor of the proposed strength model is used for the comparison between different strength models and is used in the limit state function for reliability analysis. A structural reliability analysis has been performed based on the proposed strength model using a general purpose computer code.

The above structural reliability method can be practically applied to a very few standard structural components where there exist a sufficiently robust analytical model for the structural responses. As the complexity of the model increases and in the absence of such a proved analytical structural performance model, FE analysis is the immediate option for reliability based designs. In this paper, a reliability analysis is carried out on the same structure using FE analysis and Response surface method. The FE analysis is used for the strength assessment of the structure and Response surface method is used for the limit state function and subsequently the reliability index also is calculated. The reliability indices from both the approaches are now compared and arrived at some important conclusions based on the results obtained.

pretheesh.paul-chaithanya@strath.ac.uk



## Notes

## Notes

# Notes

# Fluid Structure Interactions Research Group

The aim of the work within the research group is to explore and understand the behaviour of engineering systems in a maritime environment, with a view to better integration of design, production and operation, whilst accounting for safety, economic and societal impact. Systems of consideration include ships, submarines, submersibles, yachts and offshore structures. It seeks to unify aspects of naval architecture, marine engineering, ocean engineering, offshore engineering and maritime engineering sciences.

The research group comprises about 30 academic and research staff, 12 research and consulting engineers, and about 40 doctoral students conducting fundamental and applied research in topics related to experimental mechanics, underwater systems engineering, ocean engineering sciences, ship design, fluid structure interactions, lightweight and composite structures, hydroelasticity, marine computational fluid dynamics and dynamics of marine vehicles.

A significant feature of the work is the coalescing of fundamental research with potential application domains which are achieved in collaboration with external partners. Some examples of such partnerships are:

- The Lloyd's Register Educational Trust University Technology Centre (The LRET UTC) in Ship Design for Enhanced Environmental Performance.
- BAE Systems University Technology Partnership in Advanced Maritime Systems Design.
- Advanced Technology Partnership with the Royal National Lifeboat Institution (RNLI ATP) on Maritime Science and Engineering.
- Performance Sports Engineering in collaboration with UK Sports.
- Centre of Excellence in Marine Structures in collaboration with the Ministry of Defence, Lloyd's Register and University College London.
- Through life fatigue of composite structures with the RNLI.
- Development of autonomous underwater vehicle with the National Oceanography Centre.
- Collaboration with the Advanced Composite Group with relation to composites for deep sea cryogenic lift operations.

Image acknowledgements: Cunard (main cover image), RNLI (Nigel Ault p.14, Jim MacDonald p.38)

**The 2nd UK Marine Technology Postgraduate Conference**

The University of Southampton Fluid Structures Interactions Research Group Southampton are proud to host the 2nd UK Marine Technology Postgraduate Conference.

The conference aims to bring together postgraduate students and early career researchers to share their current research. It provides the opportunity for researchers to establish a wider knowledge base of current on-going research in other institutions, as well as enabling professionals from academia and industry to learn more about research at the forefront of the maritime industry.

Building 28
University Road
Highfield
Southampton
SO17 1BJ

sesfsirg@soton.ac.uk

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UNIVERSITY OF Southampton