The 27th ITTC Conference
Copenhagen, September 2014

Report of the 27th ITTC Seakeeping Committee

Presented by

Yonghwan Kim
SKC Chairman

ITTC SK Members (27th Term)

- **Dariusz Fathi** (MARINTEK, Norway)
- **Dan Hayden** (NSWC-CD, United States), Secretariat
- **Greg Hermanski** (National Research Council Canada (NRC), Canada)
- **Dominic Hudson** (University of Southampton, United Kingdom)
- **Pepijn de Jong** (Delft University of Technology, The Netherlands)
- **Yonghwan Kim** (Seoul National University, Korea), **Chairman**
- **Quan Ming Miao** (CSSRC, China, a new member will replace in Oct.)
- **Katsuji Tanizawa** (National Maritime Research Institute , Japan
- **Giles Thomas** (University of Tasmania , Australia)

Terms of References: 27th Term

1. Update the state-of-the-art review
2. Review/Revise ITTC Recommended
3. Liaise with ISSC and other ITTC committees
4. Update existing ITTC Recommended Procedure 7.5-02-07-02.5 for V&V of computational codes
5. Investigate methodology for V&V of fully non-linear seakeeping viscous flow codes.
6. Develop a guideline for hydroelastic seakeeping codes.
7. Jointly organize and participate in the joint ISSC/ITTC workshop
8. Establish a numerical and experimental process for estimating fw, in the EEDI calculation.
9. Develop a unified method for sloshing experiments
10. Review/update the Procedure 7.5-02-05-04, Seakeeping Tests for High Speed Marine Vehicles.

ITTC Seakeeping Committee

ITTC Procedures handled by SK Committee

- **7.5-02-07-02.1**: Seakeeping Experiments
- **7.5-02-07-02.2**: Predicting Power Increase in Irregular Waves from Model Experiments in Regular Waves
- **7.5-02-07-02.3:** Experiments on Rarely Occurring Events
- **7.5-02-07-02.5**: Verification and Validation of Linear and Weakly Nonlinear Seakeeping Computer Codes
- **7.5-02-07-02.6**: Prediction of Global Wave Loads
- **Procedure 7.5-02-05-04:** HSMV Seakeeping Tests

The Seakeeping Committee is primarily concerned with the behavior of ships underway in waves. The Ocean Engineering Committee covers moored and dynamically positioned ships, including the modeling and simulation of waves, wind and current.

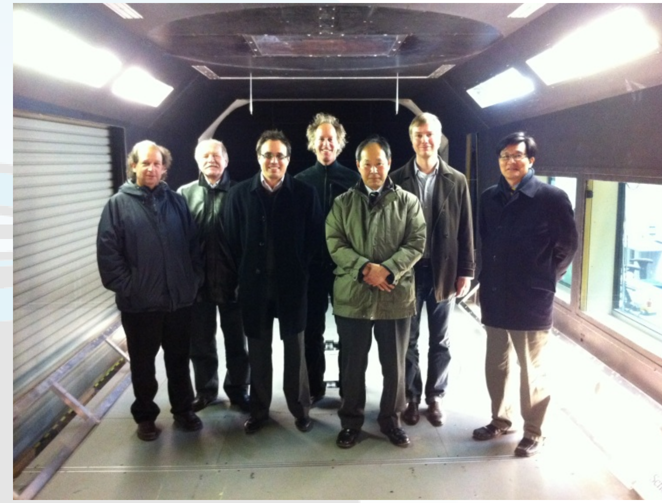
Highlights

- **Procedures**
  - Updates to four
  - Decision of no change for one
  - One withdrawn for revision
- **State of the art review** with emphasis on **sloshing, added resistance, and viscous codes**
- Underpin a common approach to predicting **added resistance** and a basic concept of ***fw*** computation for EEDI formula
- Joint organization for the **1st and 2nd ITTC-ISSC Joint Workshops**

Meetings & Events

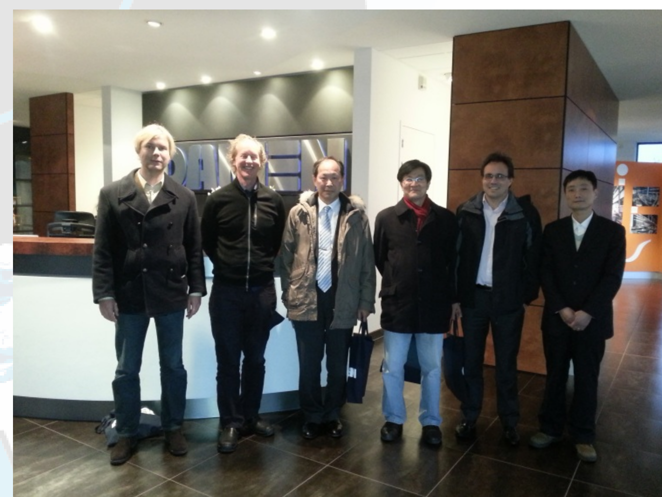
Committee meetings

- **1st Meeting**: University of Southampton, Southampton, United Kingdom, January 2012
- **2nd Meeting**: National Maritime Research Institute, Tokyo, November 2012.
- **3rd Meeting**: David Taylor Model Basin, West Bethesda, USA, July 2013
- **4th Meeting**: Delft University of Technology, Delft, Netherlands, February 2014



Additional meetings

- **1st ISSC-ITTC Joint Workshop**, Rostock, Germany, September 2012
- **2nd Joint ITTC-ISSC Joint Workshop**, Copenhagen, Denmark, August 2014




DOCK MASTER

ITTC-ISSC Joint Workshops

1st Joint Workshop

Understanding uncertainty modelling and its impact on model tests, full scale measurement, load prediction, and loads computation.

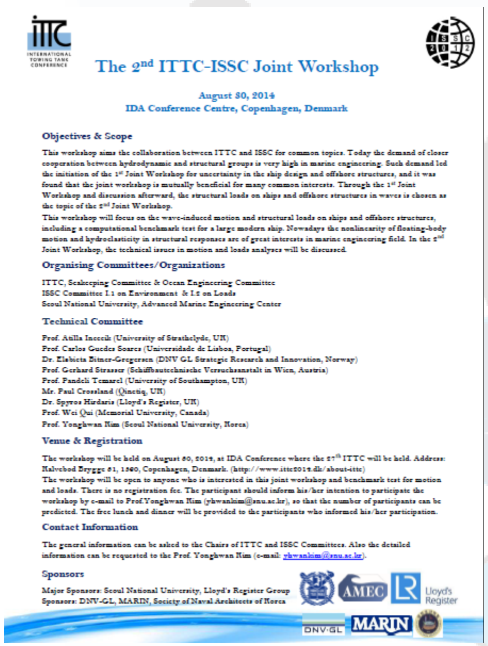
First Joint ISSC/ ITTC International Workshop

Uncertainty Modelling for Ships and Offshore Structures (UMSOS)

8th September 2012, Rostok, Germany

Organised by: ISSC/ ITTC

In Association with: Lloyd's Register Strategic Research and DNV Research & Innovation



The 2nd ITTC-ISSC Joint Workshop

August 30, 2014
IDA Conference Centre, Copenhagen, Denmark

Objectives & Scope

This workshop aims the collaboration between ITTC and ISSC for common topics. Today the demand of closer cooperation between hydrodynamic and structural groups is very high in marine engineering. Such demand led the initiation of the 1st Joint Workshop for uncertainty in the ship design and offshore structures, and it was found that the joint workshop is mutually beneficial for many common interests. Through the 1st Joint Workshop and discussion afterward, the structural loads on ships and offshore structures in waves is chosen as the topic of the 2nd Joint Workshop.
This workshop will focus on the wave-induced motion and structural loads on ships and offshore structures, including a computational benchmark test for a large modern ship. Nowadays the nonlinearity of floating-body motion and hydroelasticity in structural responses are of great interests in marine engineering field. In the 2nd Joint Workshop, the technical issues in motion and loads analyses will be discussed.

Organising Committees/Organizations

ITTC, Seakeeping Committee & Ocean Engineering Committee
ISSC Committee I.1 on Environment & I.2 on Loads
Seoul National University, Advanced Marine Engineering Center

Technical Committee

Prof. Atilla Incecik (University of Strathclyde, UK)
Prof. Carlos Guedes Soares (Universidade de Lisboa, Portugal)
Dr. Elzbieta Bitner-Gregersen (DNV GL Strategic Research and Innovation, Norway)
Prof. Gerhard Strasser (Schiffbautechnische Versuchsanstalt in Wien, Austria)
Prof. Pandeli Temarel (University of Southampton, UK)
Mr. Paul Crossland (Qinetiq, UK)
Dr. Spyros Hirdaris (Lloyd's Register, UK)
Prof. Wei Qui (Memorial University, Canada)
Prof. Yonghwan Kim (Seoul National University, Korea)

Venue & Registration

The workshop will be held on August 30, 2014, at IDA Conference where the 27th ITTC will be held. Address: Kalvebod Brygge 31, 1560, Copenhagen, Denmark. (http://www.ittc2014.dk/about-ittc)
The workshop will be open to anyone who is interested in this joint workshop and benchmark test for motion and loads. There is no registration fee. The participant should inform his/her intention to participate the workshop by e-mail to Prof.Yonghwan Kim (yhwankim@snu.ac.kr), so that the number of participants can be predicted. The free lunch and dinner will be provided to the participants who informed his/her participation.

Contact Information

The general information can be asked to the Chairs of ITTC and ISSC Committees. Also the detailed information can be requested to the Prof. Yonghwan Kim (e-mail: yhwankim@snu.ac.kr).

Sponsors

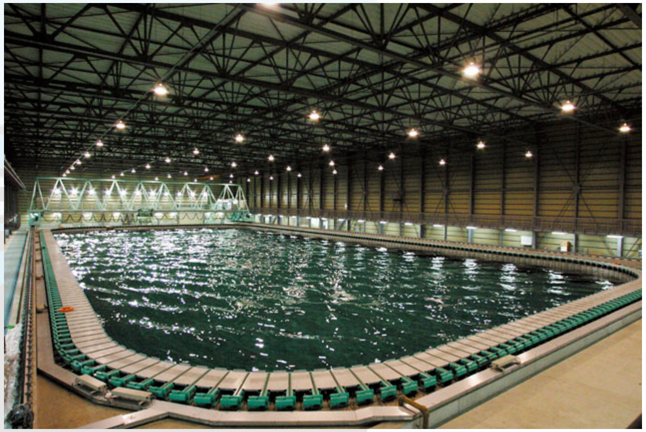
Major Sponsors: Seoul National University, Lloyd's Register Group
Sponsors: DNV-GL, MARIN, Society of Naval Architects of Korea

2nd Joint Workshop

Loads in ocean waves as a common technical issue of ITTC and ISSC, including nonlinear wave-induced motion, ocean environments, and resultant loads on ships and offshore structures. Benchmark test for a segmented model ship.

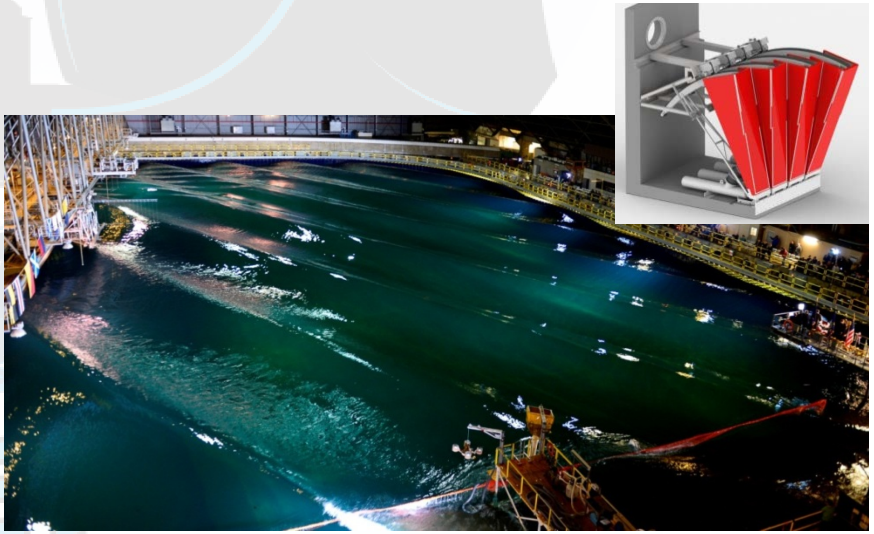
New Experimental Facility

Actual Sea Model Basin: NMRI, Japan



- LBD : 80m x 40m x 4.5m
- 382 flap type wave makers with multi-directional absorbing control
- Max synthesis speed of towing carriage: 4.6m/s
- Max wind speed : 10m/s

New Wavemaking in Manoeuvring and Seakeeping Basin (MASK): CDNSWC, USA



- 216 paddles at a 0.658 m spacing
- 108 paddles along the long wall of the tank, 60 paddles in the curve, and 48 paddles along the short wall
- Hinge depth at 2.5 meters

New Wavemaker in Depressurized Wave Basin: MARIN, Netherlands

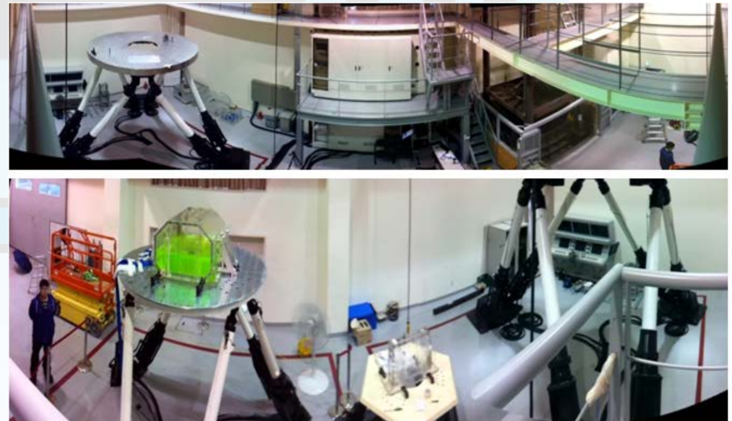
- 24 dry-back paddles with a 2.5m hinge depth and a 0.6m width along the short wall
- 200 dry-back paddles with a 1.8m hinge depth and 0.6m width along the long edge

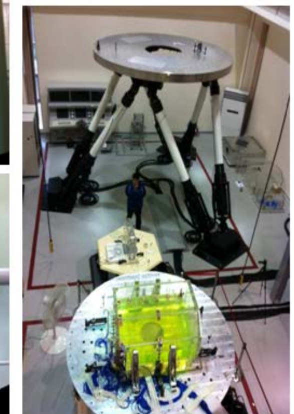
Sloshing Platform: CSSRC, China

	Displacement	Speed	Acceleration
Surge	±40 cm	±100 cm/s	± 0.6g
Sway	± 40 cm	±100 cm/s	± 0.6g
Heave	± 50 cm	±140 cm/s	± 0.8g
Roll	± 45°	± 50° /s	± 150° /s²
Pitch	± 25°	± 25° /s	± 150° /s²
Yaw	±15°	±15° /s	± 80° /s²

Sloshing Platform: Seoul National University, Korea

- 3 platforms
  - 1.5, 5, 14 tons capacities
- Largest facility in the world
- 500 dyn. pressure channels
- 2D and 3D PIV systems
- Impact test facility





14-ton platform	Displacement	Speed		Acceleration
		@1500 rpm	@2000 rpm	
Surge	±144 cm	155 cm/s	200 cm/s	> 0.9G
Sway	±138 cm	138 cm/s	180 cm/s	> 0.9G
Heave	±84 cm	84 cm/s	110 cm/s	> 0.9G
Roll	±33°	34°/s	45 °/s	> 250°/s^2
Pitch	±33°	37°/s	49 °/s	> 250°/s^2
Yaw	±33°	56°/s	74 °/s	> 250°/s^2

Tanks under construction

- UoS: New towing tank, scheduled to complete in Sep. 2014
  138m x 6m x 3.5m with max speed 12m/sec
- KRISO: 100m x 50m x 15m (45m pit) under design
- NUS: Ocean basin for offshore experiment
- A few organizations are in design or plan stage to build new facilities.

Experimental Techniques:
Added Resistance / Speed Loss in Waves

The prediction of added resistance or speed loss of a ship in waves is essential to evaluate the ship performance in a seaway.

