

# JOINT DEVELOPMENT PROJECT ON SEAKEEPING SIMULATIONS USING OPENFOAM – INDUSTRIAL PERSPECTIVE

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## 3. Concluding Remarks

# Development of OpenFOAM in HHI

# CFD in HHI

Hyundai  
Maritime  
Research  
Institute

Resistance

Self-propulsion

Added Resistance

Maneuvering

Research and Development



# CFD in HHI

Hyundai  
Maritime  
Research  
Institute



OpenFOAM

WAVIS

Resistance

Self-propulsion

Added Resistance

Maneuvering

Research and Development



# CFD in HHI

Hyundai  
Maritime  
Research  
Institute

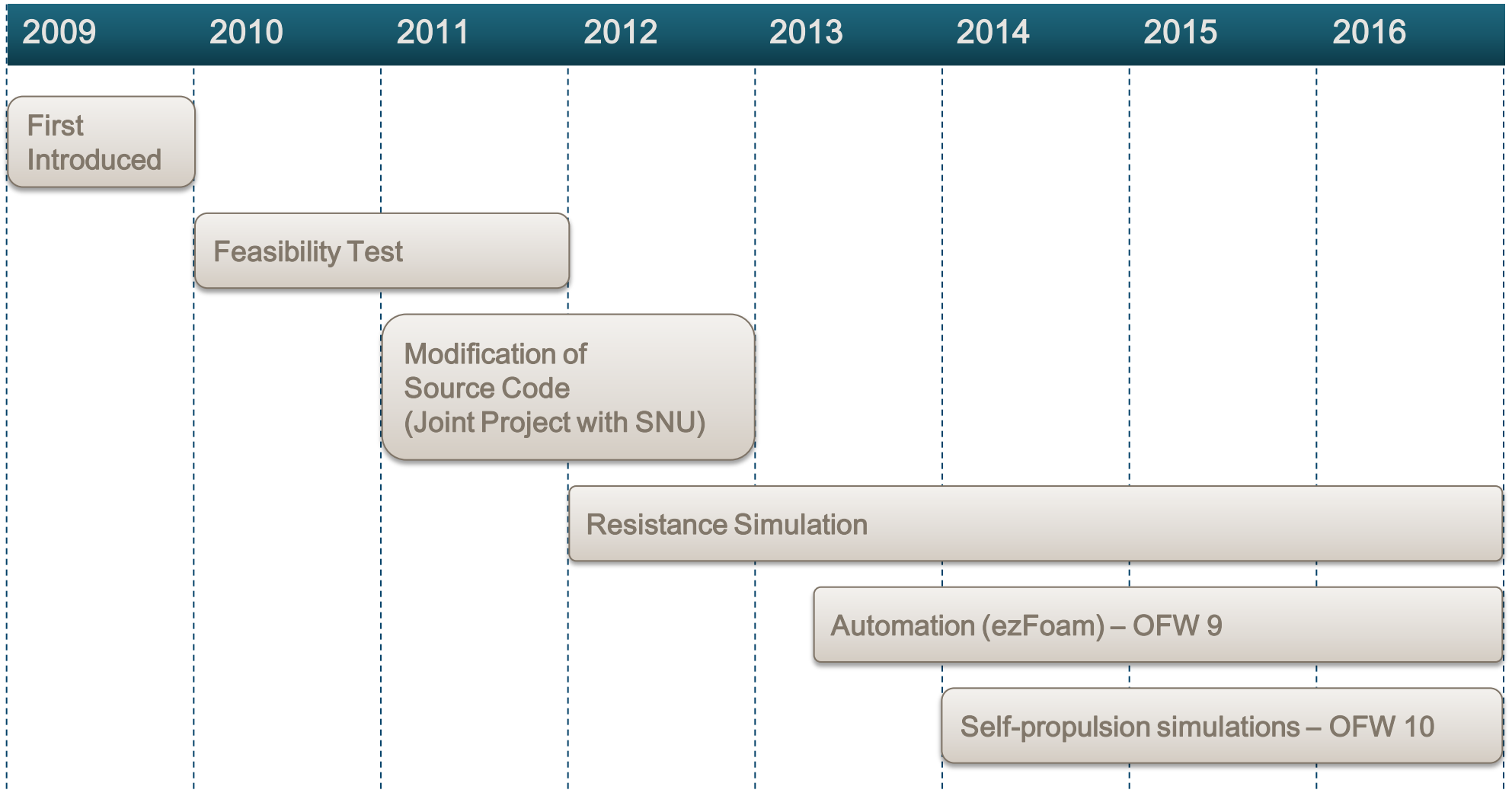


OpenFOAM

WAVIS



# OpenFOAM in HMRI



# OpenFOAM in HMRI



## Resistance Simulations



Project NEED FOAM SPEED

Enhanced speed & stability performances  
without losing accuracy

## Self-propulsion Simulations



Propeller modeling

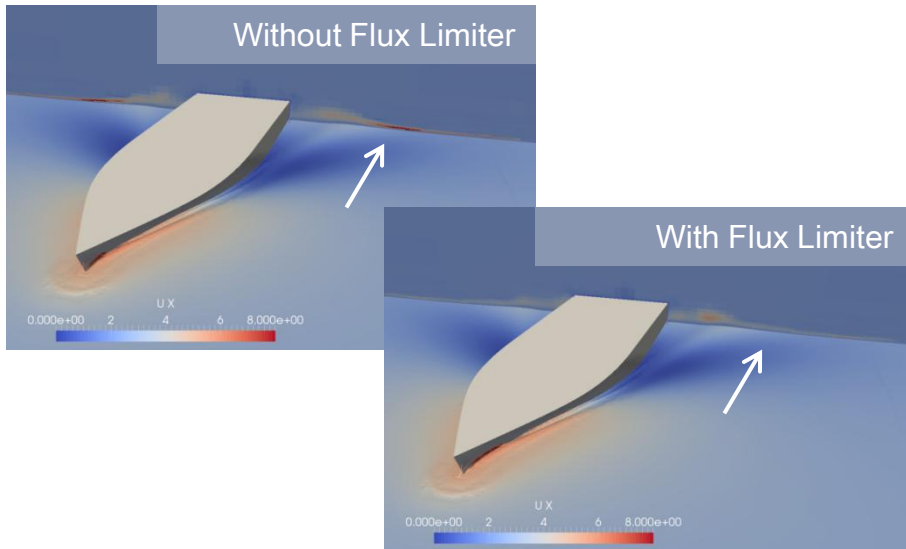
Viscous/inviscid coupling modeling  
for an efficient and robust simulation

