Report of the Ocean Engineering Committee

Presented by

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Memorial University, Canada

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Copenhagen, Denmark

27TH ITTC • COPENHAGEN

Committee Members

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

Halvor Lie (Secretary), MARINTEK, Norway

Dr. Jean-Marc Rousset, Ecole Centrale de Nantes, France

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

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Prof. Xuefeng Wang, Shanghai Jiao Tong University, China

Dr. Takashi Mikami, Akishima Laboratory (MITSUI ZOSEN) Inc., Japan

Dr. Viacheslav Magarovskii, Krylov State Research Center, Russia

Committee Meetings

Four Committee Meetings were held:

- Samsung Heavy Industries, Geoje Shipyard, Korea, December 2011.
- MARINTEK, Trondheim, Norway, September 2012.
- Ecole Centrale de Nantes, France, June 2013.
- Shanghai Jiao Tong University, China, February 2014.

Outline of This Presentation

1. Tasks assigned by the 26th ITTC
2. Structure of the final report
3. State-of-the-art reviews
4. Review of existing procedures
5. Guideline for VIV model tests
6. Benchmark study of vortex flow induced by a rigid riser
7. Benchmark study of wave run-ups on single and multiple cylinders
8. Physical and numerical modeling of vessels in side-by-side operations
9. Motions of large ships and floating structures in shallow water
10. Joint ITTC/ISSC Workshops
11. Conclusions
12. Recommendations

1. Tasks Assigned by the 26th ITTC (1)

- Update the state-of-the-art for predicting the behavior of bottom founded or stationary floating structures including moored and dynamically positioned ships emphasizing developments since 2011.
- Review ITTC recommended procedures relevant to ocean engineering.
- Complete the VIV and VIM guidelines and benchmark study initialized by the Specialist Committee in Vortex Induced Vibrations of the 26th ITTC.
- Complete and report on the wave run-up benchmark study for a single cylinder.
- Carry out a wave run-up benchmark study for cases of four columns using the experimental data from MARINTEK.

1. Tasks Assigned by the 26th ITTC (2)

- Investigate and report on the thruster-thruster interaction, ventilation and their scaling for DP systems.

- Investigate and report on physical and numerical modeling of vessels in side-by-side operations with an emphasis on wave elevation in the gap.

- Investigate and report on motions of large vessels and floating structures in shallow water.

- Jointly organize and participate in the joint ISSC/ITTC workshop on uncertainty in measurement and prediction of wave loads and responses.

2. Structure of the Final Report

- Section 2: State-of-the-art reviews
- Section 3: Review of existing procedures
- Section 4: Development of guideline for VIV and VIM model tests
- Section 5: Benchmark study of vortex flow induced by a rigid riser
- Section 6: Benchmark studies of wave run-up for cases of single and four columns.
- Section 7: Investigation of thruster-thruster interaction and scaling effect
- Section 8: Physical and numerical modelling of vessels in side-by-side operations
- Section 9: Motions of large ships and floating structures in shallow water
- Section 10: Outcome of joint ISSC/ITTC workshops
- Section 11/12: Conclusions and recommendations

3. State-of-the-Art Reviews

- Stationary floating structures and ships
- Dynamically positioned structures
- Highly nonlinear effects on ocean structures
- Vortex induced vibrations/motions (VIV/VIM)
- New experimental techniques
- New extrapolation methods

(Source: NOAA)

- Practical applications of computational methods to prediction and scaling
- Improving method of experiments, numerical methods and full-scale measurements

Stationary Floating Structures and Ships (1)

- Reviewed recent development in Spar platforms, TLPs, semisubmersibles, FPSOs, and LNG-FPSOs.
- Novel platforms have been developed and tested such as Spars, TLPs, and semisubmersibles.
- A S-Spar concept, combining the features of classic and truss spars, was developed and studied numerically.
- The new concept can lead to smaller wave forces and motions than those of the classic spars.

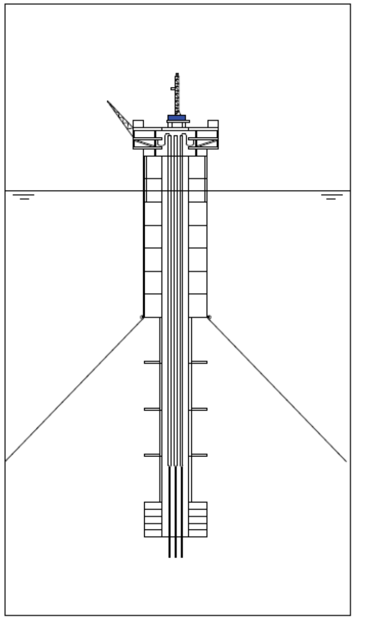


Figure 2.1.1.1 Sketch of S-Spar
(Sun and Huang, 2012)

Stationary Floating Structures and Ships (2)

- The Triceratops TLP for ultra deepwater.
- It combines the characteristics of TLP and Spar with a deck structure supported by three buoyant leg structures connected by ball joints.
- Model tests in regular waves indicated the compliancy of ball joints significantly affects the platform responses and tether tensions.
- Only surge motions are transferred from the buoyant leg structures to the deck.

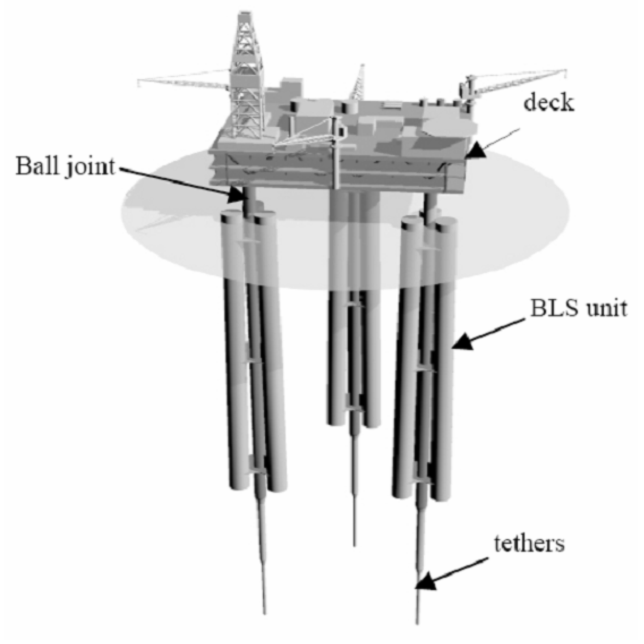
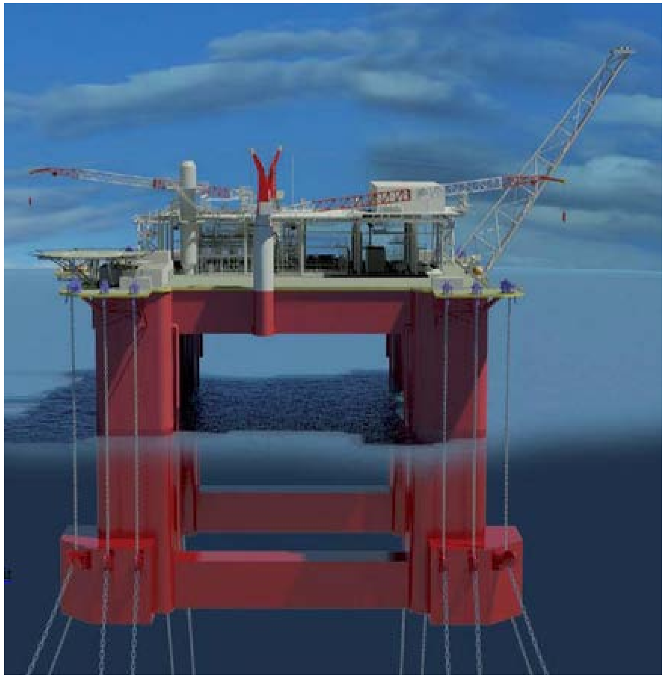


Figure 2.1.2.2 The Triceratops Concept (Chandrasekaran et al., 2011)

Stationary Floating Structures and Ships (3)

- The Heave and VIM Suppressed (HVS) semisubmersible.
- Its performance was verified by model tests and CFD simulations (Kyoung et al., 2013).
- The HVS design showed better performance than an equivalent conventional semisubmersible.



Heave and VIM Suppressed (HVS) Semisubmersible (source, Technip)

Stationary Floating Structures and Ships (4)

- The free hanging solid ballast semisubmersible.
- Mansour and Kumar (2013) studied the motion responses of a free hanging solid ballast semisubmersible in extreme hurricane.
- The numerical studies indicated that the new design improves the performance of a conventional semisubmersible.

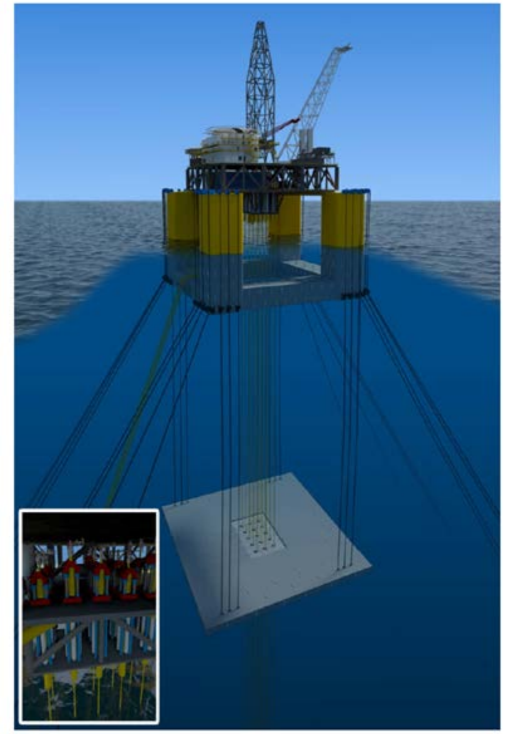


Figure 2.1.3.1 The Free Hanging Solid Ballast (FHSB) Semi (Mansour and Kumar, 2013)

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

  - Responses in extreme seas
  - Vortex induced motion
  - Wave run-up
  - Hydrodynamic interaction of multiple bodies

Stationary Floating Structures and Ships (6)

- The Cooperative Research on Extreme Seas and their impacT (CresT) JIP focuses on TLP motions and loads on tethers due to air-gap and wave impact on deck.
- Hagen (2011) indicated that the extreme tension will increase considerably if the nonlinearities beyond the second-order are included.
- Through model tests, Hennig et al. (2011) reported that the wetted deck area, depending on the type of wave impact, wave-in-deck event and design variation, affects significantly the actual responses of the TLP.

Figure 2.1.2.1 The TLP Model Used in CresT (Henning et al., 2011)

Stationary Floating Structures and Ships (7)

- Numerical methods employed in the frequency domain and in the time domain include

  - Boundary element methods/panel methods
  - CFD methods
  - Coupled methods

- Gonçalves et al. (2012) experimentally studied the Vortex Induced Yaw (VIY) motion on a large volume semisubmersible platform. The yaw motion showed a resonant behavior with considerable amplitudes.

- There is still a need of research in VIM of semisubmersibles and spars.

Stationary Floating Structures and Ships (8)

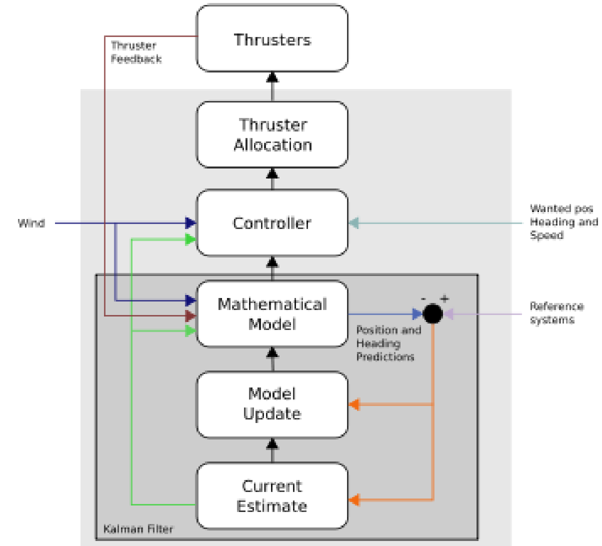
- Relative motions between two floating bodies remain as very important research topics since they concern the safe operation of floating offshore LNG vessels.

- Hydrodynamic effects of liquid in partially filled tanks have been considered in the ship motion and sloshing analysis.

- The hydrodynamic effects of tank fluid and the gap phenomena between two floating bodies still need to be studied further.

Dynamically Positioned (DP) Structures (1)

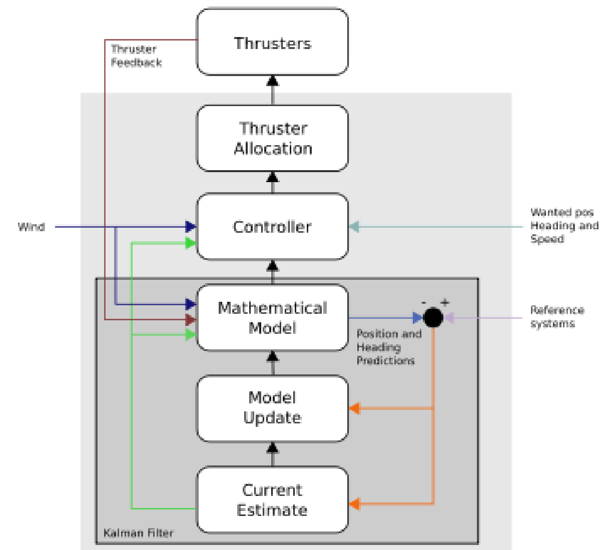
- Research has been continually carried out to improve the design and operation of DP systems.
- Xu et al. (2013) presented a new control strategy considering roll-pitch motion control.
- Smit et al. (2011) investigated to what extent the current feed forward control improves the positioning performance of dynamically positioned FPSO vessels in varying currents .



Dynamically Positioned (DP) Structures (2)

- Tannuri et al. (2012) carried out experimental tests to study the important effect of hydrodynamic interaction on DP performance in terms of station-keeping and thrust demand.

- van Daalen et al. (2011) developed a generic optimization algorithm for the allocation of thrusters for power savings.