- Segmented model test (Guo and Steen , 2011): added resistance of KVLCC2 in short waves. Ship model was divided into three segments: fore- segment, aft-segment, and parallel mid-body.
- The effect of oblique waves on ocean-going vessel behavior in realistic sea states (Chuang and Steen , 2013): a free running model in oblique waves.
- Kuroda et al. (2012): Development of energy saving device ('STEP') for the reduction of added resistance in waves
- Sadat-Hosseini et al. (2013): Experiment with KVLCC2 in surge free and fixed condition
- Tanizawa, K. (2012) and Kitagawa, Y (2014): Experimental methodology for free running test to measure the nominal speed loss in waves
- Lee et al. (2013) : Observation on different bow shapes

Experimental Techniques
Water on Deck and Slamming

Most studies have focused on slamming.

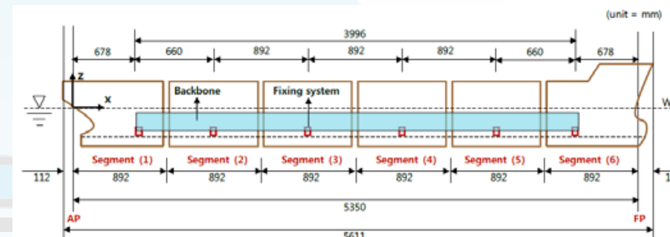
- A synergic 3-D experimental investigation was conducted for wave-ship interactions involving the water-on-deck and slamming phenomena. (Greco et al. 2012)
- Slam events experienced by high-speed catamarans in irregular waves were investigated through experiments using a hydroelastic segmented model. (Thomas et al., 2011, Lavroff et al., 2013)

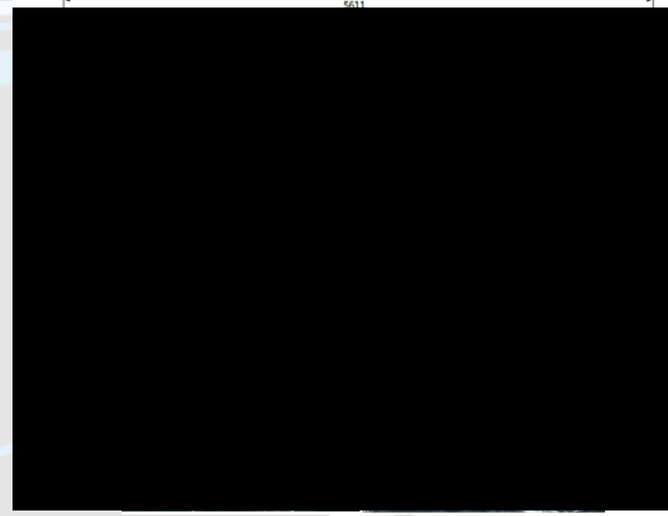
- Hydroelastic model experiments: monohull - Dessi & Chiappi (2013), Chen et al. (2012); catamaran – French et al. (2013 & 2014)
- Green water from side wall: Buchner & van den Berg (2013)

Experimental Techniques
Ship Structural Hydroelasticity

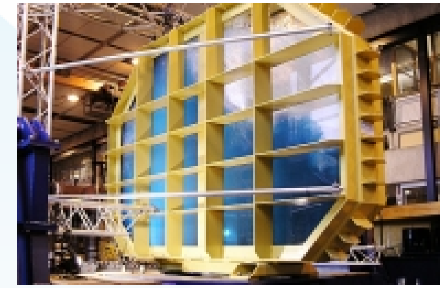
Measurement of springing and whipping.

- WILS II, III (Hong et al., 2012, 2013): Segmented model test for springing measurement (WILS II) and slamming-whipping (WILS III), a 10,000TEU containership
- SHI's segmented model test (Lee et al, 2013): Segmented mode test for 18,000 TEU containership.
- Segmented model test for a pentamaran (MARINTEK, 2013): Measurement of seakeeping performance and structural loads



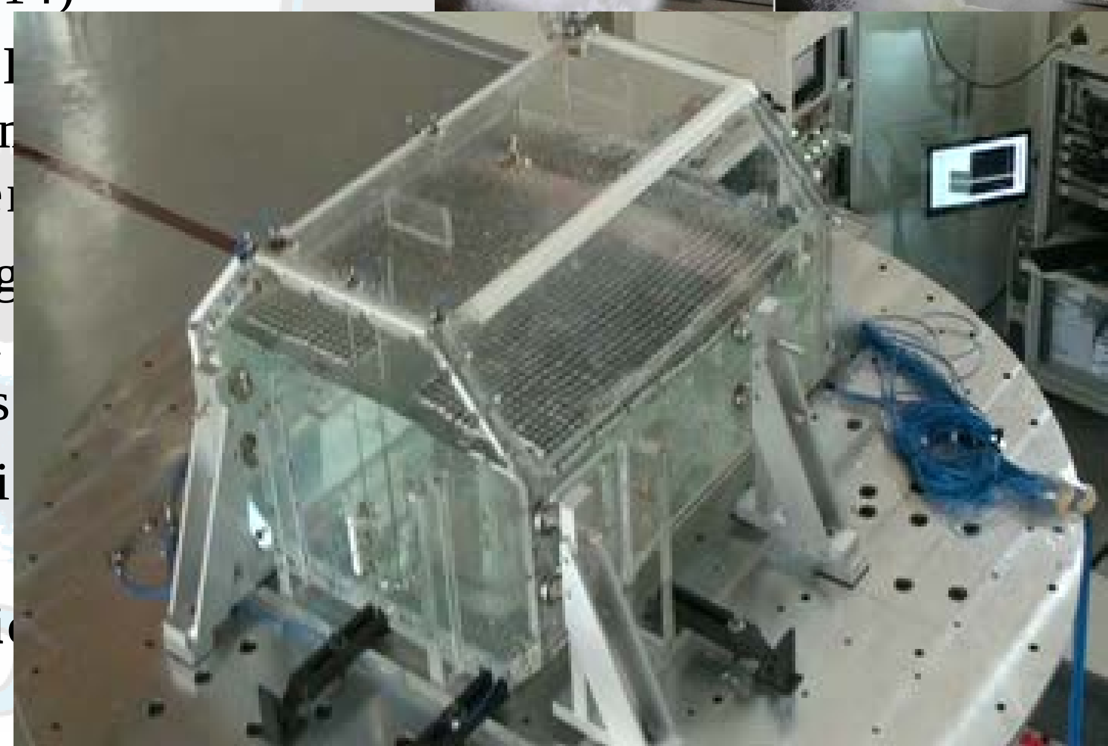


Experimental Techniques
Sloshing



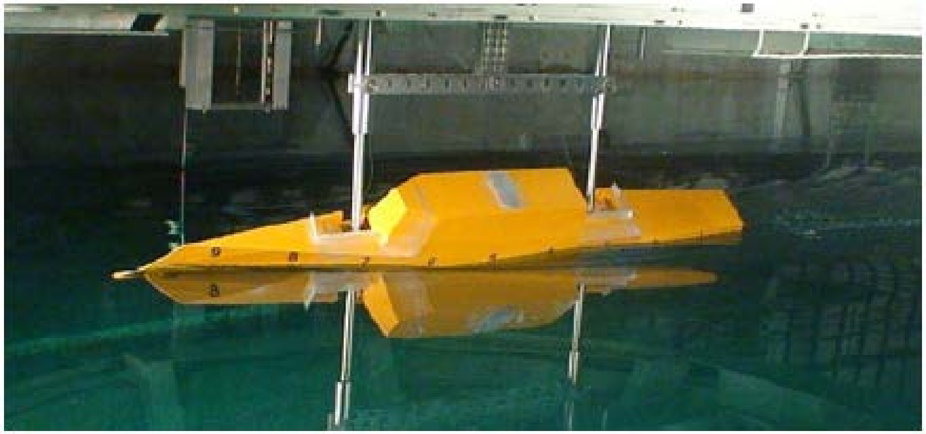
- **SLOSHEL project** (Brosset et al., 2012, 2013, Lafeber et al, 2012): organized by GTT and MARIN, participating several organizations for real-scale sloshing in shallow depth

- **Benchmark tests for single impact case**, organized by GTT (2013, 2014)
- Model tests for IMO B-type l system (Song et al, 2012, Kin LNG cargo with internal mer
- Model tests for anti-sloshing (Chung et al, 2012): blanket connected segmented foams
- Sloshing-ship motion coupli al., 2012,)
- **ISOPE Sloshing Dynami (2009~2014)**



Experimental Techniques
Full-Scale Experiment and Other Issues

- The slamming behavior of large high-speed catamarans (Jacobi et al., 2013): full-scale measurements, US Navy conducted the trials in the North Sea and North Atlantic region on a 98m wave piercer catamaran.
- A measurement campaign on board a 9,300 TEU container vessel (Koning and Kapsenberg, 2012)
- A series of captive model tests for the broaching prediction of a wave-piercing tumblehome vessel with twin screws and twin rudders (Hashimoto et al., 2011)



Numerical Methods
Frequency-Domain Methods

- Quick and efficient solutions
  - Allowing evaluation of large amount of design alternatives in early design
- Overall: **shift from FD methods towards TD methods**
  - TD methods now superseding FD methods to large extend, especially in R&D
- FD methods still very relevant for:
  - Early design slow-speed applications
  - Mooring and multi-body analysis

Numerical Methods
Time-Domain Methods (1)

- Slowly displacing FD methods also in practical applications
  - **Intuitive extension towards nonlinear motions and loads**
  - **Ease of incorporating external forces and coupling** with flexible structural modes and sloshing problems
- Increased computational demand compared to FD methods
- Nonlinear approaches rely on continuous re-panelization of body and free surface
- Many alternative approaches exist and are in development
- Applications also include combined topics such as Ocean Engineering and Manoeuvring and Stability in Waves
- CFD is expanding from resistance to manoeuvring, and then seakeeping. Potential codes are still leading in inertia-dominant problems, and CFD codes are applicable for violent flows which potential codes are limited.

Numerical Methods
Time-Domain Approach (2)

2D time domain techniques

- Relatively efficient and less complex in development
- Often based on FD extended to TD with retardation functions
- Can be combined with for instance manoeuvring models for 6DoF approaches (Chuang and Steen 2013)
- In some cases nonlinear radiation solutions (Mortola et al. 2011)
- High speed craft planning: separate class based on impacting wedge theory (Faltinsen and Sun 2011)

3D time domain Green Function Methods

- Only for linearized FS condition
- Often intermediate approaches combined with nonlinear hydrostatics and Froude-Krylov pressures
- Allows for direct inclusion of forward speed effects and used for semi-displacement vessels (Walree and De Jong 2011)

Numerical Methods
Time-Domain Approach (3)

3D time domain Rankine Panel Methods

- Much more simple singularities than GFM, but now also required on FS
- Explicit dealing with radiation condition necessary
- FS panels allow for easy extension to weakly (Song et al. 2011) or fully nonlinear analysis (Kim & Kim 2013, You & Faltinsen 2012)
- Attention paid to wave reflections on the articial boundary (Xu and Duan 2013) and to inclusion of m-terms (Nan and Vassalos 2013)

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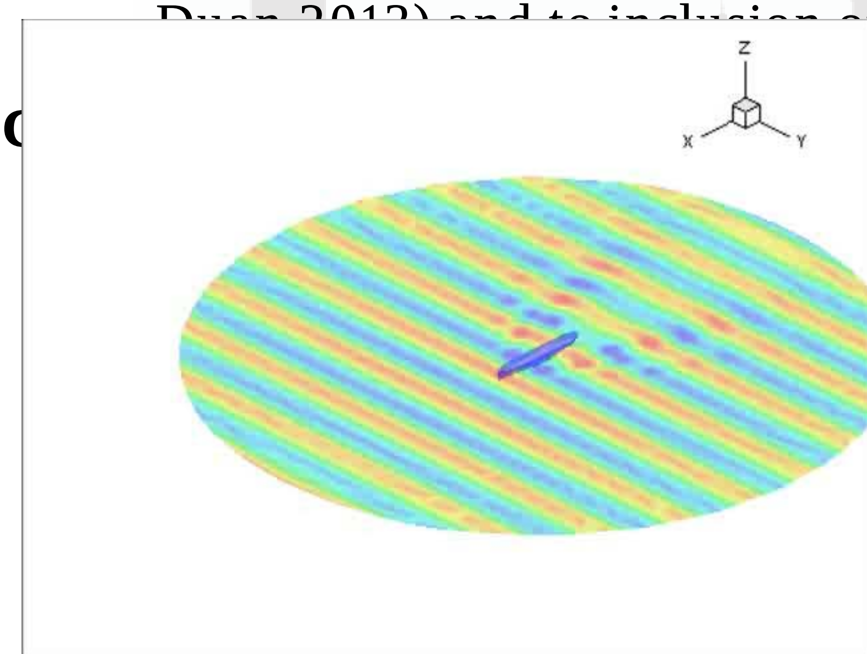
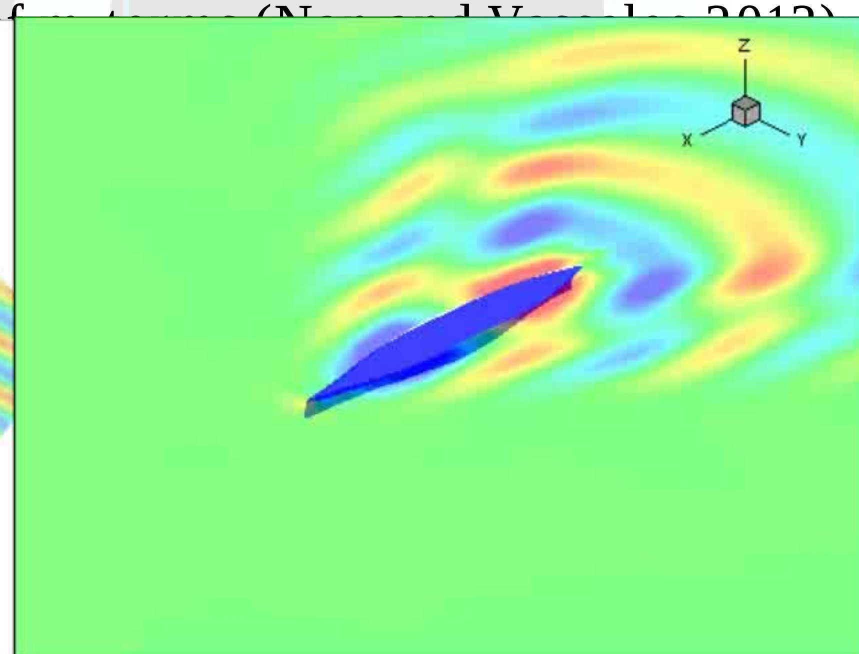




Numerical Methods
More Developments

Further developments:

- Higher Order Boundary Element Method (HOBEM)
  - Allow smoother representation of the velocity potential and its derivatives, Therefore require much less elements
  - e.g. He and Kashiwagi (2013), Shao and Faltinsen (2012)
- Finite Element Methods (FEM)
  - Hong and Nam (2010): second order wave forces
  - e.g. Yan and Ma (2011): fully nonlinear potential flow with an Langrangian-Eulerian FEM

Hybrid methods: RPM+GFM, CFD+BEM,...

- Usually a combination of a sophisticated inner domain solution combined with a more efficient outer domain solution
  - Tong et al. (2013): inner domain RPM with outer domain GFM
  - Guo et al. (2012): inner domain VOF with outer domain BEM
- Physics-based modeling by Weymouth and Yue (2013):

Numerical Methods
Ship Structural Hydroelasticity

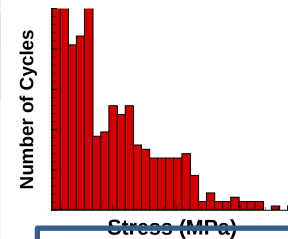
– **Required to solve the seakeeping and structural problem at the same time**
– **Springing**
- Frequency domain approach with beam based modal superposition
- Time domain approach with beam or 3D whole FE models
- 3D panel or CFD methods with direct integration for ship structure
- e.g. Kim et al. (2011,2012,2013), Senjanović et al. (2011, 2012)

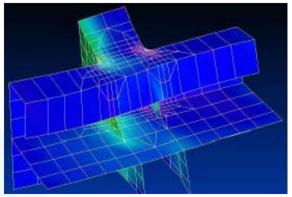
Zhu, Wu & Moan (2011)

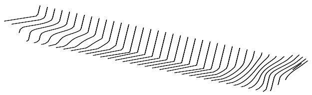
– **Whipping:**
- Requires slamming force
- Typically 2D sectional force by GWM or wedge approximation
- e.g. Derbanne et al. (2010), Tuitman (2010), Oberhageman & Moctar (2011), Kim et al. (2013), Ćorak et al. (2013)

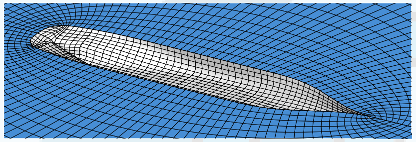
– **TULCS Project** (Tools for Ultra Large Container Ships): 2009-2012 by BV and other organizations
– **Hydroelasticity Conference: Tokyo, 2012**
– **Int. Workshop on Springing and Whipping: Split, 2012**

Analysis Procedure for Ship Design









Hydro.

