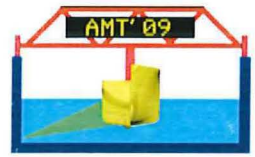
AMT'09

The 1st International Conference on
Advanced Model Measurement Technology for the EU Maritime Industry

AMT'09 is a 2 day technical conference with 34 presentations on contemporary experimentation topics such as PIV, high speed video methods and flow / wave measurement techniques. It provides a unique opportunity for test facilities, researchers, academics and other related marine stakeholders to discuss and disseminate advanced measurement technologies of model and full-scale testing.

The AMT'09 conference will provide a platform for networking between the participants and members of the FP6–Hydro Testing Alliance Network of Excellence (www.hta-noe.eu) who are organizing AMT'09 .



The AMT'09 conference (www.amt09.eu) represents an opportunity for industry and test facilities, for researchers and academics to learn more about Europe's experimental research capabilities for maritime constructions...

This project is supported by funding under the Sixth Research Framework Programme of the European Union

Preface
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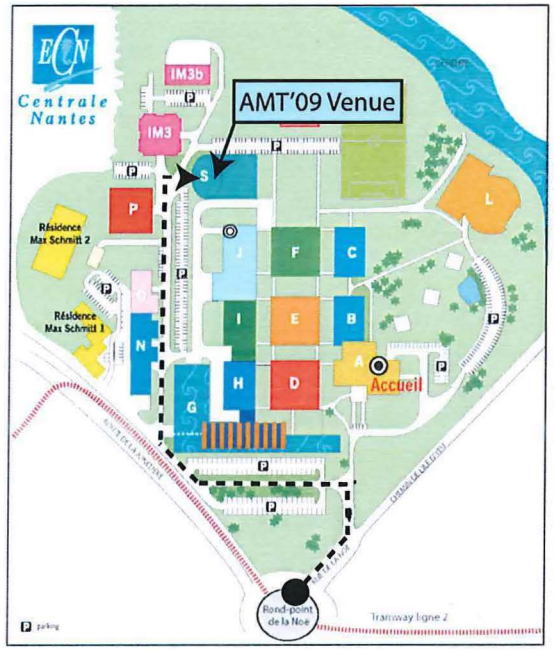
The 1st International Conference on Advanced Model Measurement Technology For the EU Maritime Industry will be held from Tuesday 1st to Wednesday 2nd September 2009 at Ecole de Centrale de Nantes, Nantes, France.



Tuesday 1st September		
8.00 - 9.00	Registration & coffee	
9.00 - 9.30	Opening Ceremony	
9.30 - 10.40	Presentation of the HTA Project JRP1 - JRP5	
10.40 - 11.00	Coffee	
11.00 - 12.15	1a - PIV/LDA flow measurement technologies	1b - Free running model/ship technologies
12.15 - 13.45	Lunch	
13.45 - 15.00	2a - H.S. video & digital imaging technologies	2b - Free running model/ship technologies
15.00 - 15.30	Coffee	
15.30 - 17.10	3a - PIV/LDA flow measurement technologies	3b - Other model testing technologies
18.00	Bus transfer to Nantes Castle: Guided tour followed by AMT'09 dinner	
Wednesday 2nd September		
8.00 - 9.00	Coffee	
9.00 - 9.50	Presentation of the HTA Project JRP6 - JRP9	
9.50 - 10.00	ITTC DFM Committee Presentation	
10.00 - 10.30	Coffee	
10.30 - 11.45	4a - PIV/LDA flow measurement technologies	4b - Wave Measurement Technology
12.00 - 13.30	Lunch	
13.30 - 14.45	Facilities Tour	
14.45 - 15.35	5a - PIV/LDA flow measurement technologies	5b - Other model testing technologies
15.35 - 16.00	Coffee	
16.00 - 16.50	6a - H.S. video & digital imaging technologies	6b - Wave Measurement Technology
16.50 - 17.15	Discussion and Closing Ceremony	

Preface

This document contains the Conference Programme and Abstracts of the papers presented in AMT'09 conference as well as other relevant conference details including local information.

Recent years have been witnessing fast developments of measurement technologies and analysis techniques that are used in testing ship models and other marine structures in model and full-scale. These developments are partly driven by the introduction of new measurement technologies and partly by the requirements of maritime industry in some emerging areas of applications. Moreover, ever growing interest to the Computational Fluid Dynamics (CFD) in marine applications, which require vital support from model tests and full-scale measurements, has been another major drive in addition to our never diminishing curiosity for many less understood complexities of flow around marine structures.

Within the above frame work, in order to exploit some of the recent developments in more integrated and sustainable manner, the European Union's (EU) 6th Framework Programme (FP) has sponsored the HydroTesting Alliance (HTA) Project starting in September 2006 over the next 5 years. The HTA Project (www.hta-noe.eu) is a Network of Excellence (NoE) with 18 members of the Europe's leading commercial hydrodynamic testing facilities and academic institutions with an ultimate goal of maintaining the Europe's leading role and competitiveness in the world at this field. Within the HTA, various new technologies are being developed and tested in 9 separate Joint Research Programme (JRP).

As part of the HTA NoE dissemination and integration activities, the members of the HTA are initiated AMT'09 Conference as the first of a long lasting AMT Conference Series in the advanced model measurement and other related technologies. Although the AMT conference appears to be a simple networking activity of the HTA project, we believe and hope that its implication on the state-of-the-art marine applications will be worldwide and sustainable, in serving as a unique international platform with a common goal.

AMT'09 Conference Chair

Mehmet Atlar (University of Newcastle)
Jean-Paul Borleteau (SIREHNA)
Albert Aalbers (MARIN)

Organising Committee

Prof. Mehmet Atlar,	University of Newcastle, U.K.
Dr. Jean-Paul Borleteau,	SIREHNA, France
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Mr. Willem Laros	CESA, Belgium.
Mr. Ivar Nygaard	MARINTEK, Norway.
Dr. ir. Jan Tukker	MARIN, The Netherlands.
Dr. Leszek Wilczynski	Centrum Techniki Okretowej S.A., Poland

Development of a laser wavegauge for dynamic wave height measurements in the B600 towing tcank

J-B Richon[1], M. Reeves[2], M. Darquier[3] & D. Fréchou
Laser & Imaging Sciences[1] & MRA Technology[2]
Bassin d'Essais des Carènes[3]

In seaworthiness tests of scaled ship models in towing tanks, it is often necessary to collect dynamic height measurements of the incident waves encountered by the model during runs. While available wave height measurement probes perform well when installed at static locations, they can exhibit serious limitations when installed in a frame of reference that moves over the water surface, as is the case in towing tanks. This observation is of particular significance to the B600 towing tank, which is capable of generating high carriage velocities (up to 12m/s) and large wave heights, up to 1m peak-to-trough.

This paper describes the principle and performance of a non-contact Laser wave gauge that was developed to address the specifics of wave height measurements in the B600 towing tank environment. The measurement method relies on projecting a collimated laser beam on the water surface and recording the time-dependent position of the resulting spot. Existing wave height measurement techniques, both intrusive and non-intrusive, are reviewed and compared in terms of applicability to towing carriage operation. We then describe the optical triangulation principle of the Laser wave gauge and its implementation in the probe installed on the B600 towing carriage, including the fibre-optic coupled Laser source, CCD imager, image processing hardware and software, and in-situ probe calibration system. A detailed assessment of the probe behaviour is presented using the operational experience and results accumulated over the course of several years in the B600. Probe performance is analysed in terms of bandwidth, signal quality and reliability, accuracy and sensitivity to factors such as water quality and laser beam characteristics. Finally we discuss optimisation and evolution paths for this technology.