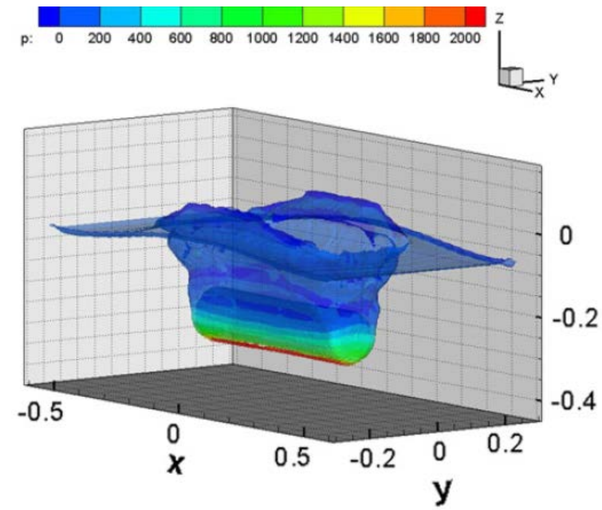


Highly Nonlinear Effects on Ocean Structures (1)

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

Highly Nonlinear Effects on Ocean Structures (2)

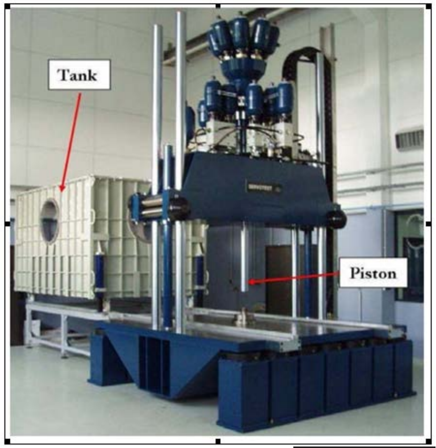
Slamming



- Model tests have been carried out for 2-D and 3-D bodies such as cylinders, cones and ship-sections (free fall and at a constant velocity)

- Numerical simulations were conducted using in-house and commercial software packages based on

  - potential-flow method
  - VOF and CIP
  - SPH
  - Fluid-Structure Interaction (FSI) method



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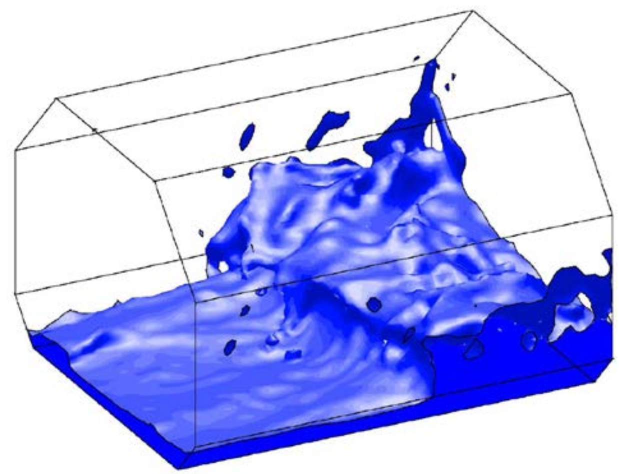
Highly Nonlinear Effects on Ocean Structures (3)

Sloshing

- The state-of-the-art methodology is based on the use of seakeeping computer codes to estimate ship or platform motions.

- Experiments on tank models and CFD simulations have been performed in order to estimate global and local fluid loadings in the tanks.



Highly Nonlinear Effects on Ocean Structures (4)

Sloshing

- Two rounds of Sloshing Model Test benchmark studies were carried out to assess the effect of many parameters on the fluid motion and pressure.

- <u>In the first round tests</u>, a 2-D rectangular tank with clear water, 14 different excitation conditions and a measurement setup were used to compare the laboratory measurements.

- The repeatability of single impact waves seems to be acceptable.

- Notable discrepancies in event rates and probabilities of pressure exceedance were clearly observed for harmonic and irregular waves.

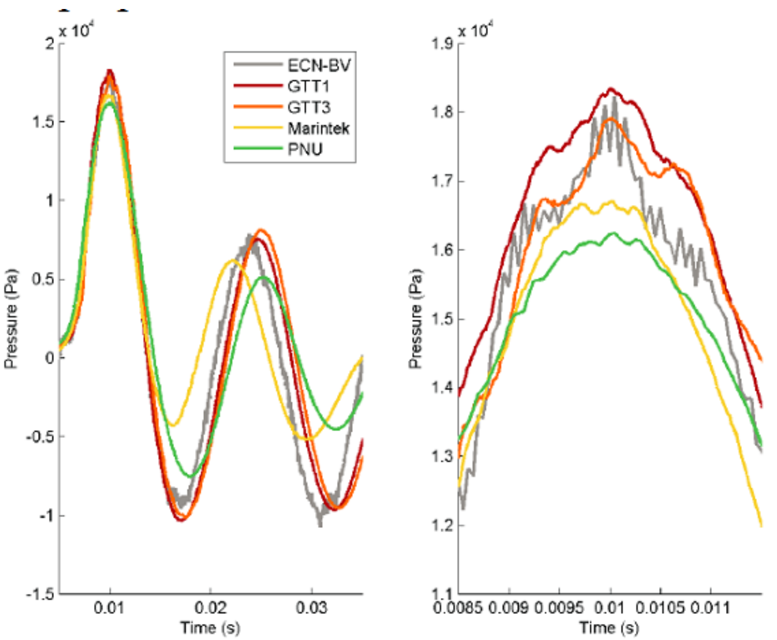


Figure 2.3.2.1: Representative Pressure Time Histories by Six Participants for A Single Impact Wave (Loysel et al., 2013)

Highly Nonlinear Effects on Ocean Structures (5)

Sloshing

- The second round tests were focused on the accurate control of three parameters: the water filling level, the positioning of the tank and the rig motion.
- Many of motion rigs were hexapods. The results for single wave impacts with large gas pockets showed good agreement. This resulted in considering this setup as a reference configuration to validate methodologies.
- Differences can be found when the impact location, the gas pocket location and its size are not accurately controlled.
- Discrepancies in the results for irregular motions still existed and they are comparable to those in the precedent benchmark studies.
- Temperature effects were highlighted and further investigations regarding this aspect were proposed.

Highly Nonlinear Effects on Ocean Structures (6)

Sloshing

- Hydroelasticity effect
- Choi et al. (2012) studied hydroelasticity effect in sloshing experiments using a hexapod and rectangular tank models
- The experiments indicated the impact pressure are higher in the case of the flexible wall.

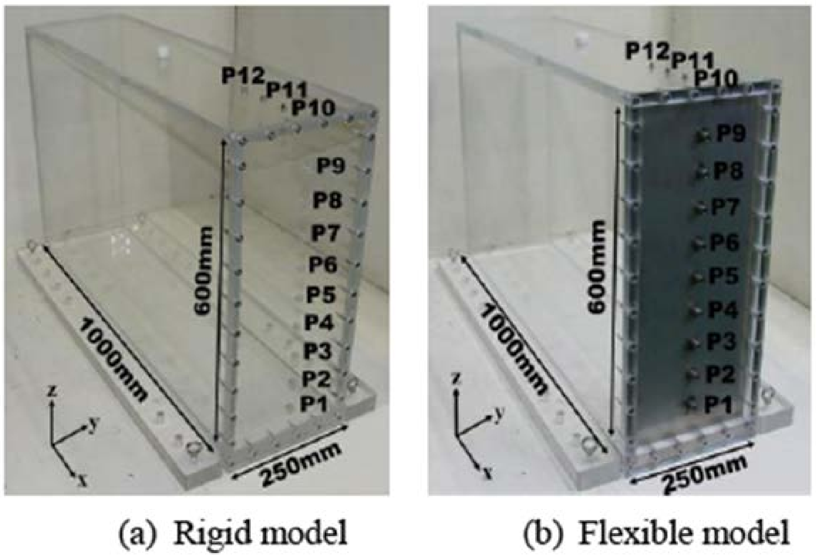


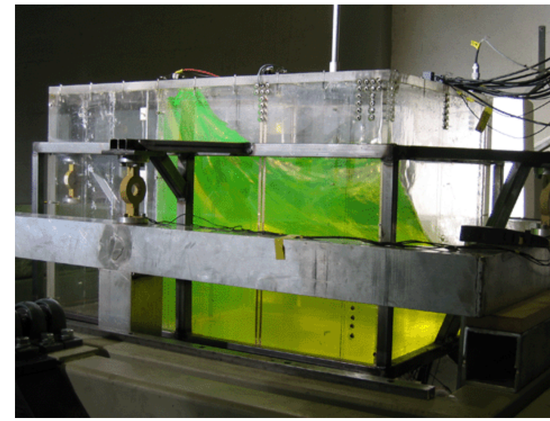
Figure 2.3.2.3 Rigid and Flexible Models and Locations of Pressure Transducers (Choi et al., 2012)

Highly Nonlinear Effects on Ocean Structures (7)

Sloshing

- In summary, progress on sloshing studies has been reported at three different levels:

  - model tests for local fluid motions and pressures
  - hydroelasticity effect
  - scale effect (using sloshing tanks in small and large scales)



Source: NTNU

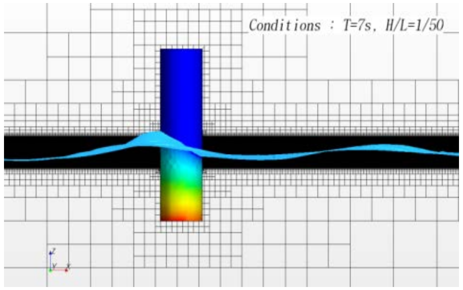
- The state-of-the-art global sloshing analysis is still based on the coupled seakeeping simulation (potential flow code/CFD).

- Scale effect remains as a challenge.

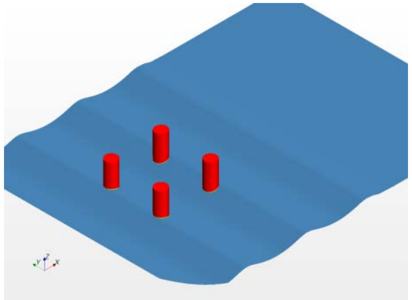
Highly Nonlinear Effects on Ocean Structures (9)

Wave Run-up

- Research has been carried out on the study of the wave run-up on different structures, such as circular cylinders, monopiles, barges and columns of large semisubmersibles using CFD methods.



- The outcome of the studies indicates the importance of high-order nonlinearities and the need of computational efforts for accurate predictions.

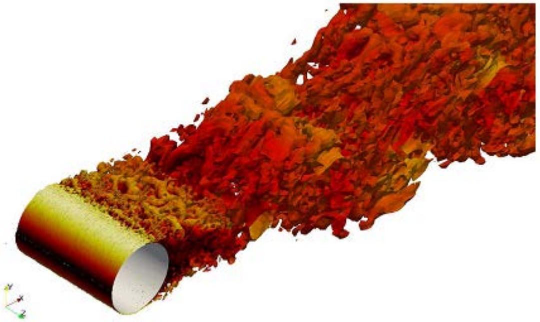


VIV/VIM (1)

- Progress has been made in development of VIV prediction programs based on empirical methods and CFD.

- Efforts have been made to develop new VIV prediction methods based on the time-domain approach using experimental database, forcing algorithms and FEM for dynamics of risers.

- The results based on the time-domain methods are encouraging.



VIV/VIM (2)

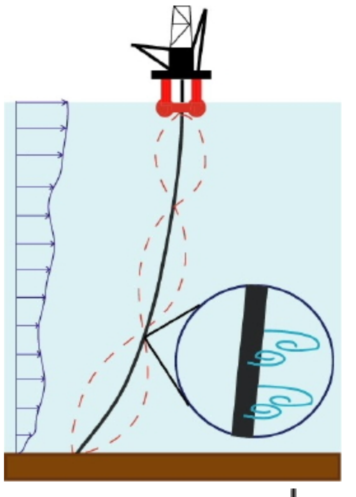
- Progress has also been made in 2-D and 3-D model tests of VIV/VIM.

- 2-D forced rigid cylinders with harmonic motions in in-line and cross-flow directions.
  Zheng et al (2011) carried out extensive forced in-line and combined in-line and cross-flow experiments were employed to provide the hydrodynamic coefficient databases.

- 2-D forced rigid cylinders with non-harmonic motions.
  Yin and Larsen (2011) investigated the VIV responses subjected to the non-harmonic motions, and forced motion tests for rigid risers using observed orbits extracted from a flexible beam.

VIV/VIM (3)

- Effect of Reynolds number
- 2-D model tests (for example, Li et al., 2013) were conducted to investigate the effect of Reynolds number on VIV using full-scale rigid risers.
- The effect of Reynolds number on the amplitude of VIV displacement was found to be significant.
- Further research was recommended to explore this subject.

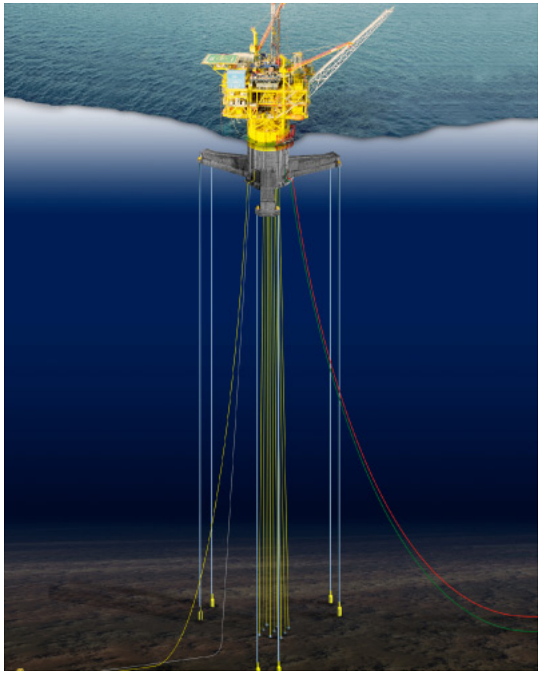


VIV/VIM (4)

- Multiple Riser Interaction

- Constantinides et al. (2013) performed the tandem riser tests at the prototype Reynolds numbers, utilizing two full-scale cylinders fitted with actual VIV suppression devices and towed either in fixed or spring supported configurations.

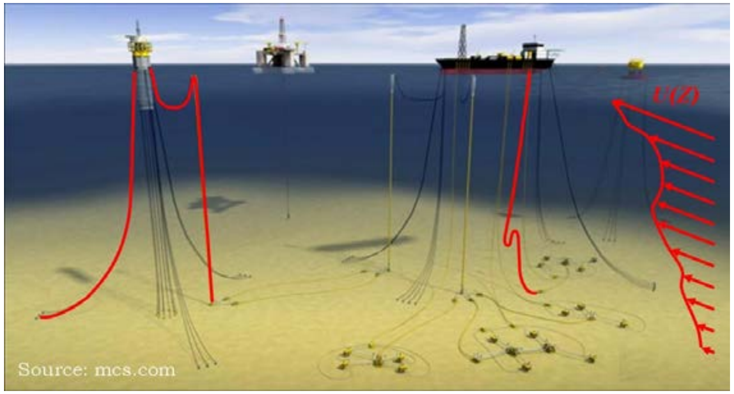
- The results revealed significant differences from those by today's design practices and industry codes.