Strip/3D panel(Rankine or Green function)/CFD

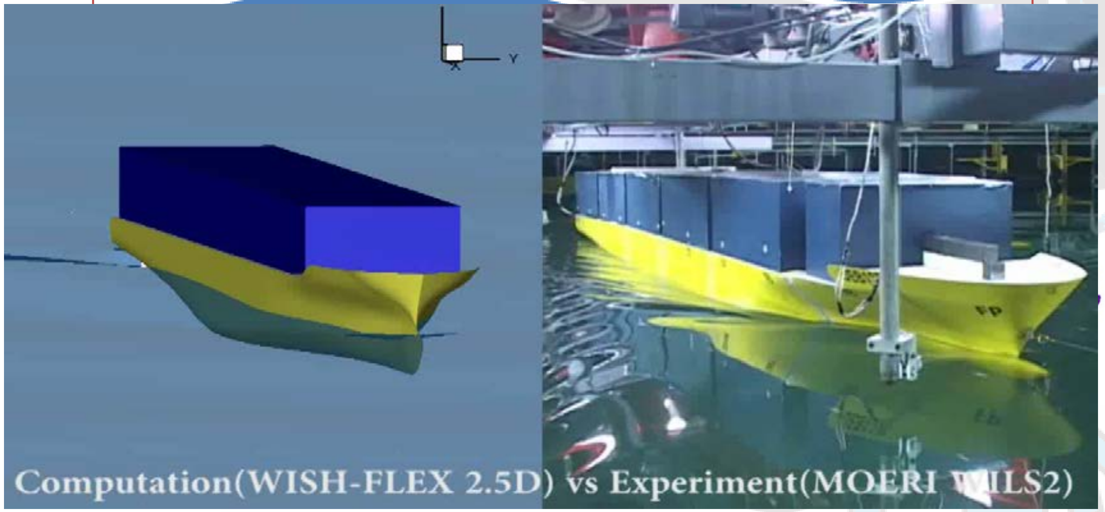
Coupling

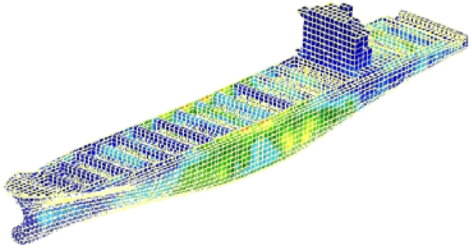
Modal/Direct

Fatigue Analysis Module

(Rainflow Counting / Miner's Rule)

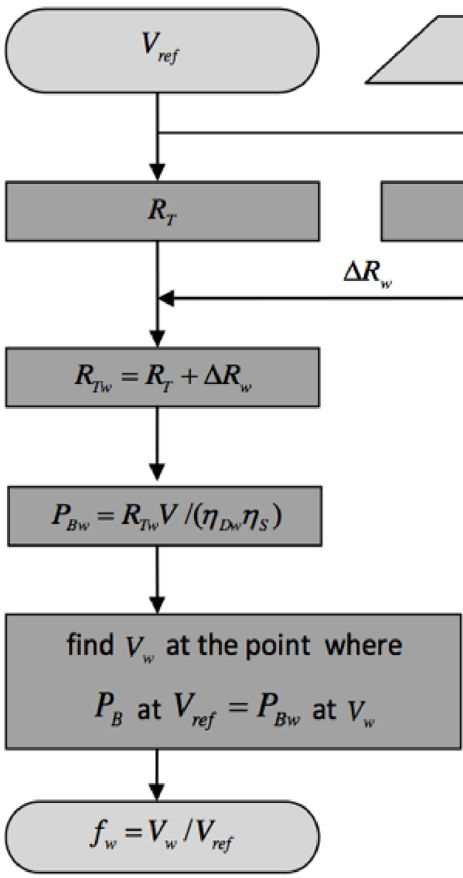
Long-Term Prediction





Process for the Estimation of Ship Speed Reduction Coefficient f_w in Waves

Calculation flow of the ship speed reduction



V : Speed

R_T : Total resistance in calm sea condition

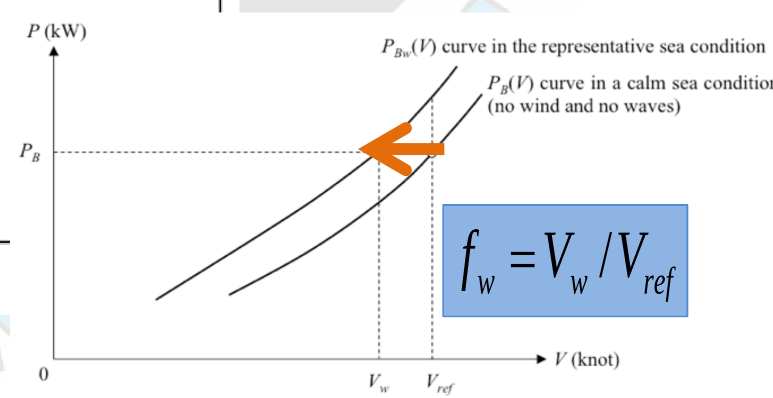
ΔR_w : Added resistance due to wind and waves

P_B : Brake power

η_D : Propulsion efficiency

η_S : Transmission efficiency

Subscript w refers to wind and wave



Process for the Estimation of Ship Speed

Resistance in Seaways

Total resistance in seaways : ΔR_w

$$R_{Tw} = R_T + \Delta R_w$$
$$= R_T + \Delta R_{wind} + \Delta R_{wave}$$

Added resistance due to wind : ΔR_{wind}

$$\Delta R_{wind} = \frac{1}{2} \rho_a A_T C_{Dwind} \left\{ \left(U_{wind} + V_w \right)^2 - V_{ref}{}^2 \right\}$$

C_{Dwind} should be calculated by a formula or measured through experiment.

Added resistance due to waves : ΔR_{wave}

$$\Delta R_{wave} = 2 \int_0^{2\pi} \int_0^{\infty} \frac{R_{wave}(\omega, \alpha; V)}{\zeta_a^2} \cdot E(\omega, \alpha; H, T, \theta) d\omega d\alpha$$

Key for the accurate estimation of f_w

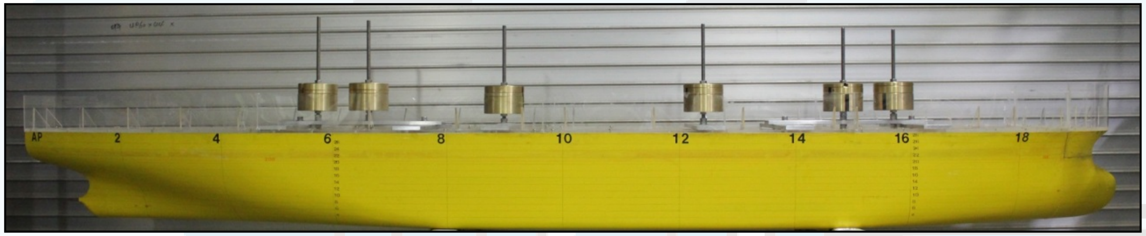
Process for the Estimation of Ship Speed

Methods for Added Resistance Prediction

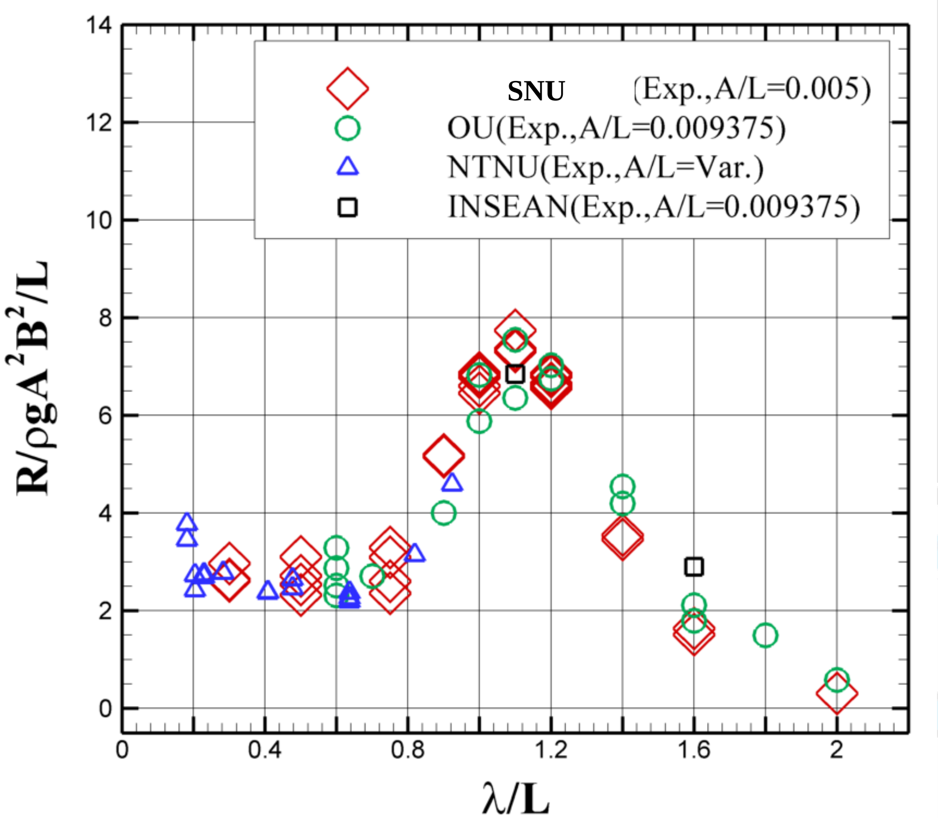
Approaches	Numerical method			Experiment
	Slender-body theory	3D panel method	CFD	
Added resistance computation	Direct pressure integration (e.g. Faltinsen et al, 1980, Kim & Kim, 2011)		Direct pressure integration: Added resistance = (Total Resistance in waves) – (Resistance in cal water)	
	Momentum conservation method (e.g. Maruo, 1960, Joncquez, 2009)			
	Radiated energy method (e.g. Salvesen, 1978)			
	Wave-pattern analysis (e.g. Kashwagi, 2013)			
Methodology	Strip method, (enhanced) unified theory	Green-function method, Rankine panel method	Commercial or in-house codes	Surge-fixed or surge-free tests
	Linear formulation for seakeeping.		Fully nonlinear formulation.	Fully nonlinear
Short-Wave Approximation	Faltinsen's approximation, NMRI's empirical formula			
Remarks	Quick computation	Different formulations for time- and frequency-domain methods.	A lot of computational time	Expensive
	In shot waves, empirical or asymptotic formula should be combined.	Grid dependency should be observed in short waves.	Strong grid dependency in short waves.	Scale dependency and repeatability should be observed.

Process for the Estimation of Ship Speed

Experiment for Added Resistance



KVLCC2

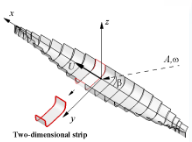


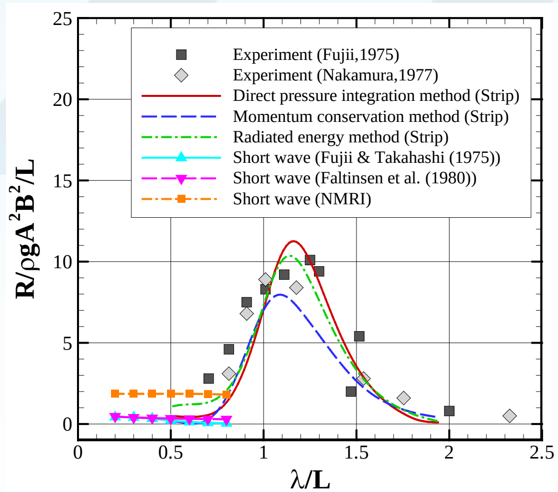
Process for the Estimation of Ship Speed

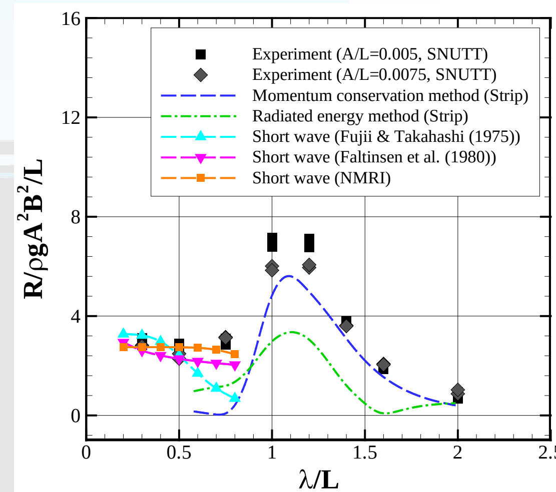
Comparison of Different Methods

S-175, Fn = 0.25 | **KVLCC2, Fn = 0.142**

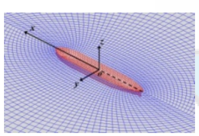
Strip method

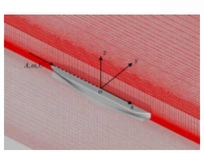


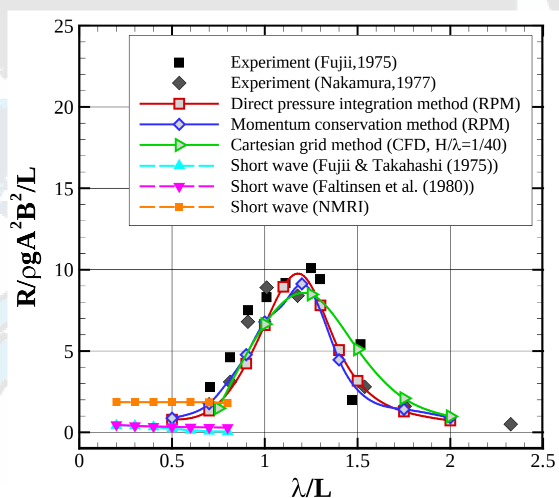


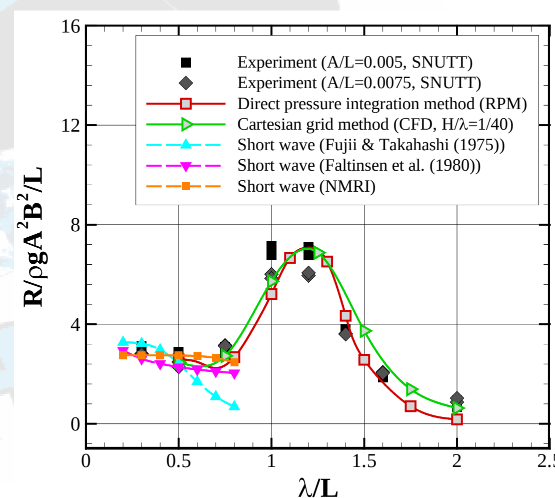


RPM & Cartesian grid method









CFD Application for Seakeeping Methodologies

Field Equations

Grid Methods
- Finite Difference Method (FDM)
- Finite Volume Method (FVM)
- Finite Element Method (FEM)

Gridless Methods
- Smoothed Particle Hydrodynamics (SPH)
- Moving Particle Semi-implicit (MPS)

Incompressible
- Velocity-Pressure Coupling (SIMPLE, PISO, Fractional step…)

Compressible
- Contact Discontinuity
- Equation of State (sound of speed)

Interface

- Capturing (Level Set, VOF, MAC…)
- Tracking

Global Flow and Force
- Global Ship Waves and Motion
- Global Force/Moment in a Computational Domain
- Mass Conservation (~natural frequency)
- Free Surface (~topology change)

Local Flow and Pressure
- Local Flow Simulation
- Local Pressure/Load Computation
- Observation on Local Flows
- Compressibility, Hydroelasticity, Gas interaction

Overall status of the art of CFD schemes for free surface flow: Field equation solvers

CFD Application for Seakeeping

The State of the Art

	C. Hu et al. (Kyushu Univ.)	D.G. Dommermuth et al. (SAIC)	J. Yang et al. (Univ. of Iowa)	P. Queutey et al. (ECN)	R. Löhner et al. (George Mason Univ.)	H. Miyata et al. (Univ. of Tokyo)	Y. Kim et al. (Seoul National Univ.)
Discretization for convective term	CIP	3rd QUICK	3rd QUICK / WENO	Improved Gamma	Galerkin	QUICK	MC Limiter
Body motion	IBM Particle	IBM Triangle panel	IBM Triangle panel	Mesh Deformation	ALE	Overlapping Grid	IBM Triangle panel
Free surface	THINC (VOF)	CLSVOF	CLSVOF	VOF	VOF	Density Function (QUICK)	THINC (VOF)
Remark		LES	LES Ghost Fluid Method	RANS		RANS	Euler eq. solver

CFD Application for Seakeeping

To be considered...

