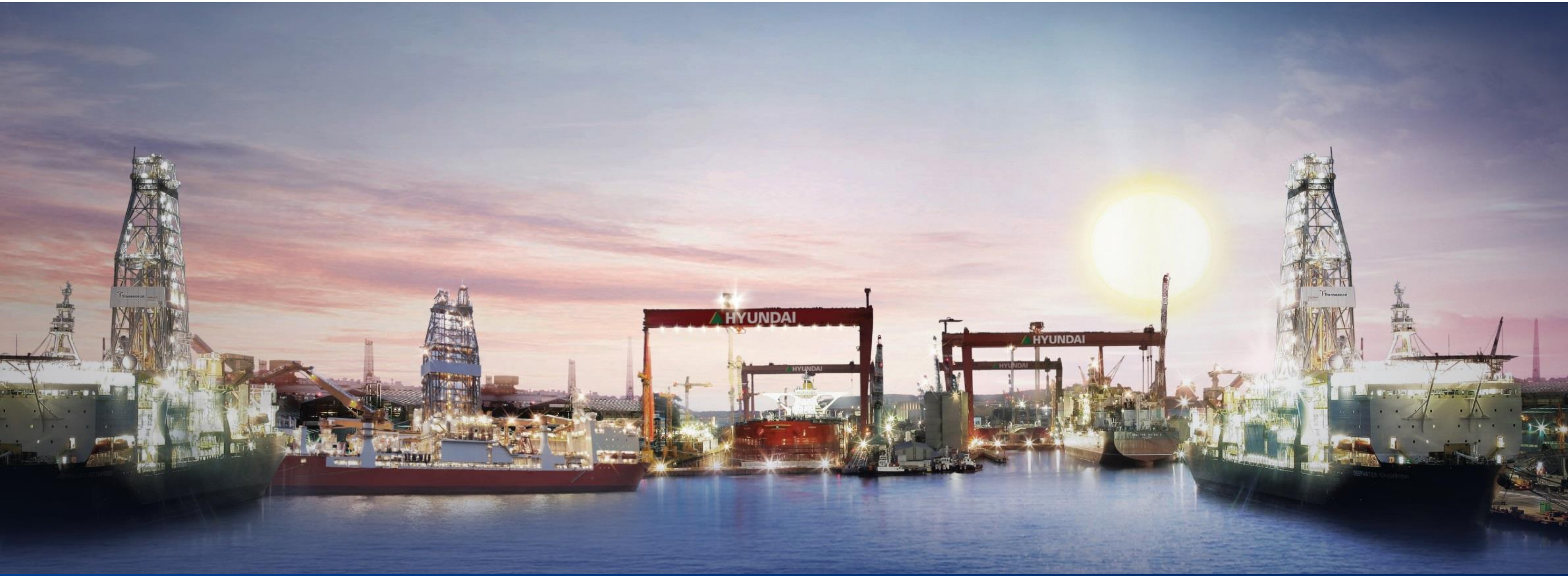
현대중공업 선박연구소의 OpenFOAM® 을 이용한 선박 성능 해석 - 현재와 미래

Hyundai Heavy Industries Co., Ltd.

김건홍 선임연구원

2016.09.30



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HEAVY INDUSTRIES

Contents

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2. Analysis of Ship Performances using OpenFOAM
   - ✓ Resistance
   - ✓ Self-propulsion
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   - ✓ Maneuvering

3. Concluding Remarks

Development of OpenFOAM in HHI

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CFD in HHI

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Hyundai
Maritime
Research
Institute

Resistance

Self-propulsion

Added Resistance

Maneuvering

Research and Development

CFD in HHI

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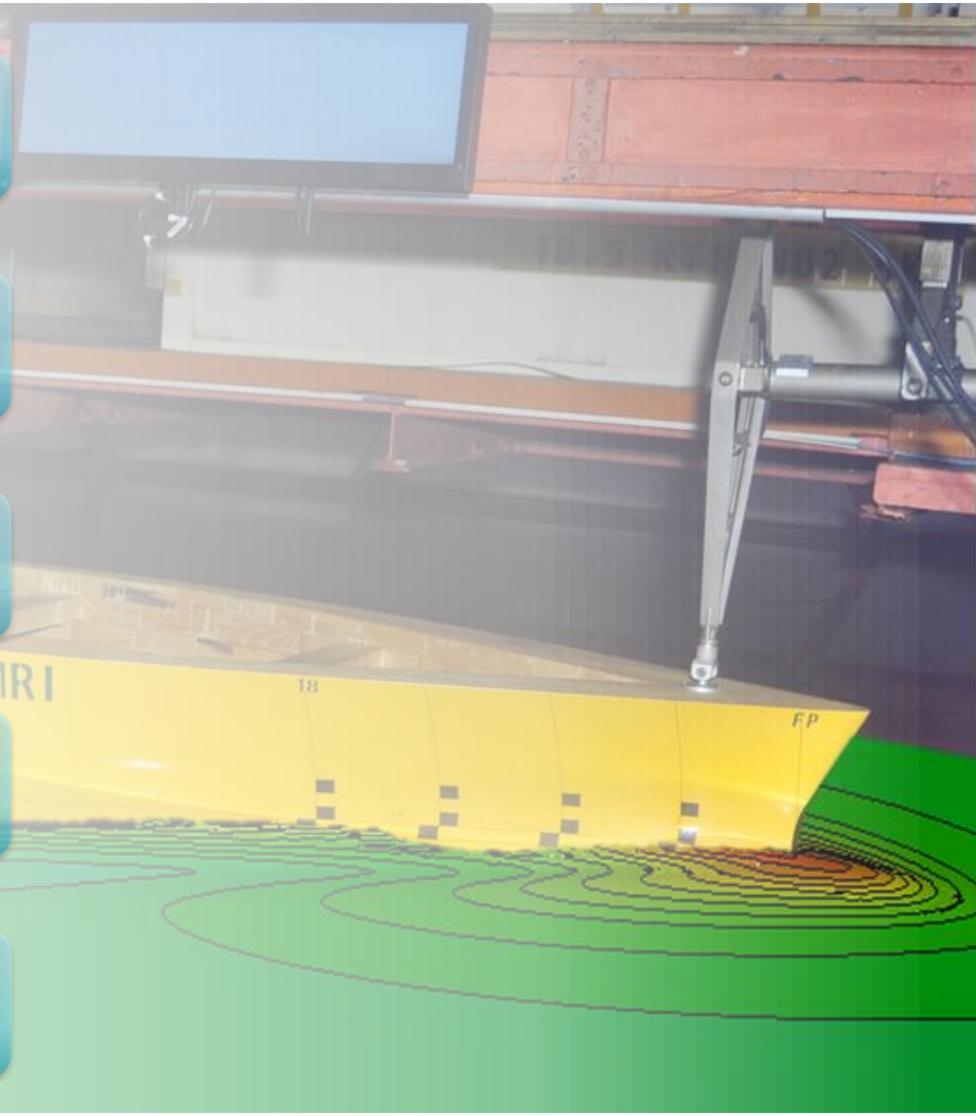
Hyundai Maritime Research Institute

STAR-CCM+

OpenFOAM

WAVIS

- Resistance
- Self-propulsion
- Added Resistance
- Maneuvering
- Research and Development



