

Report of the Ocean Engineering Committee

Presented by

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Memorial University, Canada

September 1, 2011

Rio de Janeiro, Brazil



Committee Members

Prof. Wei Qiu (Chairman), Ocean Engineering Research Centre, Memorial University, Canada

Prof. Xuefeng Wang (Secretary), Shanghai Jiao Tong University, China

Prof. Pierre Ferrant, Fluid Mechanics Laboratory, Ecole Centrale de Nantes, France

Prof. Shuichi Nagata, Institute of Ocean Energy, Saga University, Japan

Dr. Dong-yeon Lee, Samsung Ship Model Basin, Korea

Prof. Sergio H. Sphaier, LabOceano, Federal University of Rio de Janeiro, Brazil

Prof. Longbin Tao, University of Newcastle upon Tyne, UK (June 2010-present)

Dr. Ole David Okland, MARINTEK, Norway (January 2011-present)

Prof. Martin Downie
(Chairman, September 2008 to June 2010),
University of Newcastle upon Tyne, UK

Dr. Rolf Baarholm
(Secretary, September 2008 to June 2010),
MARINTEK, Norway



Committee Meetings

Four Committee Meetings were held:

- University of Newcastle upon Tyne, United Kingdom, March 2009.
- Memorial University of Newfoundland, Canada, October 2009.
- Shanghai Jiao Tong University, Shanghai, China, June 2010.
- Samsung Ship Model Basin, Daejeon, Korea, January 2011.

Outline of this Presentation

1. Tasks assigned by the 25th ITTC
2. Structure of the final report
3. State-of-the-art reviews
4. Review of existing procedure
5. Parameters causing the largest uncertainties in ocean engineering tests
6. Benchmark study of vortex flow induced by 2D cylinders
7. Hydrodynamic damping due to mooring line
8. New guideline for testing of wave energy converters
9. New procedure for testing of dynamic positioning systems
- 10/11/12. Conclusions, recommendations and future work

1. Tasks Assigned by the 25th ITTC (1)

- Update the state-of-the-art for predicting the behaviour of bottom founded or stationary floating structures including moored and dynamically positioned ships emphasizing developments since 2008.
- Review ITTC recommended procedures relevant to ocean engineering (including procedures for uncertainty analysis)
- Identify the parameters that cause the largest uncertainties in the results of model experiments, numerical modeling and full-scale measurements related to ocean engineering tests
- Conduct a study of numerical computations in comparison with existing benchmark data for wave run-up on a fixed vertical cylinder and vortex shedding from a circular cylinder for forced oscillation

1. Tasks Assigned by the 25th ITTC (2)

- Propose benchmark tests to investigate the hydrodynamic damping due to mooring lines
- Develop a guideline for hydrodynamic testing of marine renewable energy devices
- Write a procedure for the testing of dynamic positioning systems
- Liaise with the ISSC and the Seakeeping Committee

2. Structure of the Final Report

- Section 2: State-of-the-art reviews
- Section 3: Review of existing procedure
- Section 4: Parameters causing the largest uncertainties in model experiments, numerical modeling and full scale measurements related to ocean engineering tests
- Section 5: Benchmark study of vortex flow induced by 2D cylinders
- Section 6: Investigation of hydrodynamic damping due to mooring lines
- Section 7: New guideline for testing of wave energy converters
- Section 8: New procedure for testing of dynamic positioning systems
- Section 9/10: Conclusions and recommendations

3. State of the Art Reviews

- Bottom-founded structures
- Stationary floating structures and ships
- Dynamic positioning systems
- Renewable energy systems
- Highly nonlinear effects on ocean structures



(Source: NOAA)

Bottom-Founded Structures (1)

- Extensive reviews have been carried out by the two previous ocean engineering committees
- Methods of estimating the fluid loadings on the bottom-founded structures are well established.
- Significant challenges remain, concerning unusual geometries, and/or extreme conditions for which direct numerical simulation methods may take the advantage over standard fluid loading estimation methods based on Morison's equation.



Bottom-Founded Structures (2)

- This is especially the case of structures supporting marine renewable energy systems which introduce elements to the design problem not normally encountered in conventional mainstream offshore BFSs, such as
 - interaction of structural vibration and vortex shedding
 - the impulse loading from steep waves
 - damping of structural vibrations
- The most significant effort in this category concerns the numerical modeling of offshore wind turbine foundations in harsh environmental conditions.



Stationary Floating Structures and Ships (1)

- Reviewed recent development in Spar platforms, TLPs, Semi-submersibles, FPSOs, and LNG-FPSOs
- Novel platforms have been developed and tested such as dry-tree TLPs and semi-submersibles
- Dry-tree FourStar TLP for water depth of 4,300ft
- Model tests were performed at OTRC, Texas A&M at 1:52 scale. The top tensioned risers were included in the physical model
- It was confirmed that the dry-tree FourStar TLP is a stable platform for drilling and production

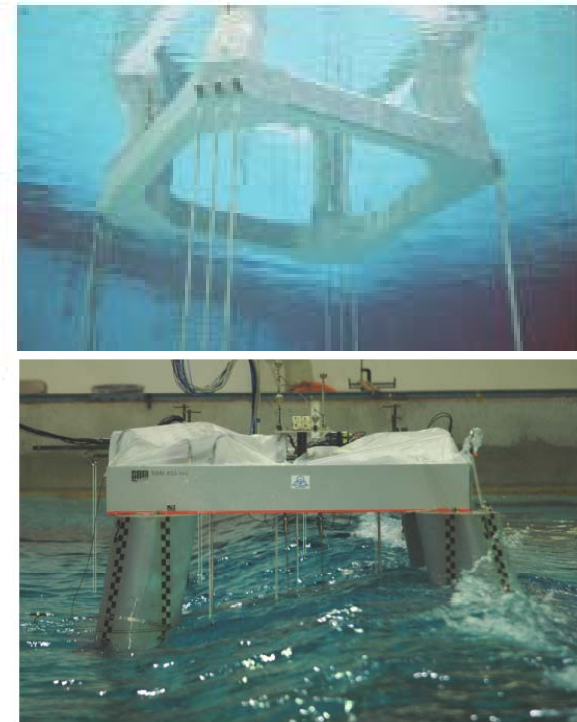


Figure 2.2.1: The Underwater View and Side View of the Dry-tree FourStar TLP (Heidari et al., 2008)

Stationary Floating Structures and Ships (2)

- Bian et al. (2010) presented the design of an integrated ultra-deepwater TLP with an air spring type vibration absorber to suppress the vertical resonance motions.
- The vibration absorbers were calibrated against the model tests results.

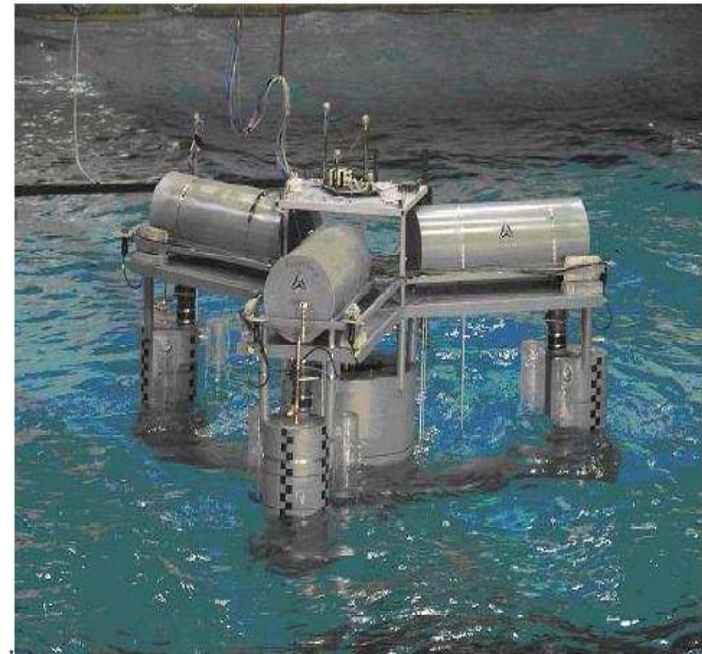


Figure 2.2.2: 1:45 Scale Model of a SeaStar TLP Hull (Bian et al., 2010)

Stationary Floating Structures and Ships (3)

- Williams et al. (2010) presented the development of SBM Atlantia's dry-tree semi-submersible platform suitable for deployment of non-hurricane/non-cyclonic environments worldwide.
- The verification of the FourStar concept was carried out through wave basin model tests.

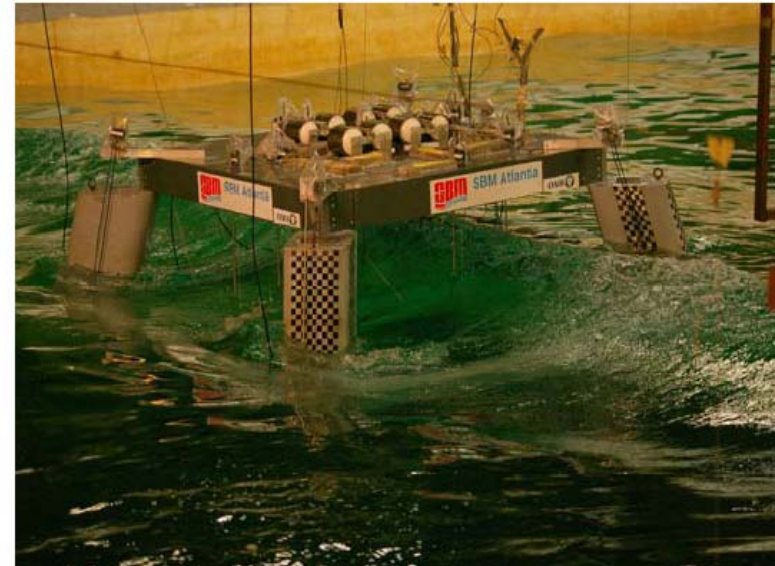


Figure 2.2.5: FourStar DTS Model
(Williams et al., 2010)

Stationary Floating Structures and Ships (4)

- Hussain et al. (2009) introduced the Extendable Semi-submersible (E-Semi) with a retractable tier pontoon (STP) to suppress heave motion in order to support top tensioned risers in the ultra deep water of central Gulf of Mexico.
- Numerical studies and model tests showed the effectiveness of the STP in suppressing the heave motion.