Source: www.atlantia.com

VIV/VIM (5)

- 3-D tests for one or two flexible risers.
- Several VIV tests with flexible beam have been carried out.
- Strain gauges are mostly used in these tests. Accelerometers are also used in some of the tests to provide redundancy in the measurements.
- All of the tests were carried out in sub-critical Reynolds numbers due to the limitation in the test facility and the cost.



VIV/VIM (6)

- The presence of higher-order harmonic frequency components and chaotic responses has been observed in many flexible beam tests.

- Price et al. (2011) studied the impact of higher-order harmonic stress components and the broad band responses on fatigue damage using the NDP high-mode VIV test data. The study indicated that both factors can lead to significant fatigue damages.

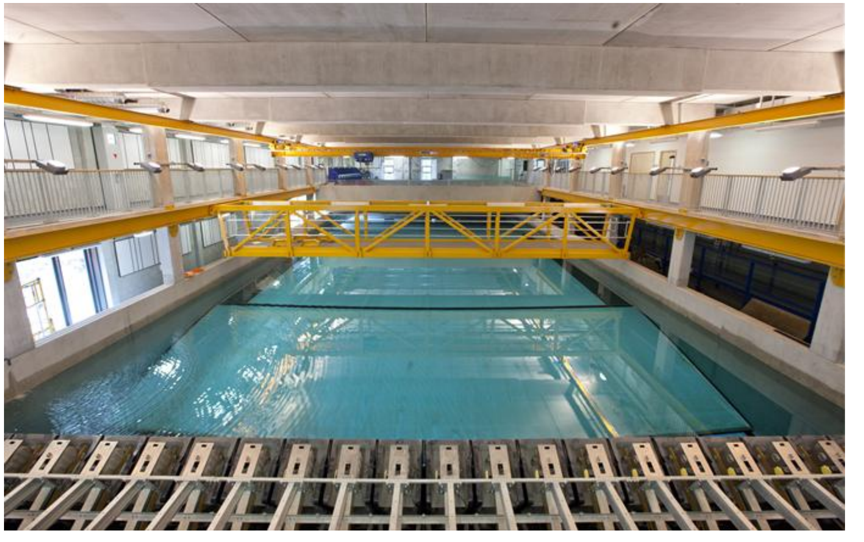
New Facility (1)

- FLOWAVE-TT, located at Edinburgh, was opened in 2014.
- It is a 25m diameter circular tank with an adjustable floor.
- Pumps around the tank allow to generate a water current up to 1.6 m/s at any direction in the tank.
- Wave height is up to 28 m in full scale.

FloWave TT

New Facility (2)

- The Plymouth Ocean Wave Basin (COAST).
- 35m long x 15.5m wide x 3m deep, operable at different depths (with an adjustable floor).
- 24 flaps of 2.0m hinge depth are able to produce waves of up to 0.9m in height.
- Multi-directional, re-circulating current generation, both inline and across the path of the waves
- Wind generation facility



New Extrapolation Techniques

- Limited investigations have been carried out on the development of extrapolation methods.
- However, challenges and issues in scaling of model test results to full scale have been indicated in problems related to sloshing, dynamic position systems, and mooring and risers.

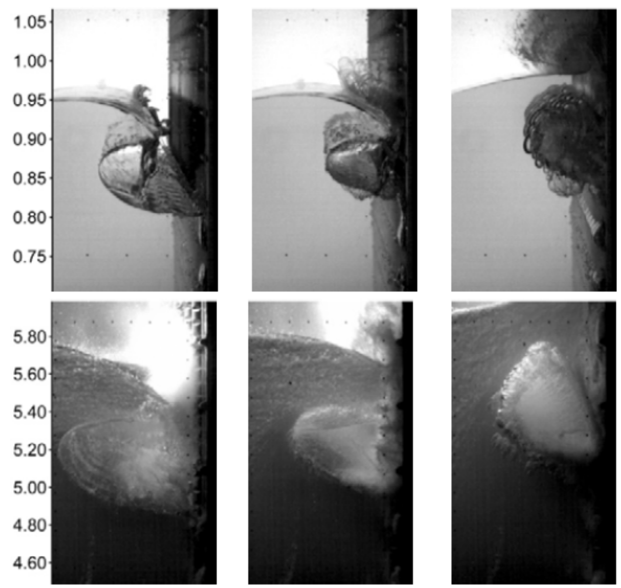
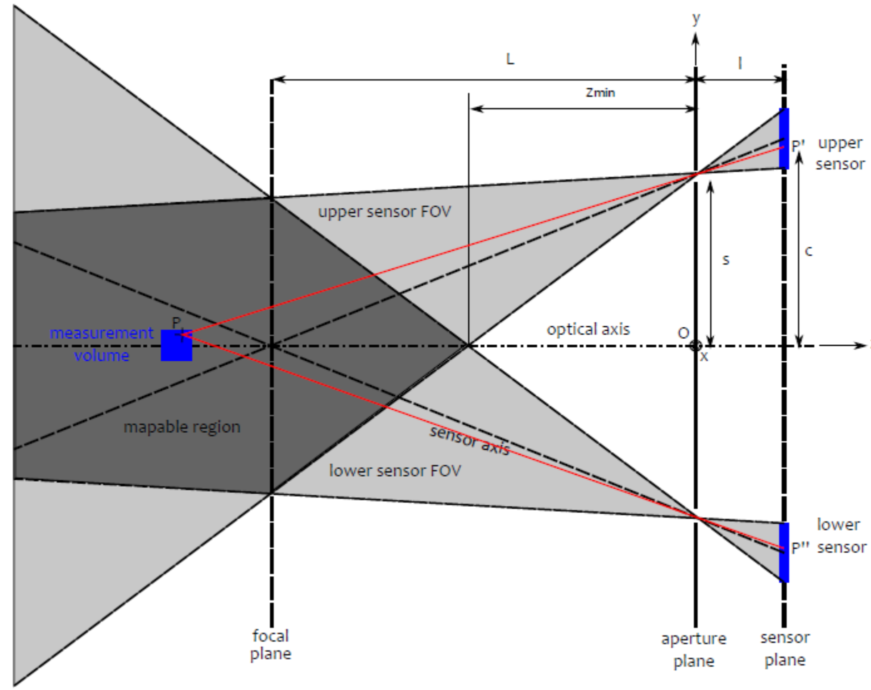


Figure 2.6.1 Air Pocket Impact on A Corrugated Wall (Upper: 1:6 Scale; Lower: Full Scale) (Bogaert et al., 2011)

Improving Method of Experiments

- Huera-Huarte (2012) used the Defocusing Digital Image Particle Velocimetry (DDPIV) method to measure vortex-induced vibrations of long flexible cylinders in wind/water tunnel.

- It was suggested the method could be used to study VIV in the laboratory. The good agreement of measured data with known results confirmed the effectiveness of the technique.



3. Reviewing Existing Procedures

- 7.5-02-07-03.1 Floating Offshore Platform Experiments
  7.5-02-07-03.2 Analysis Procedure for Model Tests in Regular Waves

  - Only very minor revisions were identified.

- 7.5-02-07-03.3 Model Tests on Tanker-Turret Systems

  - There is little information in 7.5-02-07-03.3 and the limited information in 7.5-02-07-03.3 is very similar to that in 7.5-02-07-03.1.

  - The Committee recommends to move the contents of 7.5-02-07-03.3 to 7.5-02-07-03.1.

- There is a need to develop an Analysis Procedure for Model Tests in Irregular Waves.

4. Guidelines for VIV and VIM Tests (1)

- If the vortex induced response mainly causes elastic deformation in marine structures, such as risers, cables and free spanning pipelines, this phenomenon is known as Vortex Induced Vibrations (VIV).

- If the vortex induced response mainly causes rigid body motions such as a sway motion of a platform, this response is often denoted as Vortex Induced Motion (VIM).

- The Committee focused on the development of guideline for VIV testing.

4. Guidelines for VIV and VIM Tests (2)

- The guideline for VIV testing, 7.5-02-07-03.10, has been developed.

- The purpose of this guideline is to

  (1) ensure that laboratory model tests of VIV responses of marine structures are adequately performed according to the best available techniques;

  (2) provide an indication of improvements that might be made;

  (3) ensure that any comprises inherent in VIV tests are identified and their effects on the measured results are understood.

5. Numerical Benchmark Studies of VIV (1)

- Benchmark Data from MARIN for Stationary Cylinder

  - Rigid circular cylinder (D=200mm, L=3.52m)

  - Reynolds numbers

    6.31E+04, 1.26E+05, 2.52E+05
    3.15E+05, 5.06E+05, 7.57E+05

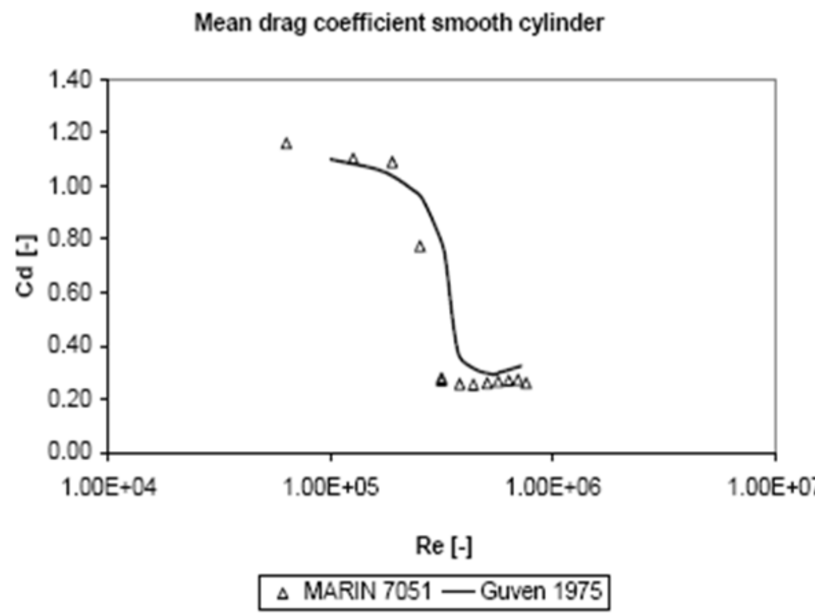


Figure 5.1.3 Drag Coefficient for Smooth Cylinder – Experimental

5. Numerical Benchmark Studies of VIV (2)

- 8 Participants

- A workshop was held at Nantes, France on October 17 and 18, 2013 and provided opportunities for participants to present and discuss the results of benchmark studies.

	Affiliation	Country
1	China Ship Scientific Research Centre	China
2	Seoul National University	Korea
3	Samsung Ship Model Basin	Korea
4	Memorial University	Canada
5	Inha University	Korea
6	University of Iowa	USA
7	University of Southampton	UK
8	Shanghai Jiao Tong University	China

5. Numerical Benchmark Studies of VIV (3)

- Numerical Methods

	Code name	2D/3D	RANS/DES/LES
A	FLUENT	2D	RANS
B	SNUFOAM (In-house code)	2D	RANS
C	FLUENT	2D	RANS
D	CFDShip-IOWA (In-house code)	3D	LES
E	Code-S (In-house code)	3D	LES
F	OpenFOAM (Open source code)	3D	LES
G	Naoe-FOAM-SJTU (In-house code)	2D	RANS
H1	STAR-CCM+	2D	RANS
H2	STAR-CCM+	2D	RANS
H3	STAR-CCM+	3D	DES
H4	STAR-CCM+	3D	LES

5. Numerical Benchmark Studies of VIV (4)

- Numerical Models

# of Grid	Type of Grid	Convection Term	Δt
87,223	Structured	Upwind	0.001/0.0005
32,280	Structured	Upwind	0.001/0.0002/0.0001
43,820	Structured	Upwind	0.001
67,000,000	Structured	QUICK/WENO	0.00008/0.0001
11,300,000	Unstructured (Cartesian)	Upwind	(CFL=0.5)
Max 4,000,000	Unstructured	Hybrid (Central + Upwind)	0.005
100,000	Chimera	Upwind	0.00017~ 0.0015
592,478	Hybrid	Upwind	0.0001~0.002
592,478	Hybrid	Upwind	0.0001~0.002
12,400,000	Structured	Upwind	0.002~0.02
12,400,000	Structured	Upwind	0.002~0.02

5. Numerical Benchmark Studies of VIV (5)

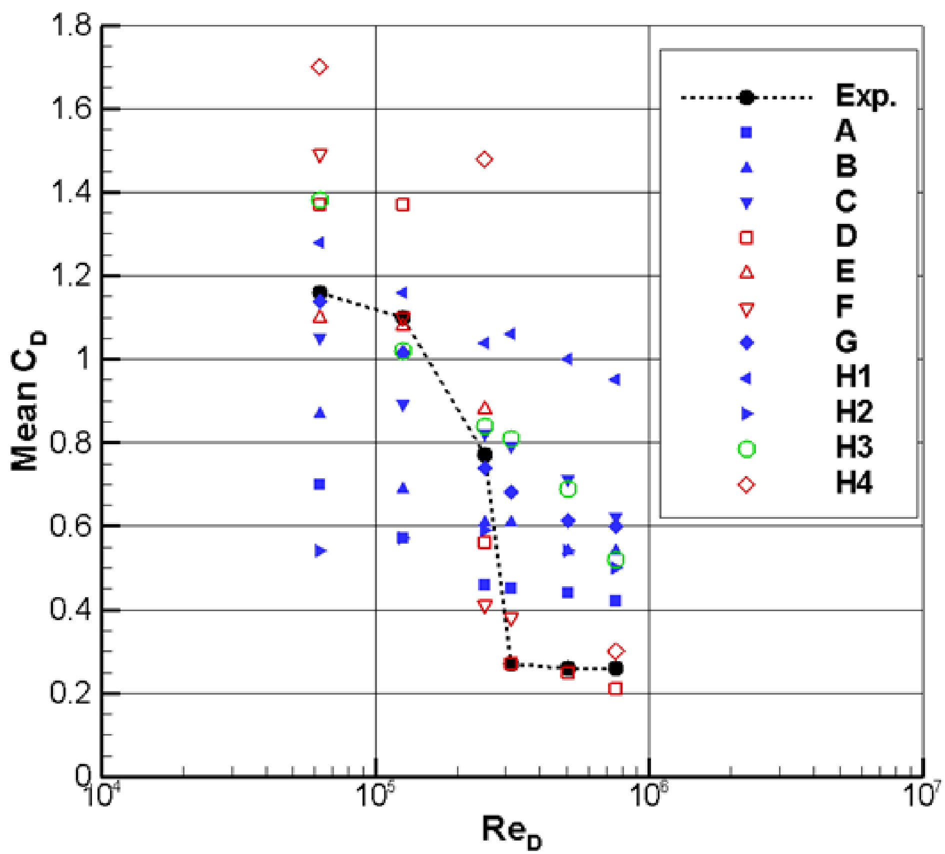
- Numerical Models

(no transition model was used.)