Conference Programme

Tuesday 1st September	
8.00 - 9.00	Registration & coffee
9.00 - 9.30	Opening Ceremony
9.30 - 10.40	**Presentation of the HydroTesting Alliance Project Joint Research Programs (1 - 5)**
10.40 - 11.00	Coffee
	SESSION 1a - PIV \ LDA FLOW MEASUREMENT TECHNOLOGIES
11.00 - 11.25	**Challenges for PIV in towing facilities** *R. Hallmann, J. Tukker & M.A.Verhulst,* MARIN, The Netherlands
11.25 - 11.50	**State-of-the-art towing-tank PIV and LDA systems** *P. Gjelstrup* Dantec Dynamics A/S
11.50 - 12.15	**Development of a new PIV technique for flow field measurements in the towing tank** *D. E. Liarokapis, G. J. Grigoropoulos & S.G. Perissakis* National Technical University of Athens (NTUA), Greece
12.15 - 13.45	Lunch

Conference Programme

Tuesday 1st September	
8.00 - 9.00	Registration & coffee
9.00 - 9.30	Opening Ceremony
9.30 - 10.40	**Presentation of the HydroTesting Alliance Project Joint Research Programmes (1 - 5)**
10.40 - 11.00	Coffee
	SESSION 1b - FREE RUNNING MODEL / SHIP TECHNOLOGIES
11.00 - 11.25	**A wireless Inertial Motion Unit (WIMU) for motion analysis in towing tank experiments** *F. La Gala & M. Gammaldi,* INSEAN
11.25 - 11.50	**Processing navigation data collected in-service on board of the ferry SeaFrance Rodin** *T. Muntean[1], H. Vincent[2], F. Irzal[3] & S. Van Eijndhoven[3],* Wärtsilä Netherlands[1], SeaFrance[2], Eindhoven University of Technology[3]
11.50 - 12.15	**Hydrodynamics of damaged ship in roll mode of motion – an experimental approach.** *J.Cichowicz, D. Vassalos & A. Jasionowski* Ship Stability Research Centre, University of Strathclyde, U.K.
12.15 - 13.45	Lunch

3D structures in wave elevation patterns

T. Stansberg[1], D. Frechou[2], R. Henn[3], J. Hennig[4], A. Bouvy[4]
J.P. Borleteau[5], M. Ollivier[5] & H. Ran[6]
MARINTEK[1], BEC[2], DST[3], MARIN[4]; Sirehna[5] & SSPA[6]

Methods for observation and analysis of surface wave elevation patterns in a model testing environment are traditionally based upon the use of single- or multi-point wave probe time series recorders. This is, from a set-up point of view, simple and straight forward, while it provides only part information of the full space-time dynamic picture history in the wave field, and interpretation of the spatial structure is quite often not developed to an efficient or optimal level In the HTA-JRP3 project, which is described in this paper, it is the aim to investigate and develop new and improved methods, tools and procedures to push this a step forward. Two quite different main areas of development are defined in the project; 1)Robust and efficient technology /methods for optimum use of point probe arrays in laboratory routine measurements; and 2)Feasibility investigation on the use of stereo-vision video recording for full spatio-temporal measurements over a limited, defined area.

Within both these areas, different types of applications are identified, and different types / lay-outs of equipment are identified. In this project, the focus within A) is on: A1 – Simple routine tool for directional wave mapping and analysis in a wave basin, and on: A2 – Development of a cheap multi-probe bottom-mounted pressure sensor array for ship wave measurements in a narrow shall-water towing tank. Within B), the focus is on assessment of the photographic lighting conditions that are needed for satisfactory video recordings of wave elevation in an indoor laboratory, and on exploring and investigation of experiences obtained with a type of photogrammetric processing system developed for this purpose at the University of Madison. Feasibility tests are being carried out in various European model test laboratories. The work shall be completed by the end of 2010.

Determination of wetted surface

B. Allenström[1], A. Chodorowski[2], H. J. Rambech[3] & J. Tukker[4]
SSPA Sweden AB[1], Chalmers University of Technology[2], Marintek[3] & MARIN[4]

For all kind of vessels subjected to model testing, there is a strong need of knowing the possible scale effects when predicting the full scale behaviour. Regarding needed power for achieving a certain speed, the prediction of the frictional resistance is the most essential part for conventional displacement ships. For these ships the wet surface at speed is normally taken the same as the still water wet surface, i.e. at zero speed. For high speed crafts and sailing yachts the wet surface differs a lot going from zero speed and up. For these ships the wet surface must be determined at the model test for the different load conditions. This is normally done by analyzing underwater photographs or video. Also above water cameras can assist in the determination of the wet surface.

Up to now the determination of the wetted surface is normally done more or less manually. This can be very time consuming having hundreds of test runs to evaluate. In the Hydro Testing Alliance Joint Research Project No. 8 'Wetted Surface', there is an attempt to find a method how to replace most of the manual work by the help of image processing. In the present paper also some alternative methods to image processing are discussed, but not found possible to use from either economical or practical point of view. The innovative part of the new method is image processing technique to detect the waterline on the 3D-shaped hull. For this type of application the so-called live-wire technique has been found to be effective. The method proposed contains also camera calibration and 2D-3D projection. Finally, the paper will briefly discuss the measuring uncertainty and the operational advantages and disadvantages for different camera set-ups.

Conference Programme

Tuesday 1st September	
SESSION 2a - HIGH SPEED VIDEO AND IMAGING TECHNOLOGIES	
13.45 - 14.10	**Analysis of high-speed video data for assessment of the risk of cavitation erosion** *M. Grekula[1] & G. Bark[2]* *SSPA Sweden AB[1] & Chalmers University of Technology[2], Sweden*
14.10 - 14.35	**Methods and procedures for high-speed video recording and analysis of pressure fluctuations in propeller cavitation** *F. Pereira[1] and G. Aloisio[1], H. Bretschneider[2] C. Johannsen[2], M. Grekula[3], G. Bark[3], E. van de Bunt[4], M. Versluis[5] & E. Gelderblom[5]* INSEAN[1], HSVA[2], SSPA/Chalmers[3], MARIN[4] & UTWENTE[5]
14.35 - 15.00	**Propeller cavitation 3D reconstruction through stereo-vision algorithms** *L. Savio, M. Viviani & M. Ferrando* Genoa University
15.00 - 15.30	Coffee
SESSION 3a - PIV \ LDA FLOW MEASUREMENT TECHNOLOGIES	
15.30 - 15.55	**A Novel Approach for Stereo PIV Calibration in Towing Tank** *S. Grizzi, F. Pereira, F. Di Felice* INSEAN, Italy
15.55 - 16.20	**Stereoscopic PIV Measurements of rudder flow and vortex systems in the towing tank** *P. Anschau & K-P. Mach* SVA, Potsdam
16.20 - 16.45	**Tip vortex measurements of a rectangular hydrofoil using stereoscopic particle image velocimetry technique (SPIV)** *J. Oh[1] & J. C. Suh[2]* Inha University[1], Seoul National University[2]
16.45 - 17.10	**Applications of Stereo Particle Image Velocimetry to Ship Wake and Propeller Flows** *T. Bugalski,* Ship Design and Research Centre S.A. (CTO)
18.00	Bus transfer to Nantes Castle: Guided visit followed by AMT'09 dinner

Conference Programme

Tuesday 1st September	
	SESSION 2b - FREE RUNNING MODEL / SHIP TECHNOLOGIES
13.45 - 14.10	**Advanced free running model technology from model to full-scale** *E. Kennedy, G. Janes & T. Ennis* National Research Council Canada - Institute for Ocean Technology (IOT), Canada
14.10 - 14.35	**Subsea communications in a towing facility** *N. Kimber[1], H. van der Schaaf[2] & I. Crowther[3]* QinetiQ[1], MARIN[2] & WFS[3]
14.35 - 15.00	**Advanced model testing techniques for ship behaviour in shallow and confined water** *G. Van Kerkhove[1], M Vantorre[2] & G. Delefortrie[1]* Flanders Hydraulic Research[1] & Ghent University[2]
15.00 - 15.30	Coffee
	SESSION 3b - OTHER MODEL TESTING TECHNOLOGIES
15.30 - 15.55	**Studies on pod propulsors and related procedures – The unified approach** *R. Glodowski[1], M. Reichel[1] & J. Richards[2]* Ship Design and Research Centre S.A. (CTO)[1], HSVA[2]
15.55 - 16.20	**Torque measurement and friction elimination in tidal turbine model tests** *M. A. R. Knös, J. Dubois-Marshall, R. A. Norman and M. J. Downie* Newcastle University, U.K.
16.20 - 16.45	**Ship model propeller manufacturing by using RPT** *T. Bazzi & L. Benedetti* INSEAN – The Italian Ship Model Basin
16.45 - 17.10	**Design of a turbulent channel flow facility for antifouling coating research** *G.Politis, M. Atlar & M. Downie* Newcastle University, U.K.
18.00	Bus transfer to Nantes Castle: Guided visit followed by AMT'09 dinner

Investigations on micro-bubble velocity and size in a water jet using Interferometric Laser Imaging

G. Lacagnina[1], S. Grizzi[1], F. Di Felice[1], & G.P. Romano[2]
INSEAN[1] & University La Sapienza[2]

The use of imaging techniques is quickly becoming essential to obtain global quantitative information. In particular, for the investigation of hydrodynamic fields, the measurement of the velocity field is performed by means of Particle Image Velocimetry (PIV) using tracer particles as seeding. In addition, it is quite simple (at least theoretically even if not so simple in practice) to employ more or less the same set-up to derive also measurements of particle size by using defocusing techniques. Among the huge variety of acronyms used to individuate such measurement techniques, we will use Interferometric Laser Imaging (ILI). The feasibility of this technique has been demonstrated especially in sprays (water droplets in air) where the spherical shape and the refractive index values allow optimal light scattering. In this paper, ILI is applied in a bubbly jet flow as a benchmark for future investigations on incipient cavitation in marine propeller wake. The relevance of these measurements to the propeller performance evaluation is straightforward.