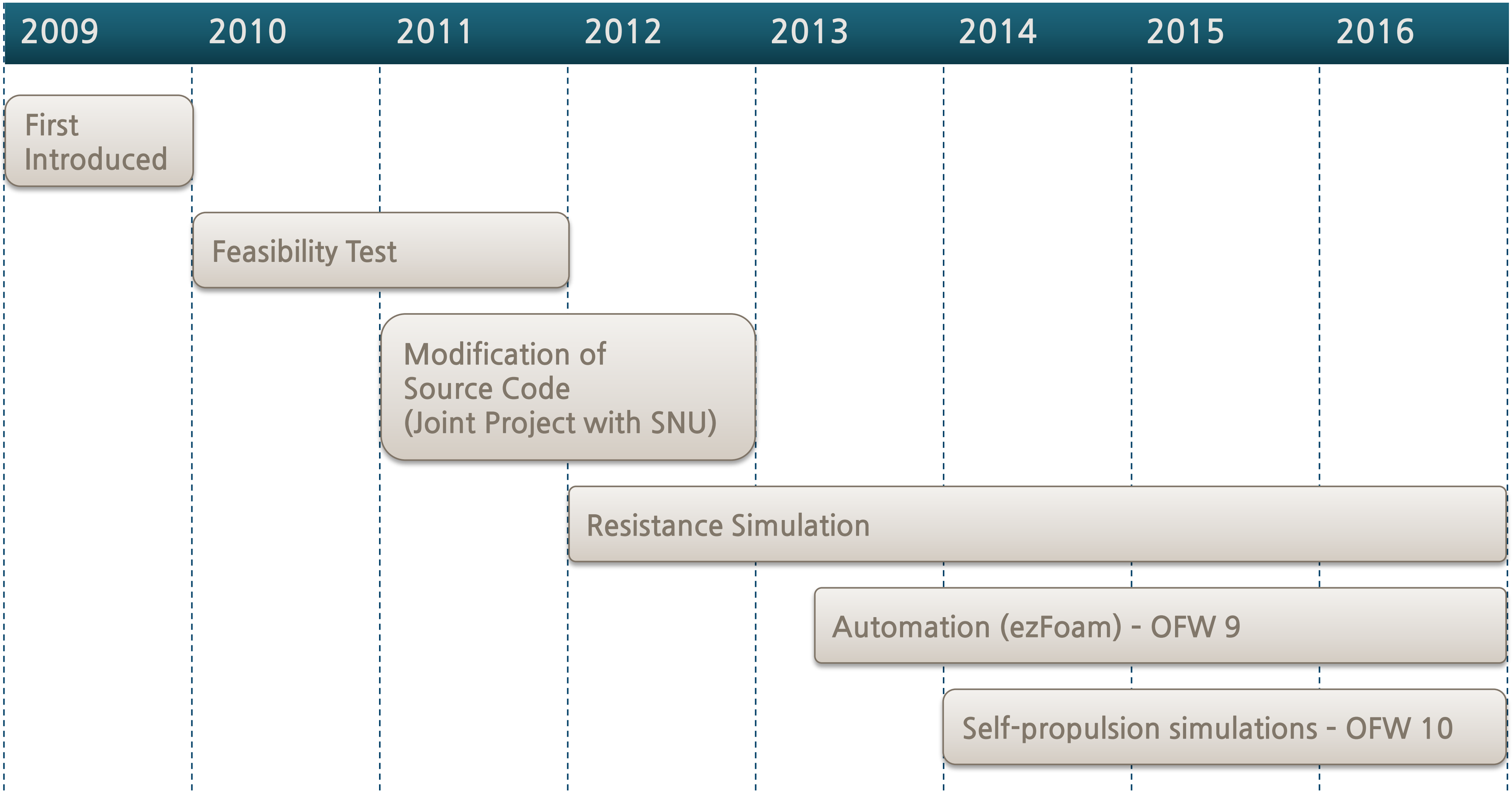
CFD in HHI

Hyundai Maritime Research Institute

- STAR-CCM+
- OpenFOAM
- WAVIS

Application	STAR-CCM+	OpenFOAM	WAVIS
Resistance	STAR-CCM+	OpenFOAM	WAVIS
Self-propulsion	STAR-CCM+	OpenFOAM	WAVIS
Added Resistance	STAR-CCM+	OpenFOAM	
Maneuvering	STAR-CCM+	OpenFOAM	
Research and Development	STAR-CCM+		

OpenFOAM in HMRI

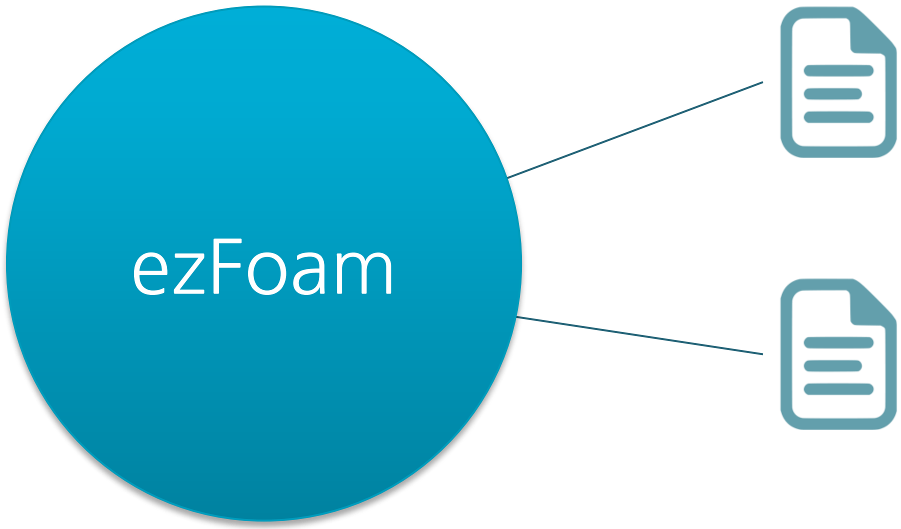


Role of HHI in JDP

Data of
about
4,000 Ships
manufactured
by HHI

Abundant
data and resources
to validate the code

OpenFOAM in HMRI



cases

Define parameters of cases for running such as model & propeller numbers, speed, draft and trim conditions

ezFoamDict

Define parameters for running OpenFOAM solver such as turbulence properties, control parameters, schemes and solver control parameters etc.

Custom Applications

HiFoam® A multiphase solver for resistance and self-propulsion simulations using LTS for temporal scheme

HiSPFoam Single phase solver for self-propulsion simulations based on geometric modeling