# OpenFOAM in HMRI

## Resistance Simulations

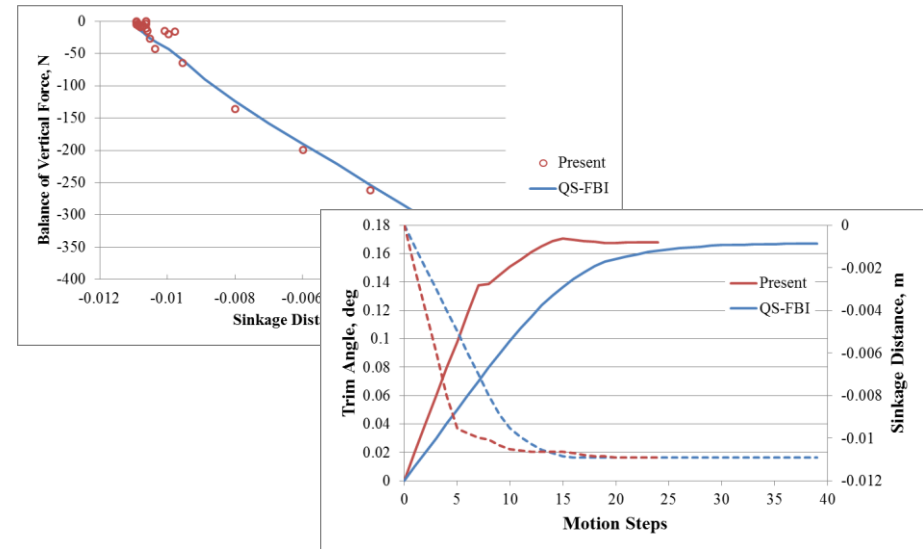
### Flux Limiter

Limit face fluxes on interface cells to enhance the stability of solver.



### QS-FBI

Predict motions by employing the least square method.



\* It has been submitted to IJNAOE

## Resistance Simulations

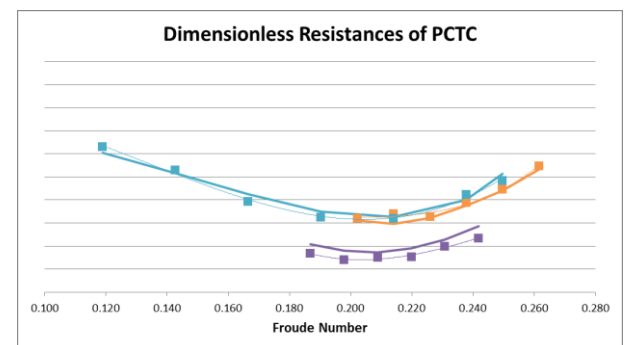
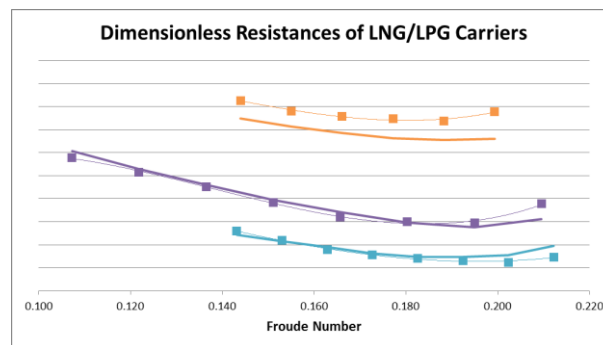
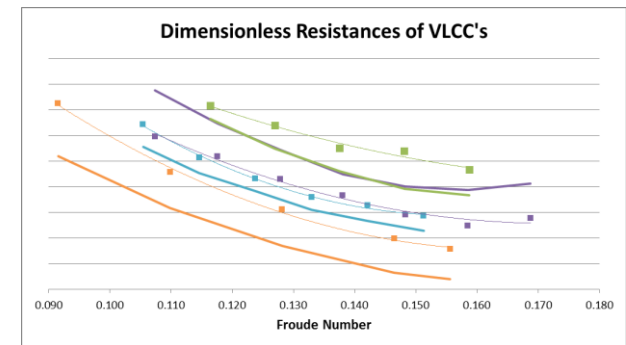
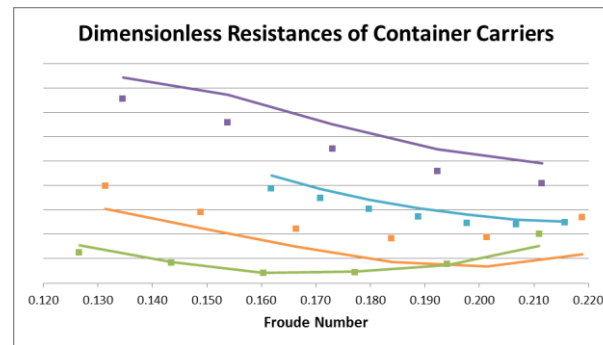


### Validations : HiFoam

The present method was applied to simulate four different types of ships to validate its performances.

The present simulation shows very good agreement to experimental data of HMRI over whole range of the Froude number.