Computational Efficiency

- Need parallelize, otherwise it is too slow for practical use
- Seakeeping analysis requires more time consuming than resistance or maneuvring problems.
- Need to compromise with accuracy

Accuracy

- Acceptable for global motion prediction
- In general, sensitively dependent on mesh resolution and time segment, particularly in violent local flows

Robustness and Applicability

- Robustness is dependent on program, but so far in a low degree.
- Still limited applicability for engineering problems in seakeeping

In-house or Commercial ?

- Commercial code is getting popular.
- In-house codes can be applied for specific interests.

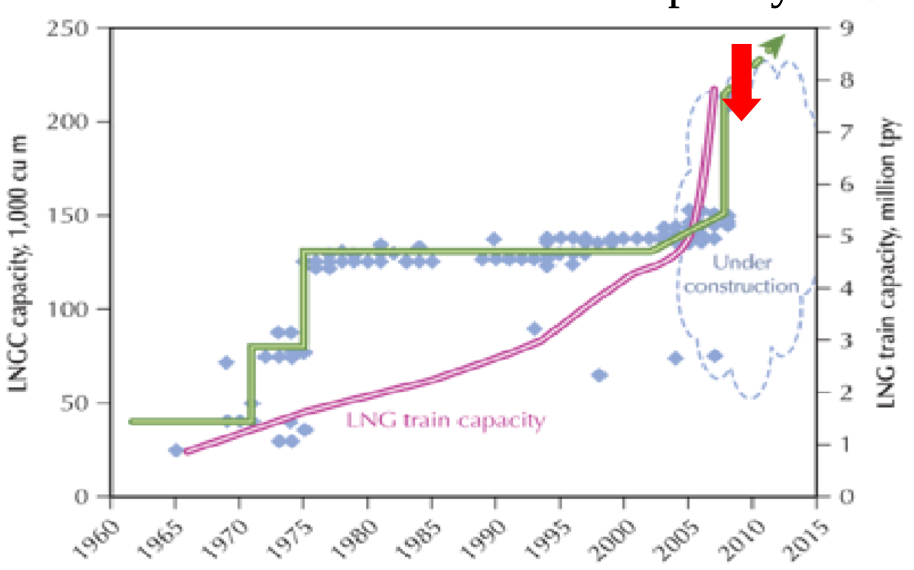
Eulerian grid-based or Lagrangian Particle Method?

- Still grid-based volume approach is popular.

Sloshing Experimental Procedure

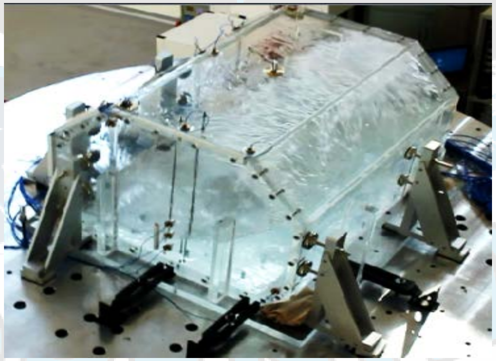
Current Engineering Demand

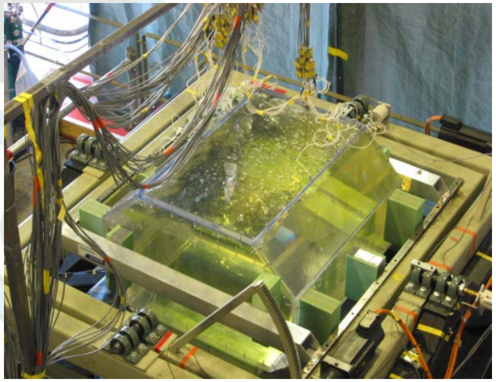
Recent trend of LNGC capacity



Potential of structural damage on LNG CCS is increased.

Experiment is most reliable so far.





Sloshing Experimental Procedure
Technical Issues

- Model Test with LNG or Similar Fluid
- Sensor Sensitivity: Reliability, Thermal Shock, Sensing Diameter
- Experimental Procedure: Time Window, Wave and Motion Conditions
- Hydroelasticity Effects of Insulation Structure
- Scale Law
- Statistical Analysis of Impact Loads
- Modeling of Impulsive Pressure for Structural Analysis: Space and Time
- Validation of FE Analysis for Dynamic Structural Responses
- Reliable and Stable CFD Computation with Small CPU Time
- Effects of Coupling with Ship Motion: Guidance for Design
- Local Structural Damage: Leakage, Debonding, Delamination,…

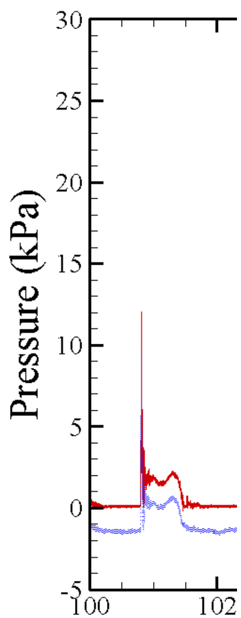
Sloshing Experimental Procedure

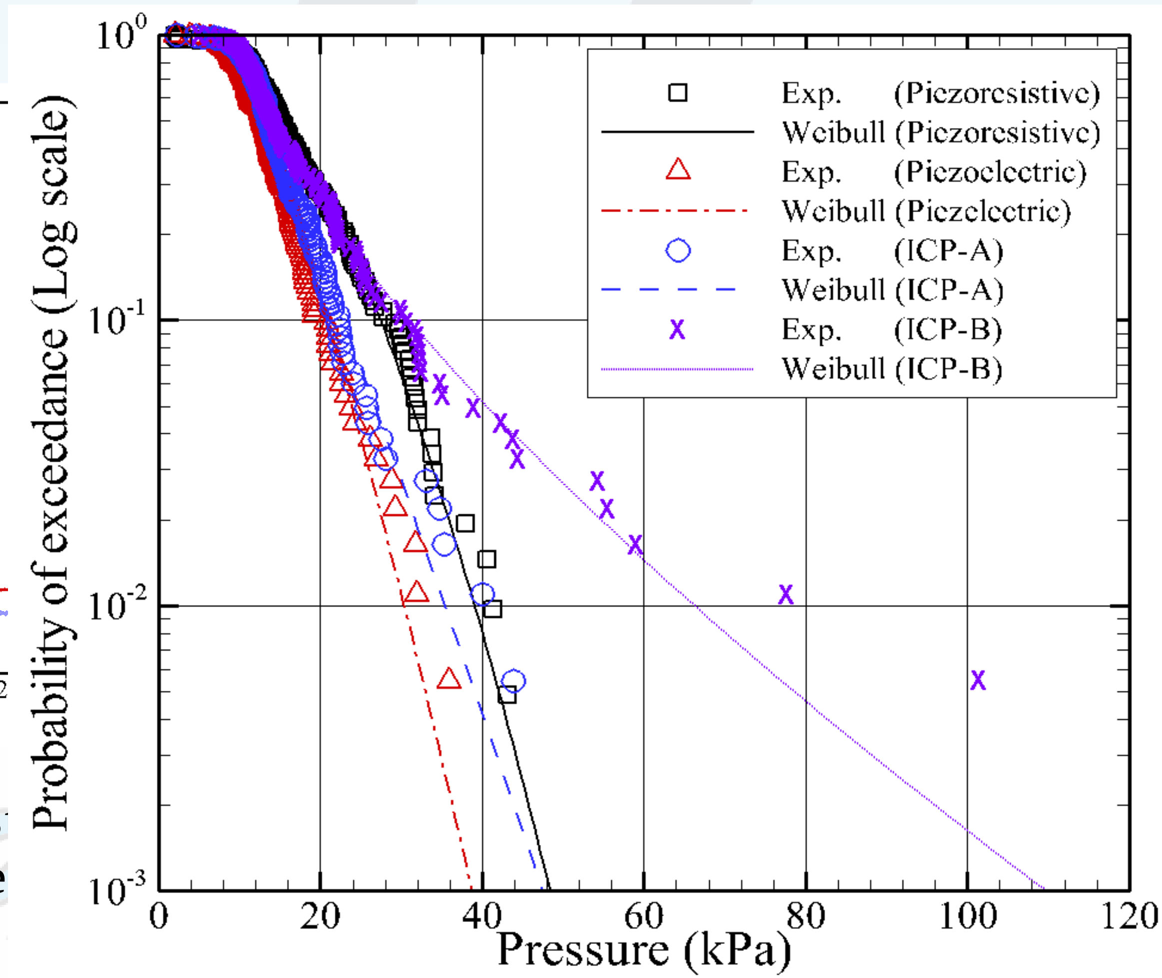
Example: Pressure Sensors

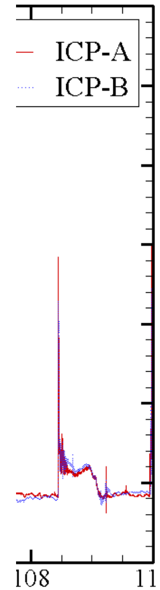
Group	Maker	Model	Diameter (mm)	Reference
Ecole Centrale Marseille	PCB	112A21	5.5	Loysel et al. (2012)
Exxon Mobile	Kulite	XCL-8M-100-3.5BARA	2.6	Yung et al. (2009)
GTT	PCB	112A21	5.5	Loysel et al. (2012)
MARINTEK	Kulite		~2.5	Loysel et al. (2012)
Pusan National Univ.	Kistler	211B5	5.5	Choi et al. (2010)
Seoul National Univ.	Kistler	211B5	5.5	Kim et al. (2011)
Technical Univ. of Madrid	Kulite	XTL-190	~2.5	Souto-Iglesias et al. (2012)
Univ. of Duisburg-Essen	Kulite	XTM-190	3.8	Loysel et al. (2012)
Univ. of Rostock	PCB	M106B	11	Mehl and Schreier (2011)
Univ. of Western Australia	Kulite	XCL-8M-100-3.5BARA	2.6	Pistani and Thiagarajan (2012)

Sloshing Experimental Procedure

Pressure Sensors: Sample Case







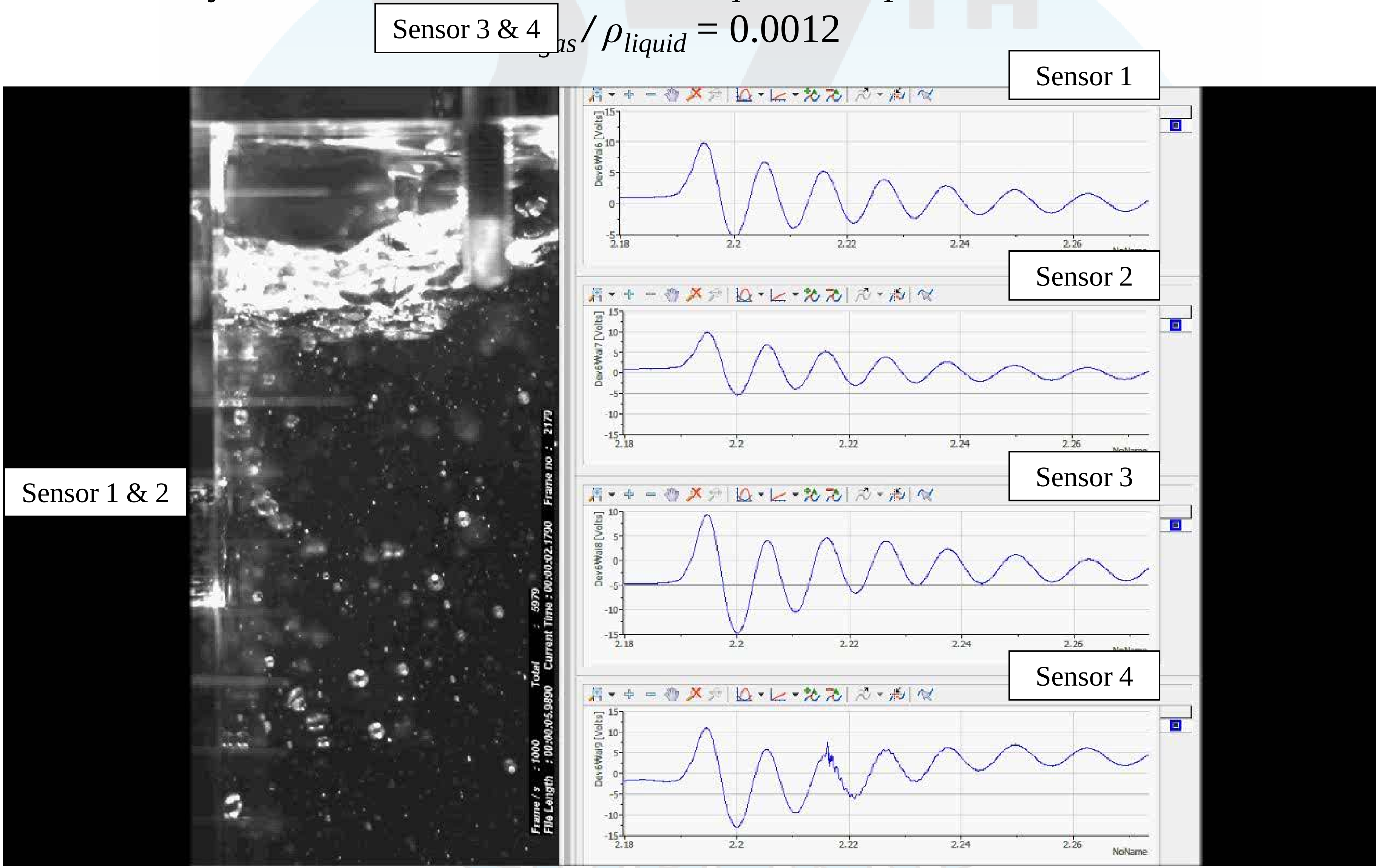
Piezoresis
Time historie

e motion

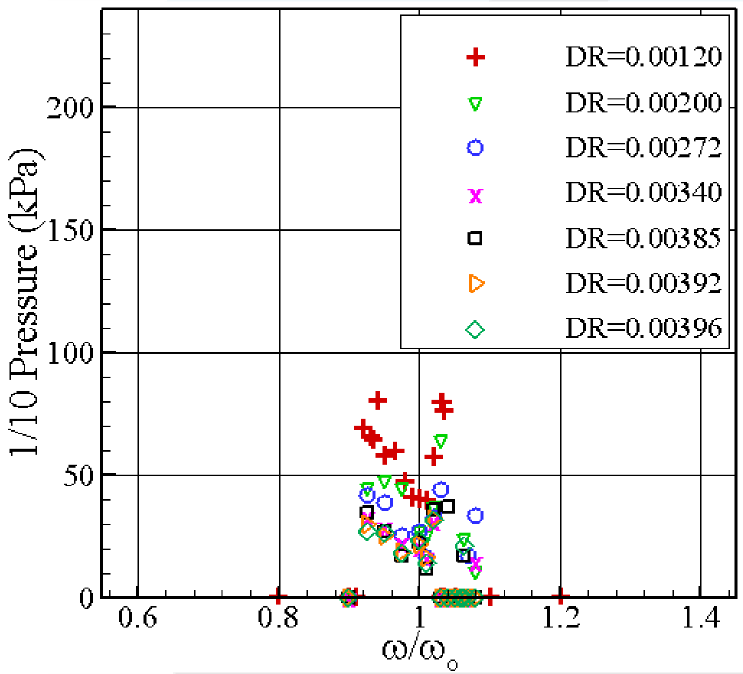
Effects of Density Ratio

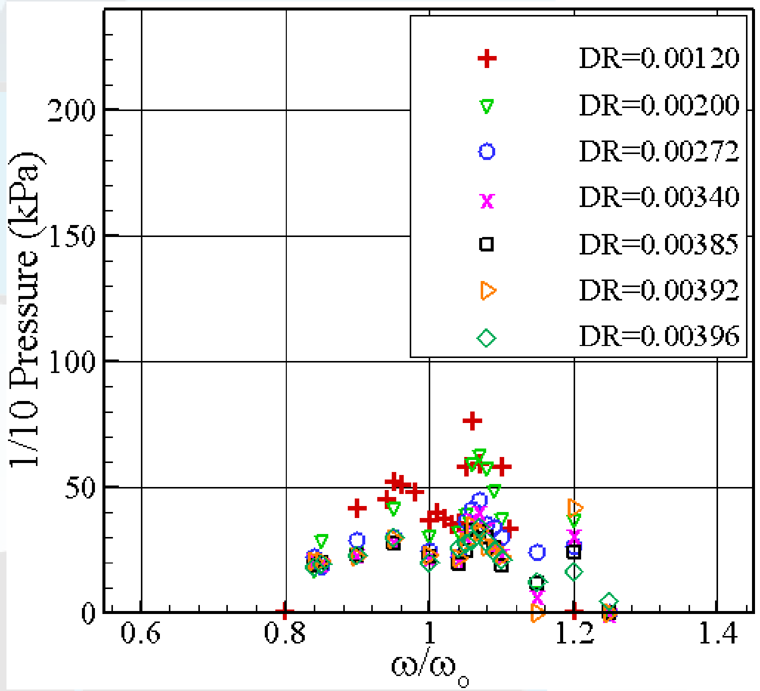
Synchronized movement of the liquid with pressures – *case 1*