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Running ezFoam

```
/*---------------------------------------------------------------------------*\
    EEEEEE  ZZZZZZ          |
    EE          ZZ   F ield         | OpenFOAM: The Open Source CFD Toolbox
    EEEEE      ZZ    O peration     |
    EE        ZZ     A nd           | Copyright  (C) 2004-2010 OpenCFD Ltd.
    EEEEEE  ZZZZZZ  M anipulation |
\*---------------------------------------------------------------------------*/
Application: ezFoam
OpenFOAM    : OpenFOAM-2.1.1
Written by  : Geon-Hong Kim, Engineer
              Hyundai Maritime Research Institute
Contact     : e-mail geonhong.kim@hhi.co.kr
              Office 3-8053
-------------------------------------------------------------------------------

Total 5 cases
============================================================
    Creating case "TXXX_D00.0_S00.0_T0.0"
============================================================

------------------------------------------------------------
Running Case
------------------------------------------------------------
Creating "runs/TXXX_D00.0_S00.0_T0.0/system" directory...Done
    Making a controlDict file...Dictionary "controlDict" is found : reading entries...Done
    Making a fvSchemes file...Dictionary "fvSchemes" is found : reading entries...Done
    Making a fvSolution file...Dictionary "fvSolution" is found : reading entries...Done
    Making a decomposeParDict file...Dictionary "decomposeParDict" is found : reading entries...Done
    Making a setFreeSurfaceDict file...Done
    Making a setFieldsDict file...Done
Creating "runs/TXXX_D00.0_S00.0_T0.0/constant" directory...Done
    Making a g file...Done
    Making a dynamicMeshDict file...Dictionary "dynamicMeshDict" is found : reading entries...Done
    Making a transportProperties file...Done
    Making a turbulenceProperties file...Done
    Making a RASProperties file...Dictionary "RASProperties" is found : reading entries...Done
Reading fluid properties...Done
Converting mesh...
    Mesh has not been created yet
    ccm file has been detected : "meshes/TXXX_D00.0_S00.0_T0.0.ccm"
    - Converting mesh "meshes/TXXX_D00.0_S00.0_T0.0.ccm"...Done
    - Removing unneccessary files in "runs/TXXX_D00.0_S00.0_T0.0/0"...Done
    - Create mesh for time = 0...Done
    Correcting boundary patches...Done
    - Create mesh for time = 0...Done
Done
    Renumbering mesh...Done
Generate field files...
    Making field alpha1...Done
    Making field p_rgh...Done
    Making field epsilon...Done
    Making field k...Done
    Making field nut...Done
    Making field omega...Done
    Making field U...Done
    Set VoF fields...Done
```

```
Decomposing computational domain...
    Running decomposePar...Done

    Time for pre-processing : 22 s

Run TXXX_D00.0_S00.0_T0.0
    "Running HiFoam..."
$ "mpirun -np 32 -hostfile machines HiFoam -case runs/TXXX_D00.0_S00.0_T0.0 -parallel "...Done

    Time for solving : 3488 s

Reconstructing computational domain
Creating a dummy file for paraview
Case Name   Pressure Force  Viscous Force   |   Total Force Standard Deviation  |   Pressure/Viscous/Total Moment
TXXX_D00.0_S00.0_T0.0    2.1682609   -4964.4115  13186.456   8.5830336   0.32045006  -0.24300461 |   10.751294   -
0.05549567  0.26038066  0.32593674  |   2486.3927   0.0074377285    2486.4002


End

Given parameters:
  targetDir: runs/TXXX_D00.0_S00.0_T0.0
  postfix  : HiFoam

- Displacement info
- Displacement = 1.0000 m3
- Weight = 10000.000 N

- Trim and Sinkage info
Total motion : trim = 0.05 deg, sink = -0.003 m


    Time for postprocessing : 7 s

End
------------------------------------------------------------
```


Analysis of Ship Performances using OpenFOAM
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Analysis on Ship Performances

Resistance Simulations

Project NEED FOAM SPEED

Enhanced speed & stability performances
without losing accuracy

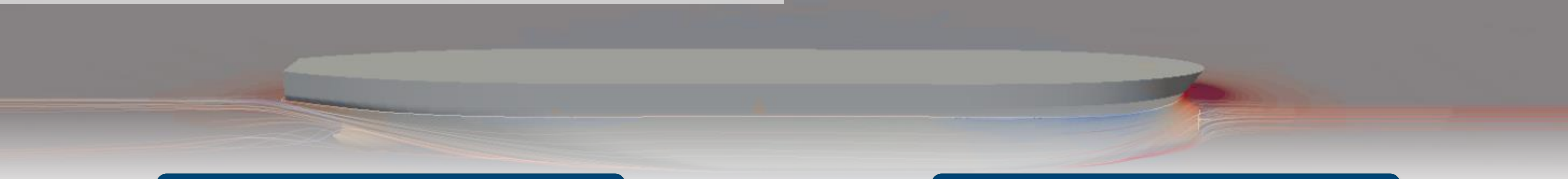
Self-propulsion Simulations

Propeller modeling

Viscous/inviscid coupling modeling
for an efficient and robust simulation

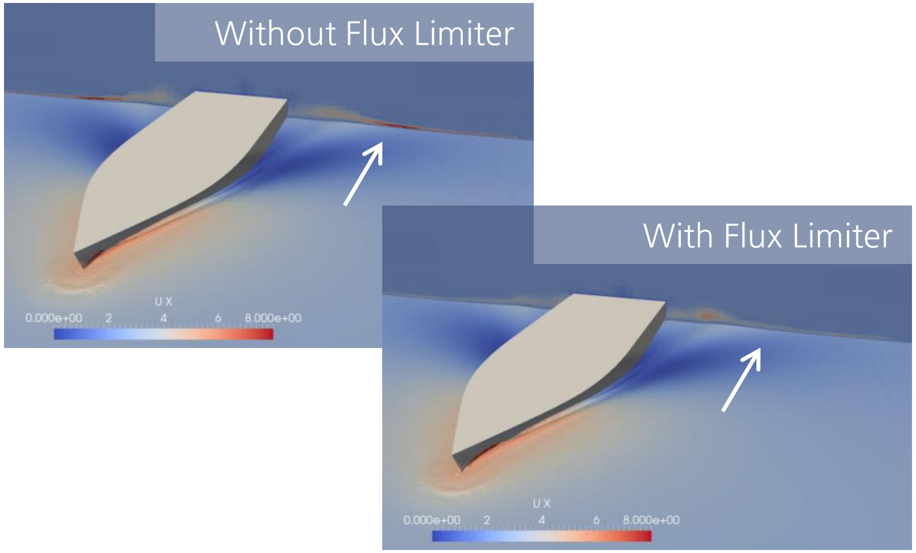
Analysis on Ship Performances : Resistance