Figure 2.2.6: E-Semi
(Hussain et al., 2009)

Stationary Floating Structures and Ships (5)

- Experimental and numerical methods have been used to deal with the responses of the platforms under waves, current and wind, especially
 - First and second-order responses
 - Coupled hull/riser/mooring responses
 - VIV and VIM
 - Wave run-up
 - Sloshing
 - Hydrodynamic interaction of multiple bodies



Figure 2.2.4: Wave Run-up
(Matsumoto et al., 2010)

Stationary Floating Structures and Ships (6)

- Numerical methods employed in the frequency domain and in the time domain include
 - Boundary element methods/panel methods
 - CFD methods
 - Coupled methods

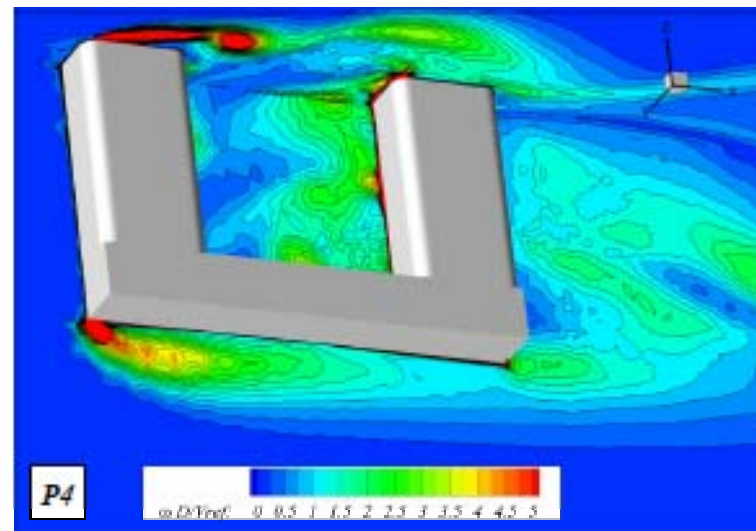


Figure 2.2.9: Results of Current Loads on a Stationary Platform
As part of the Current Affairs JIP
(Vaz et al., 2009)

Stationary Floating Structures and Ships (7)

- There is still a need of research in predicting second-order slow motion and force.
- For example, Simos et al. (2009) indicated that the semi-submersible may be subjected to second-order slow motions in heave, pitch and roll.
- These resonant motions are directly related to the large dimensions and relatively low natural frequencies of the semi-submersible.

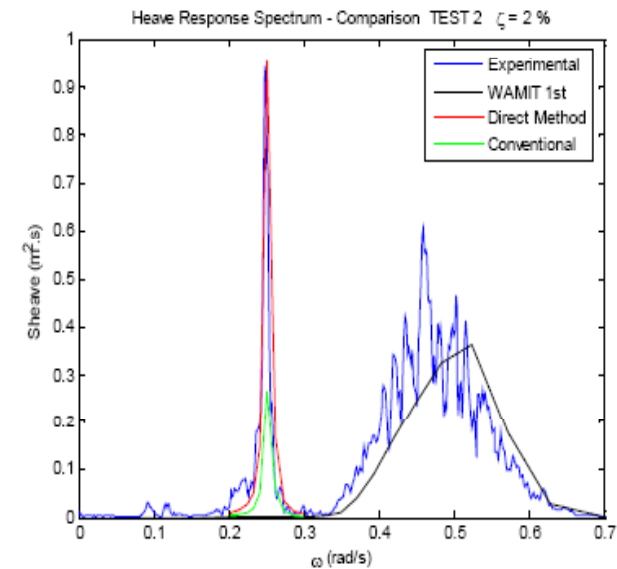


Figure 2.2.12: Heave Motion Spectra (Simos et al., 2009)

Stationary Floating Structures and Ships (8)

- Relative motions between two floating bodies became very important research topics since they concern the safe operation of a floating offshore LNG vessel.
- Hydrodynamic effects of liquid in partially filled tanks have been considered in the ship motion and sloshing analysis. In shallow water, the low-frequency component induced by nonlinear wave interactions is important for the low frequency motion of two floating bodies.
- The hydrodynamic effects of tank fluid and the gap phenomena between two floating bodies still need to be studied further.

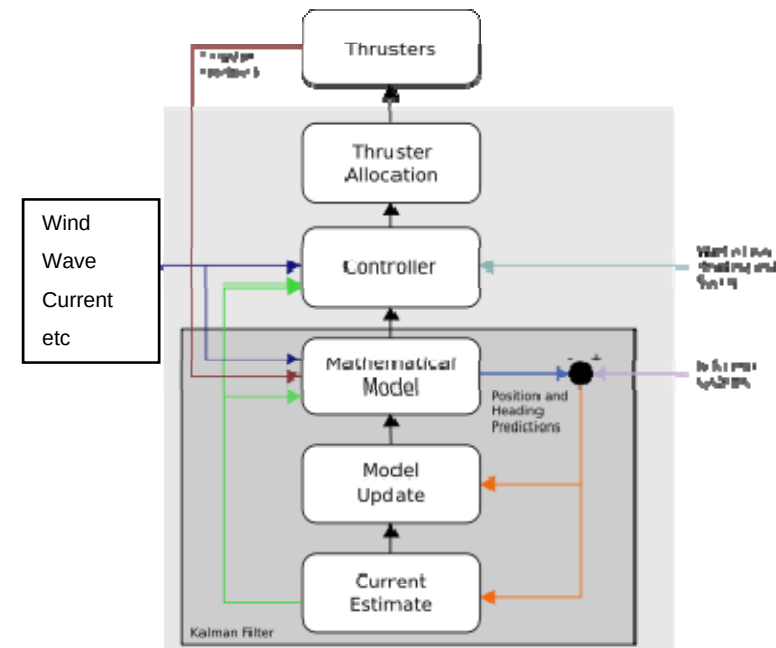


Dynamic Positioning Systems (1)

- The offshore activities for exploration and production of oil and gas have strongly stimulated the development of dynamic positioning systems for vessels.
- More than 2000 DP vessels operate all over the world with a large variety of DP systems.



Transocean's Discoverer Americas



Dynamic Positioning Systems (2)

- Tannuri et al. (2009) presented a detailed analysis of a crane pipelaying barge with a DP system. The DP system is installed to improve the position control ability and to enhance the operational time schedule.
- In the simulations of the DP-Mooring operational mode, two mooring lines at the bow were considered to counteract the force of the pipe being launched.

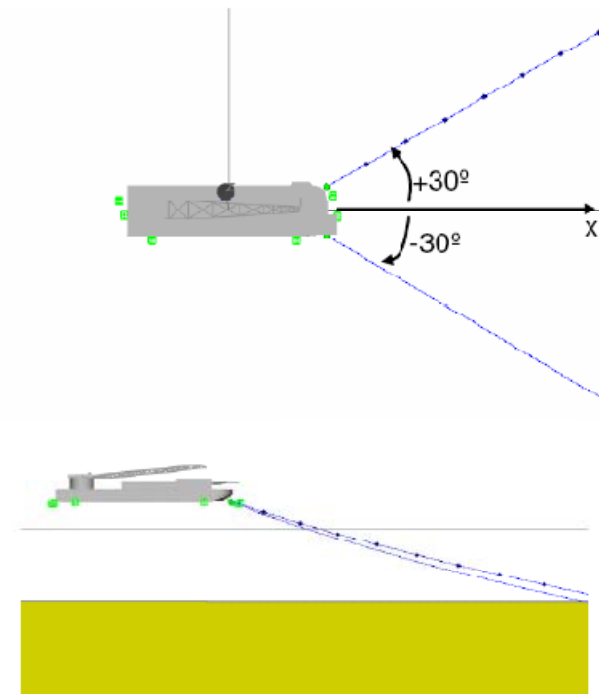


Figure 2.3.2: Mooring Lines Used in the DP-Mooring
(Tannuri et al., 2009)

Dynamic Positioning Systems (3)

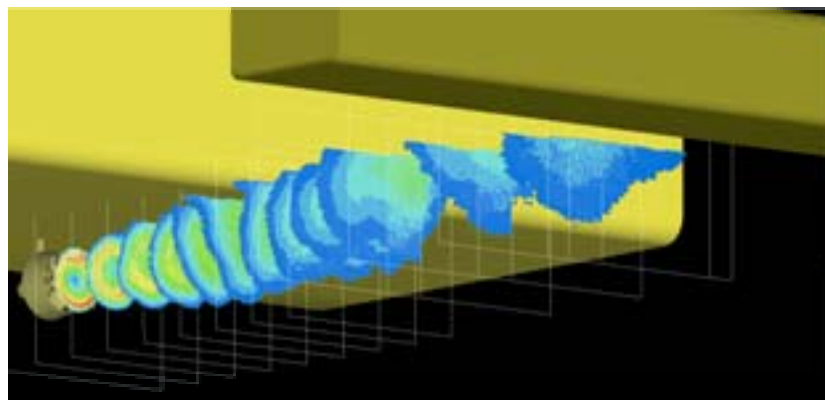
- de Wilde et al. (2010) discussed the first investigation of LNG stern-to-bow offloading with the dynamic positioned shuttle tanker based on a model test program.
- The shuttle tanker was controlled by a closed loop DP system, including extended Kalman filter, PID control and thruster allocation.
- The azimuthing thrusters, rudder and main propeller were modeled.