	y^+	Wall Function (Used/Not Used)	Turbulence Model
A	**59**	U	k-w SST
B	2	N	k-w SST
C	10	N	k-w SST
D	**0.03** ~0.15	N	Dynamic model
E	-	N	Dynamic model
F	1	N	Dynamic model
G	1~4.9	U	k-w SST
H1	0.06~0.56	N	k-w SST
H2	0.06~0.56	N	k-e (Standard)
H3	0.06~0.56	N	-
H4	0.06~0.56	N	-

5. Numerical Benchmark Studies of VIV (6)

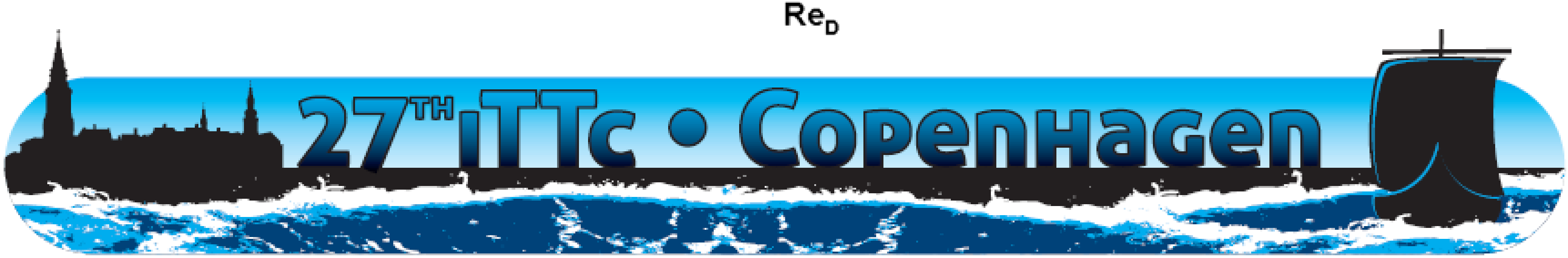
- Mean Drag Coefficient



RED – LES

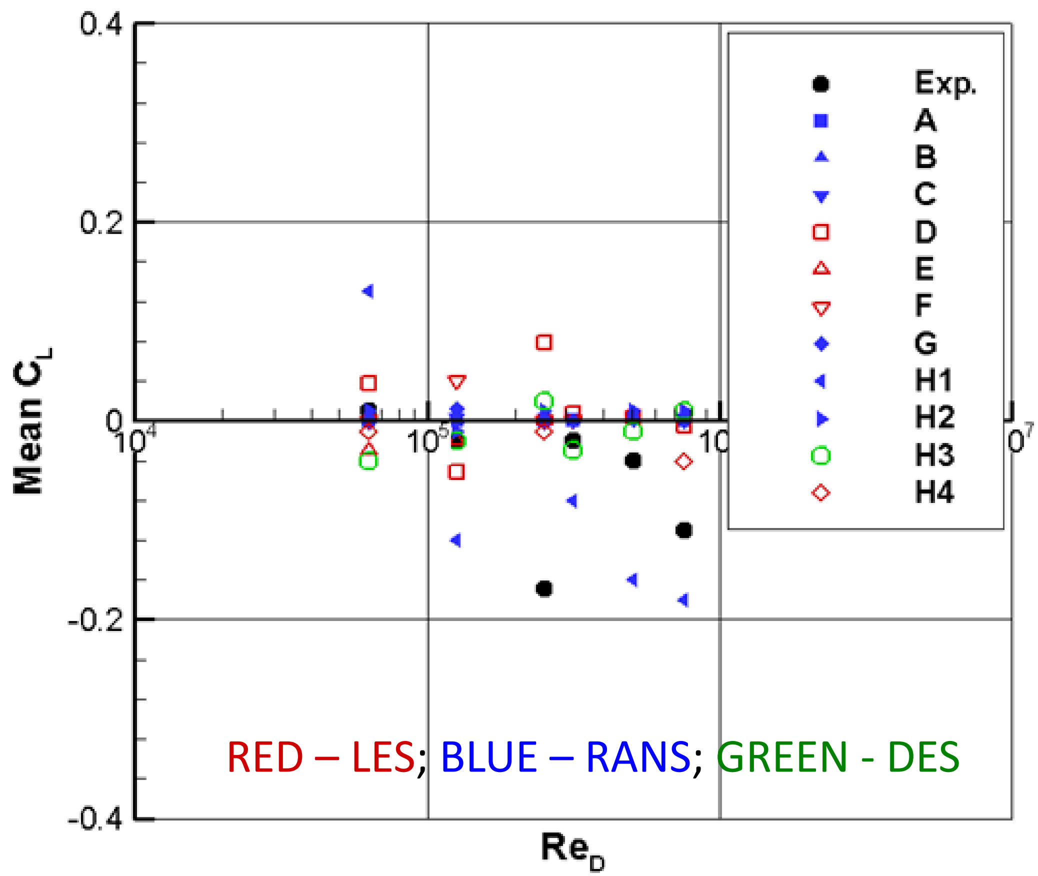
BLUE – RANS

GREEN - DES



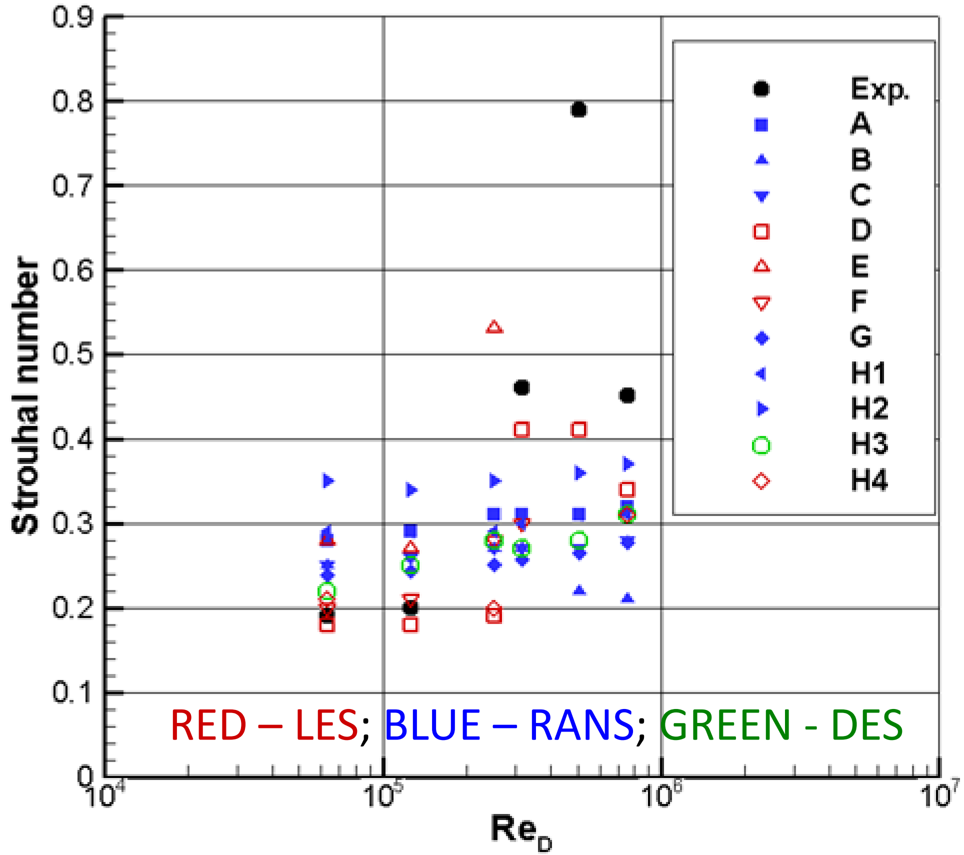
5. Numerical Benchmark Studies of VIV (7)

- Mean Lift Coefficient



5. Numerical Benchmark Studies of VIV (8)

- Strouhal Number



5. Numerical Benchmark Studies of VIV (9)

Summary

- URANS, DES and LES were used in the benchmark studies.
- In terms of overall trend, numerical predictions by DES and LES are generally in better agreement with the experimental data than those by URANS.
- It can be concluded that the LES method captured the drag crisis phenomenon and the LES solutions agree better with experimental data at most points than those by URANS.
- At high Reynolds numbers, some solutions by the URANS method agree reasonably well with the experimental data.

5. Numerical Benchmark Studies of VIV (10)

Summary

- More studies based on DES and LES are required.

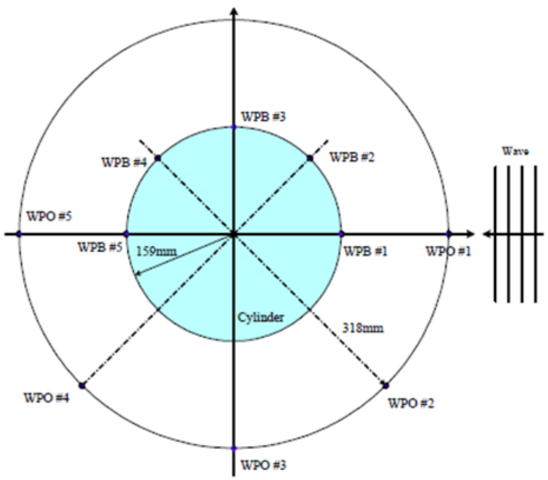
- Results of the benchmark studies will be considered for publication in a special issue of Applied Ocean Research.

6. Benchmark Studies of Wave Run-up (1)

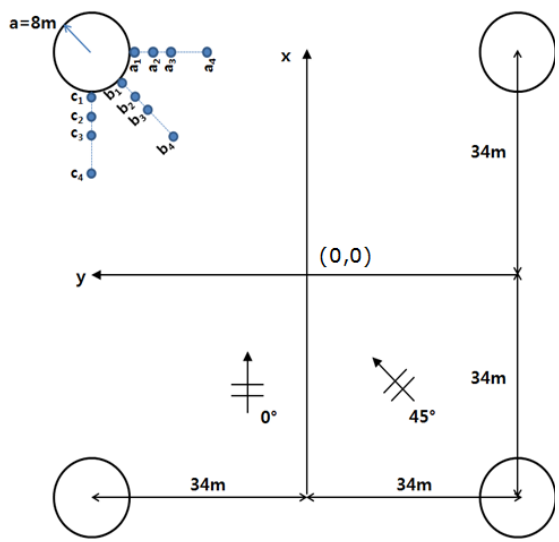
- Benchmark studies were carried out for the following cases:

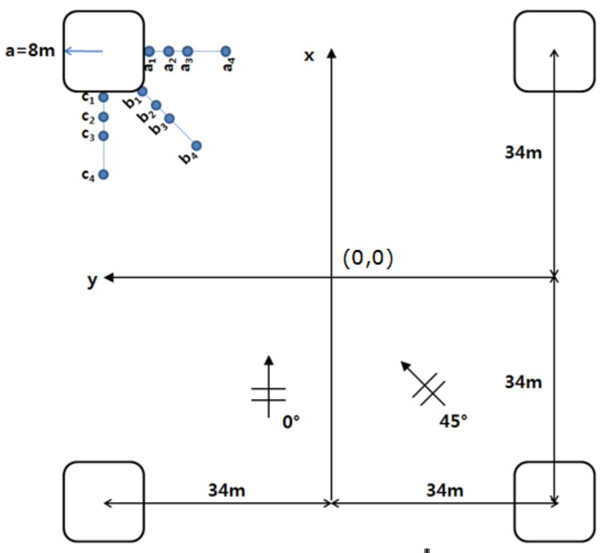
  - Single truncated circular cylinder. The experimental data are provided by MOERI.

  - Four truncated squared and circular cylinders. The experimental data are provided by MARINTEK.



Placement of Wave Probe on and around the Cylinder
WPB : wave probe at the cylinder surface (gap=4.1mm)
WPO : wave probe off the cylinder (gap=159.0mm)





6. Benchmark Studies of Wave Run-up (2)

- Test Matrix – Single Circular Cylinder

	$T = 7s$	$T = 8s$	$T = 9s$	$T = 10s$	$T = 12s$	$T = 15s$
$H/\lambda = 1/50$	T07S150	T08S150	T09S150	T10S150	T12S150	T15S150
$H/\lambda = 1/30$	T07S130	T08S130	T09S130	T10S130	T12S130	T15S130
$H/\lambda = 1/16$	T07S116	T08S116	T09S116	T10S116	T12S116	T15S116
$H/\lambda = 1/10$	T07S110	T08S110	T09S110	T10S110	T12S110	T15S110

6. Benchmark Studies of Wave Run-up (3)

- Test Matrix – Four Cylinders

H/λ	$k_0 A$	$T(s)$	$k_0 a$	$\overline{A}^{(1)}$	I	II	III	IV
1/30	0.10	7	0.657	1.22	1100	2100	4100	6100
		9	0.397	2.04	1110	2111	4110	6110
		12	0.224	3.78	1120	2120	4120	6121
		15	0.143	5.83	1130		4130	
1/16	0.20	7	0.657	2.35	1200	2200	4200	6200
		9	0.397	3.79	1210	2212	4210	6210
		12	0.224	7.06	1220	2220	4220	6220
		15	0.143	10.86	1230		4230	
1/10	0.31	7	0.657	3.66	1300	2300	4300	6300
		9	0.397	6.40	1310	2310	4310	6310
		12	0.224	10.81	1320	2320	4320	6320
		15	0.143	16.94	1330		4330	

I) single circular column, II) single squared column
III) four circular columns, IV) four squared columns

6. Benchmark Studies of Wave Run-up (4)

- The first-order, second-order harmonics and mean results of following measured items were compared with numerical solutions at various wave frequencies in terms of kR:

    1) Horizontal force
    2) Vertical force
    3) Wave elevations at various wave probe locations.