Resistance Simulations



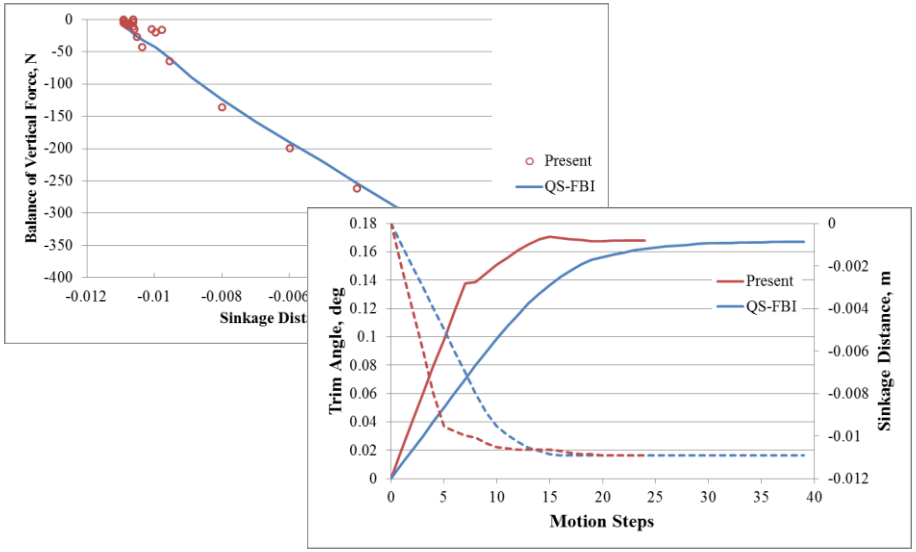
Flux Limiter

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

Analysis on Ship Performances : Resistance

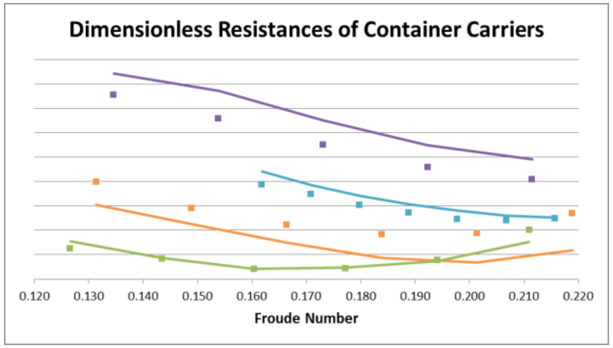
Resistance Simulations

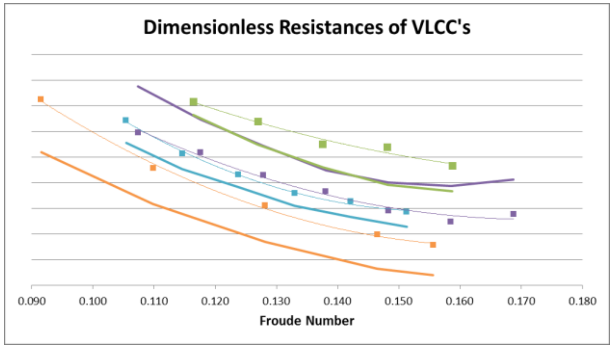
Validations : HiFoam

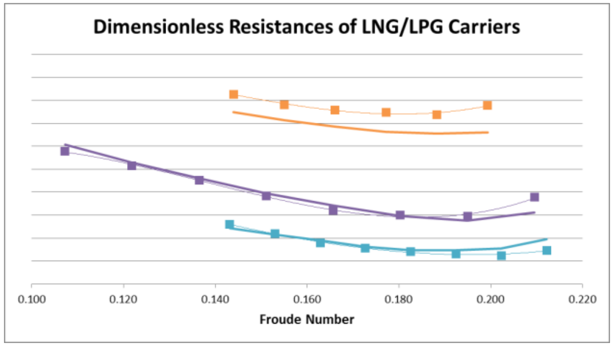
The present method was applied to simulate four different types of ships to validate its performances.

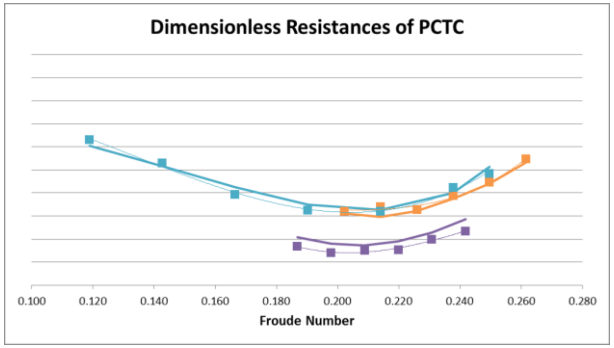
The present simulation shows very good agreement to experimental data of HMRI over whole range of the Froude number.

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









Analysis on Ship Performances : Self-propulsion

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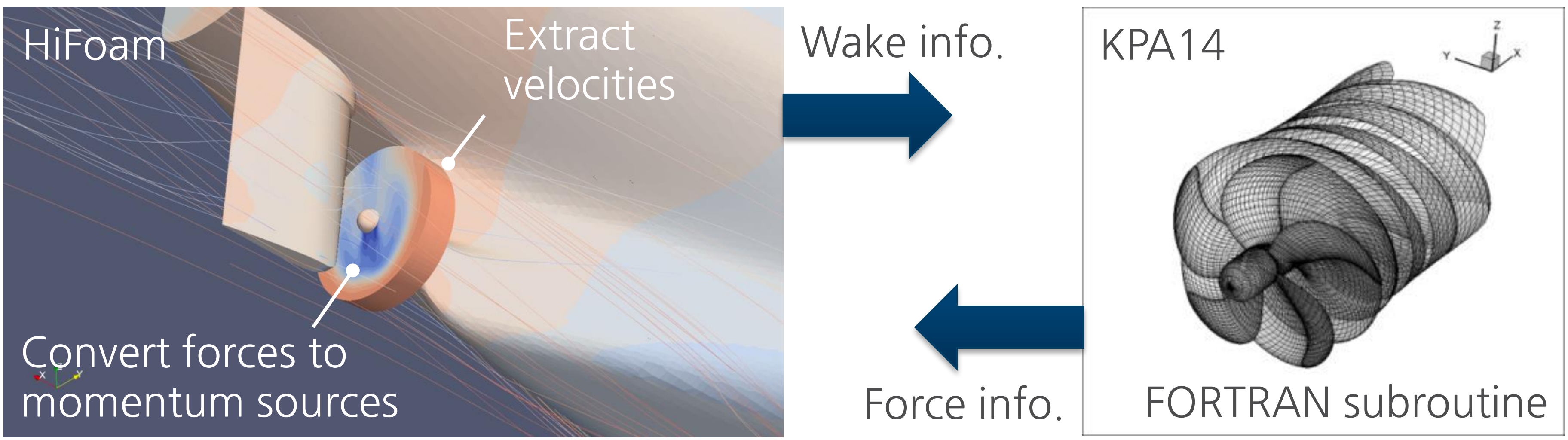
Self-propulsion Simulations

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.



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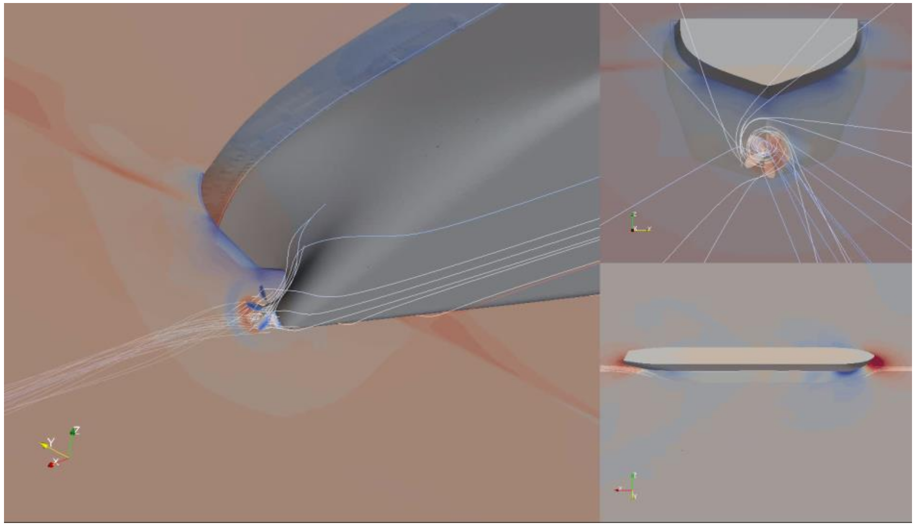
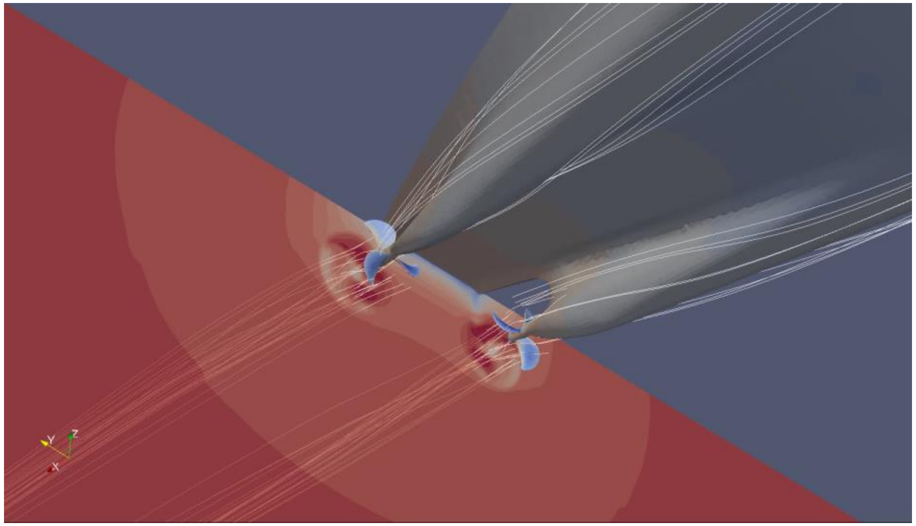
Self-propulsion Simulations