Figure 2.3.1: Examples of Side-by-side
and Tandem LNG Offloading with Dynamic Positioning
(de Wilde et al., 2010)

Dynamic Positioning Systems (4)

- Simulation systems, CFD application and model tests have been used to evaluate the performance of DP systems.
- The use of the theory of nonlinear control, robust control, reliability, and simulation of interference between thrusters has also been addressed by researchers.
- Further studies are needed in the areas of thruster-thruster interaction, thruster-hull interaction, ventilation and ingestion of air.



MARIN's PIV Measurements of Thruster-hull Interaction Flow

Renewable Energy Systems – Wave Energy Converters (WEC) (1)

- Oscillating water columns (OWC)
- Moving bodies
- Wave overtopping devices
- ...

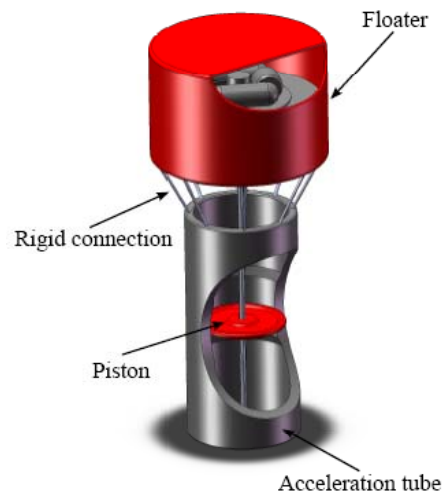


Fig.2.4.1: IPS Wave Power Buoy (Gomes et al., 2010)



Australia's
Oceanlinx
OWC



Wave Dragon
WEC

Renewable Energy Systems – Wave Energy Converters (2)

- A variety of theoretical and experimental studies have been carried out to evaluate the performance of WECs.
- The potential-flow theory has been mainly used.
- Challenges in modeling
 - Hydrodynamic interactions of WECs and optimization, especially for WEC farm
 - Power take-off mechanism
 - Survivability in extreme seas
 - Highly nonlinear effects, such as slamming, etc.
 - Viscous effects

Renewable Energy Systems – New WEC Types (3)

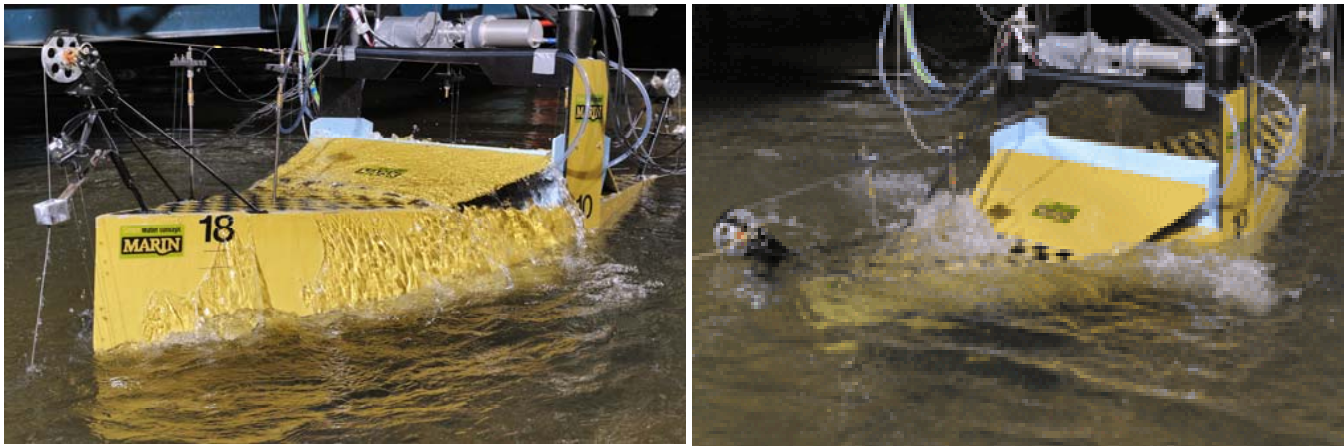
- Oyster, a seabed mounted WEC with a buoyant flap
- The buoyant flap can freely oscillate about a pivot.
- Model tests have been carried out for its performance in extreme sea conditions.



Oyster
(Howard et al., 2009)

Renewable Energy Systems – New WEC Types (4)

- Green water concept WEC
- Buchner et al. (2010) carried out pilot model tests on the “Green Water Concept” floating WEC. Linear and hydraulic PTOs were also tested.
- This device is a weathervaning vessel with a small freeboard and a water reservoir in the centre based on the concept of heaving, pitching and overtopping.



Green water WEC
(Buchner et al., 2010)

Renewable Energy Systems – New WEC Types (5)

- Kanki et al. (2010) developed a floating WEC using the gyroscopic moment by the rotation of large flywheels and the swing of a float excited by wave motion. A field test for a 45kw prototype was carried out in Japan.
- Salcedo et al. (2009) also proposed a gyroscopic WEC of the same type, OCEANTEC, and carried out wave tank tests and sea trials.



Gyroscopic WEC - Oceantec
(Salcedo et al., 2010)

Renewable Energy Systems – New WEC Types (6)

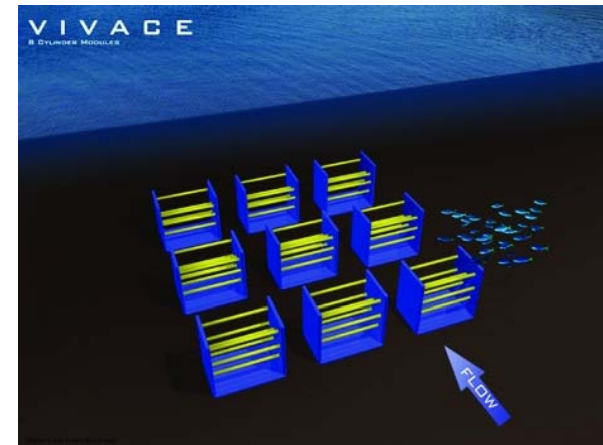
- Chiba et al. (2008) proposed a single buoy type WEC using Electroactive Polymer Artificial Muscle (EPAM), a rubber material that can generate electricity by being stretched and released to the original shape.
- Sea trials were carried out off the coast of Florida.
- This device was able to generate a peak power of 1.2W and an average power of 0.25W using 300g EPAM.



EPAM Single Buoy WEC
(Chiba et al., 2010)

Renewable Energy Systems – Tidal and Current Energy

- Devices using turbines (horizontal or vertical-axis).
- Non-turbine devices.
 - Using oscillating hydrofoils
 - Making use of vortex induced vibrations
- RANS-CFD, BEM and vortex methods have been developed for the design and performance evaluation.
- Many experiments have been carried out.



Renewable Energy Systems – Wind Energy

- Floating wind turbines include Spar-buoy, TLP, semi-submersible and barge types.
- Many studies have been carried out to understand the coupling between the support structure and the wind turbine subject to combined wind and wave loading.
- Many model and full-scale experiments have been performed.



Figure 2.4.2: Semi-sub Type Floating Wind Turbine (Phuc & Ishihara, 2009)



Figure 2.4.4: Barge Type Floating Wind Turbine (Iijima et al., 2010)

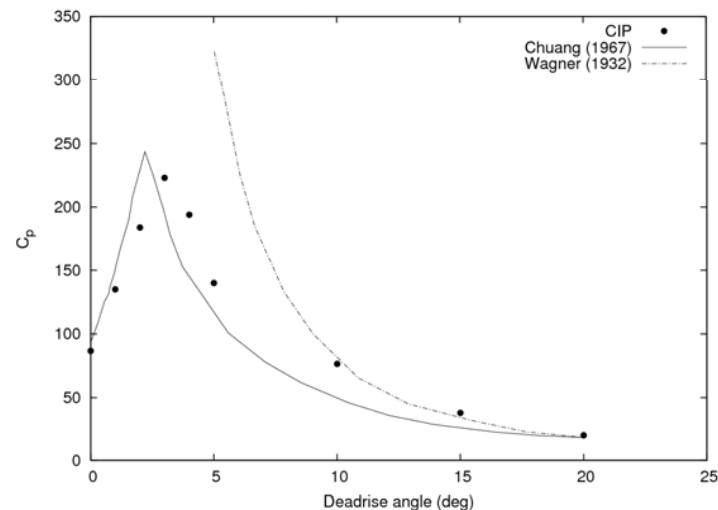
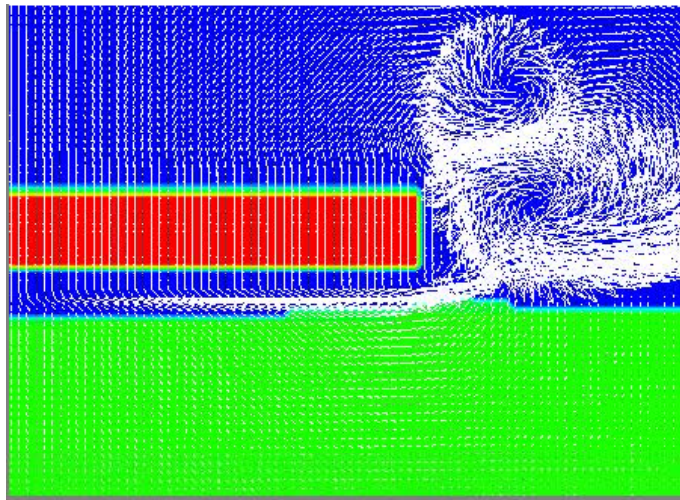
Highly Nonlinear Effects on Ocean Structures (1)

- Progress has been made on modeling slamming, green water/air gap, sloshing and wave run-up using numerical and experimental methods.
- CFD methods based on SPH, VOF and CIP are typically used to capture the highly nonlinear free surfaces.

Highly Nonlinear Effects on Ocean Structures (2)

Slamming

- Yang and Qiu (2008) computed the slamming forces on wedges of small deadrise angles with the CIP method by considering the compressed air.
- The predicted pressure coefficients were compared with experimental data and those by the Wagner theory.