6. Benchmark Studies of Wave Run-up (5)

- Participants

No.	Affiliation	Country
1	ECN	France
2	Hyundai Heavy Industries	Korea
3	Inha University	Korea
4	University of Iowa	USA
5	MOERI(KRISO)	Korea
6	University of Bath	UK
7	MARINTEK	Norway
8	Pusan National University	Korea
9	Samsung Heavy Industries with CD-Adapco Korea	Korea
10	Seoul National University	Korea
11	Shanghai Jiao Tong University	China

6. Benchmark Studies of Wave Run-up (6)

- 11 Participants

(Two carried out model tests)

Participant	Single Circular Cylinder	Single Squared Cylinder	Four Circular Cylinders		Four Squared Cylinders	
	Wave heading: 0deg	0 deg	0 deg	45 deg	0 deg	45 deg
ECN, France	O	O			O	O
Hyundai Heavy Industries	O					
Inha University	O					
University of Iowa	O					
MOERI	O					
University of Bath	O					
MARINTEK*	O	O	O	O	O	O
Pusan Nat. University	O					
Samsung Heavy Industries with CD-Adapco Korea	O		O		O	
Seoul National University	O					
Shanghai Jiao Tong University	O		O	O		

6. Benchmark Studies of Wave Run-up (7)

- CFD programs used by nine participants:

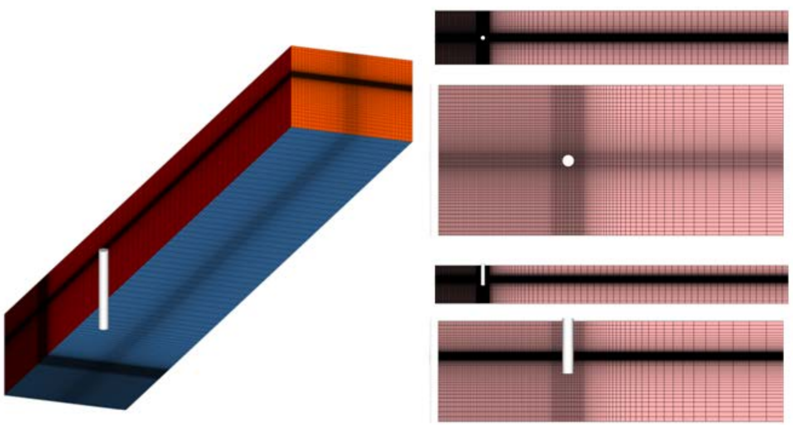
  - Star-CCM+
  - INHAWAVE-II (in-house)
  - ComFlow
  - CFDShip-Iowa (in-house)
  - Open-Foam (open-source)

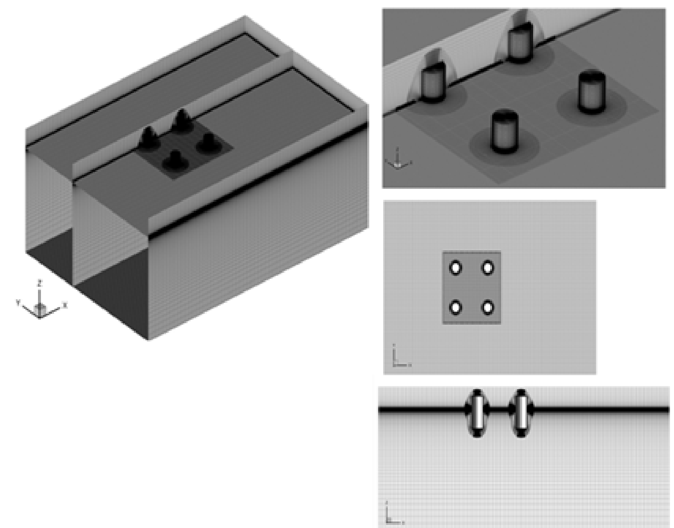
- Two participants also used potential-flow codes:

  - FEDIF (in-house)
  - DIFFRACT (in-house)

6. Benchmark Studies of Wave Run-up (8)

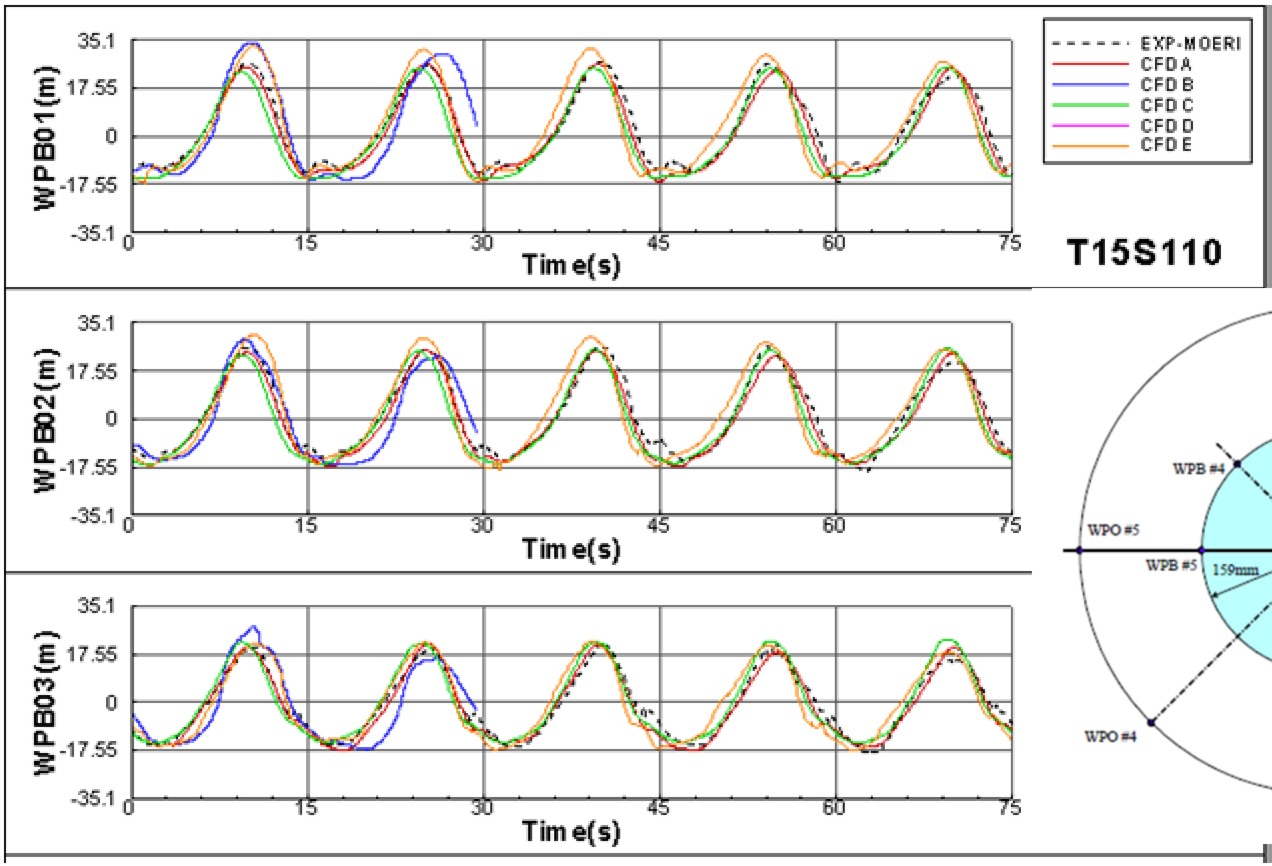
- Examples of Grids for Single and Four Truncated Cylinders:



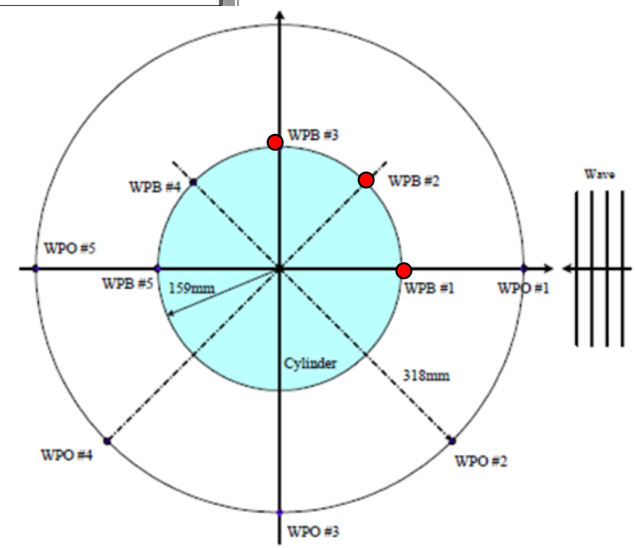


6. Benchmark Studies of Wave Run-up (9)

- Wave elevations at WPB01, WPB02 and WPB03

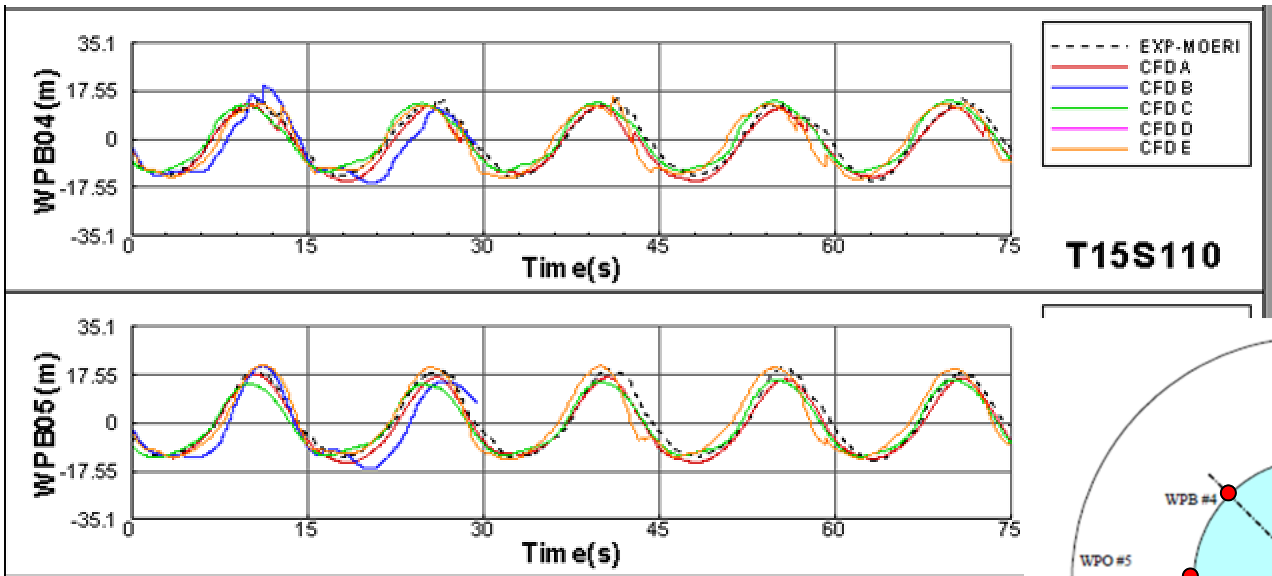


Single Truncated Circular Cylinder

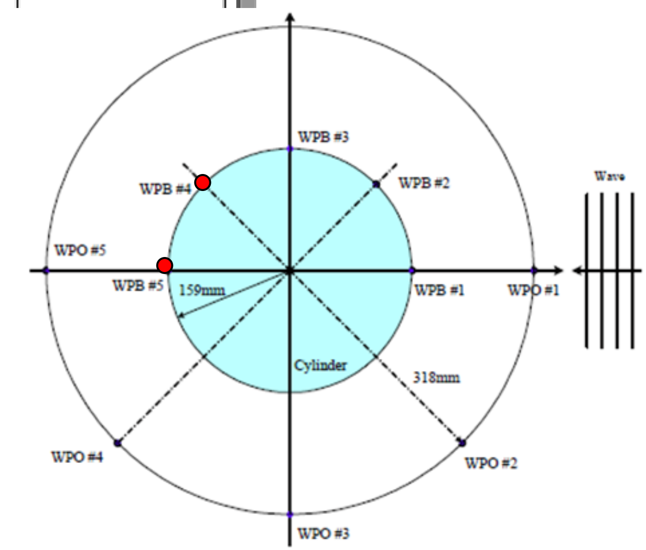


6. Benchmark Studies of Wave Run-up (10)

- Wave elevations at WPB#04 and WPB#05

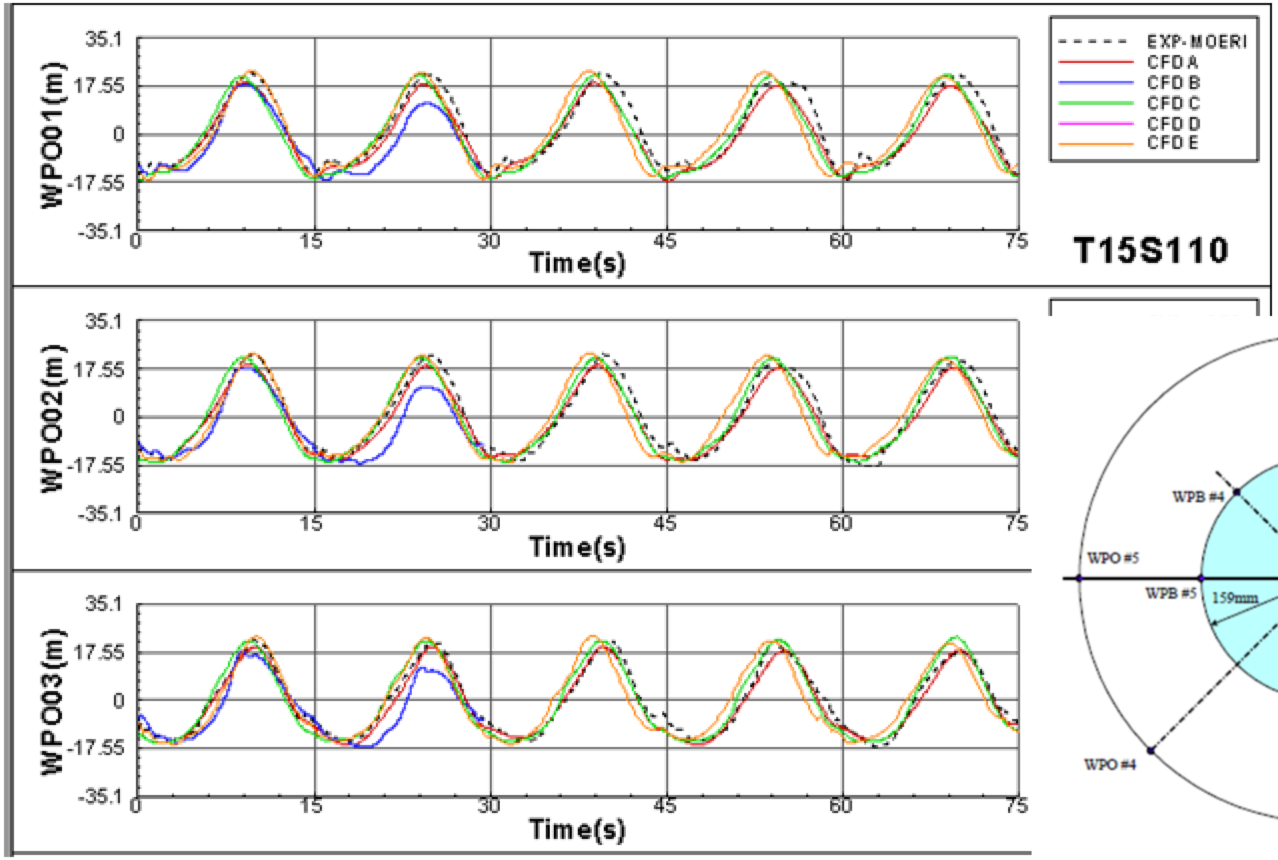


Single Truncated Circular Cylinder

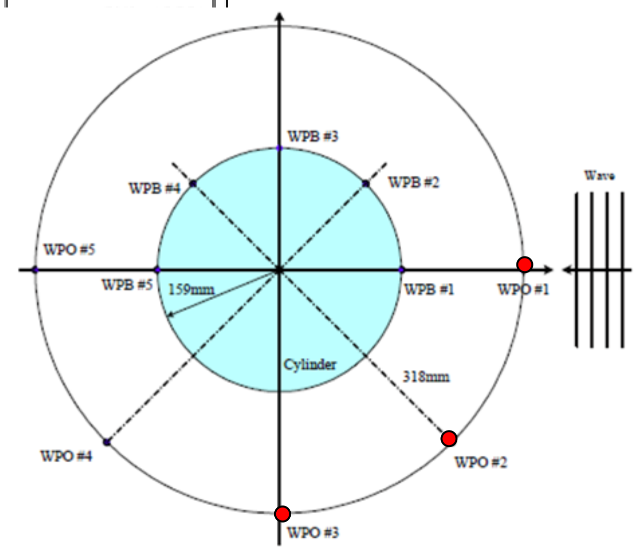


6. Benchmark Studies of Wave Run-up (11)

- Wave elevations at WPO#01, WPO#02 and WPO#03



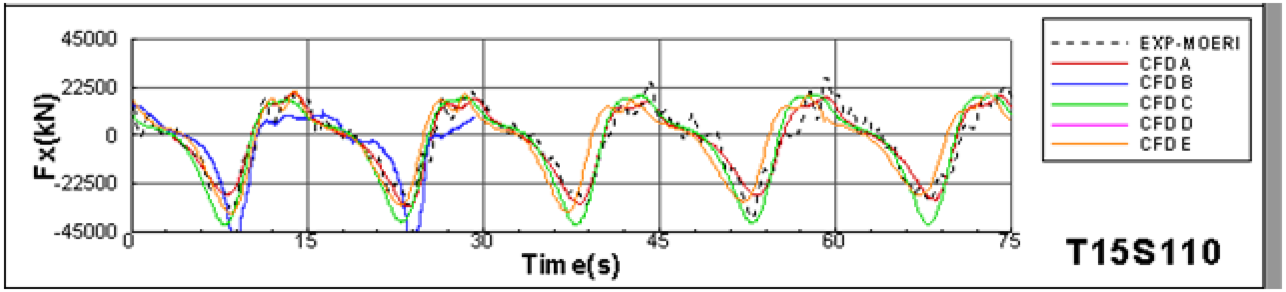
Single Truncated Circular Cylinder

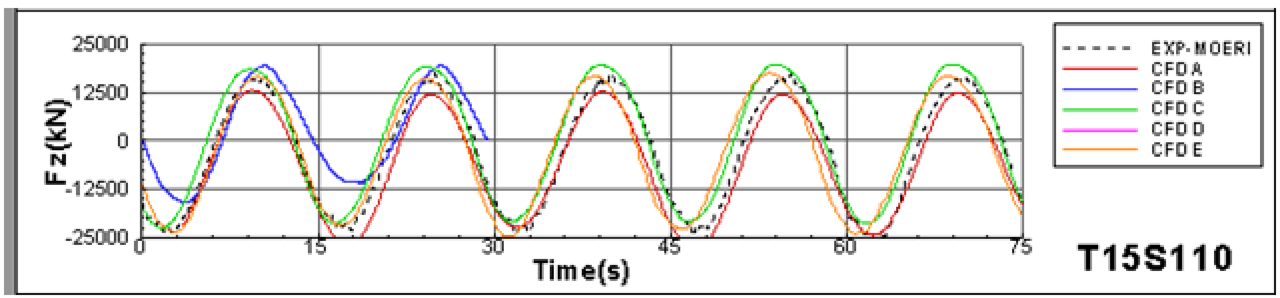


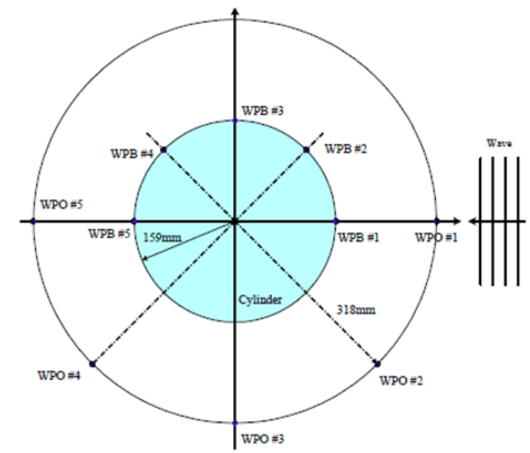
6. Benchmark Studies of Wave Run-up (12)