Geometric Modeling



Sliding mesh with multiphase flow modeling using VOF

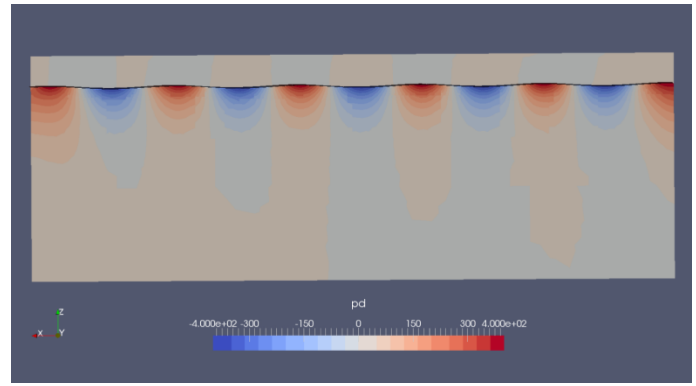


Sliding mesh with double body modeling

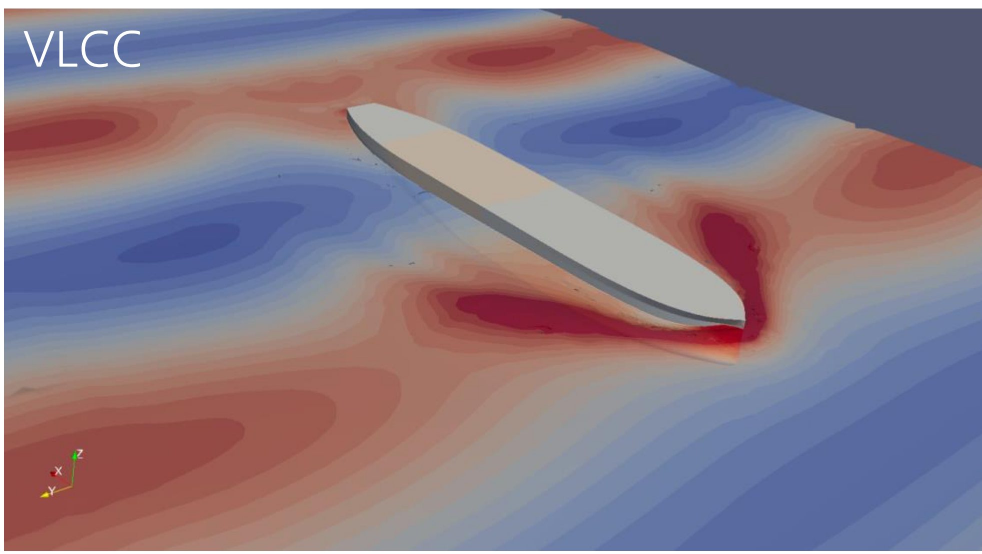
Analysis on Ship Performances : Sea-keeping

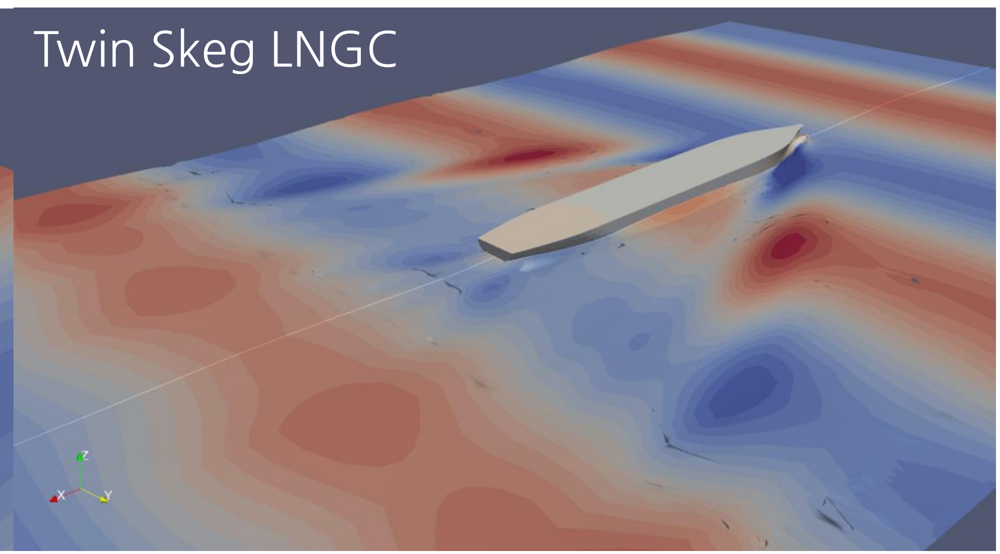
Validation on Wave Simulations

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



Validations on Seakeeping Simulations





Analysis on Ship Performances : Sea-keeping

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Wave Simulations

Test Matrix

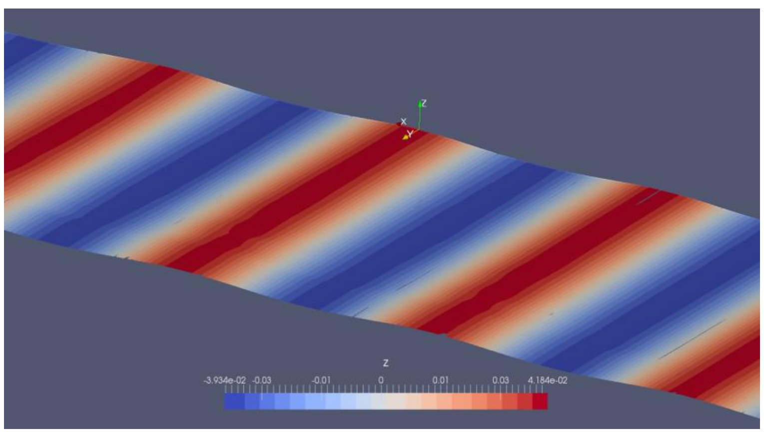
Direction	Coarse	Inter.	Fine
Δx	$\lambda/50$	$\lambda/100$	$\lambda/200$
Δy	$\lambda/25$	$\lambda/50$	$\lambda/100$
Δz^*	$H/4$	$H/8$	$H/16$