The set-up consists of an inclined Nd-Yag laser sheet (thickness 2 mm) crossing a bubbly jet generated by a pipe in which air bubbles are injected. Defocused images are acquired by means of a standard PIV CCD camera (equipped with interference filter) at a distance of about 20 cm. The water jet is placed in a perspex tank and the scattering angle is equal to about 30° (reflection ~ 1st-order refraction). Due to the inclination of the laser sheet in respect to the camera, the degree of defocusing is determined solely by this angle and can be derived by simple trigonometric relations. Image analysis is performed at each single frame to derive the size measurement (by looking at fringe spacing of defocused particle images) and on consecutive frames to derive the two velocity components on the plane (by using almost standard 2D-PIV).

Application of digital in-line holography to pipe flow visualization

N. Verrier, S. Coëtmellec, M. Brunel, & D. Lebrun
Groupe d'optique et d'optoélectronique, CORIA, France

Digital in-line holography (DIH) is a recognized optical technique for fluid diagnostics. For instance, fluid mechanics domain benefits from the 3D information contained in a digital hologram. The studied volume is seeded with tracers (e.g. small particles) and by retrieving information about these (3D position, velocity) we are able to characterise the studied fluid volume1. However, when dealing with pipe flows, astigmatism becomes a severe handicap for an accurate information retrieving.

1. Experimental set-up for a holographic pipe flow study

In this paper we apply DIH to a pipe. Due to the cylindrical geometry of the pipe, the optical set-up is astigmatic. A recently developed model allows us to deal with pipe flow holograms. By taking the pipe geometry into account, it is possible to better understand the optical set-up astigmatism and therefore to perform accurate measurements within the studied volume. Information contained in the hologram is then extracted by using the fractional Fourier transform (FRFT). As a matter of fact this operator is well adapted to wide angle astigmatism compensation.

Next the paper presents the pipe flow hologram and reconstruction using FRFT. After a short reminder about DIH, the specific case of pipe flow studies will be treated, leading to simulation, observation and reconstruction of astigmatic holograms.

Conference Programme

Wednesday 2nd September	
8.00 - 9.00	Coffee
9.00 - 9.50	**Presentation of HydroTesting Alliance Project Joint Research Programmes (6 - 9)**
9.50 - 10.00	**Presentation by Paisan Astavapranee, Chairman of the ITTC Detailed Flow Measurement Committee**
10.00 - 10.30	Coffee
	SESSION 4a - PIV \ LDA FLOW MEASUREMENT TECHNOLOGIES
10.30 - 10.55	**PIV study on the effectiveness of strakes on marine risers** *J. Visscher, S. Skarpengland, Ø. S. Hansen & B. Pettersen* Norwegian University of Science and Technology (NTNU), Norway
10.55 - 11.20	**Drag reduction estimate based on stereo PIV measurements of the wake behind a modified Ahmed Body** *R. Delfos[1], N. Semin[1], M. Hinderdael[2] & M. Harleman[1]* Delft University of Technology[1] & Stork Thermeq BV[2]
11.20 - 11.45	**PIV operation in hydrodynamic facilities** *D. Fréchou[1], L. Mèés[2], D. Lebrun[2], B. Friedhoff[3], G. Lammers[4], T. Bugalski[5], F. Di Felice[6], G. Romano[7], M. Verhulst[8], J. Hallander[9] C. Muthanna[10], N. Ireland[11], J.P. Borleteau[12], M. Ollivier[12] & R. Delfos[13]* *BEC[1],, CORIA[2], DST[3], HSVA[4], CTO[5], INSEAN[6], University ROMA[7] MARIN[8], SSPA[9], MARINTEK[10], QINETIQ[11], SIREHNA[12] & TU Delft[13]*
12.00 - 13.30	Lunch

Conference Programme

Wednesday 2nd September	
8.00 - 9.00	Coffee
9.00 - 9.50	**Presentation of HydroTesting Alliance Project Joint Research Programmes (6 - 9)**
9.50 - 10.00	**Presentation by Paisan Astavapranee, Chairman of the ITTC Detailed Flow Measurement Committee**
10.00 - 10.30	Coffee
	SESSION 4b - WAVE MEASUREMENT TECHNOLOGIES
10.30 - 10.55	**Acoustic wave height measurements in a towing facility** *A. Bouvy[1], R. Henn[2], & J. Hensse[3]* MARIN[1], DST[2], General Acoustics[3]
10.55 - 11.20	**Tow tank measurements of 3-D wave fields** *T. C. Fu & A. M. Fullerton,* Naval Surface Warfare Center, Carderock Division, USA
11.20 - 11.45	**Measuring sloshing impacts during full scale tests** *E. van de Bunt & M.L. Kaminski* MARIN, The Netherlands
12.00 - 13.30	Lunch

Introducing a seven-hole pitot arrangement for measuring wake flows in the towing tank

D. E. Liarokapis, G. J. Grigoropoulos and S. G. Perissakis National Technical University of Athens (NTUA), Greece

Pitot tube is a well established instrument to record experimentally the flow field in air and water. Seven-Hole Pitot tube is the most accurate implementation of this concept and is used widely for high precision measurements, as well as a reference tool for other flow field measuring methods or for flows where the direction can't be estimated even vaguely, prior to the experiment. The intrusive nature of the instrument, introduces certain limitations and the experimenter should adhere to its geometrical particulars. Furthermore complicated and sometimes cumbersome procedures should be followed in order to ensure minimum flow disturbance and maximum accuracy. The limitations and the recommended experimental policies depend strongly on the measurement case and the type of fluid.

The Laboratory for Ship and Marine Hydrodynamic of National Technical University of Athens (NTUA), has recently built an integrated system using a Seven-Hole Pitot tube to record the wake flow around ship models in the towing tank. It is well known that Pitot tubes measure at a single point. A 3-D traversing sub-system was used to translate the Pitot tube in the x-y-z axis directions rapidly and accurately. Various pressure sensors were fitted to suite each experimental condition. The above system as well the geometry of the probe, the calibration procedure, the positioning of the probe and the implementation of the system for underwater measurements, are issues of great importance and will be presented in detail.

Boundary layer development and shear stress measurements around an oyster table

Y. Kervella[1,2], G. Germain[1] B. Gaurier[1] , J.V. Facq[1], F. Cayocca[1] & P. Lesueur[2]
IFREMER[1], Universite de Caen-Basse Normandie[2]

An oyster table is a structure made of metallic rod on which porous plastic bags of oysters are laid. This structure which is 100m long by 1m wide is installed over muddy or sandy tidal flats. An oyster farm whose dimension can be several squared kilometres, consists of a set of rows of these tables. Due to the complex organisation and hydrodynamic context, the impact inherent to this kind of structures has been little investigated so far; and the lack of knowledge about the impact of an oyster farm on the flow remains a significant difficulty for the comprehension of sediment transport processes in oyster growing areas.

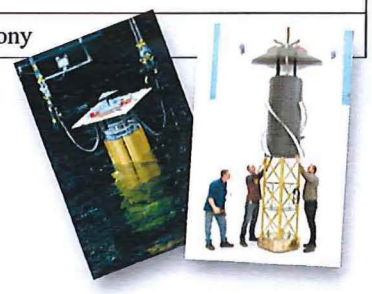
The present study aims at experimentally estimating the impact of an oyster table on the flow. The experiments were carried out in IFREMER free surface flume tank in Boulogne-sur-Mer, France.