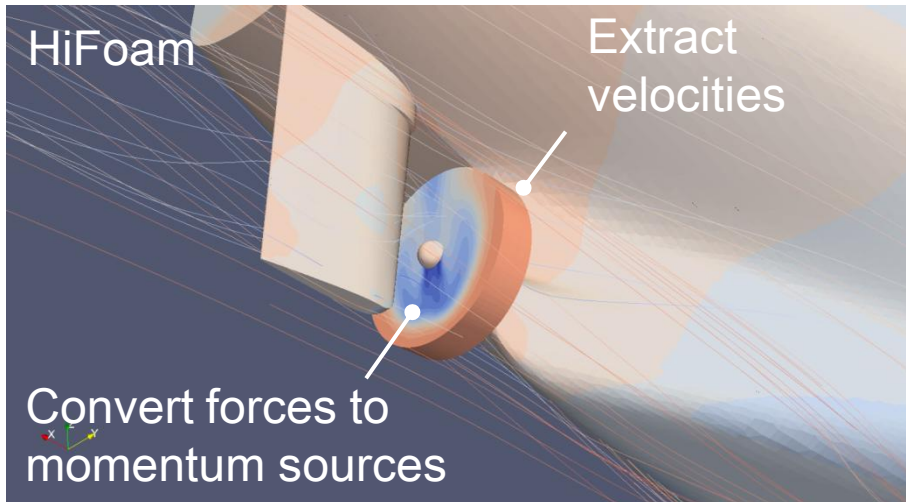
Now, it became one of the most widely used CFD tool in HMRI.



## Self-propulsion Simulations

### Viscous/inviscid Coupling

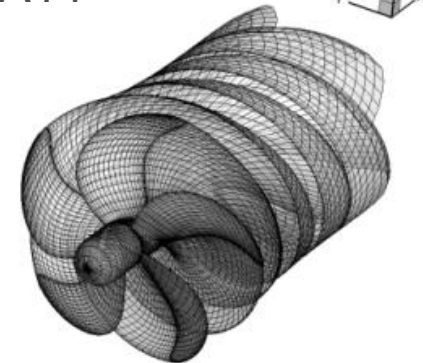
The effect of the propeller was reflected by means of momentum source method where the momentum sources were estimated from KPA14 code.



Wake info.



KPA14



Force info.



FORTTRAN subroutine

# Expectation of OpenFOAM



Sales of 2015 : **4 billion USD**

Leasing a power license of the STAR-CCM+ costs about **40,000 USD** annually.

It is only about **0.001%** of annual sales of the company!

**Does the license fee really matter?**

# Expectation of OpenFOAM

## Open FOAM

*The Open Source CFD Toolbox*

The OpenFOAM is  
**NOT FREE** at all!

\$\$\$

Hire  
OpenFOAM  
Engineers



\$

Train  
OpenFOAM  
Users



\$\$

Support  
OpenFOAM  
Development



# Expectation of OpenFOAM



Open  FOAM

*The Open Source CFD Toolbox*

The OpenFOAM  
should be **COMPARABLE**  
to other commercial codes,  
or even **OVERWELM**.

Reliable

Robust

Accurate

Fast

User Friendly

# Joint Development on Seakeeping

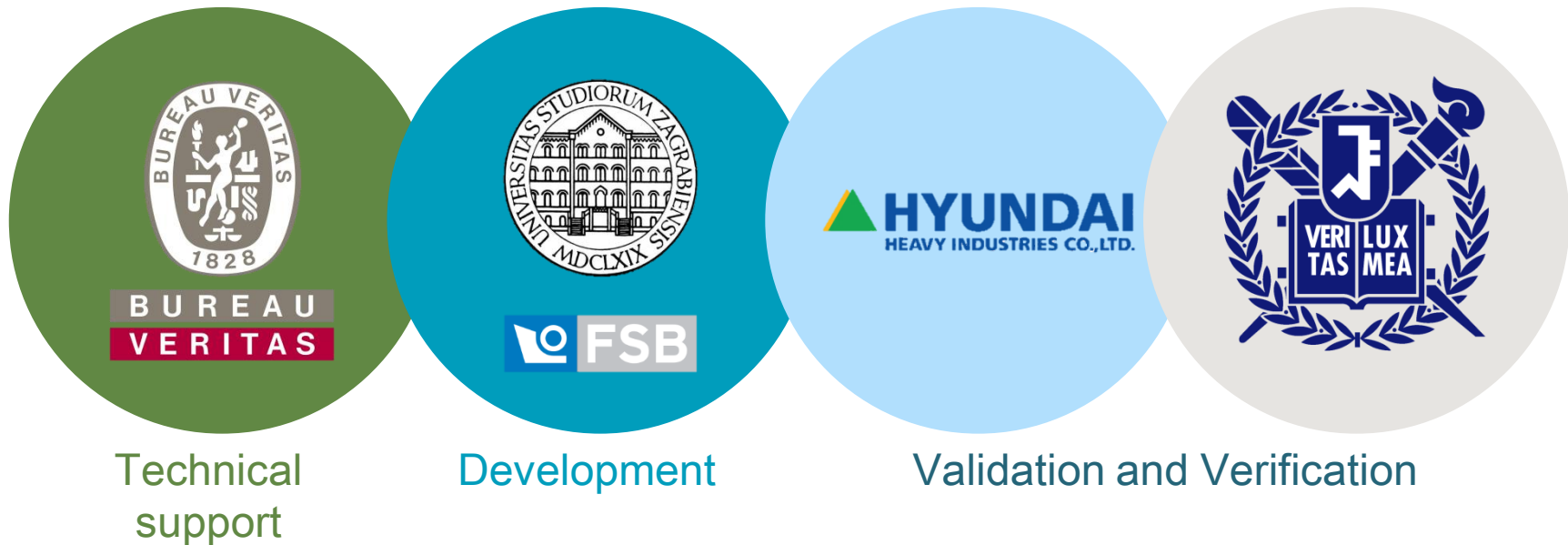


# Brief Introduction to Joint Development Project



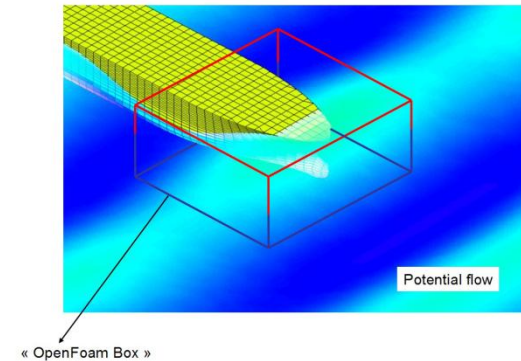
**Project Title:** Coupled Potential Flow and CFD Modeling for Off-shore and Naval Applications