$_{as} / \rho_{liquid} = 0.0012$



Effects of Density Ratio





(a) Amplitude = 40 mm (b) Amplitude = 15 mm

Measured sloshing pressure of 2D harmonic test with 70%H filling level varying the frequency and the density ratio (Ahn, et al.2012)

Procedure 7.5-02-07-02.1
Seakeeping Experiments

- **All-in-all a mature procedure that required only limited updates**
- **Changes:**
  - Editorial corrections: misspellings, missing references recovered, inconsistent and incorrect symbols corrected
  - Sections on Regular Waves, Transient Waves, and Irregular Waves were updated with some additional information, guidelines, and references
  - A number of new symbols are proposed for Appendix A on uncertainty assessment (until ITTC-QG proposes something more consistent):
- Difficult to find the source of Fig.3 for blockage effect
- Adopted QG's recommendation for minor corrections

Procedure 7.5-02-07-02.2

Predicting Power Increase in Irregular Waves from Model Experiments in Regular Waves

- **Change in procedure:** Inclusion of a section to address directional spectrum with short crested component

- There was a discussion with regards to applicability of various simulation efforts to calculate added resistance. The thought was whether there would be a future area of the procedure that might incorporate simulation combined with experimental results to determine added resistance. Based on this discussion, some sentences are revised, particularly for the wave spectrum.

Procedure 7.5-02-07-02.3
Experiments on Rarely Occurring Events

- **Task: Include the definition of slamming**
- **Question: Is Ochi's formula appropriate?**

- Ochi's formula principally looked at slamming velocity.
- It was thought that bow flare and hull shape should also be an included factor.
- Might need to break slamming into manageable pieces to provide a proper definition.
- ABS, ISSC and other classification rules should be reviewed for applicability to slamming and rarely occurring events.

- **Include the description of slamming in section 2.4.3**

Procedure 7.5-02-07-02.5
V&V of Linear and Weakly Nonlinear Seakeeping Computer Codes

- **Task: update procedure with outcomes of the Workshop on V&V for Non-linear Seakeeping Analysis**
- There was an important comment that **the current state of art shows that most authors do not include details of their V&V activities in publications** other than straightforward comparison between experimental and computed data, be it RAOs, signal statistics, or direct time trace comparison. This issue should be considered for any future revision
- **Based on this the SK committee proposes to keep to current procedure ‘as is**

Procedure 7.5-02-07-02.6
Prediction of Global Wave Loads

- Needed to look at incorporation of **hydroelastic computation into procedure**
- Current procedure concentrates on experimental procedure. Need to consider how computations can be used as interface, guide, and interpretation of experimental results.
- Changes might be more appropriate as state of art review first, but should consider appropriate changes.

- **This was not completed in the 27th term.**

- *Computational procedure can be included in 7.5-02-07-02.5 (V&V of Linear and Weakly Nonlinear Seakeeping Computer Codes) or can be a separate procedure.*

Procedure 7.5-02-05-04
HSMV Seakeeping Tests

- **Task: Review the procedure and revise if needed**

- **Changes**

- Include references (none in the previous version)
- Add paragraph on placement of ‘free to pitch’ fitting for catamaran vessels
- Add requirement to measure pitch inertia
- Updated planning craft testing to include requirement to consider sample rate for human factors measurements
- Updated free-running model testing to recognise that onboard digital storage is now possible and commonly used.
- Removed S175 from suggested benchmark/database of ship. This hull cannot be considered as an HSMV.

Recommendation for Future Works

- It is recommended that **ITTC has a combination of pure technical committees and special committee(s) for external needs.**
- It is recommended to survey and/or **collect benchmark data** for seakeeping problems, such as motions, loads, sloshing, slamming and full-scale measurements.
- It is recommended to **write a new section for the V&V of ship hydroelasticity code**s in the procedure 7.5-02-07-02.5, Verification and Validation of Linear and Weakly Non-linear Seakeeping Computer Codes.
- It is recommended to **strengthen the collaboration with ISSC committees**, including, Loads and Responses and Environment Committees.
- It is recommended to **liaison with Propulsion and Manoeuvring Committees** for seakeeping/motion effects.
- It is recommended to **create a unified procedure for sloshing experiment**.

ITTC-ISSC Joint Workshops

- Importance of cooperation recognised by 25th ITTC and continued in 26th and 27th terms.
- Further cooperation mandated by ITTC and also by the pertinent ISSC committees
- 1st joint workshop was held in one day before ISSC Conference at Rostock in 2012, and 2nd joint workshop was held in one day before this ITTC Conference.
- Attended by representatives from the ITTC SC and OEC and ISSC Loads and Environment committees
- Presentations of the 1st workshop were written into the technical papers which were published in a special edition of Ocean Engineering. The same is scheduled for the 2nd workshop.

Workshop Programme

Time	Topic	Session Chair
09:00 - 09:30	Registration	
09:30 - 09:40	Welcome from the Chairs of ITTC & ISSC	
09:40 – 10:20	Prediction of Wave Induced Loads on Ships: Progress and Challenges by Pandeli Temarel, ISSC Loads Committee	Gerhard Strasser
10:20 - 11:00	Emerging Problems of Nonlinear Seakeeping and Loads by Yonghwan Kim, ITTC Seakeeping Committee	
11:00 - 11:20	Coffee Break (supported by DNV-GL)	
11:20 – 12:00	Nonlinear Loadings on Ocean and Offshore Structures by Wei Qui, ITTC Ocean Engineering Committee	Paul Crossland
12:00 - 12:40	Sea state conditions for marine structures' analysis and model tests Elzbieta Bitner-Gregersen, ISSC Committee on Environment	
12:40 - 14:00	Lunch (supported by Lloyd's Register Group)	
14:00 – 14:50	Results of Benchmark Test for a Containership	Carlos Guedes Soares
14:50 – 15:05	Benchmark Test 1 : Lloyd's Register	
15:05 - 15:20	Coffee Break (supported by MARIN)	
15:20 - 15:35	Benchmark Test 2 : DNV-GL	Elzbieta Bitner-Gregersen
15:35 - 15:50	Benchmark Test 3 : University of Duisburg-Essen	
15:50 - 16:15	Benchmark Test 4 : Seoul National University	
16:15 - 16:30	Coffee Break	
16:30 - 17:30	Panel Discussion for Environmental Loads and Ship Responses Carlos Guedes Soares, Elzbieta Bitner-Gregersen, Pandeli Temarel, Paul Crossland, Wei Qui	Yonghwan Kim
17:40 -	Dinner (Hosted by AMEC, Seoul National University)	

Discussions

- Need to have terms of references
- Create joint committee(s) of ITTC and ISSC
- Open to all committees of ITTC and ISSC
- Topics to be considered: loads, uncertainty, ...
- A common archive can be shared by two organizations, e.g. benchmark test, ...
- Review reports each other can be considered.
- Short-term and long-term plan should be defined.
- ……

Benchmark Test: Ship Model

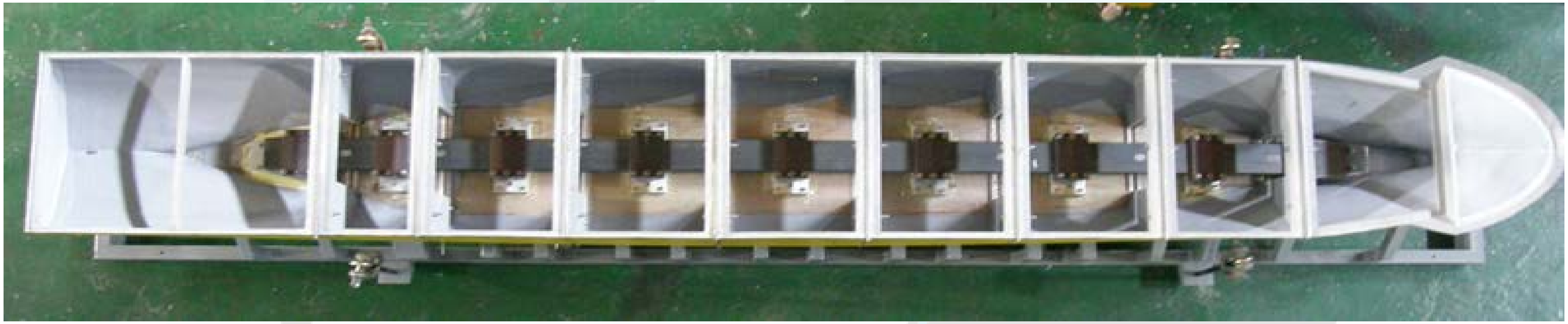
KRISO 6750-TEU Containership

Design/Model Test: designed by DSME and KRISO
Model Test: KRISO (2009)
Body Type: 8-segmented flexible ship with rectangular bar backbone

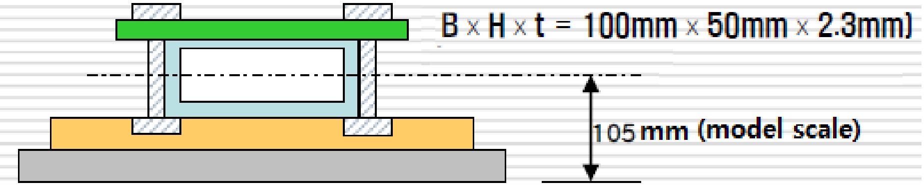
Item	Prototype	Model
Scale	1/1	1/70
LOA (m)	300.891	4.298
LBP (m)	286.6	4.094
Breadth (m)	40	0.571
Height (m)	24.2	0.346
Draft (m)	11.98	0.171
Displacement	85562.7 ton	249.454 kg
KM (m)	18.662	0.267
GM (m)	2.1	0.03
KG (m)	16.562	0.237
LCG from AP (m)	138.395	1.977
kxx (m)	14.6	0.206
kyy (m)	70.144	1.002
kzz (m)	70.144	1.002
Natural Period of Roll (sec)	20.5	2.45
Neutral axis from keel (m)	7.35	0.105

Backbone Property

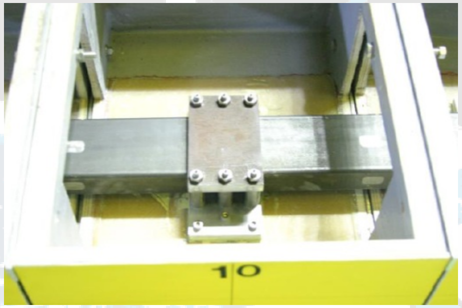
A tubular backbone of rectangular cross-section



Backbone	Real scale (m)	Model scale (mm)
B	7.000	100.000
H	3.500	50.000
t	0.161	2.300
Young Modulus	14 (TPa)	200 (GPa)
Neutral axis from keel	7.350	105.000



Mode	Natural frequency of 2-node vertical bending	
	Real scale (Hz)	Model scale (Hz)
Dry mode	0.785	6.571
Wet mode	**0.645**	5.4



***Damping ratio is approximately 2.0% of critical damping.**

Test Cases

- Linear RAOs of motion and load in head sea (Linear)
- Nonlinear motion and load in head sea (NL1, 2, and 3)
- Longitudinal distribution of sagging and hogging moment (NL1, 2, and 3)
- Forward speed effect (NL1 and 3)
- Nonlinear springing and whipping due to a large wave (NL2)

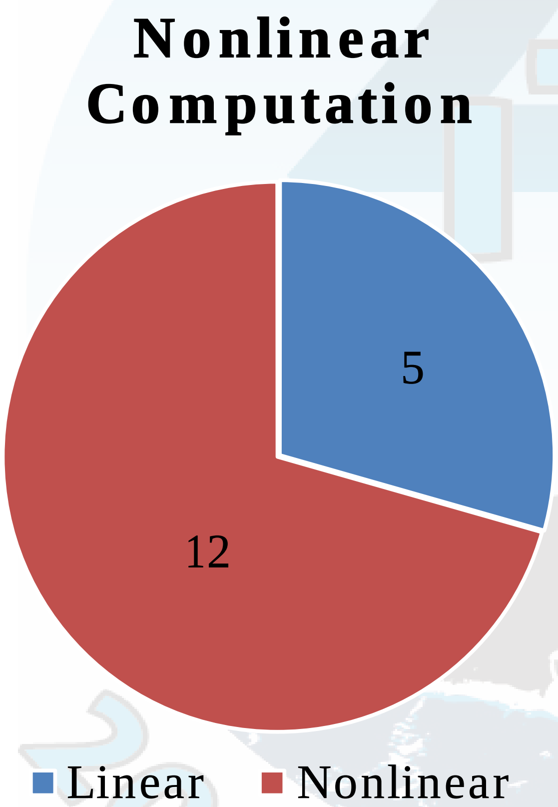
Objective	Test ID	Wave Frequency (rad/s), λ/L	Wave Height (m)	Heading angle (degree)	Forward speed (m/s), Froude No.	Output Request
Linear RAO	RAO	0.242~0.628, 0.54~3.68	small value	180	0	RAO of Heave, pitch, VBM