Conference Programme

Wednesday 2nd September	
13.30 - 14.45	Facilities Tour
	SESSION 5a - PIV \ LDA FLOW MEASUREMENT TECHNOLOGIES
14.45 - 15.10	**HTA-JRP1 Flat Plate Experiment: Assessment of SPIV Problems and Accuracy in Towing Tank Applications** *J. P. Borleteau[1], R Delfos[2], F. Di Felice[3], C Muthanna[4]* SIREHNA[1], TU Delft[2] INSEAN[3], MARINTEK[4]
15.10 - 15.35	**Boundary layer development and shear stress measurements around an oyster table** *Y. Kervella[1,2], G. Germain[1] B. Gaurier[1] , J.V Facq[1], F Cayocca[1] & P. Lesueur[2]* IFREMER[1] & Universite de Caen-Basse Normandie[2]
15 35 - 16 00	Coffee
	SESSION 6a - HIGH SPEED VIDEO AND IMAGING TECHNOLOGIES
16.00 - 16.25	**Investigations on micro-bubble velocity and size in a water jet using Interferometric Laser Imaging** *G. Lacagnina[1], S Grizzi[1], F. Di Felice[1], & G.P. Romano[2]* INSEAN[1] & University La Sapienza[2]
16.25 - 16.50	**Determination of wetted surface** *B Allenström[1], A. Chodorowski[2], H. J. Rambech[3] & J. Tukker[4]* SSPA Sweden AB[1], Chalmers University of Technology[2], Marintek[3] & MARIN[4]
16.50 - 17.15	Discussion and Closing Ceremony

Conference Programme

Wednesday 2nd September	
13.30 - 14.45	Facilities Tour
	SESSION 5b - OTHER MODEL TESTING TECHNOLOGIES
14.45 - 15.10	**Introducing a seven-hole pitot arrangement for measuring wake flows in the towing tank** *D. E. Liarokapis, G. J. Grigoropoulos and S. G. Perissakis* National Technical University of Athens (NTUA)
15.10 - 15.35	**Application of digital in-line holography to pipe flow visualization** *N. Verrier, S. Coëtmellec, M. Brunel, & D. Lebrun* Groupe d'optique et d'optoélectronique, CORIA, France
15.35 - 16.00	Coffee
	SESSION 6b - WAVE MEASUREMENT TECHNOLOGIES
16.00 - 16.25	**3D structures in wave elevation patterns** T. Stansberg[1], D. Frechou[2], R. Henn[3], J. Hennig[4], A. Bouvy[4] J.P. Borleteau[5], M. Ollivier[5] & H. Ran[6] MARINTEK[1], BEC[2], DST[3], MARIN[4]; Sirehna[5] & SSPA[6]
16.25 - 16.50	**Development of a laser wave gauge for dynamic wave height measurements in the B600 towing tank** *J-B Richon[1], M. Reeves[2], M. Darquier[3] & D. Fréchou[3]* Laser & Imaging Sciences[1], MRA Technology Ltd[2] & Bassin d'Essais des Carènes[3]
16.50 - 17.15	Discussion and Closing Ceremony



characterization for drag reduction by micro-bubbles, sloshing flows, water jets, etc.

To address these many topics and face the variety of testing facility environments, a specific benchmark test has been devised to investigate the state-of-the-art PIV technology in term of efficiency (calibration procedures, model and SPIV handling, SPIV productivity) and accuracy.

The adopted test case is a piercing surface flat plate at incidence. This is a simple and significant test case: the presence of high gradients (Tip Vortex), surface effects, bubbles nearby the free surface regions, reflections from the model surface is an important benchmark for Stereo PIV measurement systems. The plate is a steel rectangular plate of L= 500 mm x H= 800 mm with rounded leading edge and trailing edge. The test conditions defined for the benchmark require measurement on 2 cross-planes at an immersion of 300 mm an incidence of 20° and a speed of 400 mm Plane location are showed in figure 1. Detailed test specifications can be found on the HTA web site http://www.hta-noe.eu. In figure 2 is shown the flat plate benchmark setup when testing in the towing tank n°1 at INSEAN. In figure 3 is shown the velocity distribution in the measurement planes P2. The flat plate test have been already completed by some HTA partners and in the conference a detailed insight into the benchmark specifications and into the first measurements will be presented.

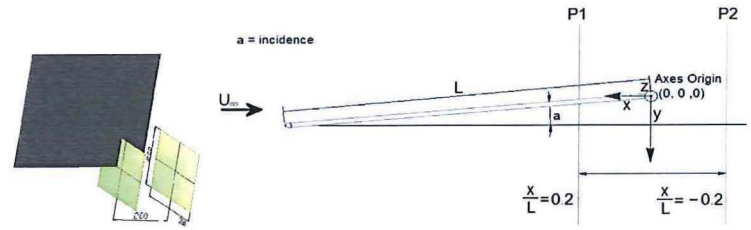


Fig1: SPIV measurement planes location: the flow is from the left to the right.

HTA-JRP1 Flat Plate Experiment: Assessment of SPIV Problems and Accuracy in Towing Tank Applications

J. P. Borleteau[1], R. Delfos[2], F. Di Felice[3], C. Muthanna[4]
SIREHNA[1], TU Delft[2] INSEAN[3], MARINTEK[4],

HYDROTESTING ALLIANCE (HTA) is the European Network of Excellence to facilitate the continuation of leadership of the European Hydrodynamic testing facilities. The objective of this alliance is to develop a formal and lasting structure to coordinate the definition and introduction of novel measurement techniques for ship model testing. Amongst the various techniques the relatively recent development of Particle Image Velocimetry (PIV) has renewed the interest in the field of experimental naval hydrodynamics and is one of topic of the cooperation within the Network.

PIV has many advantageous features that are making it popular among the Towing Tank Institutions: it allows the study of the spatial structure of the flow since it's able to characterize the flow field in planar areas; the recording time is very short and depends essentially on the technological evolution of the acquisition and processing components; the analysis can be done *a posteriori*, which is a definitive advantage when high cost facilities are being used as in ship model testing; PIV is less demanding in terms of technical expertise; stereoscopic PIV (SPIV), the latest evolution of planar PIV, allows 3-component velocity measurements in a plane.

In the particular field of naval hydrodynamics, PIV has seen its range of applications widely expanded in the last years: submarine flows, ship wake, ship roll motion, propeller flow in off-design conditions, wave breaking, freak waves, free surface flows, bubbly flows, boundary layer

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Measuring sloshing impacts during full scale tests

E. van de Bunt & M.L. Kaminski
MARIN, The Netherlands

This paper describes the measuring equipment that is used in the first full scale tests on a real membrane containment system subjected to action of breaking waves representative of sloshing impacts in LNG tanks.

The focus will be on the measurement equipment that is used to capture the wave breaking process before and during the impact using the combination of high speed video cameras and a specially designed optical instrument called the iCAM. The iCAM is a matrix of 640 optical sensors capable to differentiate between solid water, aerated water and air.

The impact of the wave on and the response of the containment system were measured using 300 sensors including pressure gauges, strain gauges and load cells. The paper will describe how the pressure sensors were designed and explain why they include a special silicone membrane of high stiffness. The dynamic calibration process of the pressure sensors will be described using a specially designed shooting device and high speed video cameras.

After that the paper will describe the data acquisition system used which is a high speed, synchronous sampling, single shot type measurement system. Finally, the performance of the measuring equipment during the 110 tests will be evaluated.

Tow tank measurements of 3-D wave fields

T. C. Fu & A. M. Fullerton,
Naval Surface Warfare Center, Carderock Division, USA

Naval Surface Warfare Center, Carderock Division utilizes a number of advanced techniques to measure the three-dimensional wave field generated by a moving ship. These instrumentation systems include a scanning Light Detection and Ranging, (LiDaR) system, a laser sheet-optical quantitative visualization (QViz) system, a Nortek Acoustic Wave and Current (AWAC) profiler, ultrasonic range finders, finger probes, and capacitance wires. These systems have been used extensively to topographically characterize the ship generated wave field both in the open ocean and in the tow tank. Recently, a number of these systems were used concurrently to measure the wave generated by a large generic transom stern model. This model was large enough (length ~10 m and beam ~1.5 m) and the speeds tested high enough (2.5 to 4.5 m/s) that a large breaking transom wave was generated. Though this work was primarily focused on providing the time averaged, and spectral content of the transom wave structure, it also provided an opportunity to directly compare measurements from a number of these instrumentation systems.