**Consortium:**



# Brief Introduction to Joint Development Project

- Supporting development of SWENSE method
- Efficient and robust CFD tool for seakeeping analysis
- Materials of state-of-the-art technology related to the OpenFOAM



Speed

Accuracy

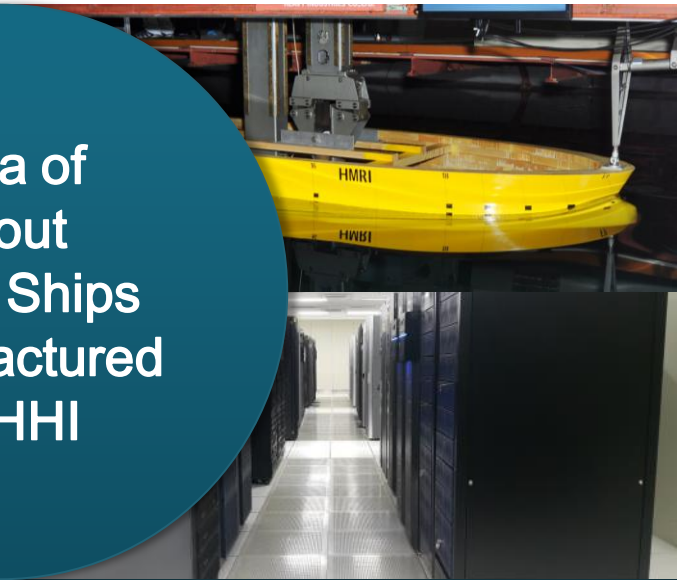
Stability

Customized  
and Efficient  
CFD Tool

# Role of HHI in JDP



Data of about 4,000 Ships manufactured by HHI



Abundant data and resources to validate the code

# Brief Introduction to Joint Development Project



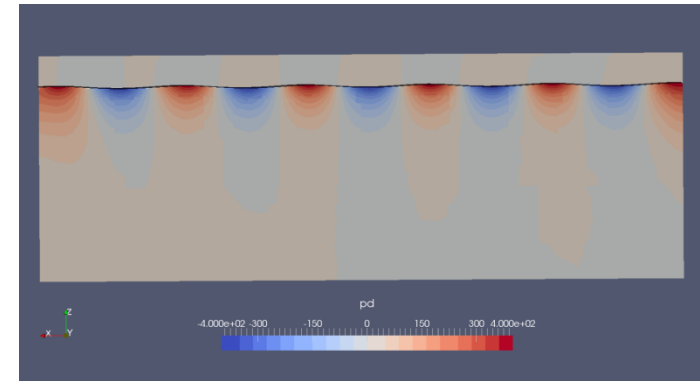
You can see the detailed technical information of development on Naval Hydro Pack on Wednesday.

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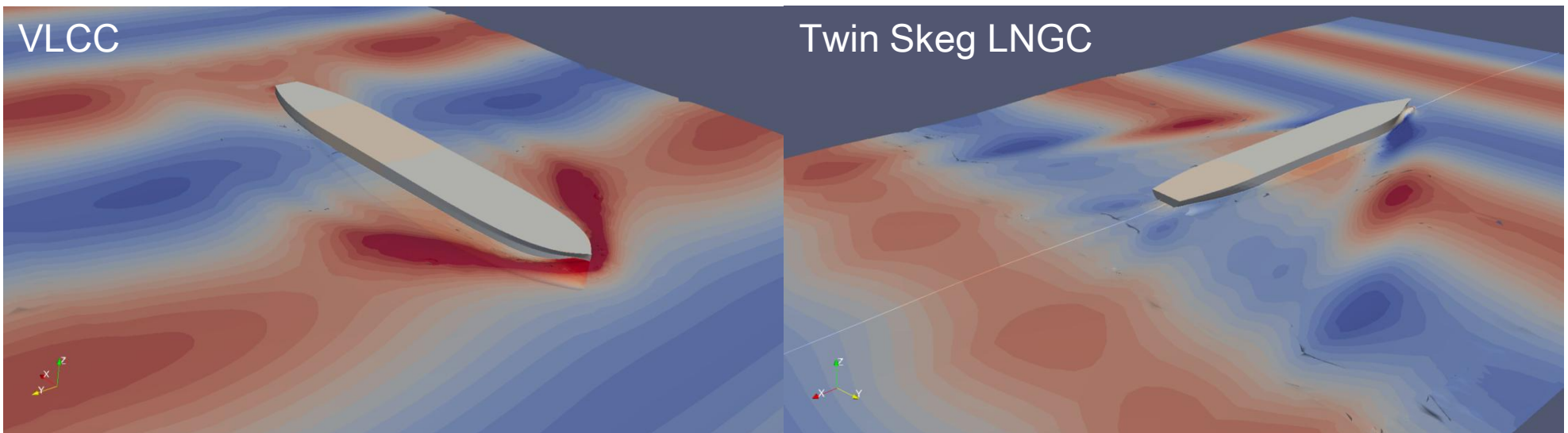
# Validations & Verifications

## Validation on Wave Simulations

- Simulate waves only
- Dependency on grid arrangements
- Compared the results to theoretical wave profile