Water entry of wedges of small deadrise angles using CIP
(Yang and Qiu, 2008)

Highly Nonlinear Effects on Ocean Structures (3)

Sloshing

- The increase in size of LNG carriers in recent years, together with the development of floating storage and regasification units (FSRUs) operating in arbitrary filling conditions, have boosted a number of R&D projects aiming at improving the design methodologies and the scientific knowledge about the physics of hydroelastic impact problems involving a complex containment system and two-phase flow of a liquefied gas and its gaseous phase.



Highly Nonlinear Effects on Ocean Structures (4)

Sloshing

- An example: the SLOSHEL JIP, initiated by MARIN, Gaztransport, Technigaz (GTT), Bureau Veritas and Shell with six other participants.
- The purpose of the project was to develop a methodology to assess membrane systems by direct comparison of the loads and structural capacity.
- The project involved full and small-scale tests, numerical developments and validation studies.

Highly Nonlinear Effects on Ocean Structures (5)

Sloshing

- One of the tasks in the project was to carry out experiments on full-scale real containment system elements, subject to impact by focusing waves.
- It was found the flip-through type of sloshing impact was very sensitive to small variations of the wave shape.
- The No.96 elements sustained 110 impact tests with 2.6MPa maximum local pressure.



Figure 2.5.3: Full Scale Impact Tests on NO96 Elements in the Delta Flume, SLOSHEL JIP (Kaminski & Bogaert, 2009)

Highly Nonlinear Effects on Ocean Structures (6)

Sloshing

- In the SLOSHEL JIP, tests at reduced scale were performed in Ecole Centrale Marseille.
- Fluid velocities were measured using PIV during wave impacts on a flexible wall.

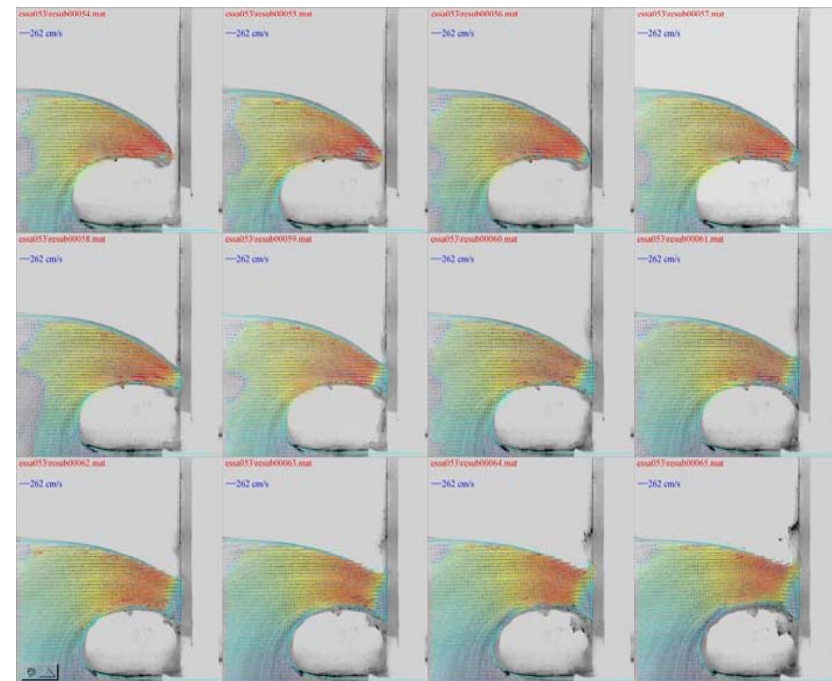


Figure 2.5.4: PIV Measurements of Fluid Velocities during Wave Impacts on a Flexible Wall (Kimmoun et al., 2009)

Highly Nonlinear Effects on Ocean Structures (7)

Sloshing

- For numerical simulations, Wemmenhove et al. (2009) used a VOF method and a compressible two-phase flow model to more accurately simulate the LNG tank sloshing.
- Oger et al. (2009) developed a 2D SPH model and applied to the hydro-elastic impacts.

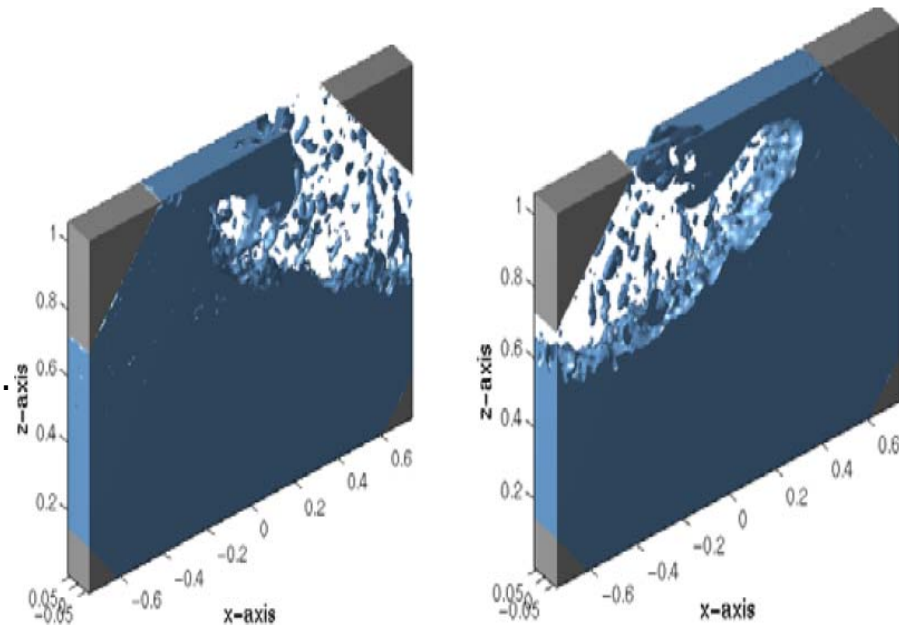


Figure 2.5.5: Fluid Configurations during Two Phase Sloshing (Wemmenhove et al., 2009)

Highly Nonlinear Effects on Ocean Structures (8)

Sloshing

- Large-scale experiments were also carried out using a sloshing facility at MARIN.

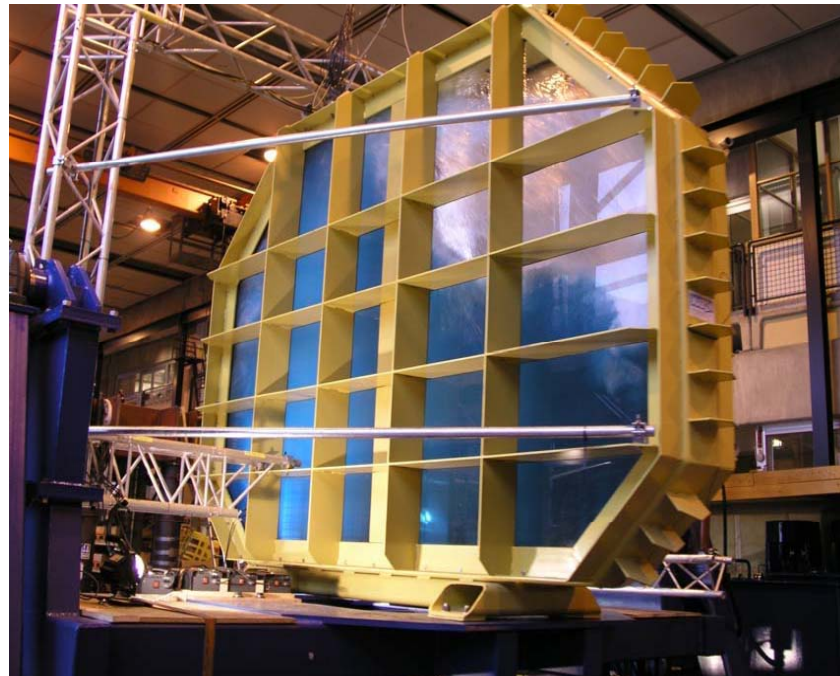


Figure 2.5.6: Large Scale Sloshing Facility
(Bunnik & Huijsmans, 2007)

Highly Nonlinear Effects on Ocean Structures (9)

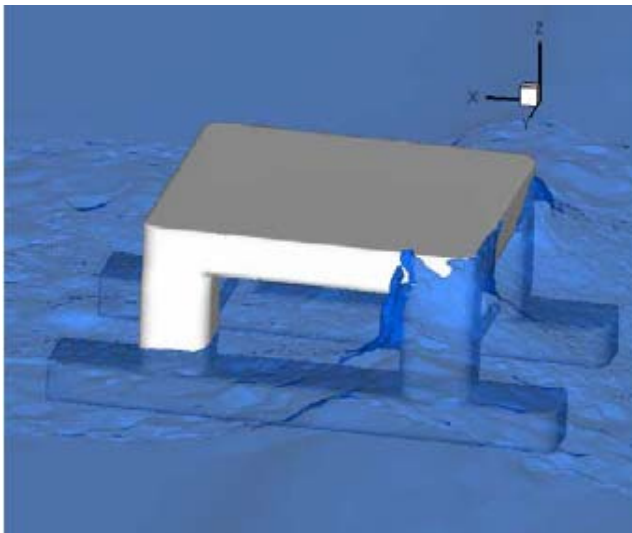
Sloshing

- In summary, significant progress on sloshing studies has been reported at three different levels:
 - global simulation of the ship and liquid cargo coupled behavior
 - numerical simulation of the local fluid structure interaction effect during two-phase impact
 - large scale impact tests
- The state-of-the-art global sloshing analysis is based on the coupled seakeeping (potential flow code)/CFD simulation.
- The estimation of the effect of impact loads on the insulation system of a LNG carrier involves the solution of a strongly coupled fluid-structure interaction problem. It is numerically and experimentally challenging !!!