This paper describes this recent effort and compares the advantages, limitations, and measurements of the LiDaR, QViz, AWAC, and ultrasonic range finder systems. Each of these systems has inherent measurement issues related to how the measurements are made, their sampling frequency, and spatial resolution. Additionally, in that the model tested generated a large (10's of cm) breaking wave the region being measured was a complex multiphase turbulent flow structure. The ability of each of these techniques to accurately characterize the time-averaged free-surface elevation, as well as the spatial and temporal content is assessed.

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Acoustic wave height measurements in a towing facility

A. Bouvy[1], R. Henn[2], & J. Hensse[3],
MARIN[1], DST[2], General Acoustics[3]

In the world of full-scale systems for wave height measurements, acoustic technology is often used and provides accurate wave height data at low to medium data rates. However, at model scale these acoustic systems cannot be easily deployed in a test basin, due to the smaller and shorter waves, and various acoustic reflections from other structures around the test setup. Challenges of this remote sensing technology are the high measuring data rate while allowing acceptable distances above the water level. Still, the advanced acoustic wave probe technology has proven itself to be a valuable solution for towing tank applications.

In the paper the technical background and application area of the acoustic wave probe will be explained. Also the experiences with these systems at DST and MARIN with their typical applications will be mentioned. The applications at DST are focused on shallow water wave fields. The design and the first experiences with the underwater probes will be described. At MARIN, the main applications are high speed models in short crested sea conditions. One of the challenges in using the acoustic technique is the appearance of spikes in the measurement signals due to multiple reflections or because very steep waves, breaking waves or bubbles at the surface make reflections to get lost. The correction of these effects requires a considerable effort during post processing of the measurement data. This effort could be reduced by utilizing further developments at the transducer technology and more complex, application orientated algorithms and user selectable settings integrated in the controller. Furthermore, a new parameter set signaling the quality of the acquired raw measuring data may ease a future post processing. With all these improvements the acoustic technology will be applicable in new very demanding applications. Finally, the paper will conclude with application guidelines, plans and recommendations for future work.

PIV operation in hydrodynamic facilities

D. Fréchou[1], L. Mèés[2], D. Lebrun[2], B. Friedhoff[3], G. Lammers[4], T. Bugalski[5], F. Di Felice[6], G. Romano[7], M. Verhulst[8], J. Hallander[9] C. Muthanna[10], N. Ireland[11], J.P. Borleteau[12], M. Ollivier[12] & R. Delfos[13]
BEC[1], CORIA[2], DST[3] , HSVA[4], CTO[5], INSEAN[6], University ROMA[7] MARIN[8], SSPA[9], MARINTEK[10], QINETIQ[11], SIREHNA[12] & TU Delft[13]

PIV has many advantageous features that are making it popular among the Towing Tank Institutions: it allows the study of the spatial structure of the flow since it's able to characterise the flow field in planar areas; the recording time is very short and depends essentially on the technological evolution of the acquisition and processing components; the analysis can be done *a posteriori*, which is a definitive advantage when high cost facilities are being used as in ship model testing; PIV is less demanding in terms of technical expertise; stereoscopic PIV (SPIV), the latest evolution of planar PIV, allows 3-component velocity measurements in a plane. In the particular field of naval hydrodynamics, PIV has seen its range of applications widely expanded in the last years: submarine flows, ship wake, ship roll motion, propeller flow in off-design conditions, wave breaking, freak waves, free surface flows, bubbly flows, boundary layer characterization for drag reduction by micro-bubbles, sloshing flows, water jets, etc. To address these many topics and face the variety of testing facility environments, a specific benchmark test has been devised to investigate the state-of-the-art PIV technology in term of efficiency and accuracy. The adopted test case is a piercing surface flat plate at incidence. This is a simple and significant test case: the presence of high gradients (Tip Vortex), surface effects, bubbles nearby the free surface regions, reflections from the model surface is an important benchmark for Stereo PIV measurement systems. The test conditions defined for the benchmark require measurement on 2 cross-planes at an immersion of 300 mm an incidence of 20° and a speed of 400 mm Plane location.

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Challenges for PIV in towing facilities

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MARIN, The Netherlands

Particle Image Velocimetry (PIV) has proven world-wide to be a promising flow measuring technique for the maritime fluid mechanics research. PIV visualizes the spatial structure of steady and unsteady flows and delivers data sets for validation of numerical Computational Fluid Dynamics (CFD). This technique is supplementary to other flow measuring techniques, for example, paint tests, pitot tubes and Laser Doppler Velocimetry. Over the last 5 years various PIV measurements campaigns have been conducted at MARIN with the SIREHNA-MARIN PIV system. This modular PIV system has been used in multiple configurations, for various purposes and in different towing facilities. An overview will be given of the projects, their results and the major findings of using the PIV system. During these tests campaigns the PIV technique has shown his strengths but also his weaknesses. In this paper both aspects will be discussed.

The next challenge is to improve the PIV-system and the measuring and analyzing procedures so that PIV will become more and more a standard tool for towing facilities. The aim for the future is to perform PIV tests at low operational costs. This will be an essential condition to increase the use of PIV for the maritime market. PIV gives more detailed information about the spatial structure and dynamics of the flow. This information can be used for validation of numerical CFD-codes and to improve the design of ships and propulsion systems. To fulfill this new challenge MARIN had ordered a new stereo-PIV system end 2008. The design of this system, the supporting systems and the measuring and analyzing procedures, are based on the latest developments and lessons learned. The system will be operational mid 2009.

Drag reduction estimate based on stereo PIV measurements of the wake behind a modified Ahmed Body

R. Delfos[1], N. Semin[1], M. Hinderdael[2] & M. Harleman[1]
Delft University of Technology[1] & Stork Thermiq BV[2]

Stereoscopic PIV measurements were carried out to study the influence of spoilers on the turbulent wake behind the 'Ahmed body'. This geometry is frequently used as a model for bluff road vehicles. Possible way to reduce aerodynamic form drag is by adding a 'boat tail' behind the body; a tapering section that pulls the side wall boundary layers inwards in order to decrease the width of the wake. An alternative could be rounded spoilers. The goal of the present investigation is to compare the wake flow with and without the spoilers.

Measurements were carried out with a fixed model on a 'false floor' in a water tunnel. The same mechanical and optical settings are used as reported in the SPIV measurements done for the HTA-JRP1 benchmark 'plate' geometry, i.e. planes perpendicular to the mean flow. Two tunnel velocities were used, with corresponding body length Reynolds numbers of 2.0x104 and 1.8x105; the former being accessible also using DNS. The model, of which the boundary layers were tripped using zig-zag tape, was mounted on a sliding platform to enable measuring in 12 successive planes, each shifted over 2 cm without moving laser or cameras. In each cross section 500-1000 PIV recordings were taken to acquire appropriate flow statistics.

The paper presents the results of the study, including some of the peculiarities of the measurement technique.

PIV study on the effectiveness of strakes on marine risers

J. Visscher, S. Skarpengland, Ø. S. Hansen & B. Pettersen
Norwegian University of Science and Technology (NTNU)

Vortex induced vibrations (VIV) is one of the key sources in fatigue damage of marine risers and thus contribute considerably to their design conditions. From experience and previous studies, helical strakes – screw like obstacles wrapped around the cylinder – are known to have a supressing effect on VIV. However, little is known about the actual physics of the flow field around such a straked cylinder, nor about how exactly the wake is being reshaped by the strakes.

Baarholm and Lie (2005) studied extensively the effect of the single strake parameters like height, pitch and number. From their 20 different cylinder models, two characteristic ones were picked and painted for PIV purposes. For the paint, a mixture of Rhodamine B and black water-based paint was used. Thereafter, a transparent varnish was applied to prevent paint particles to be dissolved into the water and to enhance the reflectivity. Together with high-quality 532nm band pass filter glasses, which were mounted directly into the C-mount of the cameras, this eliminated effectively bothersome reflections in the images. The experiments were done in NTNU's "MClab" towing tank facility. Unlike previous PIV studies performed in this lab, a new combination of equipment was used in the present study. From the available material it is obvious that the chosen set-up has proven to work very well. First vector field results indicate that the strakes have a strong breaking effect on the wake. Unlike the characteristic vortex street behind smooth cylinders, the wake behind a straked cylinder shows a larger area of strong turbulent mixing, with rather small size eddies to be formed.