## Validations on Seakeeping Simulations



# Validations & Verifications

## Wave Simulations

### Test Matrix

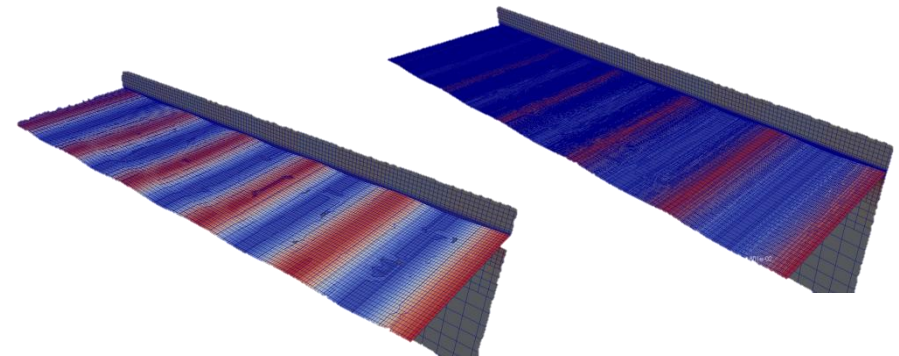
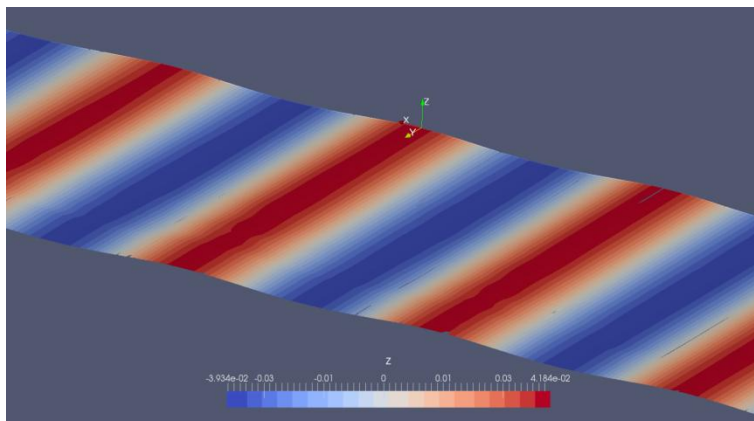
Direction	Coarse	Inter.	Fine
$\Delta x$	$\lambda/50$	$\lambda/100$	$\lambda/200$
$\Delta y$	$\lambda/25$	$\lambda/50$	$\lambda/100$
$\Delta z^*$	$H/4$	$H/8$	$H/16$

\* Additionally tested two more cases :  $H/32$  and  $H/64$

### Wave Parameters

- Length : 3.821 m
- Height : 0.07811 m
- Depth : 6 m

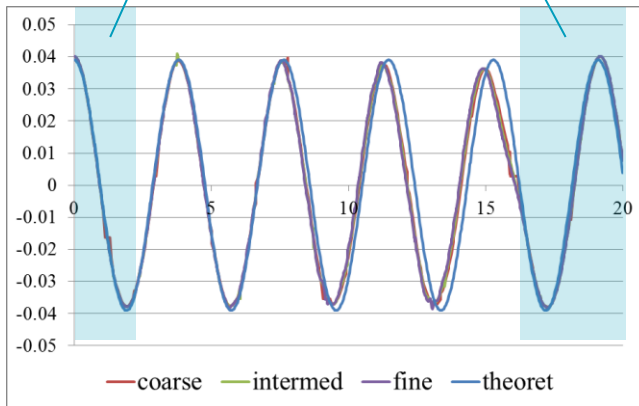
# Cells : 0.2 Mil. ~ 6.5 Mil.



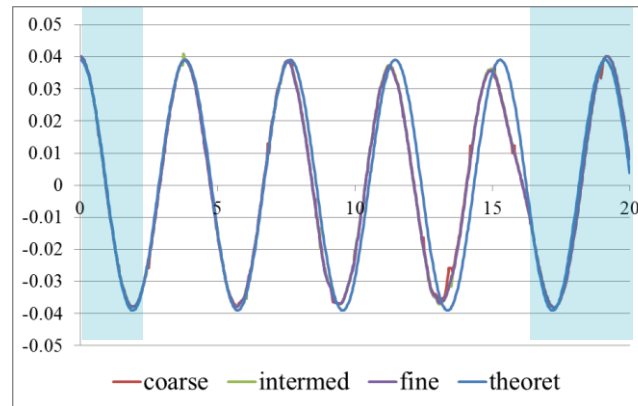
# Validations & Verifications

## Wave Simulations : Results

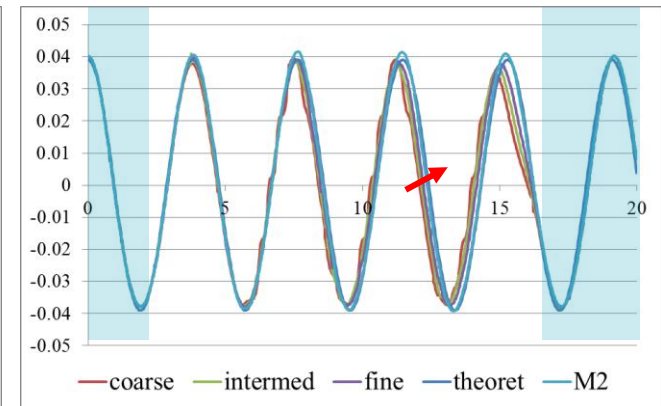
Relax & blending region



$\Delta x$



$\Delta y$



$\Delta z$

- The number of grid points along wave and transverse direction does not affect to the solution.
- The number of grid points along vertical direction mostly affected to the resultant wave profile.
- Additionally, test on aspect ratio may be conducted.



$$\Delta x \leq \lambda/60, \quad \Delta z \leq H/30. \quad \text{for } \Delta y, \quad \Delta y/\Delta x = 2\sim 4$$

## Seakeeping Simulations

### List<Check>

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- ✓ Boundary size
- ✓ Relaxation zone
- ✓ Parameters in fvSolution

### Test on Boundary Size

---

- Upstream :  $0.5 \sim 1.5 \times L_{PP}$
- Downstream :  $1.5 \sim 2.5 \times L_{PP}$
- Top :  $2.0\text{m} \sim 1.5 \times L_{PP}$
- Bottom :  $6.0\text{m} \sim 2.0 \times L_{PP}$