Highly Nonlinear Effects on Ocean Structures (10)

Wave Run-up

- Second-order potential theory and CFD methods have been explored on the study of wave run-up on columns of TLPS, semi-submersible platforms, wind turbine structures, and vertical piles, along with experimental methods.



Wave run-up along the fore column with the VOF method
(Liang et al., 2010)



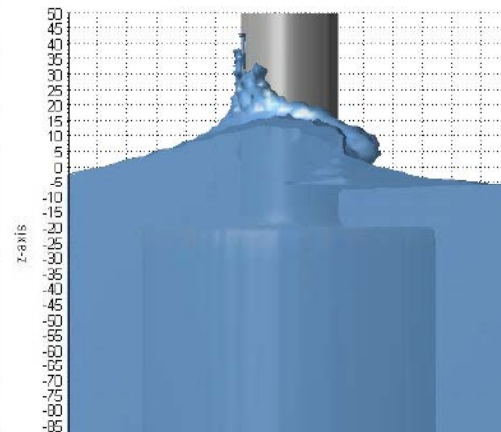
Wave run-up for TLP using SPH
(Rudman et al., 2008)



Highly Nonlinear Effects on Ocean Structures (11)

Wave Run-up

- Danmeier et al. (2008) evaluated two computational tools, WAMIT and the VOF program ComFlow, for wave run-up around a GBS.
- The differences between the WAMIT prediction and the model tests results are presumably due to the jet-like nonlinear phenomena.
- The ComFlow computations revealed that the wave run-up was sensitive to the incident wave and the maximum amplification occurred when the incident wave was nearly breaking.



Wave Run-up Around a GBS.
ComFlow was used for the simulation (Danmeier et al., 2008)

Highly Nonlinear Effects on Ocean Structures (12)

Wave Run-up

- Iwanowski et al. (2009) computed the wave run-up on a semi-submersible's columns and the under-deck fluid impact using ComFlow with an improved VOF method.
- The computed wave run-ups were compared with model tests with short, medium and long waves. They are in general correlated.
- In summary, the developed numerical methods for wave run-up predictions give results in a reasonable agreement with experimental data

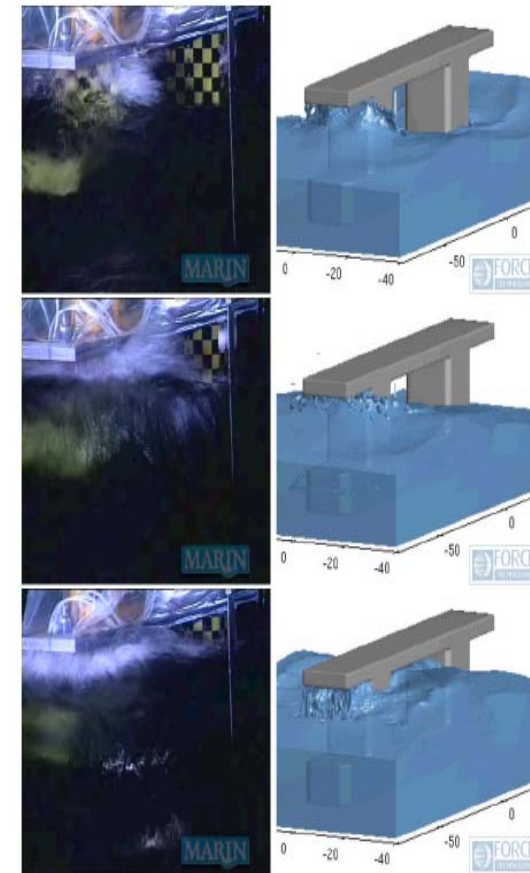


Figure 2.5.7: Wave Run-up. Videos from Tests with Short, Medium and Long Waves are Synchronized with Simulation Using ComFLOW (Iwanowski et al., 2009)

4. Reviewing the Existing Procedure

- 7.5-02-01-01 Uncertainty Assessment Methodology for Uncertainty Analysis in EFD
 - Recommended to include definitions of the precision error, the bias error, the random error, and the systematic error.
 - Recommended to include the application of the methodology to complex seakeeping and ocean engineering experiments.
 - Two references were added.

5. Parameters Causing Largest Uncertainties In Ocean Engineering Tests (1)

- Identified a list of parameters that possibly cause uncertainties in ocean engineering model tests, full-scale tests and numerical simulations according to the following categories:
 - Physical properties of fluid
 - Initial conditions
 - Model definition
 - Environments
 - Scaling
 - Instrumentation
 - Human factors
- Identified the parameters causing the largest uncertainties in model tests involving mooring lines and risers and in model tests involving DP systems.

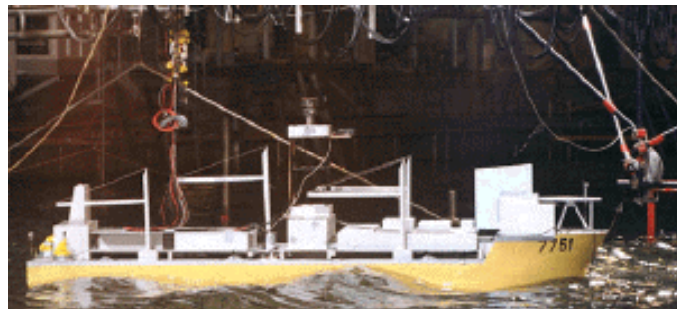
5. Parameters Causing Largest Uncertainties In Ocean Engineering Tests (2)

- Model tests involving mooring lines and risers
 - Scaling of the elastic and mass characteristics of prototype lines
 - The instrumentation of mooring lines (in-line load cells change the properties of the line segment)
 - Location of an anchor point on the basin bottom and bottom friction coefficient
 - Truncated mooring line (maybe different from the prototype)
 - Drag effects



5. Parameters Causing Largest Uncertainties In Ocean Engineering Tests (3)

- Model Tests involving DP systems
 - Scale effects on model friction forces due to low Re number
 - Hydrodynamic effects of thrusters and propellers
(uncontrolled effects due to thruster-thruster interaction and thruster-hull interaction)
 - Propeller air suction effects
 - Propeller emersion effects
 - Control parameters of model and prototype (control parameters of a prototype from DP manufacturers are often not available for model tests)
 - Bundling propellers or changing propeller/thruster position due to space limitation of model
 - Quality of feed values used in the control system of the model different from those of the prototype



6. Benchmark Studies – VIV (1)

- Benchmark Data from MARIN for Stationary Cylinder

- Rigid circular cylinder ($D=200\text{mm}$, $L=3.52\text{m}$)

- Reynolds numbers

6.31E+04, 1.26E+05, 2.52E+05

3.15E+05, 5.06E+05, 7.57E+05



Figure 5.1.1: Smooth Cylinder of MARIN

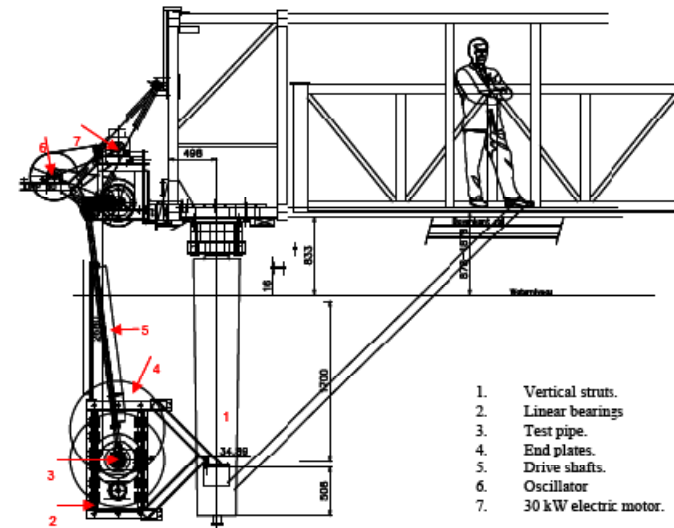


Figure 5.1.2: High Reynolds VIV Test Apparatus

6. Benchmark Studies – VIV (2)

- Participants

Affiliation	Nationality
China Ship Scientific Research Center (CSSRC)	CHINA
Seoul National Univ. (SNU)	KOREA
Samsung Ship Model Basin (SSMB)	KOREA

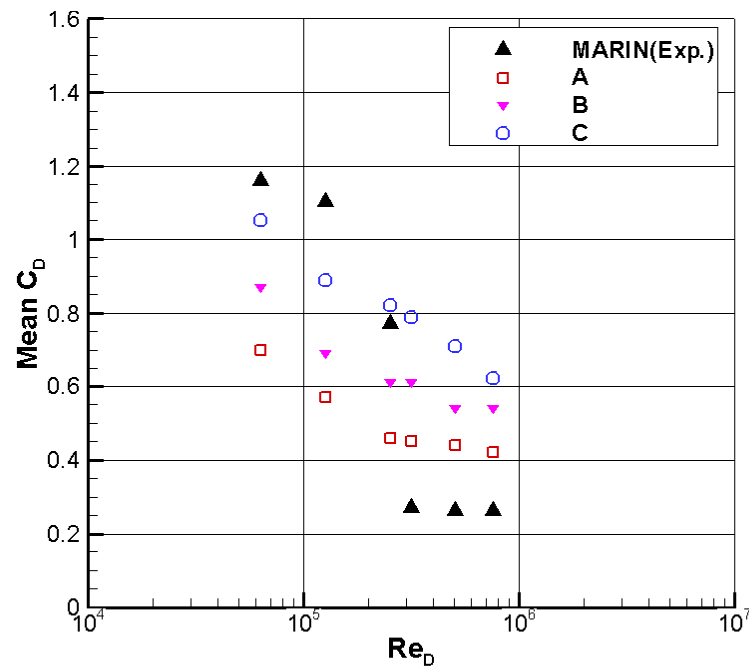
	y^+	Wall function (Use / No use)	Turbulence model	Transition model (Use / No use)
A	59	U	k-w SST	N
B	2	N	k-w SST	N
C	10	N	k-w SST	N