State-of-the-art towing-tank PIV and LDA systems

P. Gjelstrup
Dantec Dynamics A/S

In the last decades the demands for high quality experimental results about flow structures and quantitative flow measurements increased tremendously. These results are necessary, for example, to validate and verify codes and models used in Computational Fluid Dynamics (CFD). Depending on whether turbulence models or Large Eddy Simulations need to be tested, the best-suited measurement technique must be chosen. Nowadays, two laser-optical flow velocity measurement techniques are widely used towing tanks: the highly accurate and highly time-resolved point technique Laser Doppler Anemometry (LDA) and the whole field Particle Image Velocimetry (PIV) with the ability to measure instantaneous planar sections of the flow field with a moderate temporal resolution. Both LDA and PIV can be configured to measure all three components of the velocity vector simultaneously. While LDA has become a very mature technique, PIV is still rapidly evolving both in terms of the hardware used (cameras and lasers) and the software (algorithms used to determine velocities and graphical user interface to make the handling of a PIV system as user friendly as possible). To be of practical use in towing tank applications, the systems must have a low weight, a streamlined shape and be able to acquire e.g. propeller shaft angle or wavemaker data. Rapid feedback about the quality of the measurement is important, and acquisition, storage and analysis of data must be distributed over computer networks in order to shorten the post processing process.

Development of a new PIV technique for flow field measurements in the towing tank

D. E. Liarokapis, G. J. Grigoropoulos & S. G. Perissakis
National Technical University of Athens (NTUA), Greece

PIV measurement is nowadays a common tool for studying the flow field around ship models in the towing tank. Although the PIV technique is considered relatively inexpensive method, it still needs extremely high frequency cameras in order to measure the flow field for model speeds corresponding to the service speeds of modern ships models. In this paper we introduce a new approach for 2D PIV measurements which utilizes normal frequency cameras. The concept is based on the use of two or more standard cameras, which are triggered with a precise small delay, as short as desirably. The delay can be reduced to a small fraction of time between two subsequent recordings of each camera. Combining the recordings of different cameras focusing on the same flow field region, the respective velocity vectors of the flow field can be recorded. Special electronic hardware and software was devised to control and synchronize the cameras. The aforementioned technique developed at the Laboratory for Ship and Marine Hydrodynamics of National Technical University of Athens (NTUA) for PIV measurements in towing tank will be presented

Design of a turbulent channel flow facility for antifouling coating research

G.Politis, M. Atlar & M.J. Downie
Newcastle University, U.K.

The development of novel marine antifouling coatings has led to the need for better test methods to evaluate their performance. A fast and economical method to test such coatings is the turbulent channel flow apparatus most widely know as flowcell. There are currently a limited number of flowcells that are used in the antifouling coating research worldwide. The main advantage of such a facility is that it can cater for the testing of marine coated surfaces and help us understand the interaction of those surfaces with biofouling in natural sea water, under optimum flow conditions. A new flowcell has been designed and manufactured in Newcastle University within the framework of AMBIO (FP6) EU project. This flowcell is unique in terms of size, flow characteristics and the fact that operates under realistic full scale flow conditions. The main innovation involves the ability to test not only adhesion strength of biofouling over coated surfaces but also its effect on skin friction.

The paper presents the CFD study performed for the design of the present facility. Experimental results are also included that compare well with CFD data. The paper includes preliminary results from bio-fouled surfaces and recommendations for the design of a flowcell.

Ship model propeller manufacturing by using RPT

T. Bazzi and L. Benedetti,
INSEAN, Italy

The manufacturing process of ship models components (i.e. rudders, propellers, fins, brackets, etc.), can be a time consuming and expensive procedure. For these reasons in the last 10 years, the research community in collaboration with the industries has developed new manufacturing techniques aimed at reducing the prototyping cost and provide rapidly models ready to be tested; moreover, a significant reduction of the necessary surface treatments and hand finishing has been achieved.

In the present paper a review of the possible applications of rapid prototyping techniques for the production of model scale ships components is presented. A comparison of the hydro-dynamical behaviour of similar propellers at model scale, made with different materials and produced using SLS and SLA techniques, is reported. The results of open water tests carried out at INSEAN towing tank on the geometry of the E779 propeller are presented to establish the range of better use of the several tested propellers.

A wireless Inertial Motion Unit (WIMU) for motion analysis in towing tank experiments

F. La Gala & M. Gammaldi,
INSEAN

In This paper is described the work done in designing and fabricating a miniaturised inertial measurement units (IMU) which can be used in a wireless sensor network in towing tank tests. In particular this IMU is designed to be used in sea keeping test and in general for free model tests. The main purposes are set-up time reduction, error free data transmission, time base synchronization with other data acquisition systems, and to eliminate experimental error due to mechanical interactions of connection cables.

The IMU developed is a high-dynamics sensor module that includes a 3-axis magnetometer 3-axis gyro and 3-axis accelerometer. The mechanical dimensions are 50x30x20 mm and its weight is 20g + 60g of battery. The imu is obviously battery operated and has an autonomy of 30 hours in continuous operation. The wireless data transmission is realized with an wide bandwidth embedded bluetooth module easy to interface to a laptop or handheld computer. To prevent loss of data in case of momentary radio link unavailability , on the module is implemented a data recovery system using an additional mass memory storage The total system is packaged in a modular form factor which gives the capability for the module to be utilised in a wide variety of projects incorporating a multitude of actuators/sensors in miniaturised, mobile, autonomous systems. For outdoor applications the imu can be used, for example to implement an high frequency complete attitude and position sensor connecting a gps antenna to one of its additional inputs. This paper outlines the development of the system with particular emphasis on the IMU l and wireless layer and some benchmark test are performed.

Processing navigation data collected in-service on board of the ferry SeaFrance Rodin

T. Muntean[1], H. Vincent[2], F. Irzal[3] & S. Van Eijndhoven[3],
Wärtsilä Netherlands[1], SeaFrance[2], Eindhoven University of Technology[3]

In this paper we reconcile full scale measurement data with forecast data obtained from a ship kinematic model and thus obtain reconciled ship's speed-through-water, speed-over-ground, position, and heading. Our findings are based on measurements collected by a tailored monitoring system installed on-board of the SeaFrance Rodin. Measurements are logged continuously and the raw signals are transferred via remote access connection to the research department at Wärtsilä Netherlands for processing. Analysis of the raw signals reveals distortions due to ship motions, sensors, and measurement equipment. Since the distorted signals do not reflect the real ship kinematics, the navigation information obtained from these signals must be corrected. Correction of signals is done by a dynamic data reconciliation approach that balances the data retrieved from the full scale measurements with the forecasted data from the kinematic model. Noise level in the data determines to what extend data are to be corrected by the model. We introduce a multi-resolution analysis to decompose the signal into trend, harmonics, and noise. The trend and the periodic component are determined such that they reflect the true motion of the ship and the natural oscillation characteristic for this motion, respectively. The measured ship motions, the trends, are reconciled with the motions predicted by the ship kinematic model. Ship kinematics is modeled in two dimensions and with four degrees-of-freedom. The comparison between the measured ship motion data and the reconciled ship motion data shows significant improvement in terms of variations and undesired harmonic components. As a result of the dynamic data reconciliation procedure, the noise component of each measured signal is suppressed and the influences of pitch and roll harmonics on surge and sway are removed.

Torque measurement and friction elimination in tidal turbine model tests

M. A. R. Knös, J. Dubois-Marshall, R. A. Norman and M. J. Downie
Newcastle University, U.K.

The drive to find cleaner, sustainable energy sources has changed the focus of research in the marine industry. The testing of marine renewable devices presents a new set of problems that differ from those associated with traditional hydrodynamic testing. Most renewable energy systems can be described as small volume devices as their hulls are designed for equipment and buoyancy not storage. Therefore finding a means of measuring the power take off of a small scale free floating tidal turbine can be problematic. This paper looks at the problems associated with model scale friction and measuring shaft torque inside a compact turbine body. Equipment and test procedures have been developed to overcome model turbine shaft friction during torque measurement.

To test the solution data was obtained from a calibrated clutch in a 40th scale model of the Evopod tidal turbine. The tidal turbine tests were conducted in the combined Wind Wave and Current tank at Newcastle University.