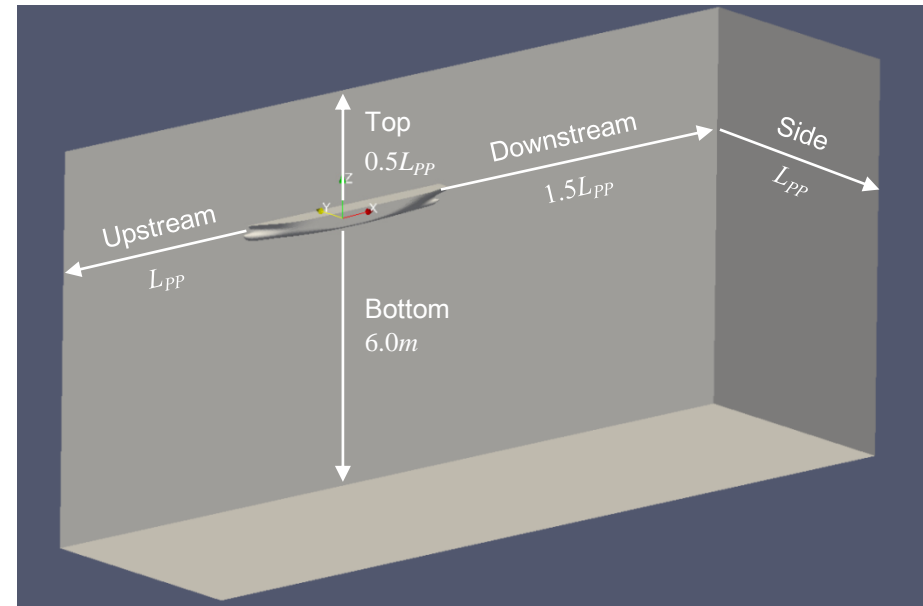
### Remarks

- The solution diverged for the deepest domain size
- Too short inlet showed less stable behavior

### Common Parameters

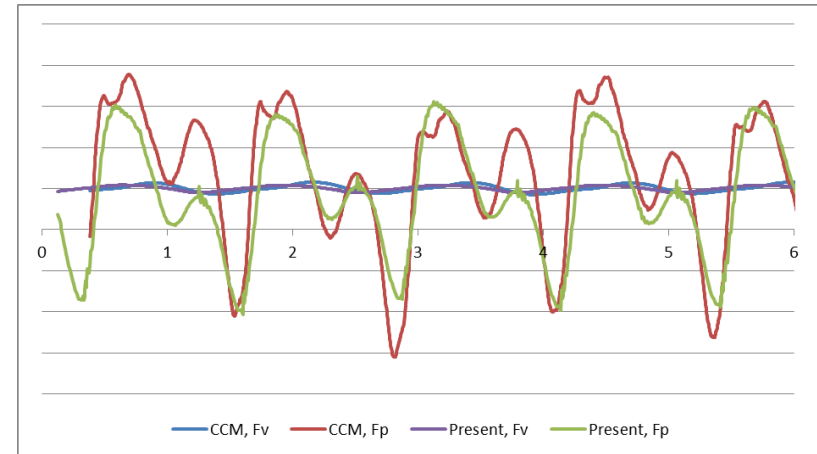
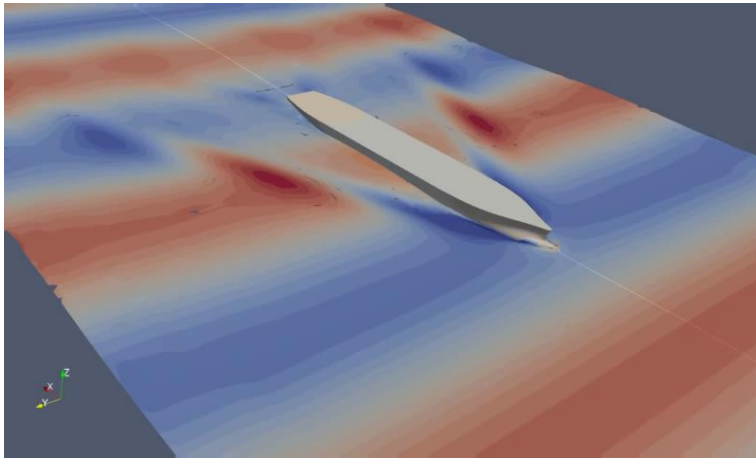
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- ✓ Time step was limited to be no larger than  $T/180$
- ✓ Relaxation zone varied in  $[0.5, 1.0] \times L_{PP}$

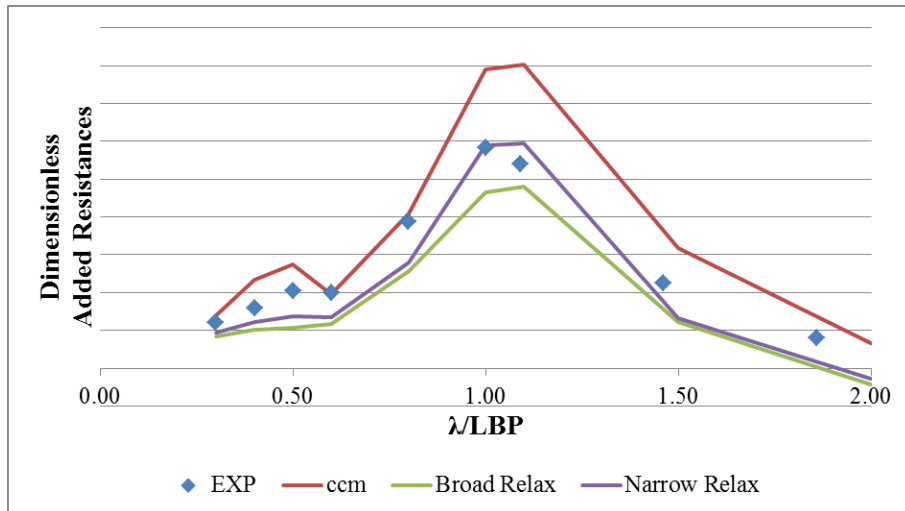


# Validations & Verifications

## Seakeeping Simulations : Twin Skeg LNG



History of pressure and viscous forces  
(OpenFOAM vs CCM)