- Numerical Methods Used by Participants

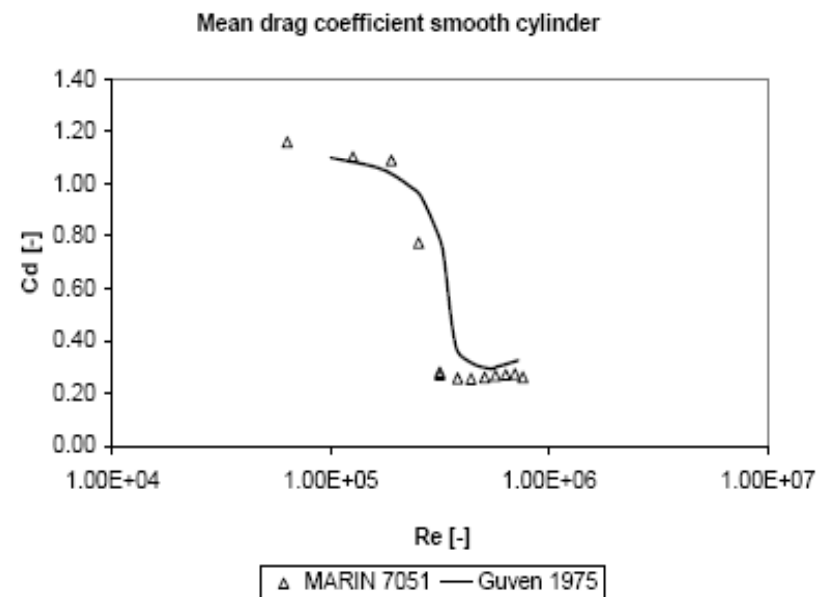
Participant	Code name	2D/ 3D	Steady/ Unsteady	RANS/ LES/ etc
A	FLUENT (Commercial Code)	2D	Unsteady	RANS
B	In-house Code	2D	Unsteady	RANS
C	FLUENT (Commercial Code)	2D	Unsteady	RANS

	Number of Grid	Type of Grid	Convection term	Δt
A	87223	Structured	Upwind	0.001/0.0005
B	32280	Structured	Upwind	0.001/0.0002 /0.0001
C	43820	Structured	Upwind	0.001

6. Benchmark Studies – VIV (3)

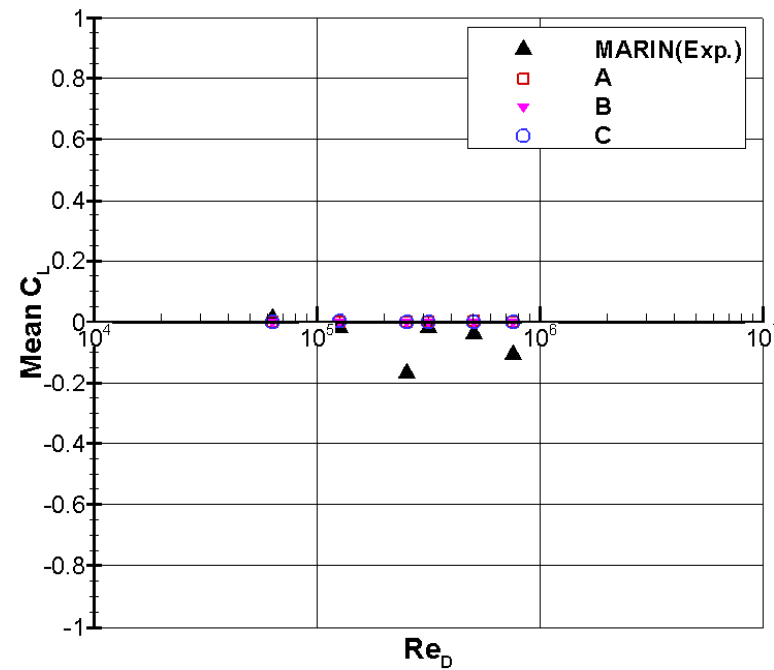


Mean drag coefficient



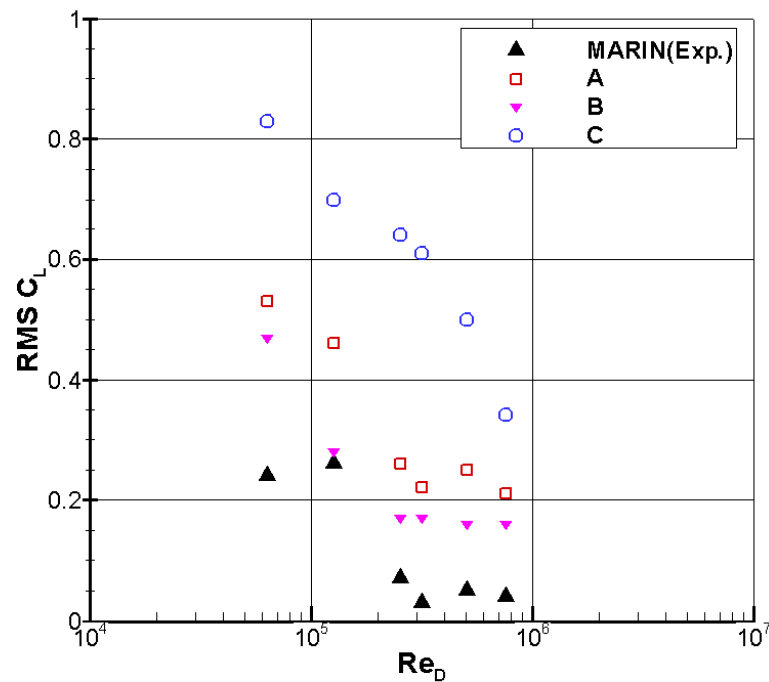
Mean drag coefficient - experimental

6. Benchmark Studies – VIV (4)

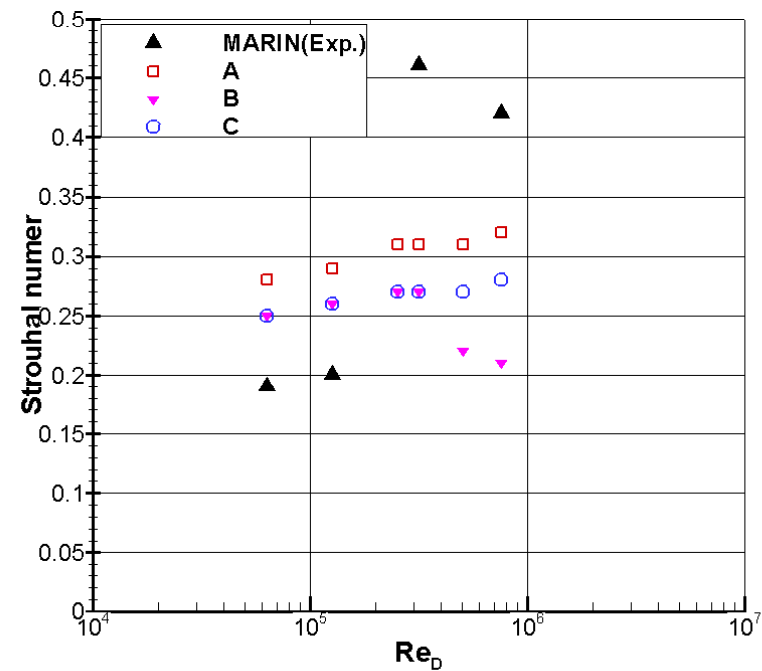


Mean lift coefficient

6. Benchmark Studies – VIV (5)

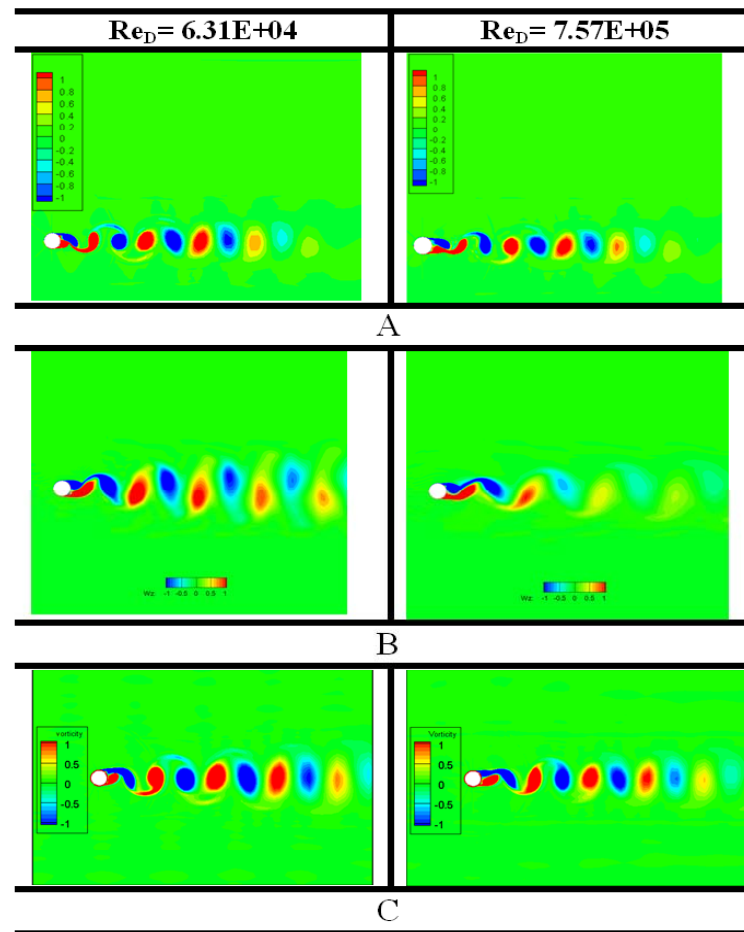


RMS of lift coefficient



Strouhal number

6. Benchmark Studies – VIV (6)



Vorticity contours

6. Benchmark Studies – VIV (7)

- All participants used 2D unsteady RANS method. The k-omega SST turbulence model was used. None of them used the transition model.
- The drag crisis phenomenon, in the critical range ($3 \times 10^5 < Re < 3.5 \times 10^5$) due to instability of separated shear layer, was not captured in the numerical studies.
- More participants are needed in order to draw a conclusion.
- It may be necessary to predict the complex flow phenomenon using LES or DNS method.