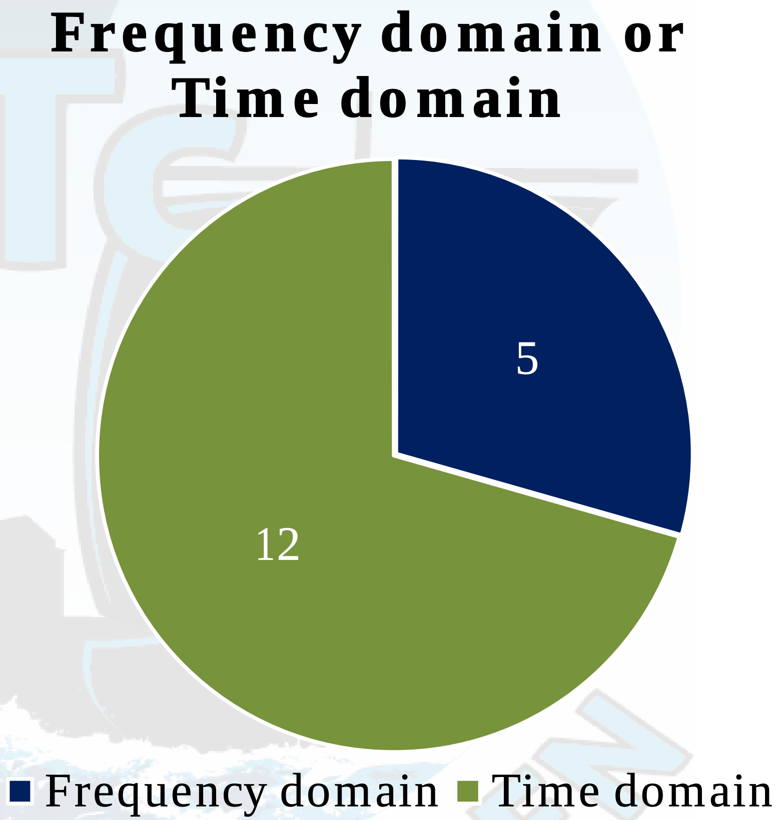
Optional objective	Test ID	Wave Frequency (rad/s), λ/L	Wave Height (m), H/λ	Heading angle (degree)	Forward speed (m/s), Froude No.	Output Request
Nonlinear load & whipping	**NL1**	0.449, 1.07	**6.118, 1/50**	180	2.572, 0.05	Time series of heave, pitch, and VBM Longitudinal distribution of VBM
	NL2	0.449, 1.07	**10.926, 1/28**	180	2.572, 0.05	
	NL3	0.449, 1.07	**6.118, 1/50**	180	6.173, 0.12	

Participants: 17 programs from 11 organizations

Institutes	Codes	Method	RAO	NL1	NL2	NL3
CSSRC (China Ship Scientific Research Center)	THAFTS	3D BEM	O	X	X	X
DNV GL (Det Norske Veritas Germanischer Llyod)	GL Rankine1	3D BEM	O	O	O	O
	GL Rankine2	3D BEM	O	O	O	O
HEU (Harbin Engineering University)	COMPASS-WALCS-LE/NE	3D BEM	O	O	O	O
IST (Instituto Superior Tecnico)	In-house	Strip	O	O	O	O
LR (Llyod's Register)	CRS PRECAL, PRETTI, TDWHIP	3D BEM	O	O	O	O
MUN (Memorial University of Newfoundland)	MAPS0	Panel-Free Method	O	X	X	X
NMRI (National Maritime Research Institute)	NMRIW	Strip	O	O	O	O
NTUA (National Technical University of Athens)	NEWDRIFT	3D BEM	O	X	X	X
	HYBRID	IRF	X	O	O	O
SNU (Seoul National University)	WISH	3D BEM	O	O	O	O
	WISH-FLEX 2.5D	3D BEM	O	O	O	O
	WISH-FLEX BEAM	3D BEM	O	O	O	O
UDE (University of Duisberg-Essen)	COMET	RANSE	O	O	O	O
UZUR (University of Zagreb and University of Rijeka)	Waveship	Strip	O	X	X	X
	HydroSTAR	3D BEM	O	X	X	X
	Gretel	Strip	O	O	O	O

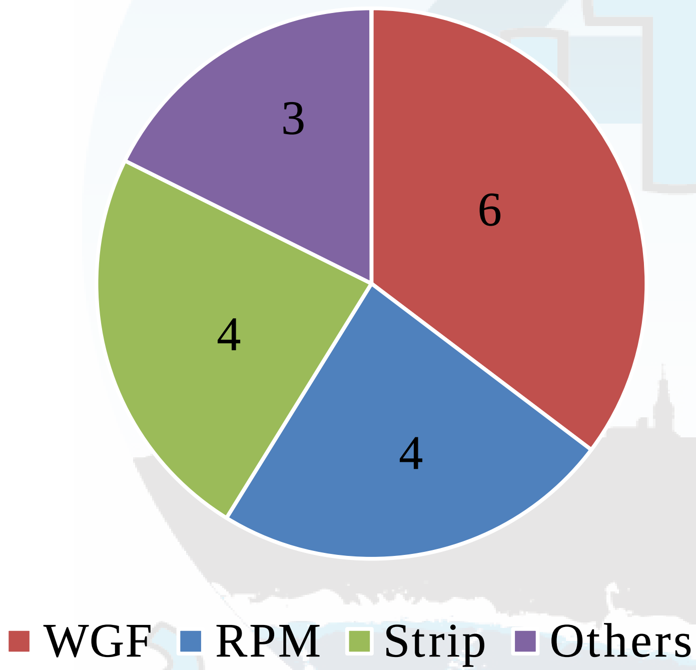
Participants Analysis



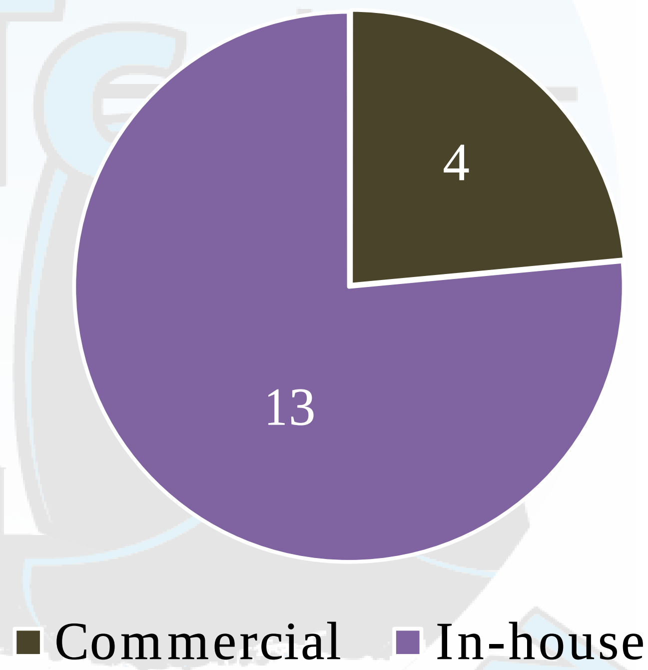


Participants Analysis

Analysis Method



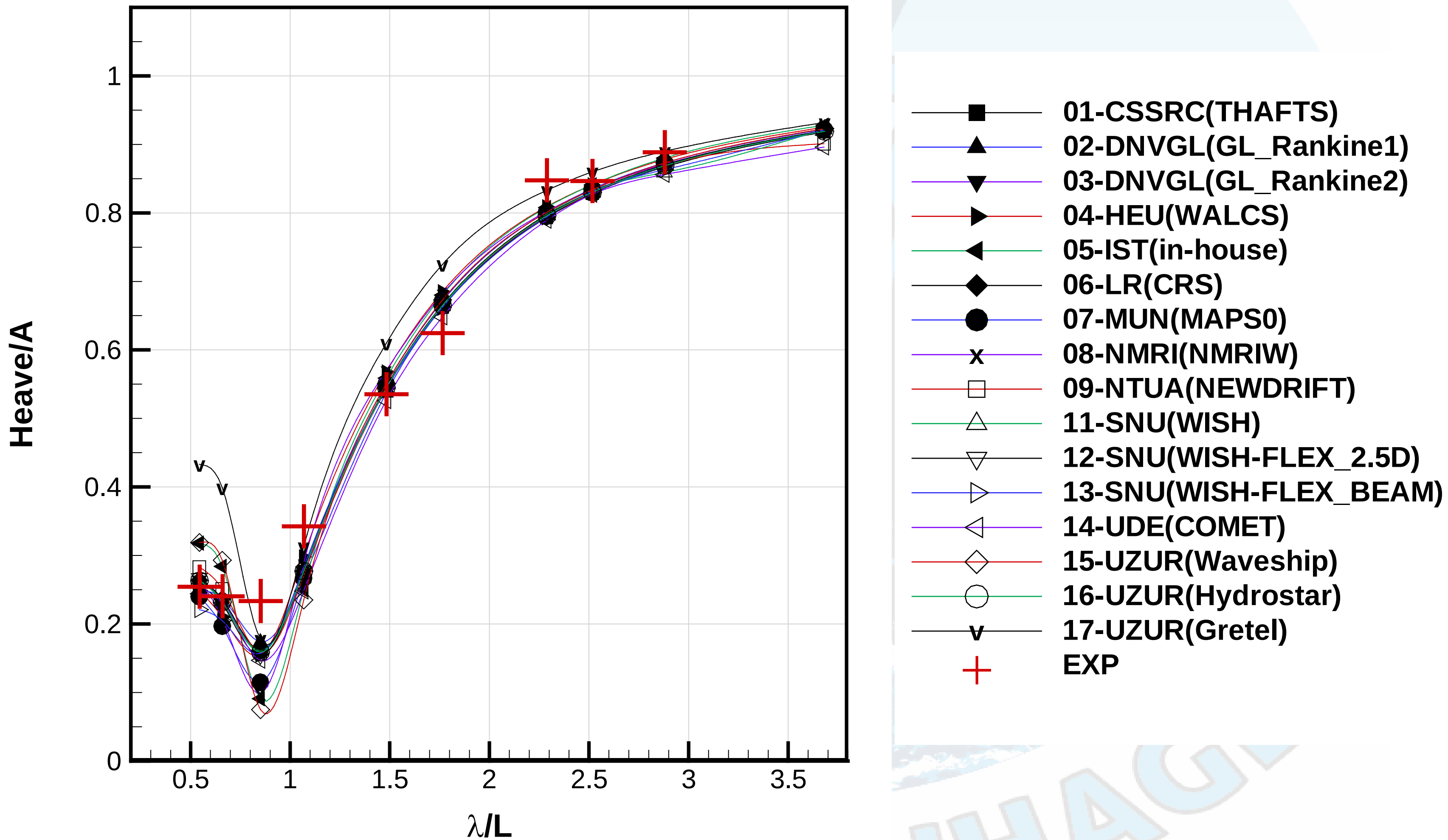
Commercialization



*Others (3): CFD (1), IRF (1), Panel-Free-Method (1)