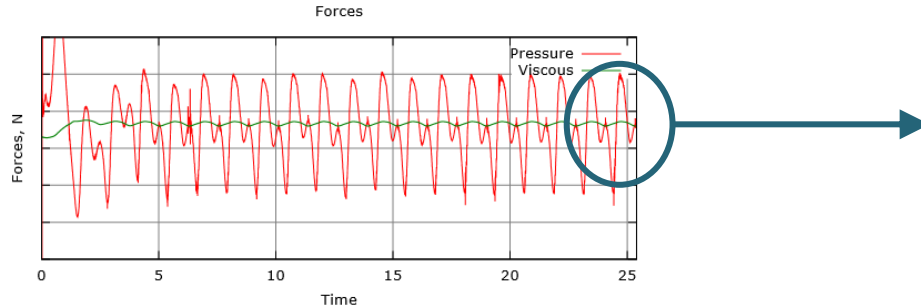


- Comparable to STAR-CCM+
- Relatively good agreement to experimental data
- Need to review the results of high length wave

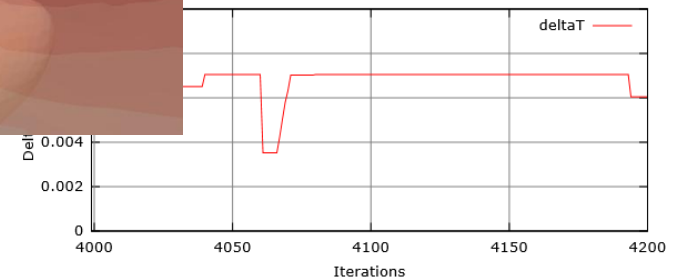
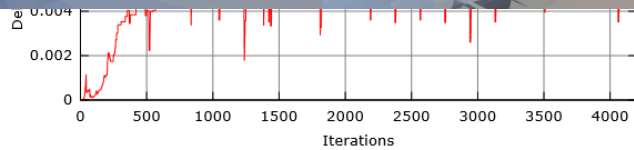
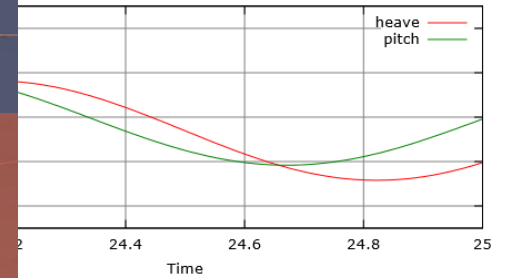
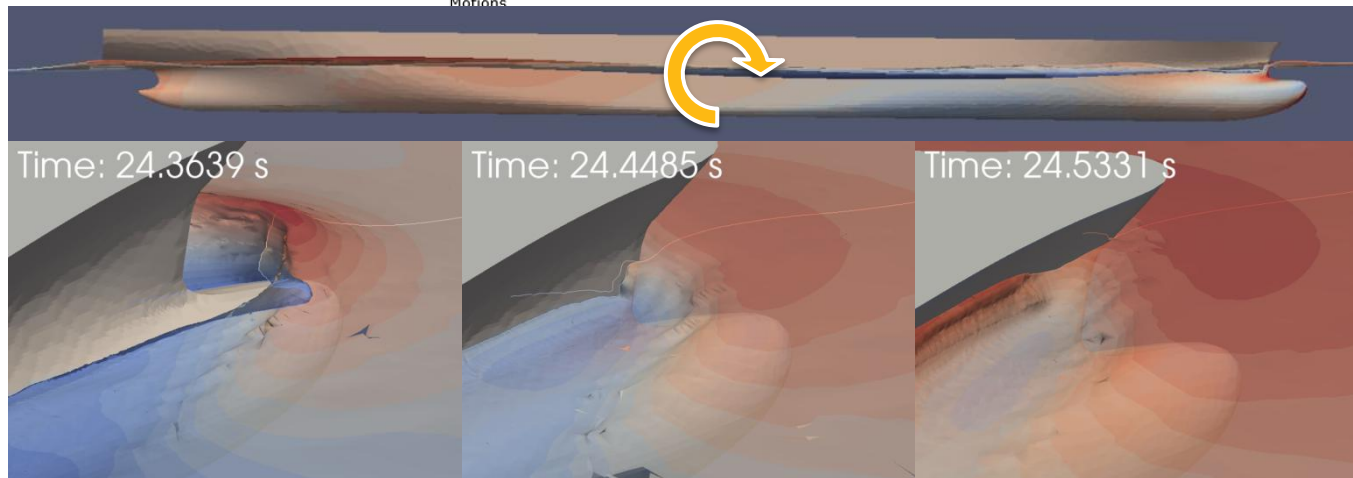
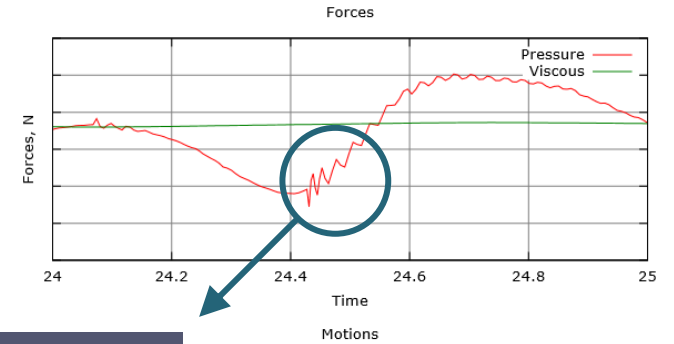
# Validations & Verifications