7. Mooring Line Damping (1)

- Huse (1986) indicated that the drag forces on mooring lines provide a great source of surge damping for moored semi-submersibles.

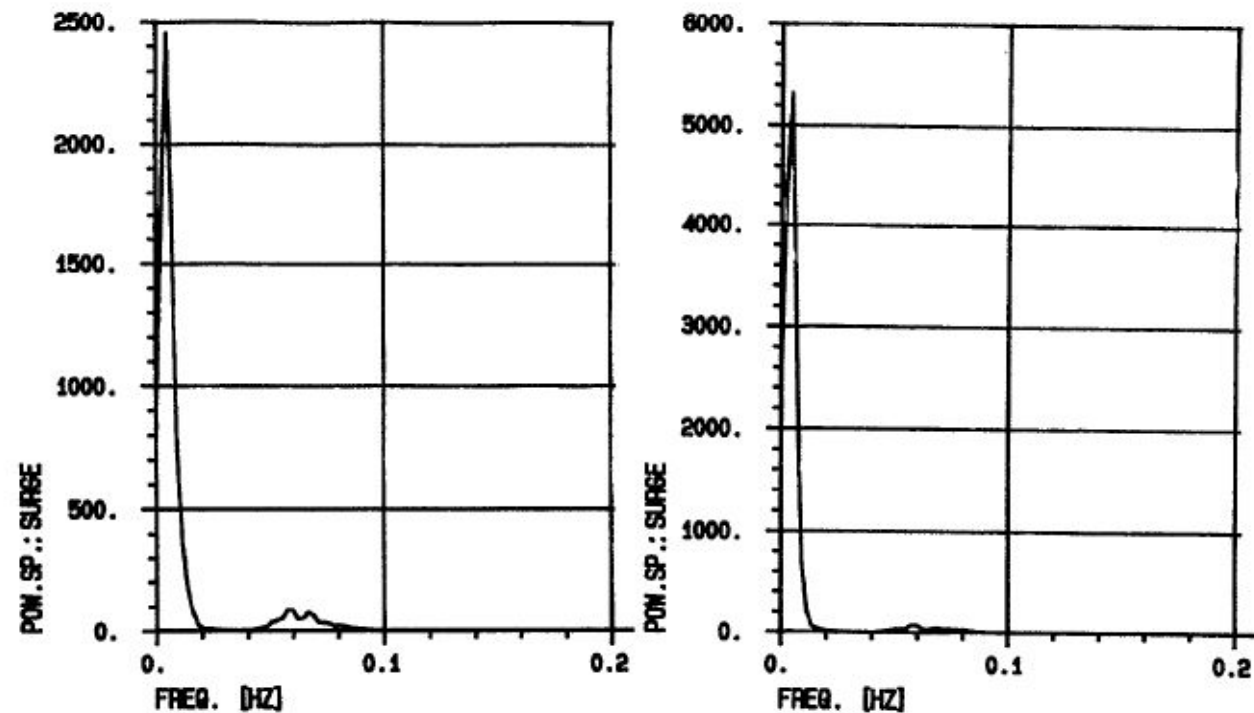
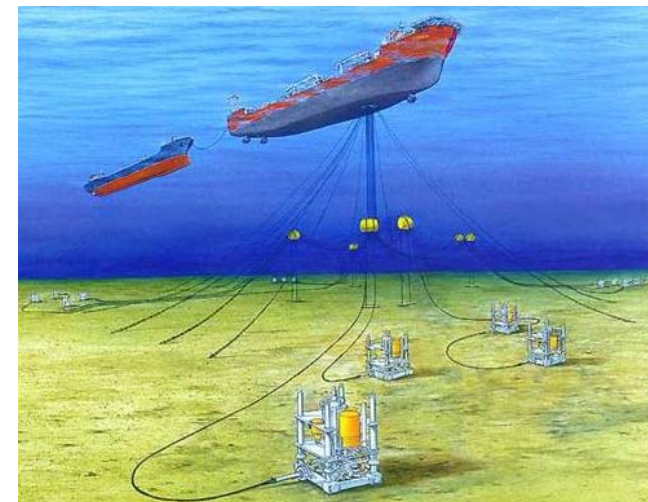


Figure 6.2.1: Surge Spectrum for Platform A.
Left: Complete Modelling of Catenary Mooring System.
Right: Model Suspended in Horizontal Lines and Springs (Huse, 1986).

7. Mooring Line Damping (2)

- A few model and field experiments have been identified in the literature review.
- The most practical approach to obtain the mooring system damping is to perform two calm water decay model tests:
 - A. tests with a complete modeling of the vessel and its mooring system
(total damping energy from viscous hull effects + mooring system)
 - B. tests for a model suspended by horizontal lines and springs
(total damping energy from viscous hull effects)
- This approach can also be applied to obtain the mooring line damping due to low frequency motions in regular and irregular waves.



7. Mooring Line Damping (3)

- Full-scale tests are very few.
 - JIP: Mooring Line Damping and Current Loads on Semi-Submersible (Triantafyllou et al., 1994)
 - Full-scale experiments on the ALAGOAS tanker moored in the southern part of Brazilian coast (Nishimoto et al., 1999).

Two sets of data were obtained from two decay tests with 70 tonf and 100 tonf pulling forces, respectively.

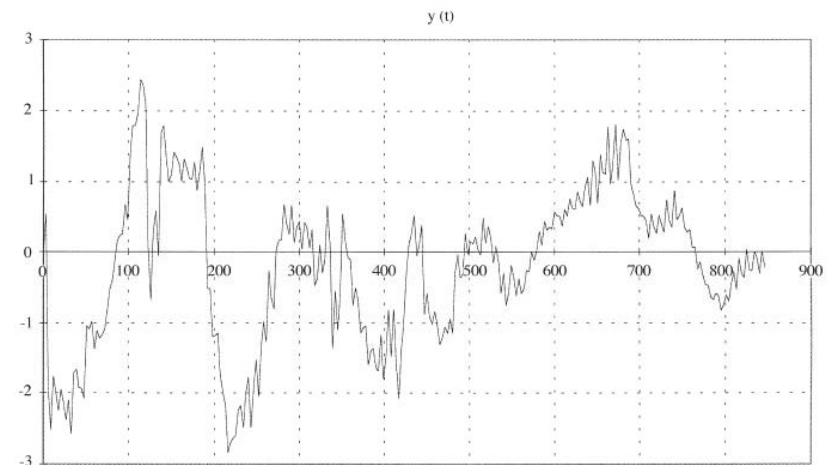
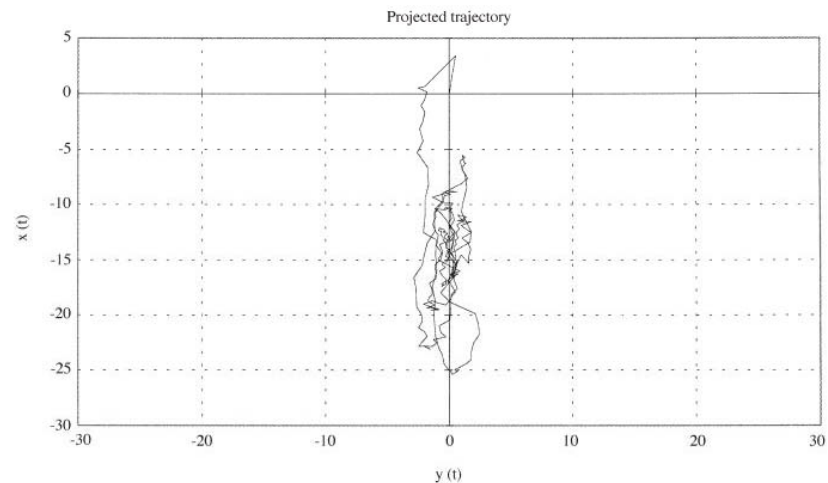


Figure 6.2.6: 70 tonf Pulling Force.
 Top: Ship's Position in xy Plane.
 Bottom: Sway Motion

7. Mooring Line Damping (4)

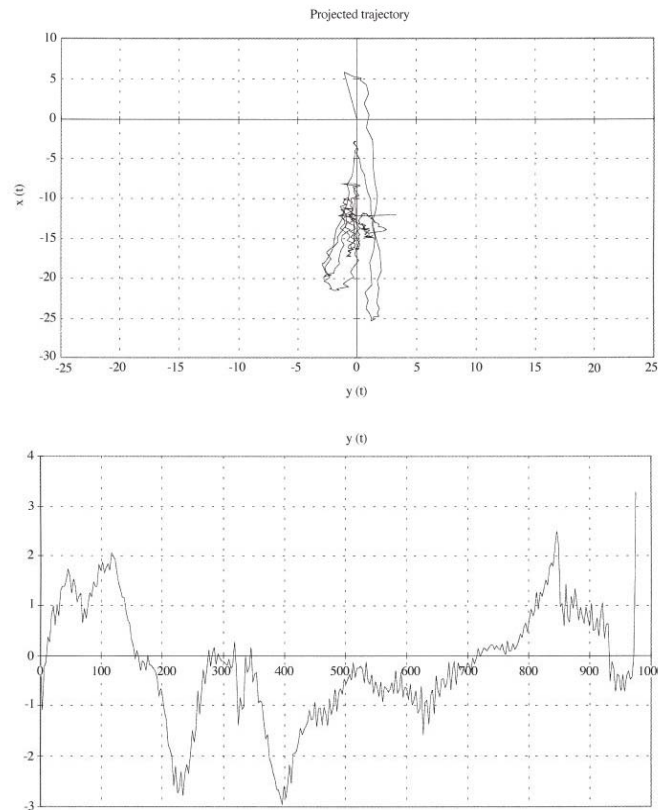


Figure 6.2.7: 100 tonf Pulling Force.
 Top: Ship's Position in xy Plane.
 Bottom: Sway Motion