- Horizontal and Vertical Forces, Fx and Fz

Single Truncated Circular Cylinder

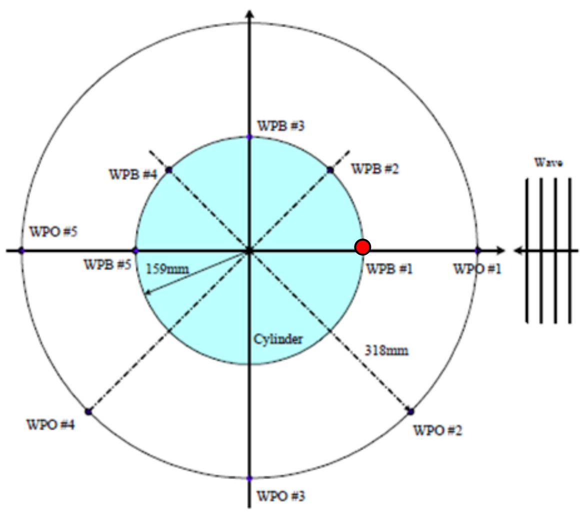




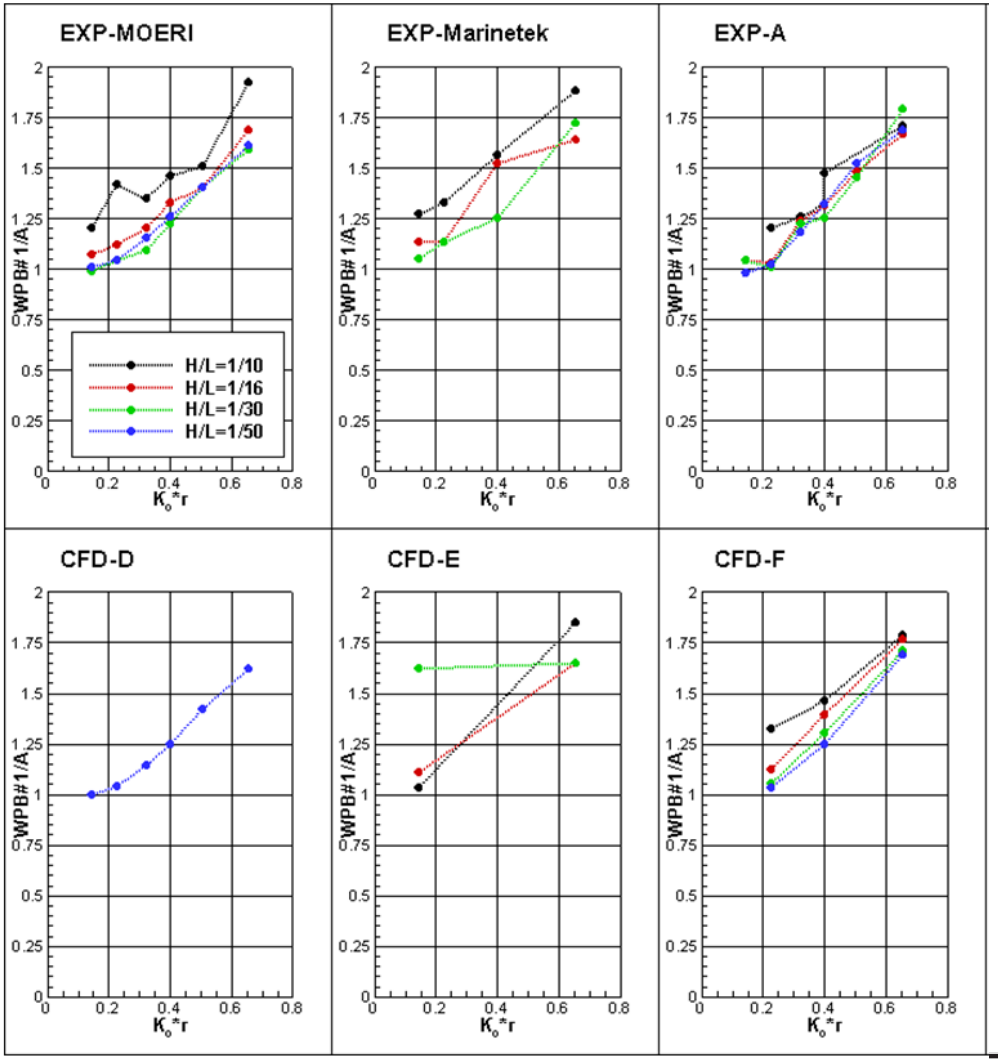


6. Benchmark Studies of Wave Run-up (12)

- First Harmonic Component of Wave Elevation at WPB#01

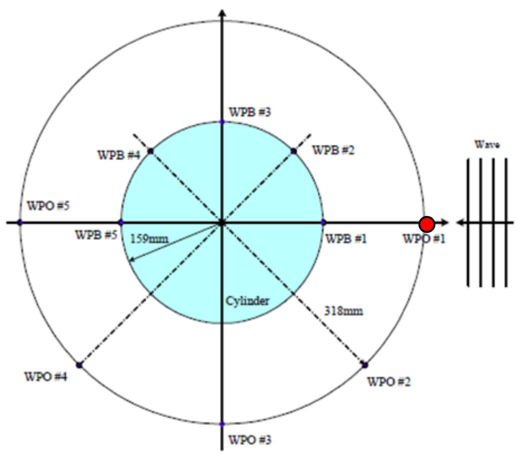


Single Truncated Circular Cylinder

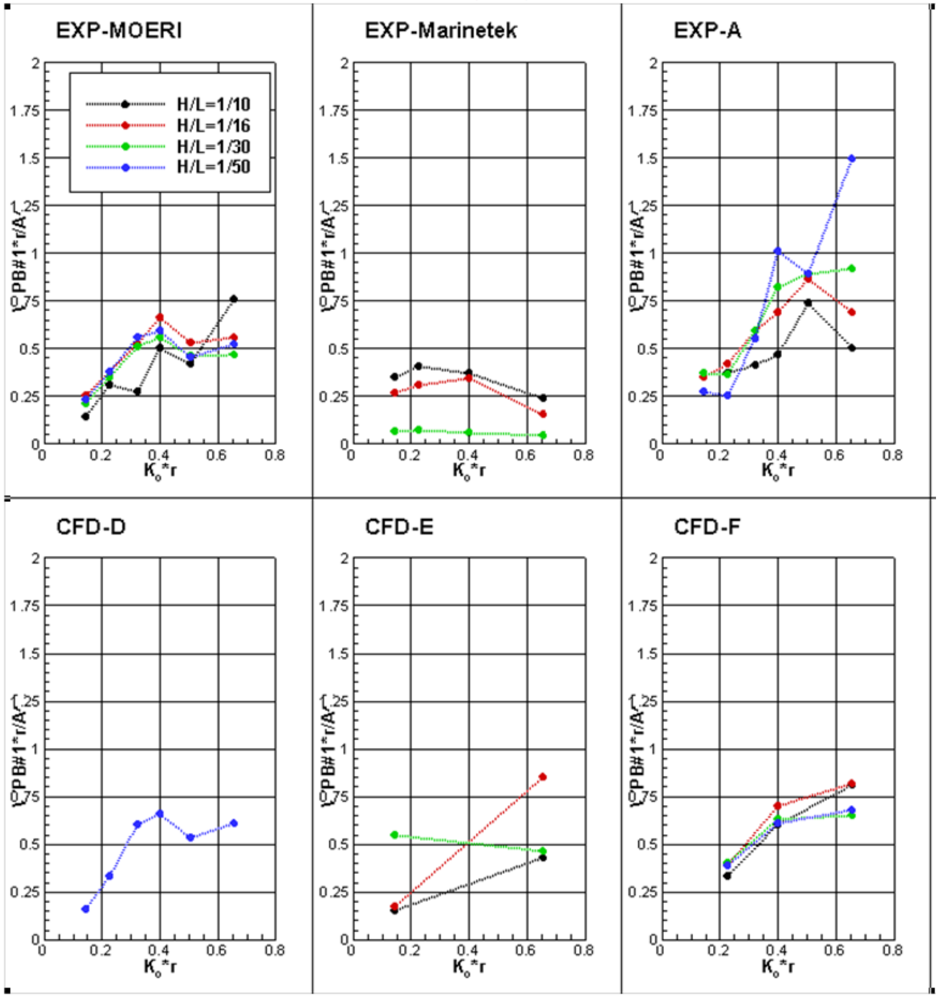


6. Benchmark Studies of Wave Run-up (13)

- Second Harmonic Component of Wave Elevation at WPB#01

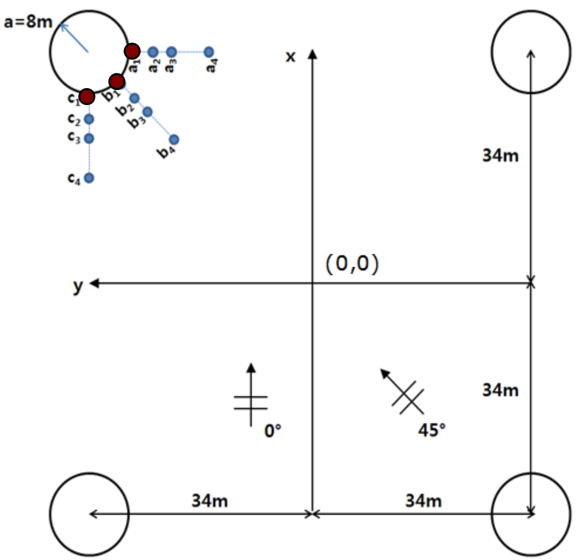


Single Truncated Circular Cylinder

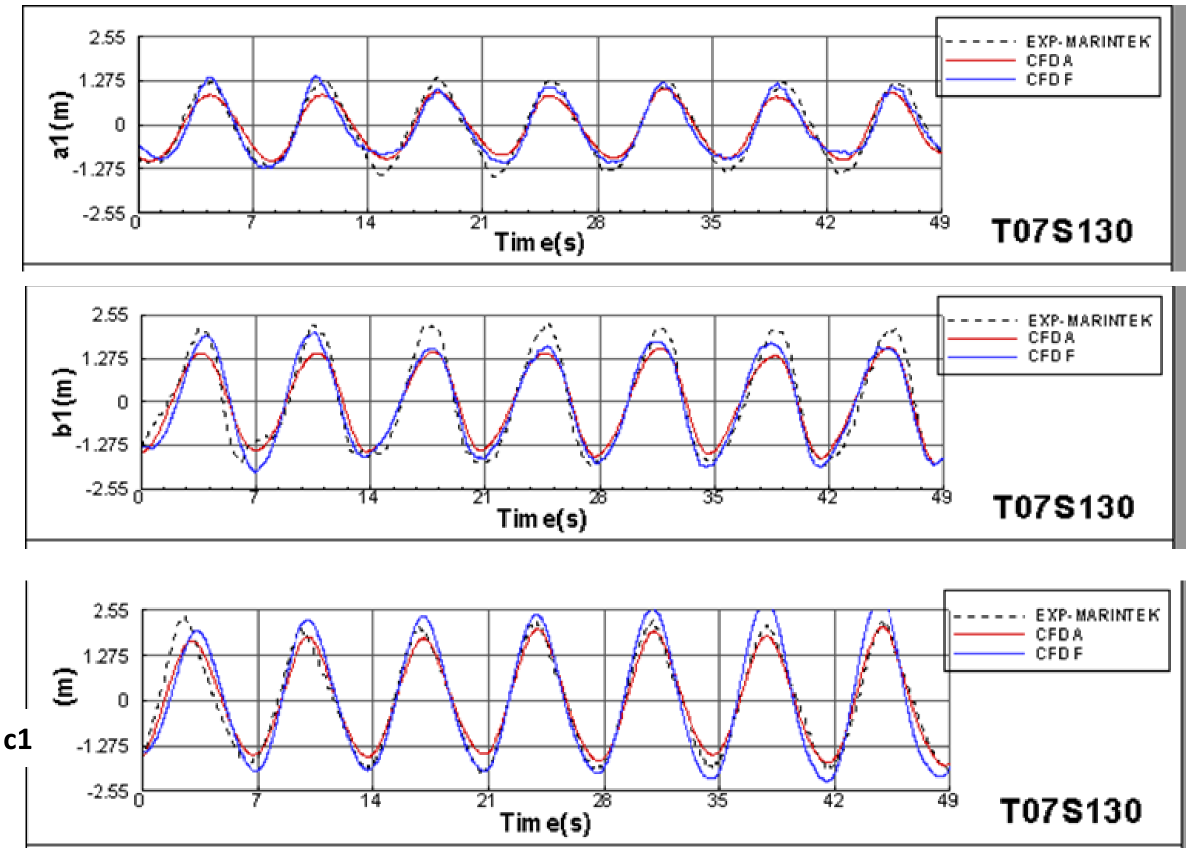


6. Benchmark Studies of Wave Run-up (13)

- Time Histories of Wave Elevations at a1, b1 and c1



Four Truncated Circular Cylinders



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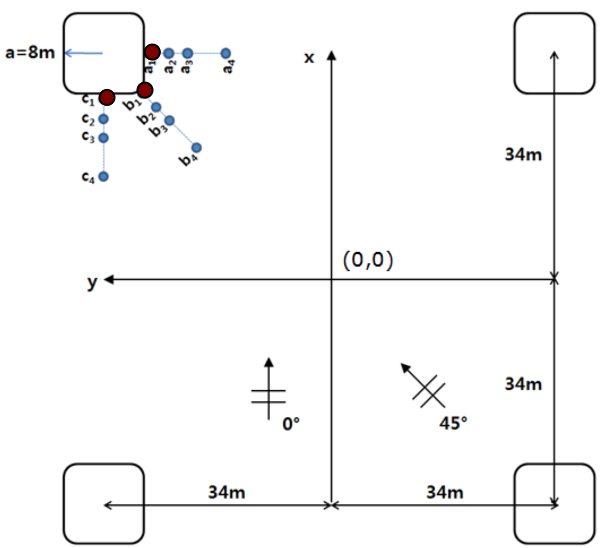
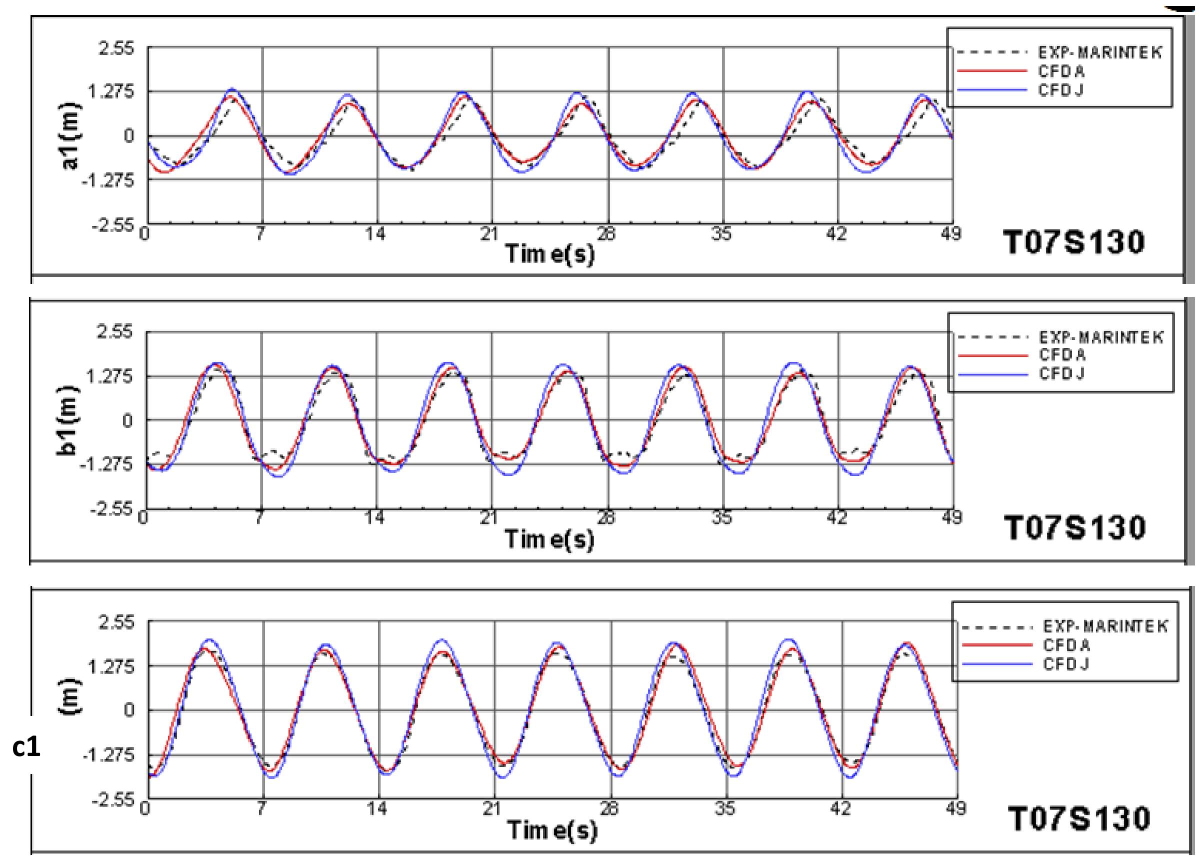
6. Benchmark Studies of Wave Run-up (14)

- Time Histories of Wave Elevations at a1, b1 and c1



Four Truncated Squared Cylinders



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6. Benchmark Studies of Wave Run-up (15)

Summary

- Eleven organizations participated in the benchmark studies on the cases of the single truncated cylinder.
- Four organizations participated in the benchmark studies on the cases of four truncated cylinders.
- Nine participants employed CFD methods in their studies.
- The FFT analysis was performed to predict the harmonic values, and the results of harmonic values were compared with the experimental results.
- The values and trends of the computed wave elevations and forces by CFD methods are in good agreement with the experimental results for the cases of single and four cylinders.
- Results of the benchmark studies will be considered for publication in a special issue of Applied Ocean Research.

6. Benchmark Studies of Wave Run-up (16)

Summary

- The differences between the prediction and the model tests results are presumably due to nonlinear breaking phenomena.

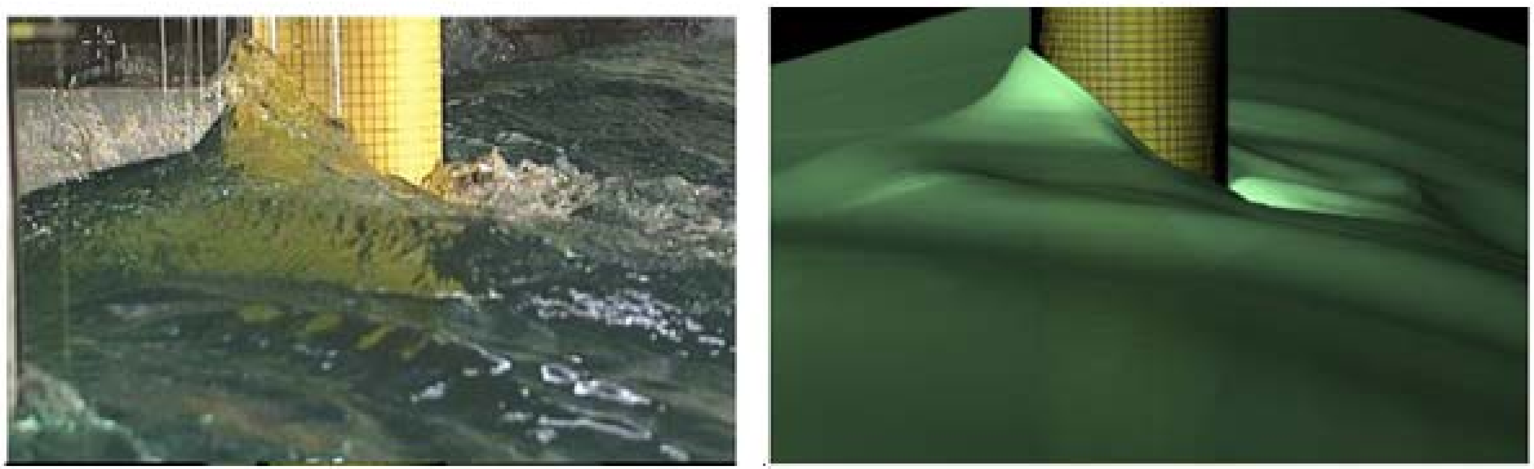
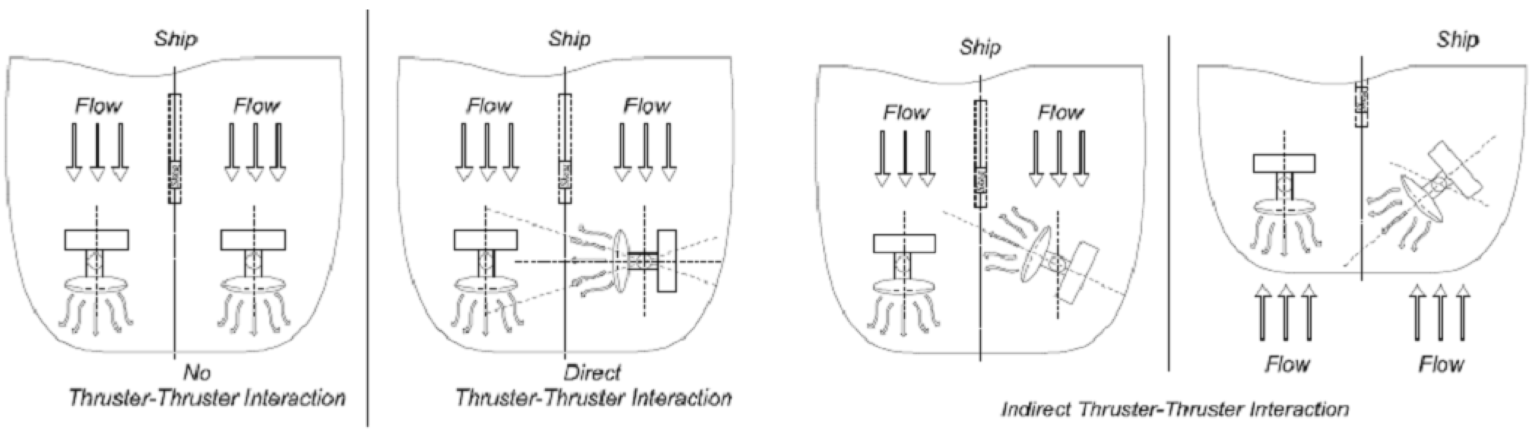


Figure 6.5.1 Experimental Wave Profiles (Stansberg and Kristiansen, 2005) and Numerical Predictions for the Case of T=15s, H=35m (Yoon et al., 2013)

7. Thruster Interaction and Scale Effect in DP Tests (1)

- Effective force generated by thrusters can be significantly smaller than those obtained from their open-water characteristics.

- This is a result of thruster interactions with the hull, current and the wake of neighbouring thrusters. These phenomena are often referred as thruster-thruster and thruster-hull interactions.



7. Thruster Interaction and Scale Effect in DP Tests (2)

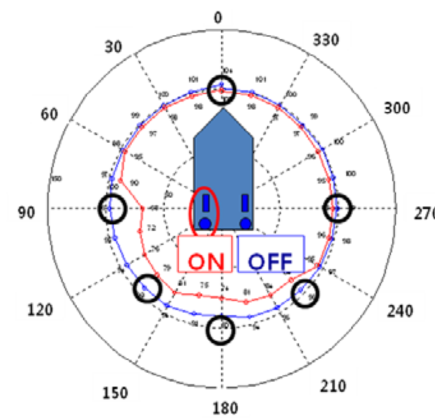
- Effects of thruster-thruster interaction on the performance of DP vessels have been studied using semi-empirical, model test and numerical methods.

- The JIP on the hydrodynamics of thruster interaction (TRUST) was initialized to investigate the thruster interaction effects using both experimental and CFD methods.

- The practical approach for quantifying the thruster-thruster interaction uses data available from literature, guidelines, or from dedicated model tests.