The tank data was then used on a test bench to mimic the torque and speed produced by Evopod in a controlled environment. The torque measurement equipment was calibrated and then used to produce reliable repeatable results through the range of real test data. In this approach it is possible to reduce the shaft friction to zero. This allows a near zero torque maximum turbine speed to be measured when it is incorporated into a small scale tidal turbine. Near linear results were obtained across the speed range for device output against torque.

Studies on pod propulsors and related procedures – The unified approach

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Since they appeared on the market, pod propulsors have been gaining increasing interests in shipbuilding industry due to their operational advantages; this growing popularity forced research institutions to activate number of studies, incl. domestic and European projects. Specification of the pod systems results in alternative approach to the related analyses, starting from unique dedicated measuring equipment applied for pods experimental investigations up to the testing and full scale recalculations procedures. Therefore pods have been specified as one of Joint Research Programme (JRP no. 4) within Hydrotesting Alliance network.

Within the scope of JRP4 different issues related to pods performance are considered. Short summary of the common research problems (gathered as a feedback from both: research hydromechanics institutes involved in the project and pod propulsors end-users) and areas of interests, related to the investigations of pods propulsors are described in the actual document. Moreover, results of the actual JRP studies focused on standardization of the testing procedures regarding pods performance are presented - the joint procedure and following benchmark tests have been proposed in relation with preceding comparative studies (ABB case), which exposed significant discrepancies between the results of pods related investigations, caused by inconsistent procedures applied by different research institutes. In case of the JRP4 works, the unified approach, regarding main parameters of the tests, has been elaborated and confirmed by set of the measurements at Partners' facilities.

Hydrodynamics of damaged ship in roll mode of motion – an experimental approach.

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From the earliest times of the naval architecture the problem of describing roll motion has been matter of great interest to the designers, shipbuilders, owners and operators. The first systematic approach to the problem can be accounted to William Froude and later by Vugts who performed his systematic experimental studies on rolling cylinders, which finally proved compliance of the theory and observations. Also of relevance to the current paper, Himeno and Ikeda published research on semi-empirical techniques for estimating non-linear damping phenomena. Until now such combined approach (the linear theory predictions supplemented with semi-empirical correction factors) constitutes standard way of predicting hydrodynamics of intact ship. Obviously there are new methods presented nearly each year but so far the standard seems to be unalterable, although the limitations of present approach are well known (e.g. small-amplitude motions assumption). In case of damaged ship problem is far more complex. Usually, dynamical models of damaged ships make use of the hydrodynamic coefficients derived for intact ship models but such hybrid method seems to be unsatisfactory for numerous reasons (e.g. much larger number of degrees of freedom in the configuration space or strong time dependency of flooding phenomenon). This paper presents some technical aspects of hydrodynamic forces measurements on free-to-float cylindrical body with use of gyroscopic roll generator, performed at University of Strathclyde facilities. Although the concept is not entirely original there are certain new features introduced for improved measurements quality. The paper explains principles of the design and demonstrates scope of intended application. Particular operating aspects are also discussed in details and some early-stage results presented.

Analysis of high-speed video data for assessment of the risk of cavitation erosion

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The risk of cavitation erosion on particularly propellers can e.g. be estimated by the soft paint technique, i.e. an evaluation of the removing that may occur, due to cavitation, of a soft paint applied on the propeller during a test in a cavitation tunnel. This technique is systematically developed by e.g. SSPA into a very reliable and fast procedure. The reliability, and particularly the links to design, can be further extended by supplementing the paint test by high-speed video recording. In the paper is presented a simple analysis of high-speed video data, extending the analysis originally suggested in the "EROCAV Observation Handbook" (Chalmers 2004).

The extended method is based on the cavity collapse as described by the Rayleig-Plesset equation. The solution describes primarily the motion of the cavity interface, and via the pressure equation, also the generated pressure, both being of interest. By making an approximation of the pressure expression and combining this with knowledge of the micro-hydrodynamics of the erosion process, it can be concluded what would be expected as the optimal way of plotting high-speed video data. The so derived plotting does not only capture the focusing in space and time of collapse energy, according to the erocav handbook, but also points towards design considerations in a general way. The plotting does not, of course, indicate unique design actions but indicates, for the experienced engineer, directions to follow by application of advanced CFD analysis, with or without simulation of cavitation, or by application of an experimentally based analysis. By applying this plotting in a number of projects it is also believed that a systematic knowledge of design actions with respect to cavitation erosion can be created. The suggested plotting is applied to some cases with cavitation of different aggressiveness.

Applications of Stereo Particle Image Velocimetry to Ship Wake and Propeller Flows

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Over the past years, Particle Image Velocimetry (PIV) has a rapid development and is now a reliable experimental technique for naval research applications This technique could be implemented in towing tanks for the complex study of propeller flows. The growth of the PIV is linked to the improvement of hardware components: high energy lasers, nanosecond pulse duration, low –noise and higher –resolution of CCD cameras, faster frame grabbers and computers. The CTO's submersible stereo PIV system for contact free investigation of ship stern and propeller flows, designed for the use in the towing tank is described. Flow conditions can be analyzed with a resolution of a few thousand points simultaneously providing a deep insight into flow characteristics without disturbing the flow. The paper will describe three applications of the system that have already been carried out (nominal and effective wake fields – EFFORT project and flow about blades of working propeller in stern of ship condition –Leading Edge project) and will discuss problems and advantages of the 3D PIV system.

The potentials for validation of CFD calculations will be also discussed. Future CTO plans for further applications of the PIV system will be introduced.

Tip vortex measurements of a rectangular hydrofoil using stereoscopic particle image velocimetry technique (SPIV)

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Tip vortex is of great importance because of both fundamental and practical interest for its impact on various aspects of aerodynamic/ hydrodynamic performance. Especially, tip vortex of a propeller on ship causes vibration and noise. Prior to measuring propeller tip vortex, hydrofoil is adopted to confirm the SPIV system including the analysis algorithm.

In this paper, tip vortex of a 3-dimensional rectangular hydrofoil with NACA0012 section was measured in the cavitation tunnel at Seoul National University. Test section sizes of the cavitation tunnel are $0.3m^H$ x $0.3m^W$ x $1.5m^L$, and the maximum speed is 16m/s. The test model was made with acryl using 5-axis CNC (computer numerical control) machine in order to let the light sheet transmit the test model. Chord and span of the model are *200mm* and *148mm*, respectively. The equipments for the test are like these: Nd-YAG pulse type laser, two *1k* x *1k* CCD cameras, two tilt and shift lenses (PC Micro-Nikkor 85mm f/2.8D), synchronizer, and two mirrors. In order to diminish the distortion of the image due to the three different media (air, acrylic window, and water), mirrors are attached inside of the cavitation tunnel. Tip vortex was measured at 11 locations (z/c = *-0.4~1.0*) at Reynolds number $4x10^5$ based on the chord length (c) when the angle of attack of the model is 10 degrees. *1,300* pairs of images are used to analyze tip vortex at every measuring location. The time interval of each pair of image is *100*μs. Tip vortex core location and tip vortex core radius in the mean flow fields are analyzed and the variation of tip vortex core location and tip vortex core radius in the instantaneous flow fields are analyzed. Finally, in order to verify test results, computations are conducted using commercial code, Fluent.

Methods and procedures for high-speed video recording and analysis of pressure fluctuations in propeller cavitation

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Propeller cavitation tests at model scale are a reliable tool to assess the risk and extent of cavitation blade erosion or induced hull vibrations at full scale. The high speed video (HSV) recording technique has been demonstrated to be an invaluable tool, since it offers a time-resolved recording of the cavitation pattern during the propeller revolution. However, the technique implies a significant increment of resources, and know-how. For instance, HSV requires very high intensity illumination in order to obtain acceptable signal-to-noise ratio, because of the short exposure times imposed by the high frame rate. Also, an HSV system generally generates very large image datasets, thus requiring adequate storage hardware and management software. Finally, dedicated and efficient analysis algorithms are necessary to process the image data in a reasonable frame of time and to extract meaningful quantitative information.
The intent of the present work is to establish guidelines for the use of HSV in combination with pressure and noise measurements. In the first part, we review the technical requirements for an adequate implementation of HSV. A state-of-the-art of the high-speed video hardware is presented, as well as guidelines on its best use and recommendations on the illumination and image preconditioning in order to obtain the optimal image quality for analysis. In a second part, we describe practical implementations and cases of interest, which illustrate the procedures and methods used in different hydrodynamic testing facilities. These examples provide an overview of the various measurement setups and analysis techniques for pressure and noise data, as well as indications of the possible correlations that can be established when the aforementioned data are taken synchronously to the HSV image recording.