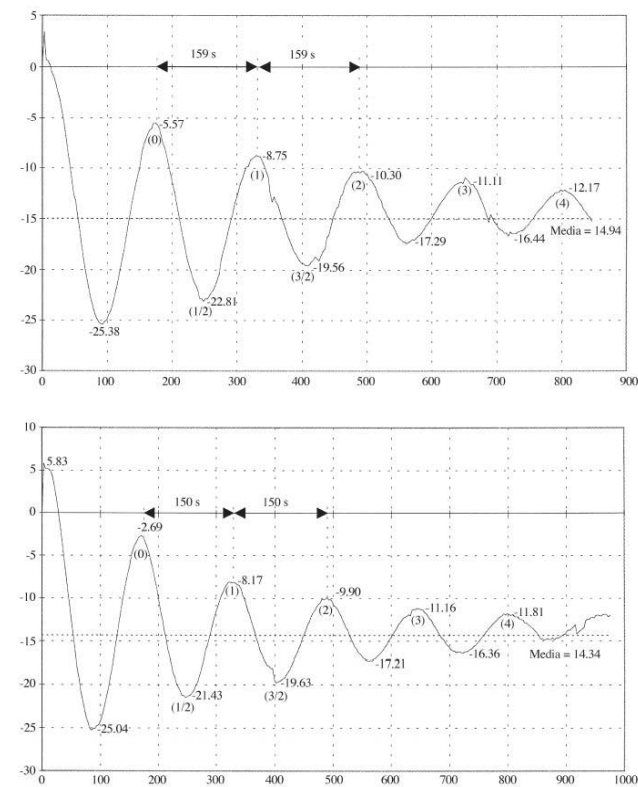
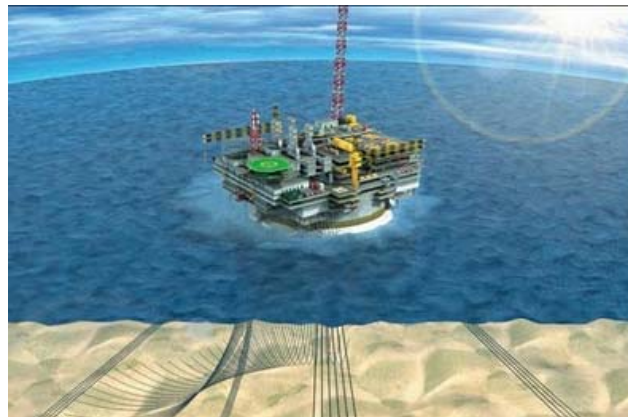


Figure 6.2.8: Surge motions for
 cases of 70 tonf and 100 tonf

7. Mooring Line Damping (5)

- Main challenges for obtaining mooring line damping in model tests
 - Geometry modeling of lines
 - Scale effects, more severe with water depth increased.
 - It is difficult for platforms operated in ultra-deepwater due to the limitation of today's test facilities.
- A rigorous field measurement is needed. But it is difficult due to financial and operational reasons.



8. Guidelines for Hydrodynamic Testing of Wave Energy Converters (1)

- The main differences between the WEC tests and offshore structure tests have been considered while developing the guidelines for hydrodynamic testing of wave energy converters:
 - The inclusion of a simulator of the power take-off mechanism
 - The involvement of various experimental stages – concept validation, design validation, system validation, prototype and demonstration stages. The model scale depends on the test stage.
 - Model tests of WEC farms

8. Guidelines for Hydrodynamic Testing of Wave Energy Converters (2)

- A new guideline (7.5-02-07-03.7) has been developed.
- The purpose of this guideline is to ensure that wave energy converter (WEC) experiments are performed according to the state of the art.
- In general, model tests on WECs are employed
 - to validate the device concept,
 - to quantify the technical performance variables,
 - to acquire information on power take-off (PTO) and data for optimized performance design,
 - to confirm survivability characteristics, and
 - to validate numerical models.

9. Procedure for Model Tests of Dynamic Positioning Systems (1)

- Questionnaires have been sent to ITTC members to understand the current practice. Eight organizations have responded.
- The questionnaires included the following subjects
 - Model scale
 - Environmental parameters
 - Measuring system
 - Control system
 - Filtering system
 - Thrust allocation logics
 - Feed forward
 - Actuator calibrations
 - ...

No.	Affiliation	Nationality
1	China Ship Scientific Research Centre (CSSRC)	China
2	FORCE Technology (FORCE)	Denmark
3	Institute for Ocean Technology (IOT)	Canada
4	Lab Oceano and Sao Paulo University	Brazil
5	MARIN	Netherland
6	MOERI	Korea
7	Samsung Ship Model Basin (SSMB)	Korea
8	AKISHIMA Laboratories (MITSUI ZOSEN) Inc.	Japan
9	Shanghai Jiaotong University	China

9. Procedure for Model Tests of Dynamic Positioning Systems (2)

- A new procedure (7.5-02-07-03.6) for the model tests of dynamic positioning systems has been developed.
- In general, the DP model tests are employed to investigate the effects arising from the simultaneous action of waves, wind and current, combined with multiple thrusters, and to provide systematic data for the development of reliable DP simulation tools.
- The purpose of this procedure is to ensure that model tests of dynamic positioning (DP) systems are conducted according to the best available techniques and to provide an indication of improvements that might be made.
- The procedure is also to ensure that any comprises inherent in dynamic positioning system tests are identified and their effects on the measured results are understood.

10. Conclusions (1)

- **State-of-the-art reviews:**

- **Bottom-founded structures:** experimental and numerical design procedures are well established, but challenges remain concerning unusual geometry and extreme conditions.
- **Stationary floating structures and ships:** experimental and numerical methods are in general well established. Studies have been carried out for novel structures such as dry-tree semi-submersibles. There is a need of further research in predicting second-order motions and loads, multiple body interactions and hydrodynamic effects of partially filled tanks.
- **Dynamic positioning systems:** progress has been made in using simulation systems, CFD application and model tests to evaluate the performance of DP systems. Further studies are needed to address thruster-thruster interaction, thruster-hull interaction, ventilation, and ingestion of air.

-

10. Conclusions (2)

- **State-of-the-art reviews:**
 - **Renewable energy systems:** research on wave energy, current energy and wind energy systems has progressed rapidly. Appropriate experimental techniques and procedures should be developed for this expanding field.
 - **Highly nonlinear effects on ocean structures:** green water, air gap, slamming and sloshing, representing the highly nonlinear effects, becomes important for the design and operation of offshore structures in extreme sea conditions. Progress has been made in experimental and numerical procedures. The development of the relation between the measured pressure and the design pressure for structures and the fluid-structure interaction need to be studied further.

10. Conclusions (3)

- **Parameters causing largest uncertainties in ocean engineering tests**
 - Many parameters may cause uncertainties in ocean engineering tests.
 - The parameters that cause the largest uncertainties in experiments involving mooring lines, risers and dynamic positioning systems have been identified.
- **Benchmark studies on VIV**
 - More participants are needed for the benchmark studies on VIV.
 - As expected, the drag crisis phenomenon on stationary smooth cylinder was not predicted by 2D RANS solvers with turbulence models.
 - It is necessary to investigate the application of other methods such as LES, DES and DNS or to develop a new method to predict the complex flow phenomenon.

10. Conclusions (4)

- **Mooring line damping**
 - A literature review has been conducted for mooring line damping.
 - Existing model tests and full-scale tests have been reviewed.
 - The main challenges for obtaining the mooring damping in model tests lie on the geometry modelling of lines and scale effects.
 - The desirable approach is to determine the mooring damping from the full-scale tests. A rigorous field measurement is needed.
 - It is recommended to conduct large-scale model tests of a semi-submersible in a lake and in a model basin to study the scale effect on the mooring line damping.

11. Recommendations to the 26th ITTC

- Adopt the new procedure 7.5-02-07-03.6, "Dynamic Positioning System, Model Test Experiments"
- Adopt the new guideline 7.5-02-07-03.7, "Wave Energy Converter, Model Test Experiments"

12. Recommendations for Future Work

- Wave run-up benchmark studies for multiple cylinders
- VIV benchmark studies for circular cylinders with/without forced oscillations
- Investigation of the need of benchmark data for sloshing in LNG tanks and the interaction with the insulation systems
- Investigation of the need of benchmark data for vessel responses in side-by-side operations with an emphasis on wave elevation in the gap
- Development of guidelines for hydrodynamic testing of wind and current renewable energy devices
- ...

Liaison with ISSC and Seakeeping Committee

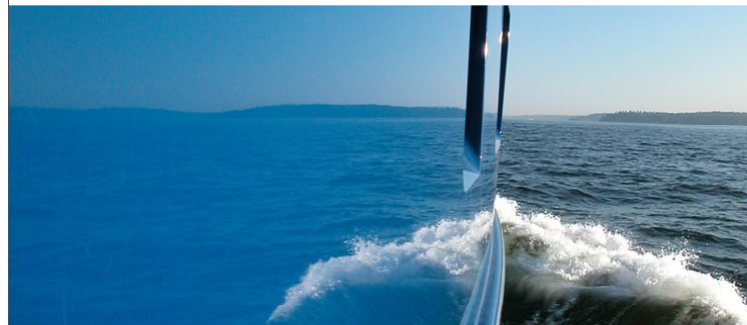


International Towing Tank Conference

First Joint ISSC/ITTC International Workshop

Uncertainty Modelling for Ships and Offshore
Structures (UMSOS)

8th September 2012, Rostok, Germany



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