Ship Model for Thruster-Thruster/Hull Interaction Tests

(Song et al. , 2013)



Thrust Loss due to Thruster-Thruster Interaction (Song et al., 2013)

7. Thruster Interaction and Scale Effect in DP Tests (3)

- The CFD simulation could be an alternative method but there is little experience in the application of CFD as an engineering tool for thrust degradation effects.

- With the rapidly increasing capabilities of CFD models and computer hardware, it is feasible to develop CFD tools to analyze the thruster interactions.

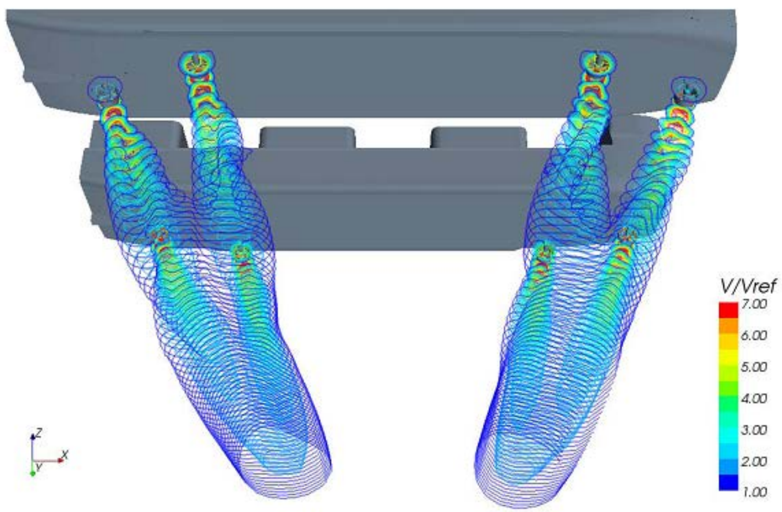


Figure 7.2.5 Downwash of Active Thrusters, Azimuth 270 deg (Ottens et al., 2011)

7. Thruster Interaction and Scale Effect in DP Tests (4)

- The thruster interaction effects have been studied by measuring the detailed wake flow using PIV systems.

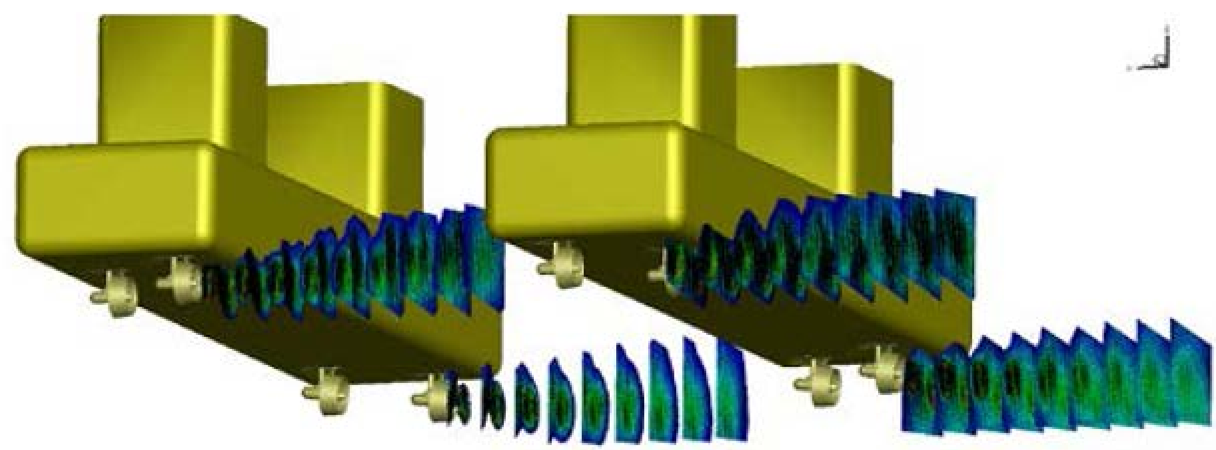


Figure 7.3.3 Measured Wake Velocity Field
(Cozijn and Hallman, 2013)

7. Thruster Interaction and Scale Effect in DP Tests (5)

- Challenges and Recommendations

  - Suitable CFD modeling methods should be investigated and developed in the near future.

  - Thorough validation studies of CFD models against measurement results, both at model-scale and at full-scale, are required.

  - CFD computations for thruster interactions should first focus on the velocities in the wake of a thruster in open water.

  - The accurate computation of the velocities, especially at large distances from the thruster, is crucial for the accurate prediction of thruster interaction effects in a later stage.

8. Multiple-Body Interactions in Waves (1)

- When two vessels are in a close proximity, the large resonant elevation of free surface occurs in the gap.

- Most of the linear seakeeping programs over-predict the free surface elevation between the vessels and hence the low-frequency loadings on the hull.

8. Multiple-Body Interactions in Waves (2)

- Methods to overcome the problem of over-prediction:

  - Huijsmans et al. (2001) developed the lid technique, in which the free surface in the gap is replaced by a flexible plate, to suppress the unrealistic values of low-frequency forces.

  - A linear dissipation term has also been proposed by Chen (2004) to modify the free-surface boundary condition.

  - Newman (2003) used the generalized mode technique to model the free surface.

- These methods in general require the input of artificial damping factors.

8. Multiple-Body Interactions in Waves (3)

- Challenges and Recommendations

  - Extensive studies have been carried out on choosing the damping factors. Further research is still required to determine the damping for practical applications.

  - CFD computations should be conducted to determine the viscous effect.

  - Benchmark studies using available experimental data are recommended.

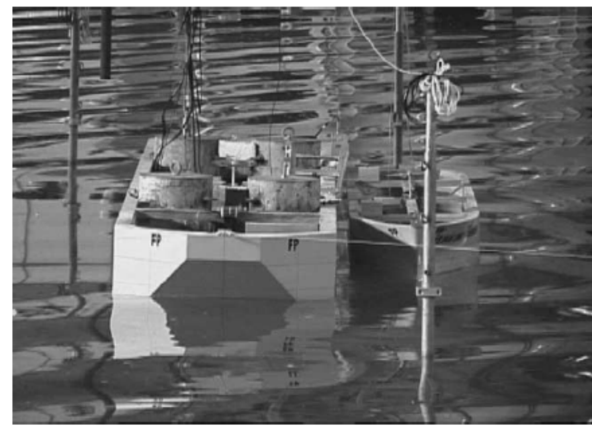
8. Multiple-Body Interactions in Waves (4)

- The Committee recommended benchmark studies using results of model tests for two floating bodies (without inter-mooring lines and fenders).

- The experimental data should include at least measured wave elevations in the gap, motions of bodies, and/or mean drift forces at various gaps, wave frequencies and headings.

- Potential experimental data for benchmark studies

  - Model tests of side-by-side LNG FPSO and LNGC at the KRISO Ocean Engineering Basin (Hong et al., 2005)



Side-by-side LNG FPSO and LNGC
(Hong et al., 2005)

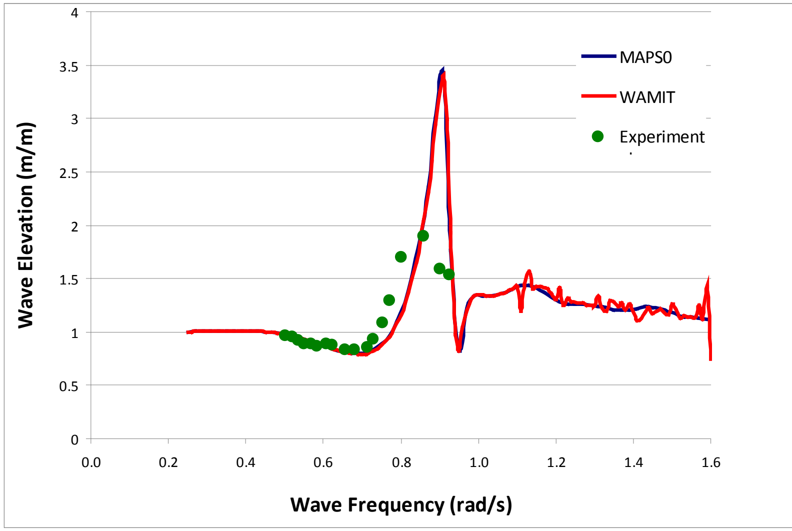
8. Multiple-Body Interactions in Waves (4)

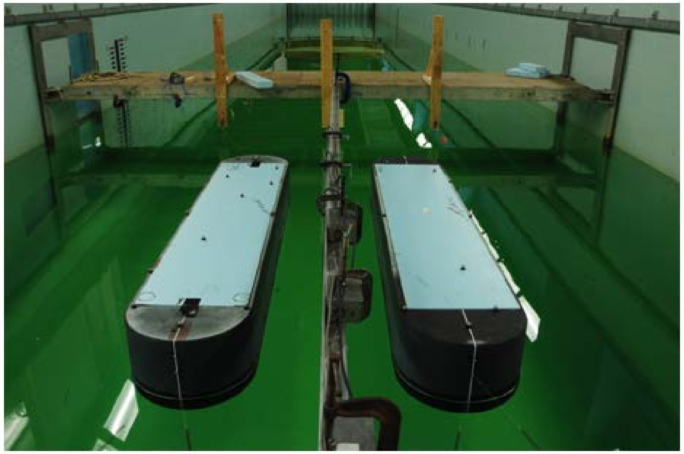
- Potential experimental data for benchmark studies

  - Model tests of two identical bodies with simplified geometry (L=2m, L/B=5, B/T=4) in regular waves initialized by the Committee.

  - Tests and numerical studies were carried out at Memorial University. Motions and wave elevations were measured at various frequencies and gaps.

  - The Committee recommended to continue the tests in wave basins at different facilities and to carry out thorough uncertainty analysis.





9. Motions of Large Ships and Floating Structures in Shallow Water (1)

- The shallow water wave problem has become one of the important issues in offshore hydrodynamics as the need for floating LNG terminals increases.

- The amplitude of the long period resonant motion of moored structures in shallow water is greatly influenced by the low frequency part of the incident waves.

- Progress has been made based on numerical and experimental methods.

Figure 9.1 Tower Yoke Mooring System (Kim et al., 2011)

9. Motions of Large Ships and Floating Structures in Shallow Water (2)

- Recommendations

  The Committee recommended to identify benchmark data to validate numerical methods, including those based on the potential flow theory, CFD and those based on solving the Boussinesq equations.

10. ITTC/ISSC Workshops (1)

- The first ISSC/ITTC joint workshop on uncertainty modeling for ships and offshore structures has been successfully organized by ISSC, ITTC Ocean Engineering Committee and ITTC Seakeeping Committee.

- The Committee presented the uncertainties related to predictions of loads and responses for offshore structures at the Workshop on September 8, 2012 at Rostock.

- The joint effort between ISSC and ITTC has led to the publication of a special issue on uncertainty modeling for ships and offshore structures in the journal of Ocean Engineering.

- In collaboration with the Quality Group, the Committee published the paper "Uncertainty related to predictions of loads and responses for ocean and offshore structures".

10. ITTC/ISSC Workshops (2)

- The second ISSC/ITTC joint workshop was held in August 30, 2014 at Copenhagen, focusing on the wave-induced motion and structural loads on ships and offshore structures, including a computational benchmark test for a large modern ship.

- It was jointly organized by ISSC, ITTC Seakeeping Committee and ITTC Ocean Engineering Committee.

- The Committee presented highly nonlinear loads on ocean and offshore structures.

- The Committee will prepare a paper on this topic for publication in a special issue of Ocean Engineering.

11. Conclusions (1)

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

  - Stationary Floating Structures and Ships: Experimental and numerical procedures for predicting motions of floating structures are in general well established. There is still a need of research on vortex induced motions of spars and semisubmersibles, and on the platform responses in extreme seas. Relative motions between two floating bodies remain as very important research topics, especially for the safe operation of floating LNG production and storage and offloading vessels.

  - Highly Nonlinear Effects on Ocean Structures: Slamming, sloshing and wave run-ups remain as important issues for the design/operation of offshore structures in extreme sea conditions. CFD methods such as VOF, SPH and CIP, along with experiments, are the primary tools to address these highly nonlinear phenomena. Uncertainties, scale effect and hydroelasticity need to be studied further.

11. Conclusions (2)

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

  - VIV and VIM: Progress has been made in the prediction of VIV and VIM using empirical prediction programs, CFD methods and experimental methods. A few new prediction programs have been developed based on the time-domain methods. Further research is required in this area.

  - New Extrapolation Methods: Limited investigations have been carried out on the development of extrapolation methods. Challenging issues in scaling of model test results to full scale have been indicated in various applications throughout the report, particularly in sloshing tests.

11. Conclusions (3)

- **Benchmark studies on VIV**

  - URANS, DES and LES were employed.

  - In terms of overall trend, numerical predictions by DES and LES are generally in better agreement with the experimental data than those by URANS.

  - The LES methods captured the drag crisis phenomenon.

  - The Committee recommended to continue the benchmark studies based on LES and DES.

11. Conclusions (4)

- **Benchmark studies on wave run-up**

  - The values and trends of the computed wave elevations and forces by CFD methods are in good agreement with the experimental results for the cases of single and four cylinders.
  - It is recommended that more studies be extended to the four-column cases.

- **Thruster-thruster interactions**

  - Great progress has been made in investigating the interactions using experimental and CFD methods as well as detailed wake flow measurement.
  - Suitable CFD modeling methods should be investigated and developed in the near future.
  - Thorough validation studies of CFD models against measurement results, both at model-scale and at full-scale, are required.

11. Conclusions (5)

- **Side-by-side body interaction**

  - Progress has been made in investigating the damping effect on wave elevation in the gap using model tests and CFD simulations.
  - The determination of wave elevations and drift forces using the potential-flow based methods remains as a challenge.
  - The Committee recommended to collect the available experimental data for benchmark studies.

- **Motions of large ships and floating structures in shallow water**

  - The focus was on the LNG ships and terminals as well as FPSO and their mooring systems.
  - The hydrodynamic effects of sloshing tank and the gap phenomena for two floating bodies in shallow water need to be studied further.
  - The Committee recommended to identify benchmark data to validate numerical methods.

12. Recommendations to the 27th ITTC

- Adopt the new guideline 7.5-02-07-03.10, "Guideline for VIV Testing"

Recommendations for Future Work

- To continue wave run-up benchmark studies for cases of four columns (circular and squared cross-sections) using the experimental data from MARINTEK.
- To develop an analysis procedure for model tests in irregular waves.
- To further quantify the uncertainty sources in ocean engineering model tests.
- To investigate the modeling of wind load in model tests and numerical simulations for offshore structures.
- To continue investigating thruster-thruster interaction, ventilation and their scaling for DP systems.
- …