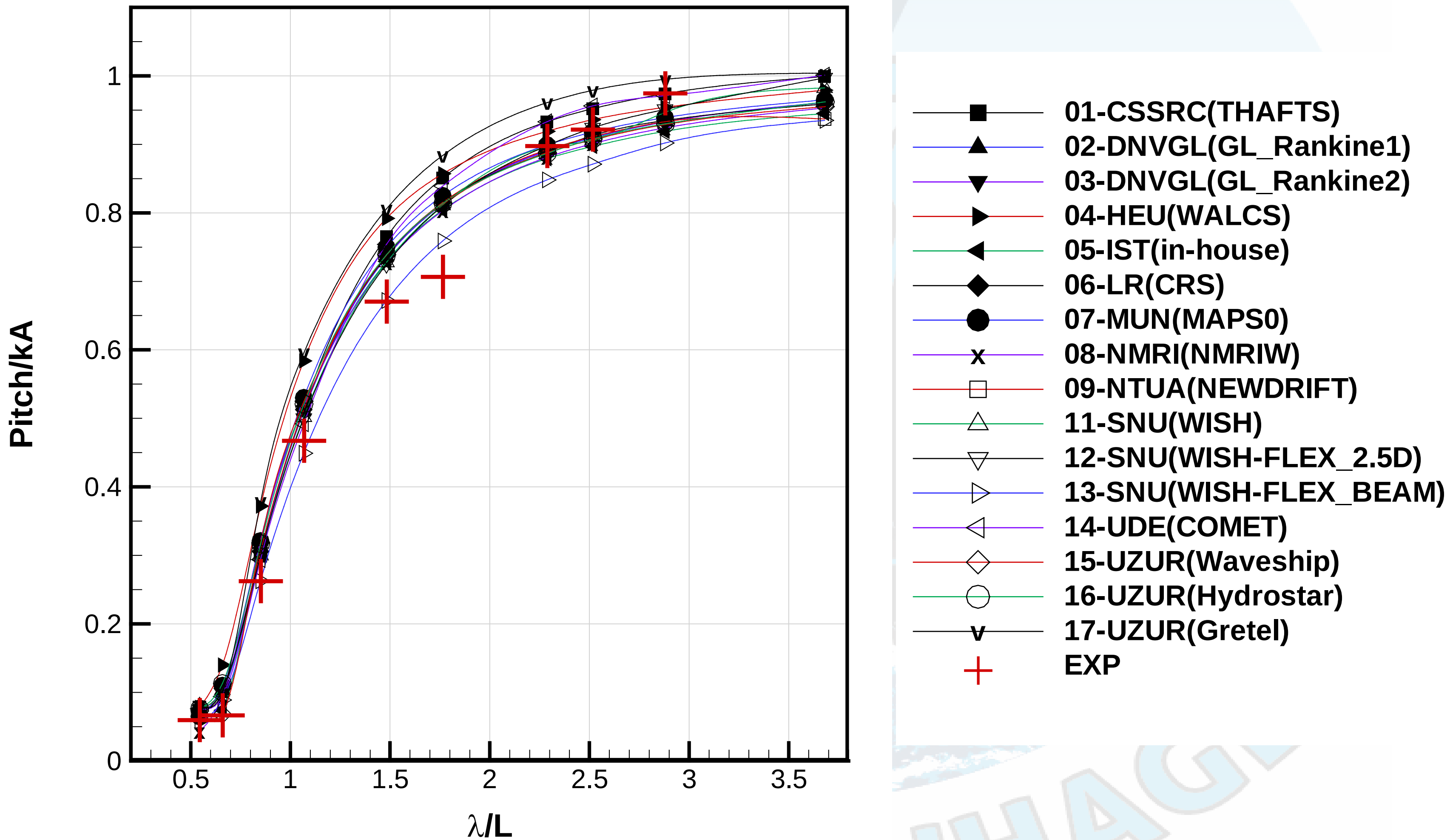
Linear RAO - Heave

Linear RAO	λ/L= 0.54~3.68	Small amplitude	180° heading angle	Fn=0	Heave



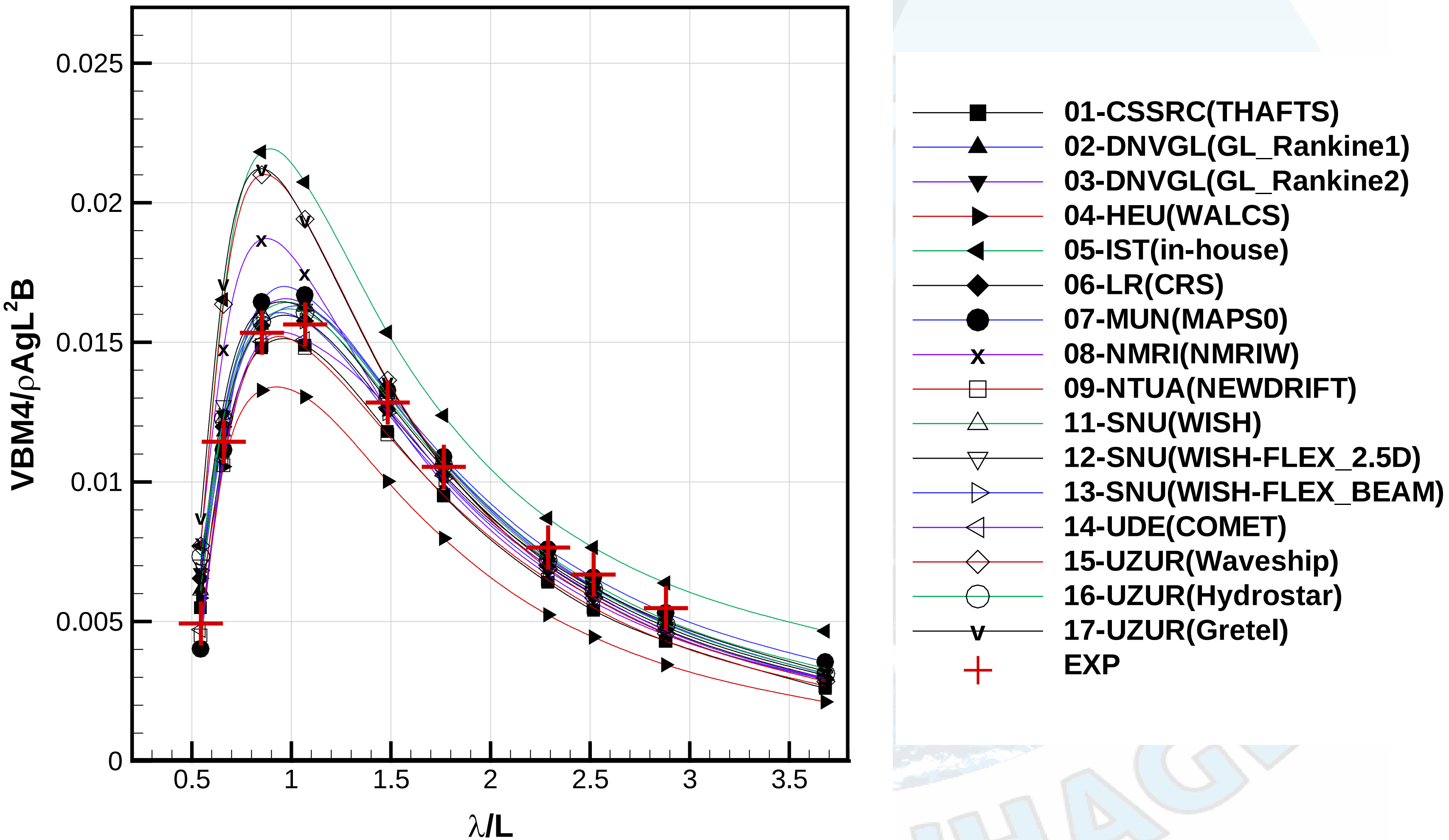
Linear RAO - Pitch

Linear RAO	λ/L= 0.55~3.68	Small amplitude	180° heading angle	Fn=0	Pitch

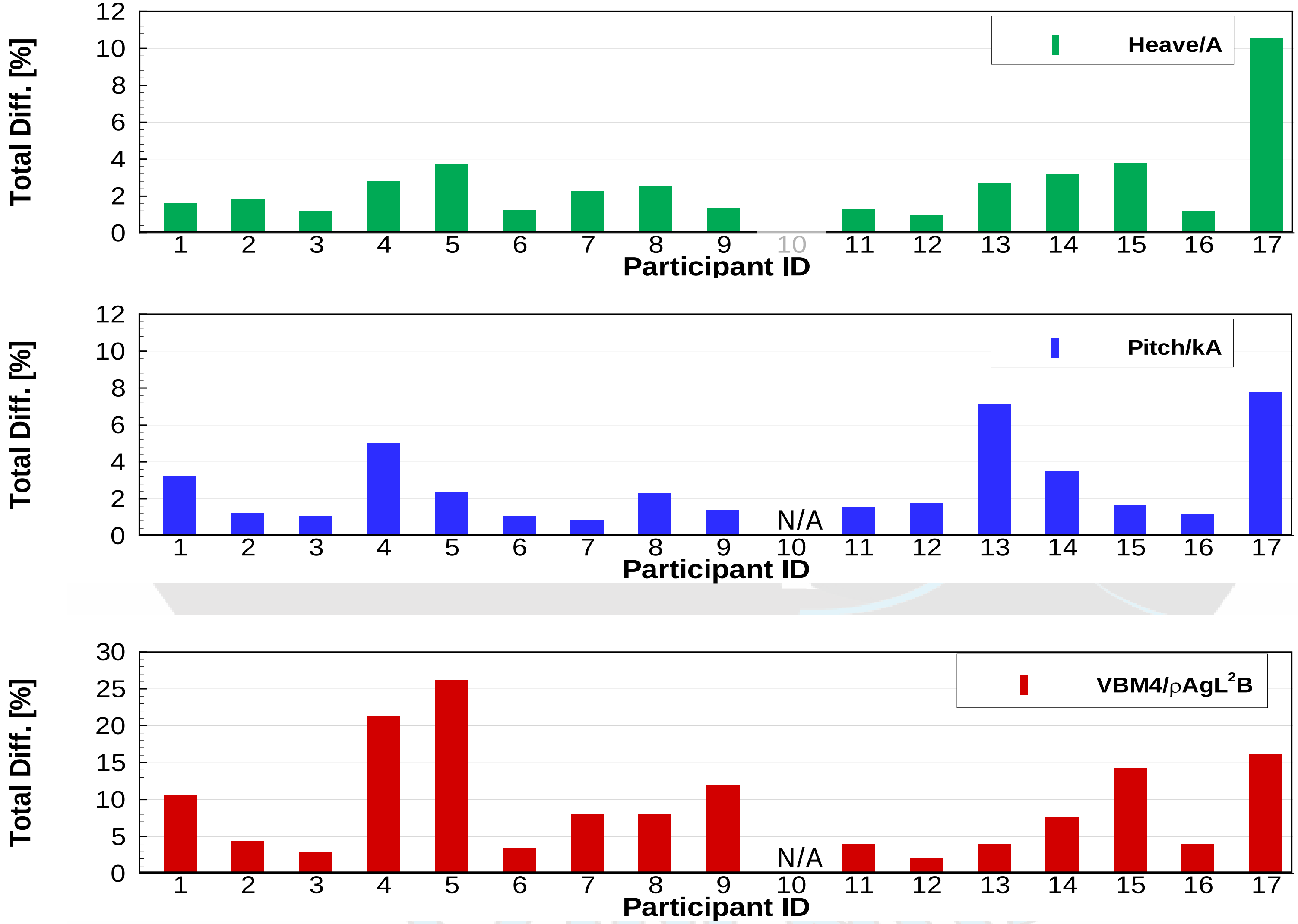


Linear RAO - VBM

Linear RAO	λ/L= 0.55~3.68	Small amplitude	180° heading angle	Fn=0	VBM at Section 4

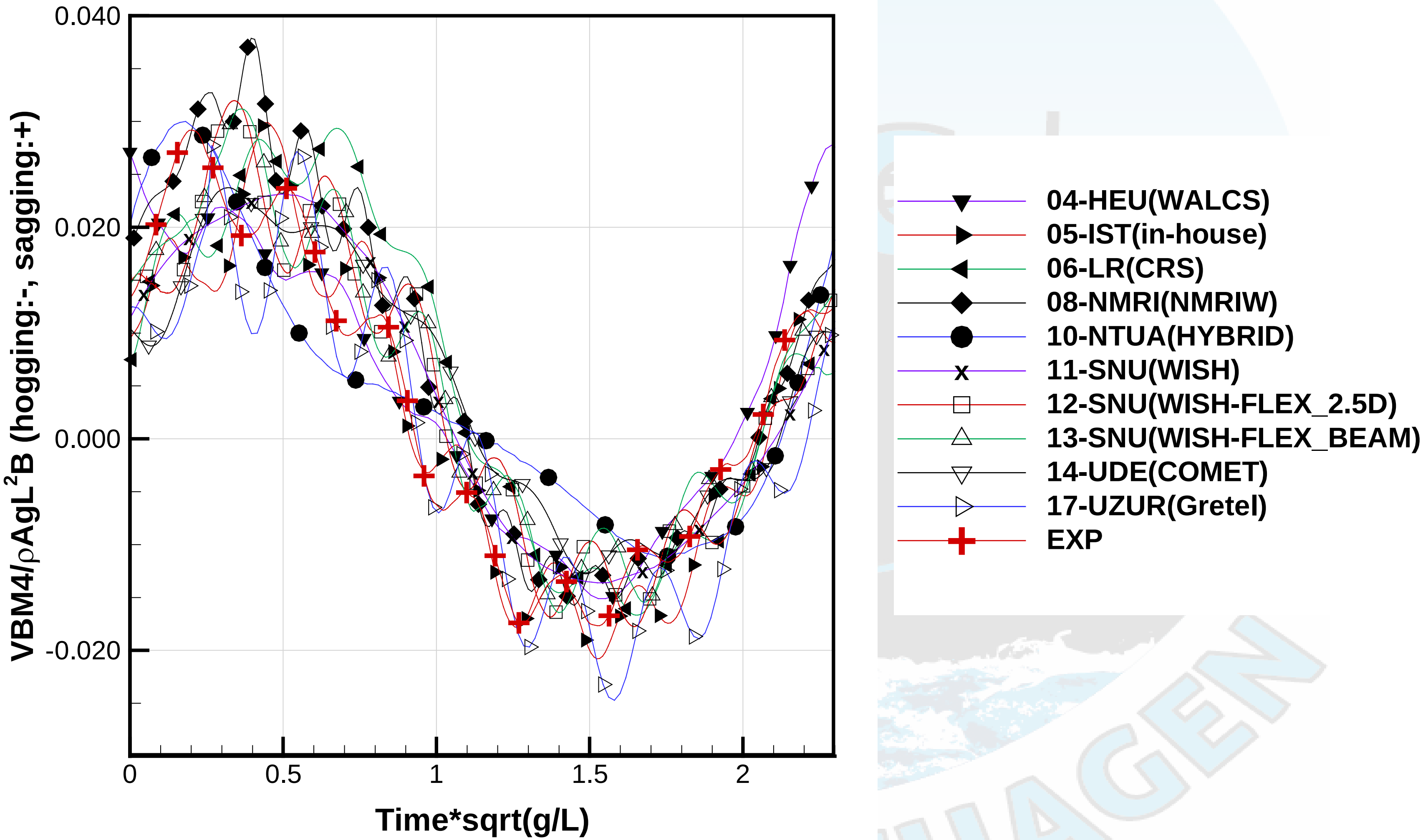


Linear RAO – Total Difference



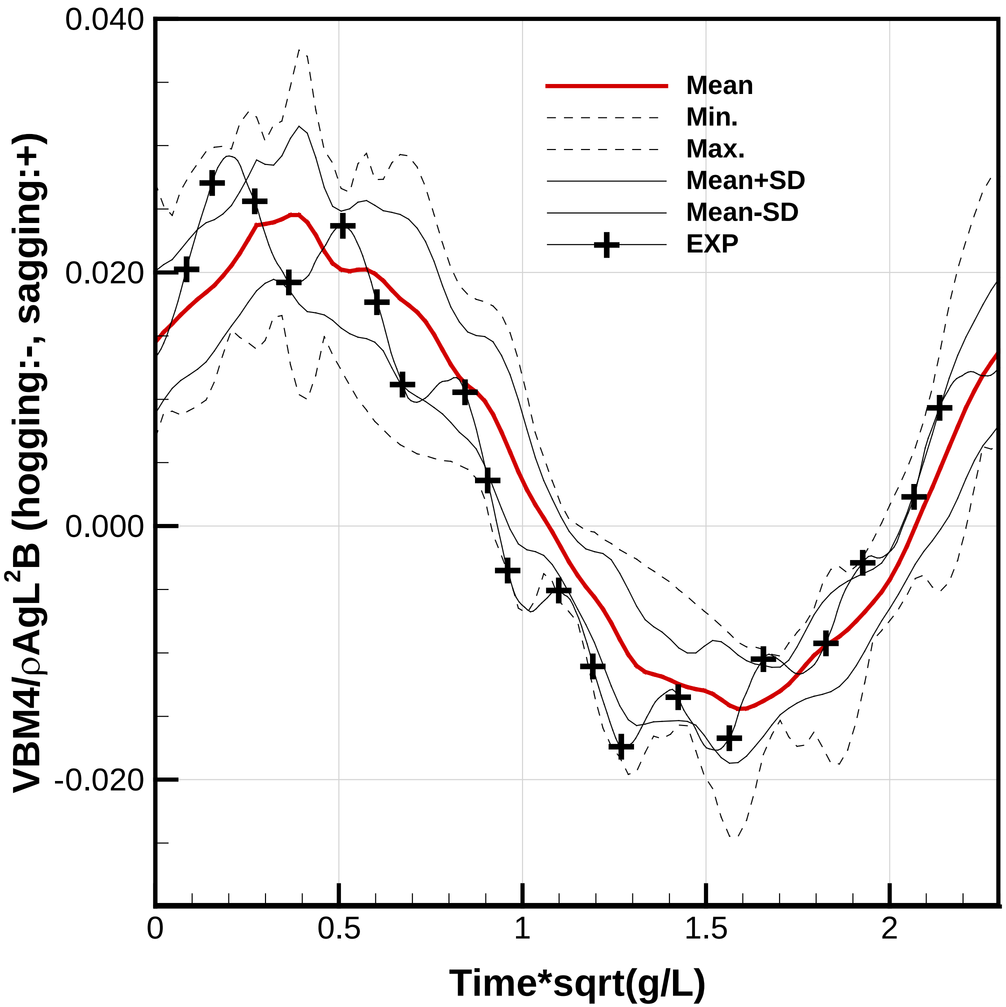
Nonlinear - NL2, VBM

NL2	λ/L=1.07	**H/λ=1/28**	180° heading angle	Fn=0.05	VBM at midship



Nonlinear - NL2, VBM

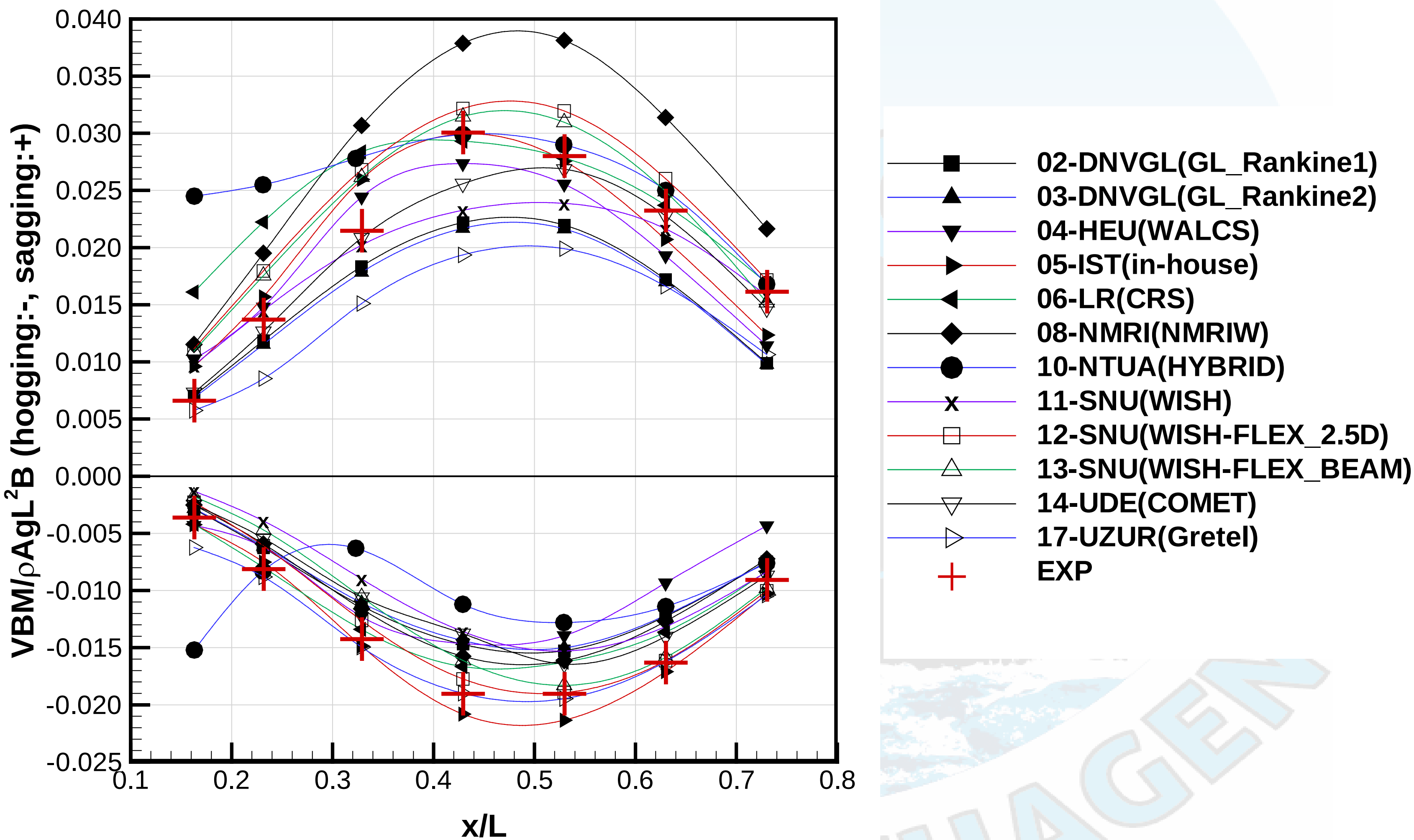
NL2	λ/L=1.07	**H/λ=1/28**	180° heading angle	Fn=0.05	VBM at midship