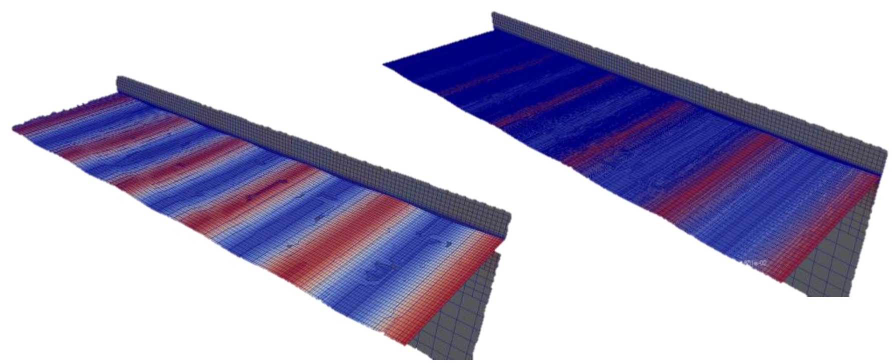
* Additionally tested two more cases : $H/32$ and $H/64$

Wave Parameters

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

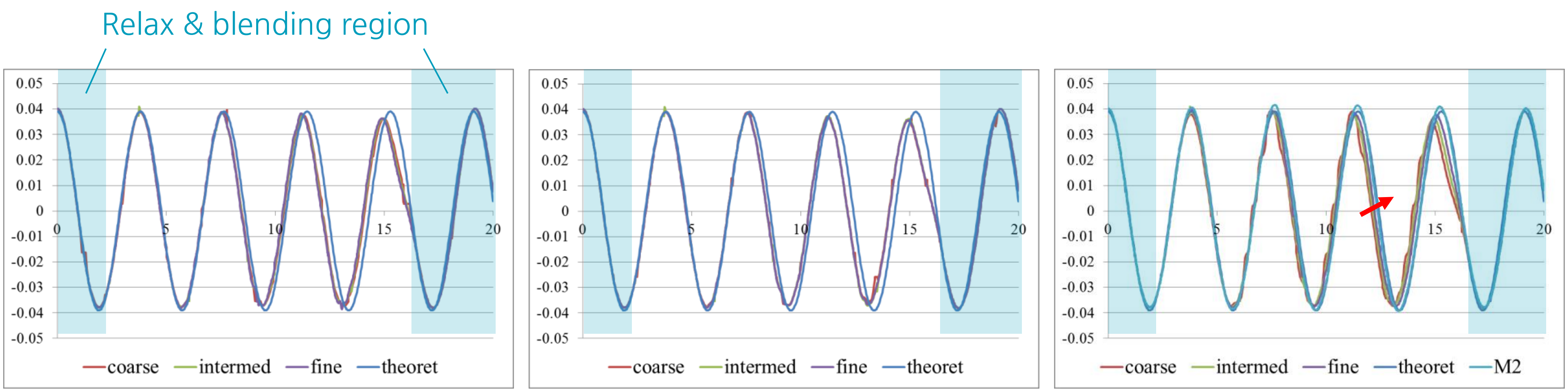
Cells : 0.2 Mil. ~ 6.5 Mil.





Analysis on Ship Performances : Sea-keeping

Wave Simulations : Results



Δx Δy Δz

- 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.

$\Delta x \leq \lambda/60,\ \ \Delta z \leq H/30.$ for Δy, $\Delta y/\Delta x = 2\sim4$

Analysis on Ship Performances : Sea-keeping

Seakeeping Simulations

List<Check>

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

Common Parameters

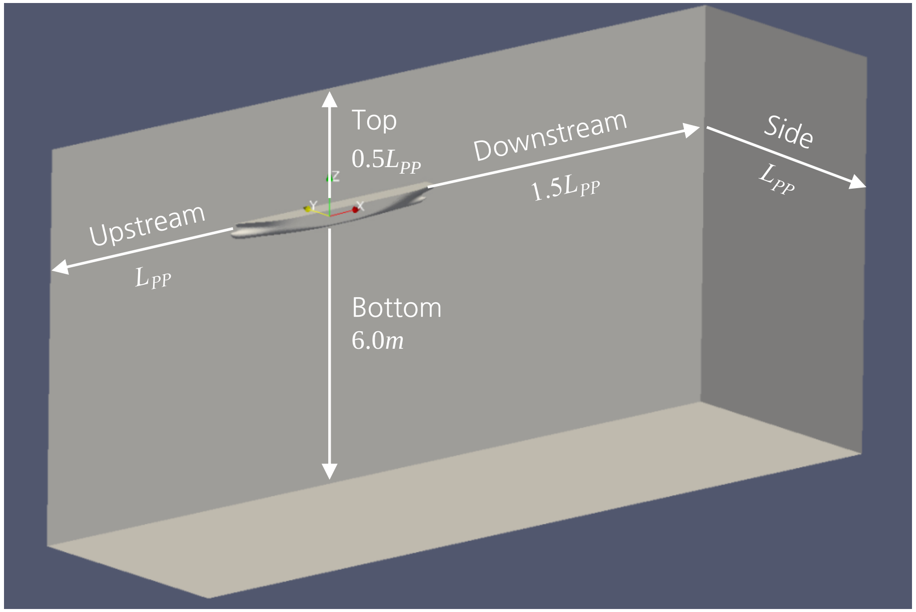
- ✓ Time step was limited to be no larger than T/180
- ✓ Relaxation zone varied in $[0.5, 1.0] \times L_{PP}$

Test on Boundary Size

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

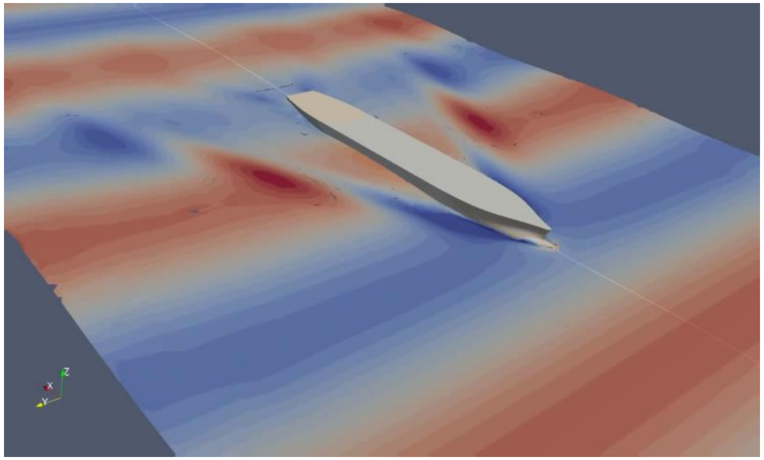
Remarks

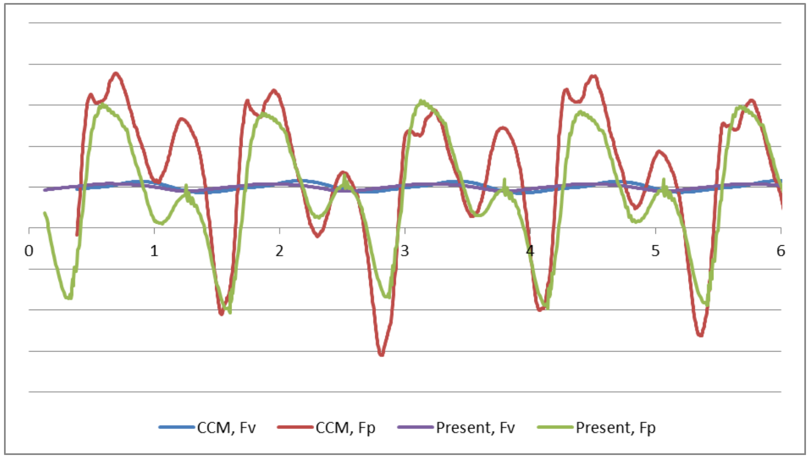
- ➢ The solution diverged for the deepest domain size
- ➢ Too short inlet showed less stable behavior