## Seakeeping Simulations : Twin Skeg LNG

Added Resistance Simulation for Twin Skeg LNG Carrier

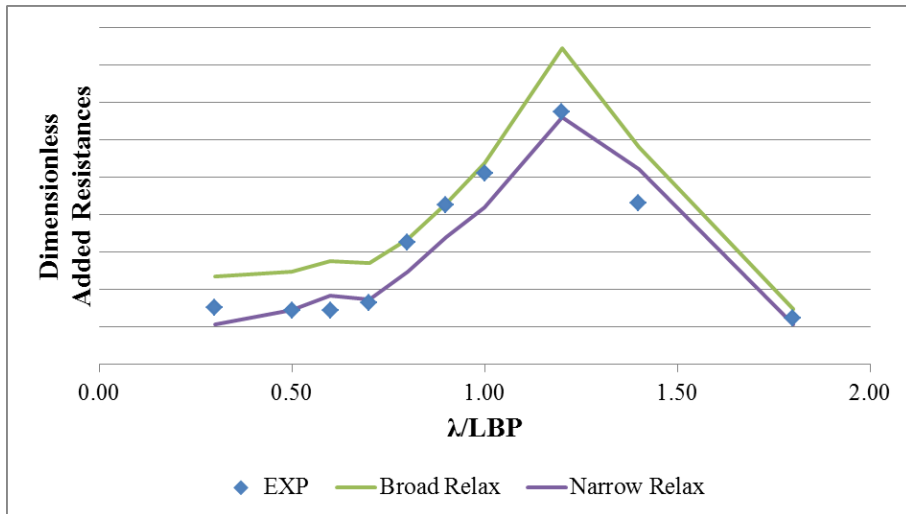
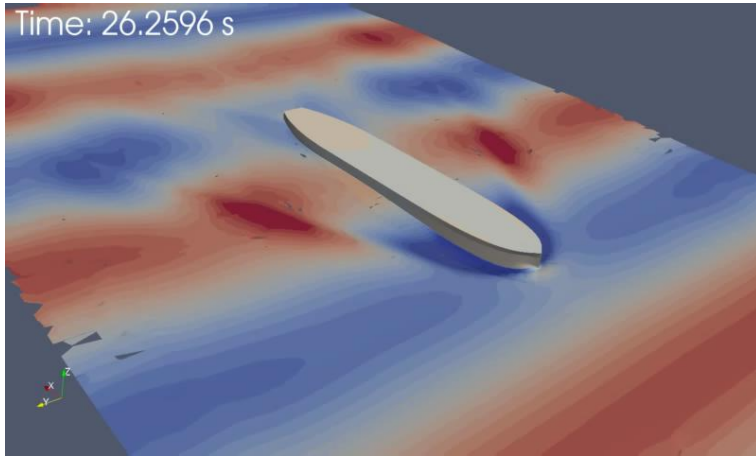


Added Resistance Simulation for Twin Skeg LNG Carrier

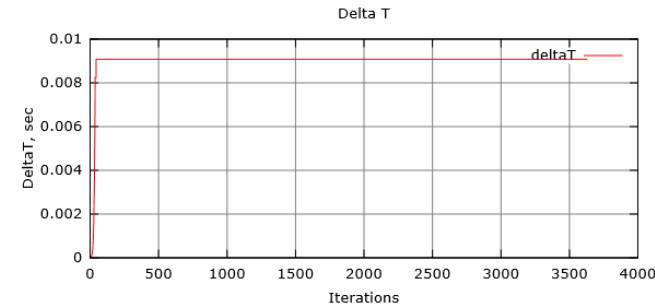
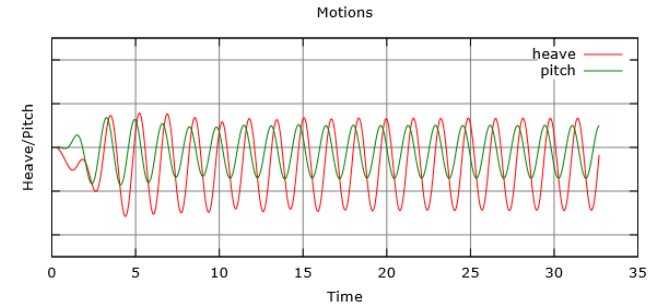
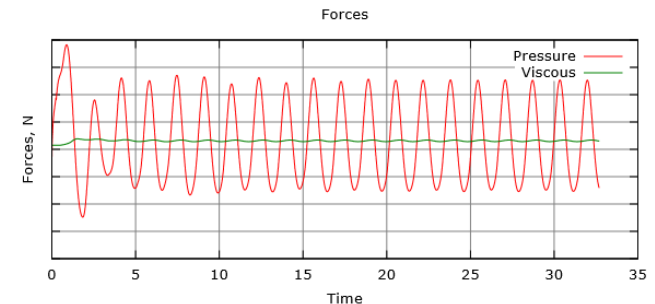


# Validations & Verifications

## Seakeeping Simulations : Single Skeg VLCC



T772 Added Resistance Simulations



# Concluding Remarks



# Concluding Remarks

As I am a CFD Engineer of a shipbuilding company, I would like to note that

- OpenFOAM started to play **an important role** in shipbuilding companies for the last couple of years.
- OpenFOAM is, of course, **cost effective** but it might be **more expensive** in industrial perspective than we commonly think.
- It should be **comparable to** or **overwhelm** commercial codes to have merits, rather than being free to use.

HMRI has developed CFD techniques based on the OpenFOAM.

- We **developed HiFoam**, a multi-phase solver based on OpenFOAM, to evaluate resistance and self-propulsion performances of a ship.
  - We continued to **improve** the HiFoam to be **more efficient and robust**.
-

# Concluding Remarks

We validated the Naval Hydro Pack and it is worthy to note that

- Grid arrangement along **vertical direction** mostly affected to the solution in wave simulations.
- It has been **applied** to simulations of **two different ships** in head wave successfully and showed **comparable performances** to STAR-CCM+ results and experimental data.
- As our future work,
  - ✓ Apply the present method to various ships of different types.
  - ✓ Look for the optimum parameters for controlling solver, such as parameters defined in waveProperties or fvSolution files.
  - ✓ Carry out feasibility tests on quatering waves.
  - ✓ Simulate ship motions under various wave conditions.

THANK YOU