Time* sqrt(gL)	Mean Amp.	SD	SD/Mean Amp. [%]
0.00	0.0195	0.00562	28.9
0.23	0.0195	0.00485	24.9
0.46	0.0195	0.00502	25.8
0.69	0.0195	0.00678	34.8
0.92	0.0195	0.00573	29.4
1.15	0.0195	0.00265	13.6
1.38	0.0195	0.00353	18.1
1.61	0.0195	0.00377	19.4
1.84	0.0195	0.00388	19.9
2.07	0.0195	0.00296	15.2

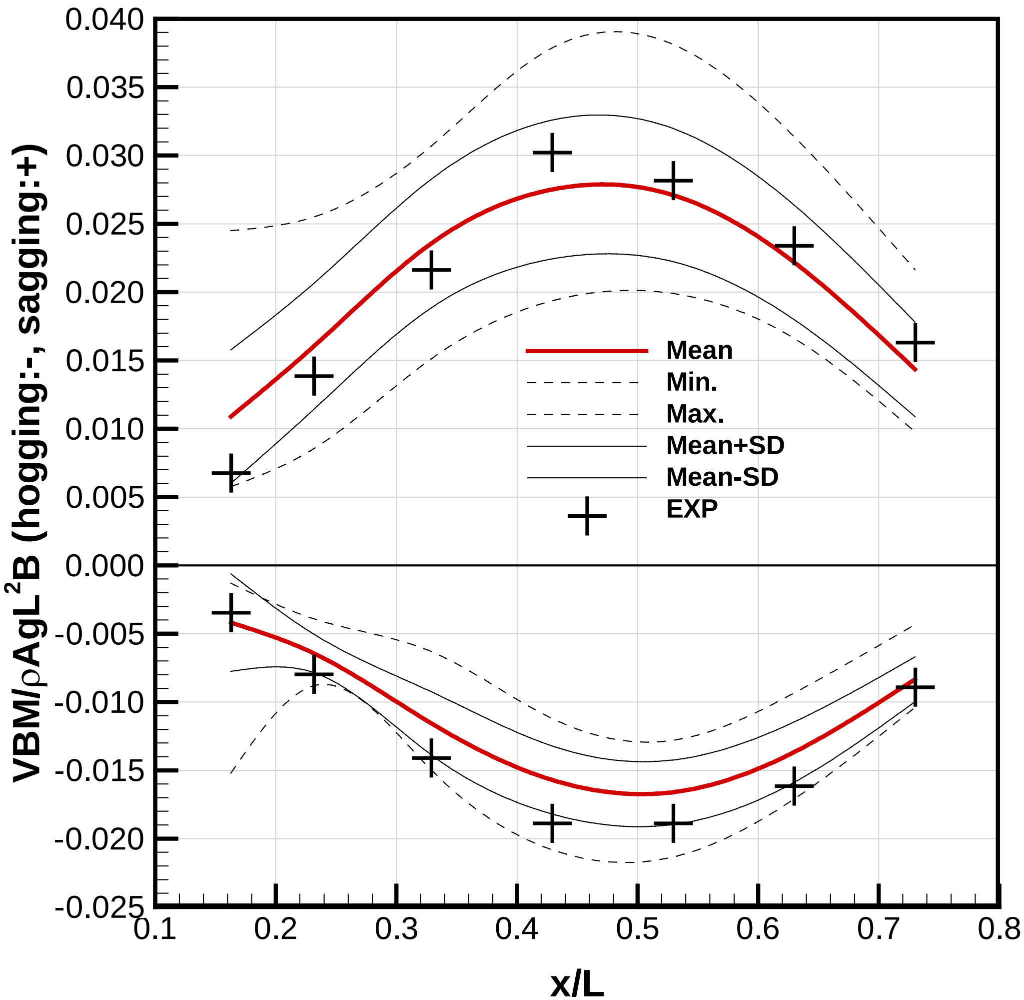
Nonlinear - NL2, VBM

NL2	λ/L=1.07	**H/λ=1/28**	180° heading angle	Fn=0.05	Longitudinal distribution of VBM



Nonlinear - NL2, VBM

NL2	λ/L=1.07	**H/λ=1/28**	180° heading angle	Fn=0.05	Longitudinal distribution of VBM

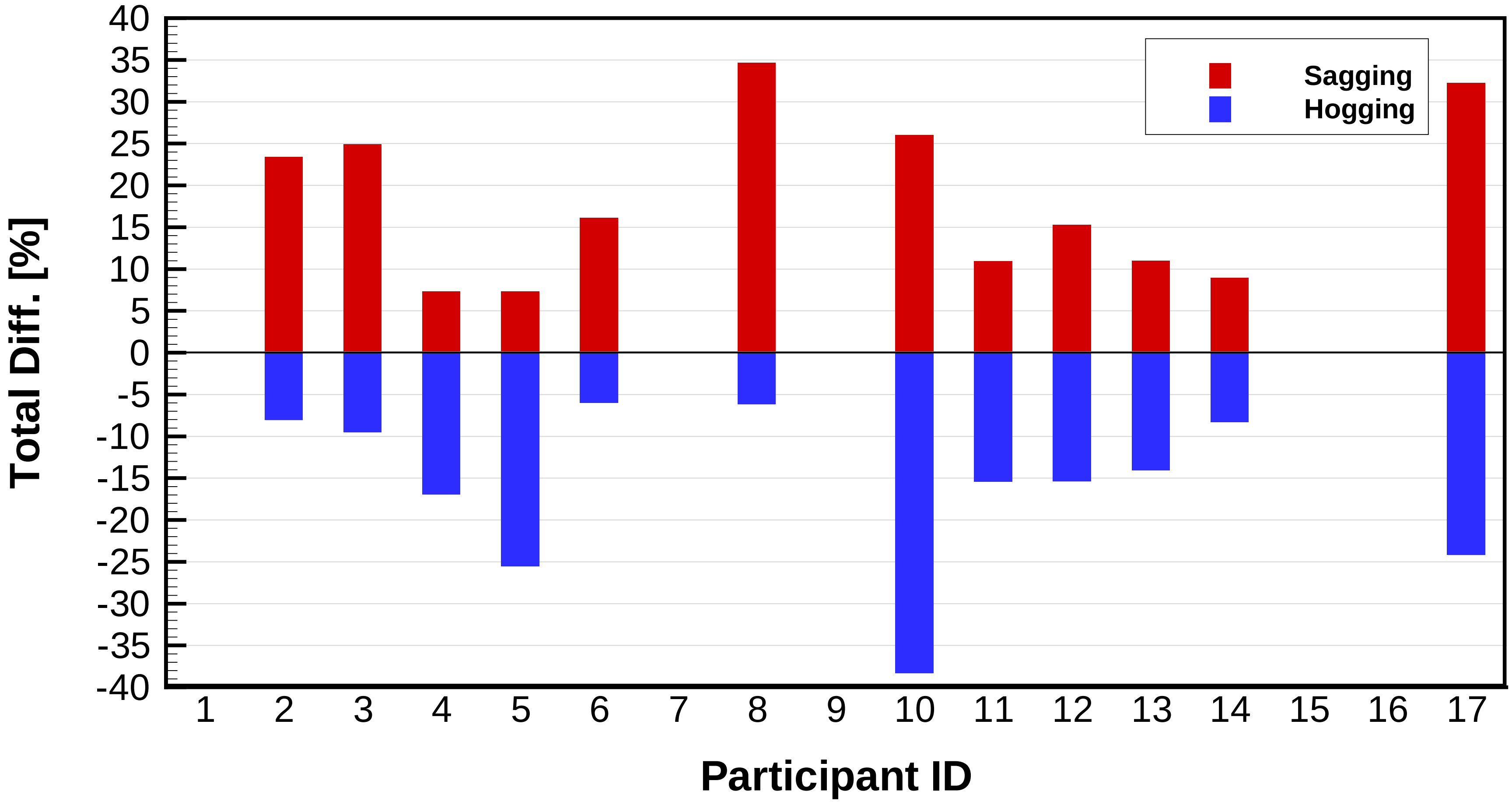


x/L	Sagging		
	Mean	SD	SD/Mean [%]
0.16	0.0109	0.00489	44.9
0.23	0.0160	0.00461	28.8
0.33	0.0236	0.00470	20.0
0.43	0.0275	0.00508	18.5
0.53	0.0271	0.00488	18.0
0.63	0.0222	0.00419	18.9
0.73	0.0144	0.00346	24.1

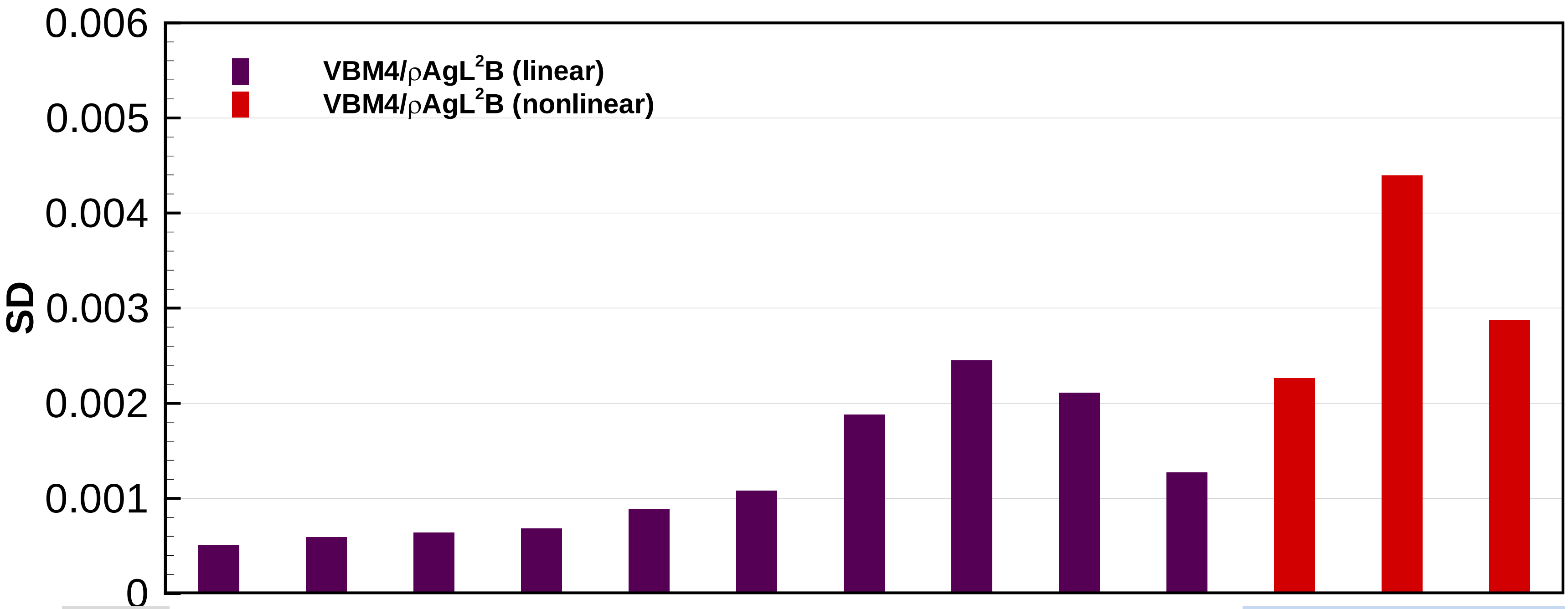
x/L	Hogging		
	Mean	SD	SD/Mean [%]
0.16	-0.0042	0.00357	-85.2
0.23	-0.0064	0.00141	-21.9
0.33	-0.0116	0.00231	-20.0
0.43	-0.0157	0.00249	-15.9
0.53	-0.0166	0.00236	-14.2
0.63	-0.0137	0.00221	-16.2
0.73	-0.0083	0.00164	-19.7

Nonlinear - NL2, VBM

NL2	λ/L=1.07	H/λ=1/28	180° heading angle	Fn=0.05	Longitudinal distribution of VBM

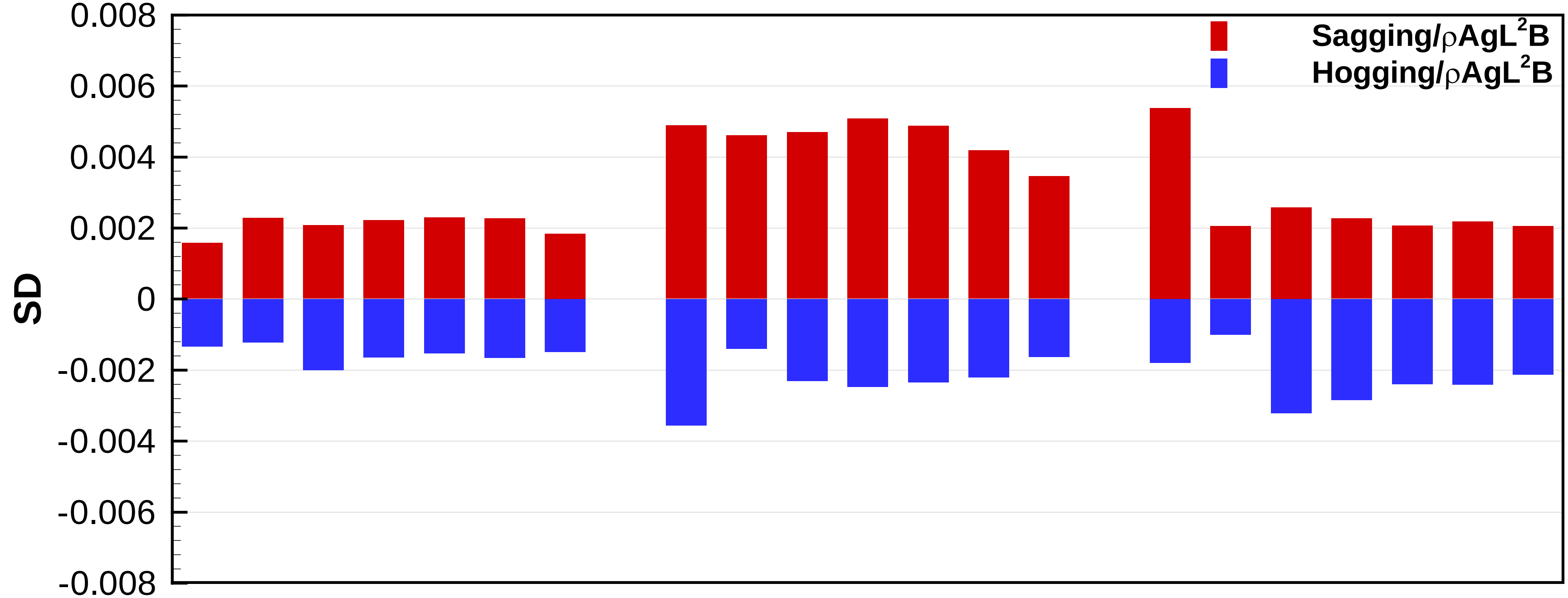


Comparison of SD – VBM4 (x/L=0.43)



ID	LIN	LIN	LIN	LIN	LIN	LIN	LIN	LIN	LIN	LIN	NL1	NL2	NL3
λ/L	3.68	2.82	2.52	2.29	1.77	1.48	1.07	0.85	0.66	0.55	1.07	1.07	1.07
H/λ	≪1	≪1	≪1	≪1	≪1	≪1	≪1	≪1	≪1	≪1	1/50	**1/28**	1/50
Fn	0	0	0	0	0	0	0	0	0	0	0.05	0.05	**0.12**

Comparison of SD – Sagging & Hogging



x/L	0.16	0.23	0.33	0.43	0.53	0.63	0.73	0.16	0.23	0.33	0.43	0.53	0.63	0.73	0.16	0.23	0.33	0.43	0.53	0.63	0.73
H/λ	1/50							**1/28**							1/50						
Fn	0.05							0.05							**0.12**						
ID	NL1							NL2							NL3						

Remarks for Benchmark Test

- 17 seakeeping analysis codes participated from 11 organizations. (12 nonlinear, 5 linear)
- The mean of all the numerical results show reasonable agreement with the experimental result.
- The numerical results are more scattered in VBM than motions.
- The numerical results are more scattered in the conditions of higher wave height, faster forward speed, or shorter wave length ($\lambda/L < 1.0$).
- The results of VBM near stern ($x/L < 0.2$) violently dispersed, whereas the results of VBM at mid-ship and bow are more convergent.

Thank you !

Q & A