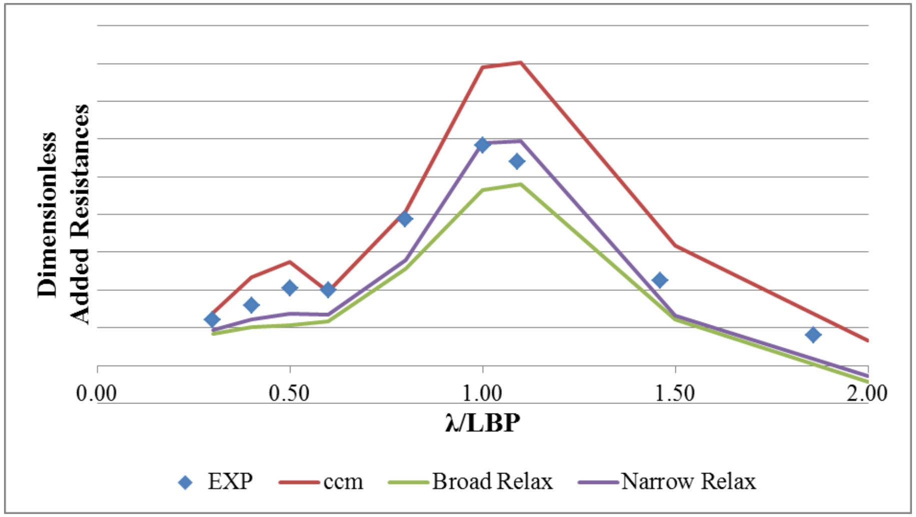
Analysis on Ship Performances : Sea-keeping

Seakeeping Simulations : Twin Skeg LNG





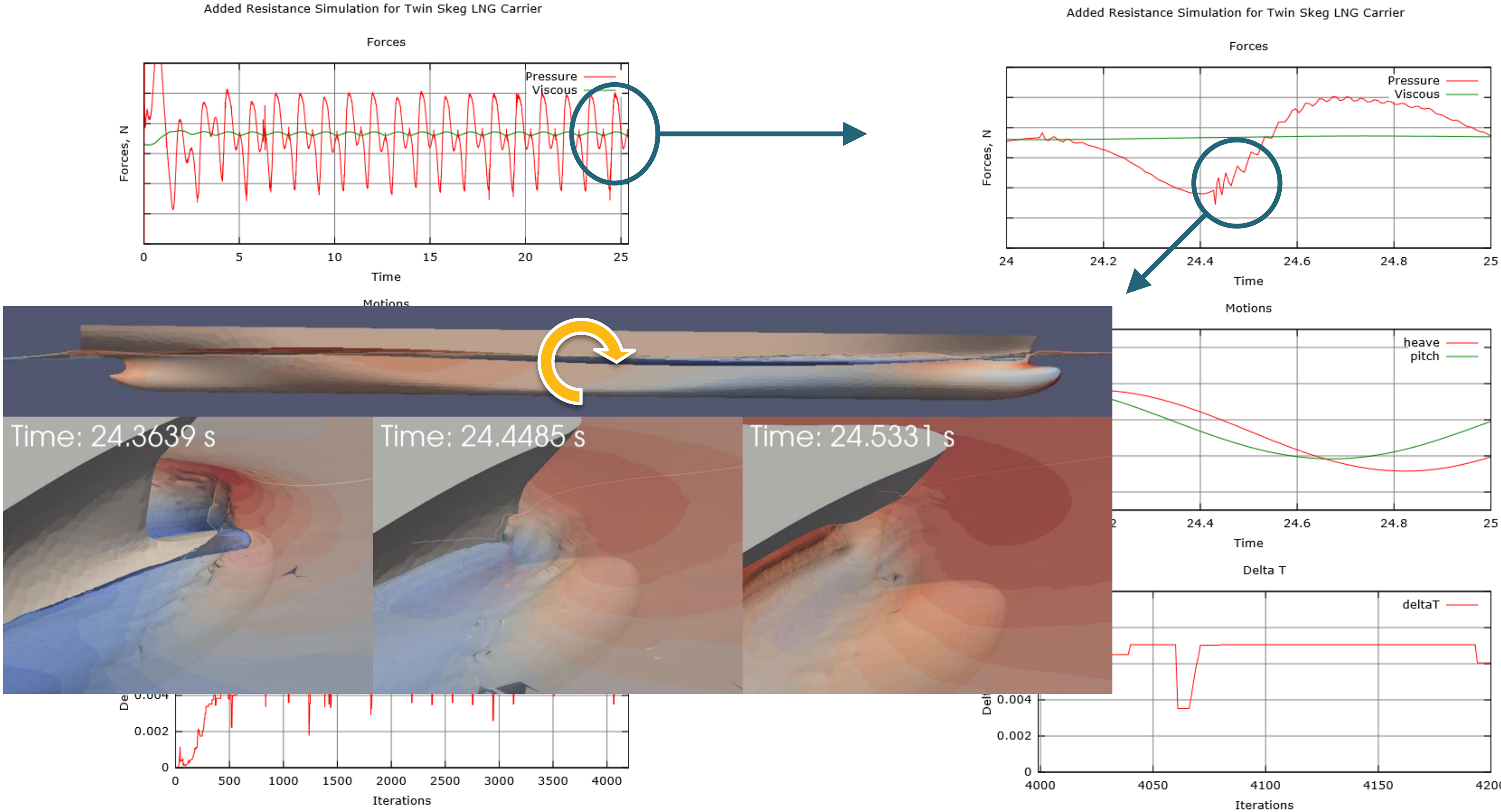
History of pressure and viscous forces (OpenFOAM vs CCM)



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

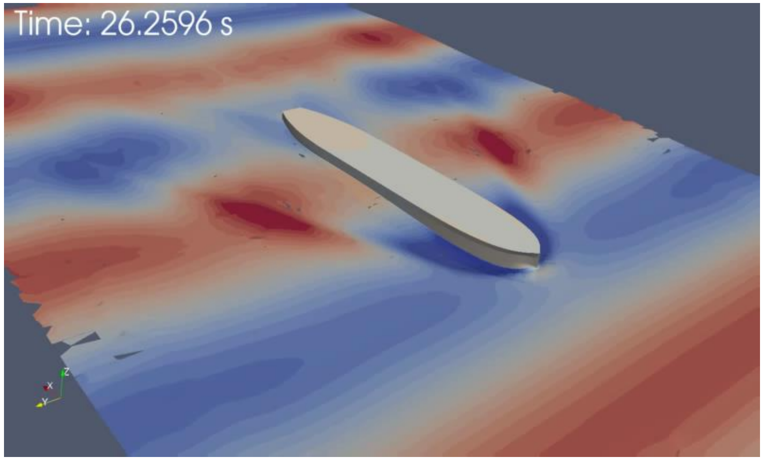
Analysis on Ship Performances : Sea-keeping