Propeller cavitation 3D reconstruction through stereo-vision algorithms

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In recent years an increasing interest towards innovative techniques to be applied in usual experimental facilities has grown. From cavitation tunnel point of view, attention has been given to measurement of dimensions of propeller cavitation bubbles. The need arise from the increase in ship performance and environmental/comfort requirements, leading to new standards in propeller design. In addition Computer Fluid Dynamics developed in recent years new tools to investigate these phenomena, but they still lack in validation with experimental data. Therefore the usual simple human observation seems to be no more adequate to determine propeller behaviour with respect to cavitation. Moreover it does not supply data directly and objectively comparable with numerical results.

In this scenario computer vision seems to be a promising research tool, because of relative limited hardware cost and of the availability of many software libraries. Additionally, computer vision is continuously spreading in many fields providing new algorithms and techniques. In this paper the experimental setup and software tools currently under development in the cavitation tunnel of Genoa University are presented. In particular three standard video surveillance cameras are adopted, while the OpenCv computer vision library is used for software development. Although this library provides a good support to 3D reconstruction its application in this environment is not straightforward, mainly because the optical path is not standard. Currently a volume reconstruction method and an active stereo technique, with source light produced by a triggered laser, are studied. In present paper both techniques are presented along with preliminary results, clearly outlining their merits and shortcomings.

Stereoscopic PIV Measurements of Rudder Flow and Vortex Systems in the Towing Tank

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Thorough knowledge of flow conditions is an important prerequisite for competitive ship and propeller design. In ship model basins conventionally used five-hole pressure probes are well established and reliable tools for standard flow analysis, and LDV measurements have been serving the same purpose for a long time, providing non-intrusive access to the targeted area. In some regards, they suffer from several deficiencies in terms of spatial resolution, limited inflow directions, capability to indicate flow separation, and so on. With the development of affordable high-performance digital image recording technologies Particle Image Velocimetry (PIV) has become a widely spread tool for flow analysis, mainly for gaseous media and smaller amounts of liquids. Since 2006, the Potsdam Model Basin (SVA Potsdam) is able to perform stereoscopic PIV measurements in the towing tank and the cavitation tunnel by means of a submersible PIV system. It allows the contact-free determination of all three components of arbitrary velocity fields in the towing tank and cavitation tunnel with a spatial resolution of several thousand points simultaneously, with a frame rate of up to 15 pictures per second, thus providing a good insight into flow characteristics without disturbing the flow.

The paper will describe the setup of several applications of the system that have already been carried out in the towing tank of SVA Potsdam and will present some results of measurements, e. g. of rudder flow with working propeller and of vortex systems behind an airplane like wing configuration

A Novel Approach for Stereo PIV Calibration in Towing Tank

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Particle image velocimetry (PIV) is a well-established, non-intrusive technique for the measurement of velocity in a plane of interest within a flow domain. The accuracy of the velocity measurement depends upon two principal factors: the accuracy with which the image displacements can be determined and the accuracy with which these image displacements can be transposed to the physical space. The first aspect is normally taken care of by the processing algorithms of PIV, and a lot of work has been done in this area to extract the most of the image information in order to reach the highest levels of accuracy in the image space. On the second point, the general approach relies on a calibration phase where a target of known geometrical characteristics is placed accurately in the plane of the laser light sheet and is imaged by the PIV cameras, exactly as in the conditions of the experiment. The present work introduces a method that eliminates the need of a target to determine the mapping function, simply by replacing it by a reference flow. The novel method has a number of unique advantages. In the first place, the PIV user is relieved from the need to place a target in the plane of the light sheet. The target-based calibration is also impracticable in many instances of interest. In these situations, where PIV measurements are to be done in tow tanks, large circulating water tunnels, wind tunnels, or in full-scale experiments (e.g. at sea), not only the optical parameters are not changeable, but also the target placement might be very difficult, if not impossible. In all these cases, a target-free calibration is highly desirable. The proposed method has been devised with this objective, without the drawbacks and redundancy of some recent proposals. The paper describes the full analytical development of the principle, its assessment and its application to a real-world case. In fact, the technique is applied to the data of the flow around an underwater vehicle obtained in a half-mile towing tank, and measured with the underwater stereoscopic PIV probe .

Advanced free running model technology from model to full-scale

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Advancements in instrumentation and control systems for model testing are often driven by new and demanding test program requirements. The EER (Emergency, Evacuation and Rescue) was such a program for us at IOT (the Institute for Ocean Technology, a branch of Canadian National Research Council).

Improved off-the-shelf actuators and servos along with advanced software and hardware developed at IOT have been combined to achieve an integrated solution for model control. Software has been developed to implement a customizable remote control Operator console, which features programmable course keeping autopilot capabilities employing Kalman filtering.

Ever-improving battery technology, wireless communications, miniaturization of digital and power electronics along with computer systems and software have made it possible to achieve control and instrumentation objectives that were not practical in smaller model test programs in the past. This paper describes model tests conducted at IOT over the past number of years involving a diverse collection of free running models ranging from lifeboats to patrol boats and from fast rescue craft to submarines (surface). Recently, remote control technologies developed from model tests were adapted and deployed on field trials of a full-scale totally enclosed motor propelled survival craft (TEMPSC). This exercise validated the model control system at full scale. The IOT control technology has now been used at 1:13, 1:17 and 1:1 scales for a similar craft, this will help mitigate operator differences between full and model scale testing, improving data correlations. Another important benefit was the Operator's personal safety in ice manoeuvring test conditions.

Subsea communications in a towing facility

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Real-time wireless data and control communication of free running submerged scale models of submarines is essential for flexible and interactive research. Wireless underwater communication is also a complicated field of technology when applied indoors in a test basin. As a result, it has become one of the main topics in JRP9 Free running model technologies with special interest from QinetiQ and MARIN for the indoor application in towing tanks.

In the real world of full-scale systems, acoustic technology is often used and can provide low to medium data rates reliably. These acoustic systems cannot be easily deployed in shallow water situations like a test basin, due to reflections from flat concrete walls and large amounts of noise generated by motors in the submarines, towing carriages and wave makers. Free Space Optical systems provide smaller viewing angles and require complicated tracking systems to be used during free running model tests. In order to overcome this situation HTA-JRP9 partners share experiences and knowledge, and have started to work with European supplier Wireless Fibre Systems (WFS). WFS develops underwater to air radio communication links. At this moment, first versions of these systems have been purchased, installed and part of the systems are operational. The technology is promising and usable in basins and therefore research is continued and improvements are being made.

In the paper the technical background and application area of the radio link will be described. Also the applications at QinetiQ and MARIN will be described. Finally a conclusion with application guidelines, plans and recommendations for future work will be given.

Advanced model testing techniques for ship behaviour in shallow and confined water

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Flanders Hydraulics Research (Antwerp, Belgium) belongs to the Mobility and Public Works Department of the Flemish Government, which is responsible for the access channels to the Flemish seaports (Antwerp, Ghent, Ostend, Zeebrugge). Therefore, one of the main research topics concerns the behaviour of ships in shallow and confined water.

A short overview of the infrastructure will be given, followed by a more detailed description of specific features that have been introduced to improve the quality and the efficiency of the testing facility, or to study specific effects. To guarantee the quality of the test results, the rails on which the carriage moves are aligned with high accuracy: the level difference of both rails and the lateral deflection of the guiding rail are less than 0.5 mm. The level difference over the whole length of the rails is less than 1 mm. Measuring techniques have been developed to evaluate the deflections regularly. A high level of accuracy is also imposed to the bottom, as navigation with a gross under keel clearance of 10% of draft is not exceptional. Recently the bottom was flattened so that the difference between the lowest and highest point of the bottom is less than 2 mm. Interaction test setup. To improve the quality of the mathematical model of the full mission bridge simulators, comprehensive ship-bank and ship-ship interaction tests have been executed. A description of the test setups developed for these purposes will be given. Free running model technology. Presently the facilities are being adapted to allow the execution of free running tests for validation of the mathematical models developed from captive manoeuvring tests. In this case, the planar motion mechanism is controlled to follow the free running model and the relative position between the carriage and the model is measured.