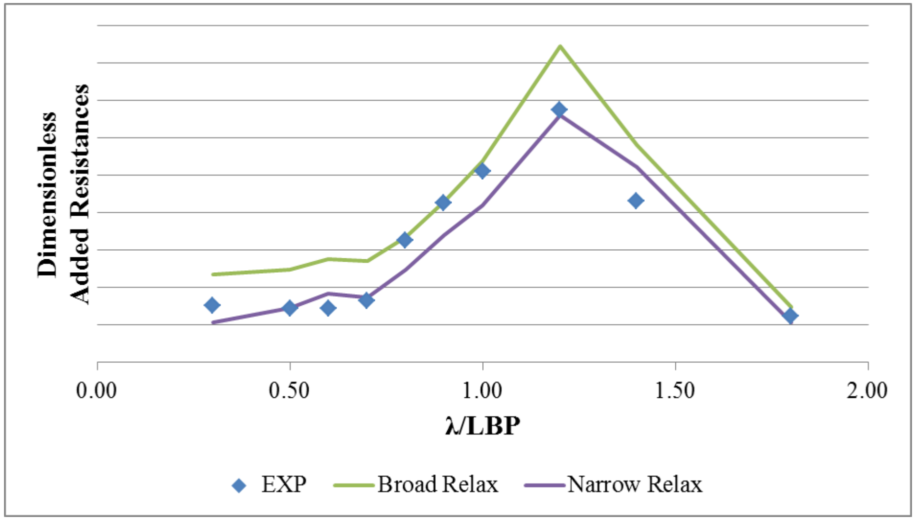
Seakeeping Simulations : Twin Skeg LNG

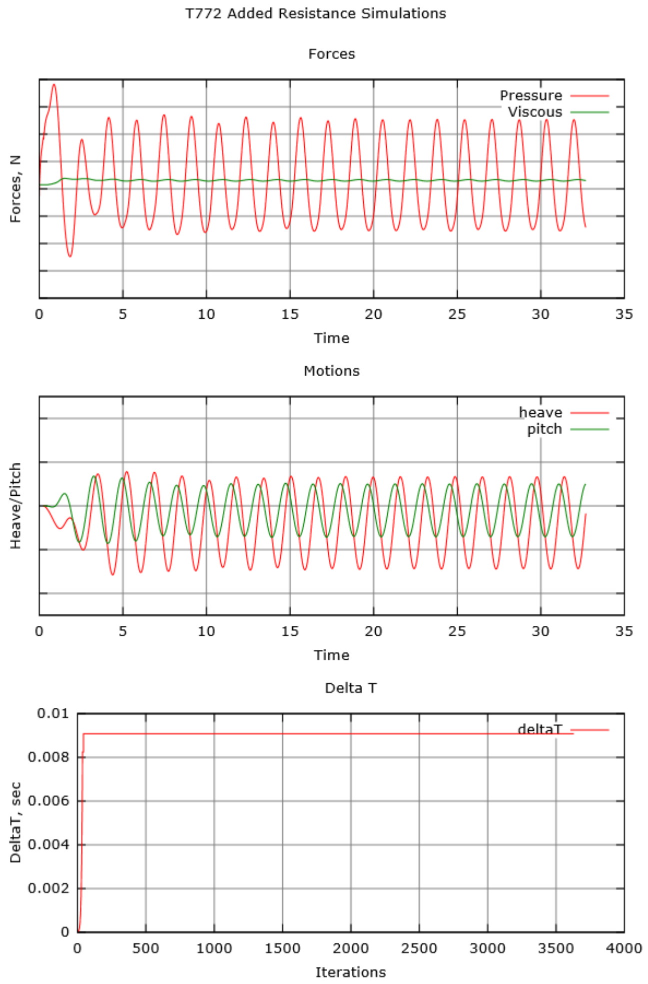


Analysis on Ship Performances : Sea-keeping

Seakeeping Simulations : Single Skeg VLCC







Analysis on Ship Performances : Maneuvering

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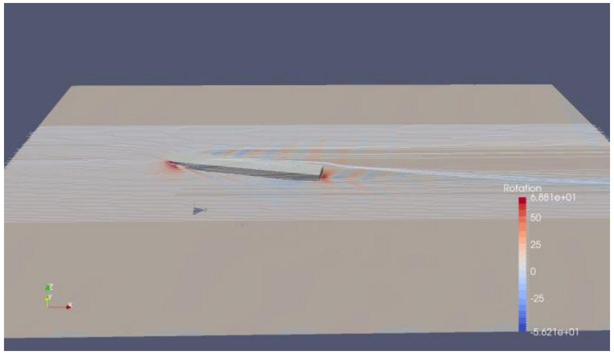
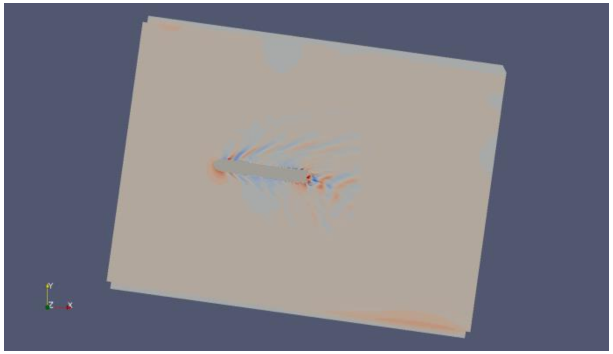
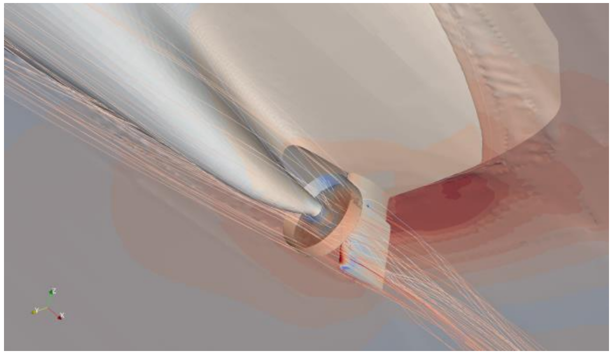
Static drift / rotating / drift rudder







Maneuvering simulations using HiFoam®

- Static drift with various yaw angle
- Estimate hydrodynamic coefficients of pure yaw motion by running rotating simulations
- Run self-propulsion simulations using viscous/inviscid coupling modeling for estimating performances of drift rudder cases

Concluding Remarks

Concluding Remarks (1/3)

HYUNDAI HEAVY INDUSTRIES

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**.
- **HiSPFoam** has been developed to simulate self-propulsion cases using double body modeling based on the geometric modeling for propellers.
- **ezFoam** is an automation program for the analysis of ship performances, developed by HMRI
- Those developed solvers were applied to analyze performances of resistance, self-propulsion, and maneuvering of various ships.

Concluding Remarks (2/3)

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We carried out sea-keeping simulations by using Naval Hydro Pack which is a resultant OpenFOAM code of JDP with UNIZAG

- 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 on sea-keeping simulations,
  - ✓ 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.

Concluding Remarks (3/3)

Future of OpenFOAM development in HHI

- We will continue to develop OpenFOAM® techniques to replace the commercial CFD codes.
- It may contain following items:
  - Free-running with improved motion solvers, e.g. overset mesh etc.
  - Evaluate performances of a ship in real scale
  - Real time simulations
  - CAD handling for using in design stage


THANK YOU
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