Investigation of the capability of RANSE-CFD for propeller calculation in practical use

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Propeller calculation - Why and How ?

- To estimate power demand of a ship

$$(\textit{delivered power})\ P_D = \frac{P_E\ (\text{effective power})}{\eta_O \quad \eta_H \cdot \eta_R}$$

Open water test

Self-propulsion test

- RANSE solver: ISIS code in Fine Marine software

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Selection of propeller test case

- Potsdam propeller test case
  - 5 blades
  - Right hand rotation
  - Diameter D = 0.25m

- Validate CFD calculation by experiment results

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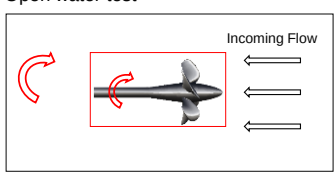
Method for open water simulation

- Open water test



- Rotating Domain
- Rotating Reference Frame
- Sliding Grid

Comparison of 3 methods

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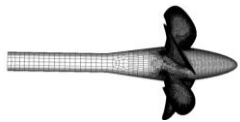
Mesh generation and simulation setup

- Same mesh size for 3 methods
  - 3.9 million cells
  - Refinement at leading edge and trailing edge



- Simulation setup
  - Turbulence model: k-ω SST
  - Wall function approach
  - Advance coefficient J = 0.6, 0.8, 1.0, 1.2 and 1.4

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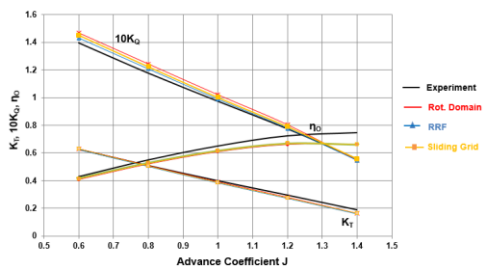
Accuracy level of Open water simulation

- Open water Curve



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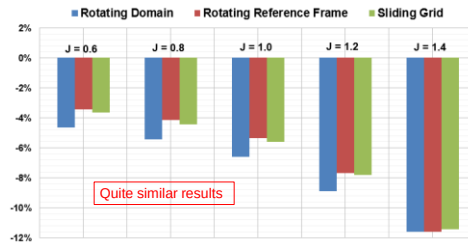
Accuracy level of Open water simulation

- Difference of open water efficiency to experiment ($\Delta\eta_O$) for 3 methods



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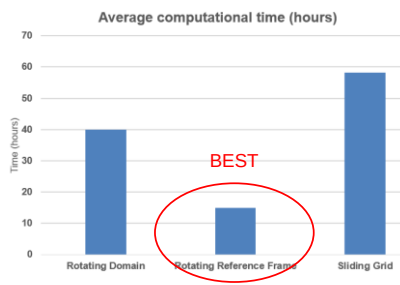
Time consumption of Open water simulation

- The computations are performed in parallel over 16 cores



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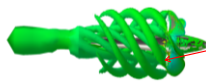
Post processing of Open water simulation

- Comparison in terms of vortex identification
- Using λ_2 criterion for vortex identification ($\lambda_2 = -50$)
- Advance coefficient J = 1.4

Rotating Domain

Rotating Reference Frame



Sliding Grid

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Conclusion of Open water simulation

- Rotating Reference Frame method is the best method for practical use
- The results are quite good (5%) for low advance coefficient (J), but under estimation (10%) for high J
- Vortexes are well captured by Sliding Grid method

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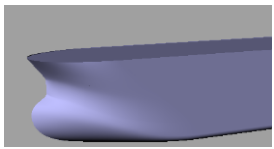
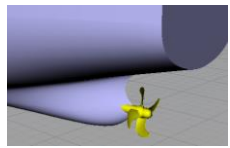
Self-propulsion Test Case

- Bulk carrier with 4-blade, right hand propeller
- Propeller Diameter = 0.23m
- Service speed Vs = 14.5 knots
- Froude number: Fr = 0.159





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Two simulations in Self-propulsion Test

- Simulation WITHOUT rudder
  - Calculation with 2 numbers of revolution (n)
  - Interpolate the results to find self-propulsion point
- Simulation WITH rudder
  - To see the influence of rudder to self-propulsion test

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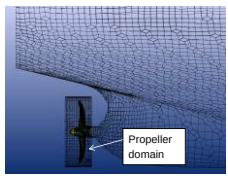
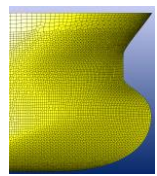
Mesh for propulsion simulation without rudder

- Sliding Grid method
- Mesh size: 5.0 million cells
  - 2.9 million cells for propeller domain
  - 2.1 million cells for ship domain
  - Free surface is also meshed





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Setup of propulsion simulation without rudder

- Calculation with revolution n = 7.62rps and n = 8.2rps
- Turbulence model: k-ω SST
- Wall function approach
- Computations are performed on 96 cores
- Computational time is about 48 hours

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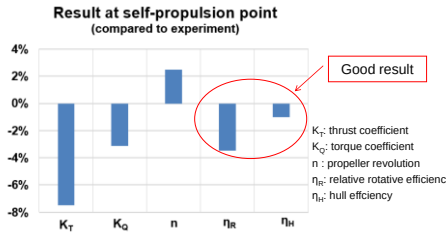
Result of propulsion simulation without rudder

- Self-propulsion point is found by interpolation
- Validate by experiment result: the experiment is carried out WITH rudder



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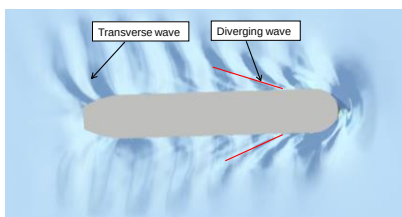
Free surface wave pattern

- The free surface is meshed and solved
- Transverse and diverging wave can be captured by doing post-processing



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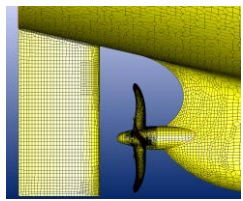
Propulsion simulation with rudder

- A rudder is added to ship domain
- Perform simulation at only n = 7.62rps (same with experiment)



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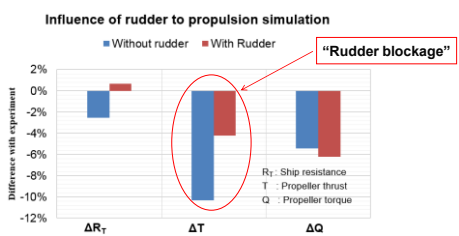
Result of simulation with rudder

- Comparison only: ship resistance, propeller thrust and torque (at same revolution n =7.62rps)
- The experiment is performed WITH rudder



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Conclusion of self-propulsion simulation

- Self-propulsion point is found for simulation without rudder
  - Good result of hull efficiency (η_H), and relative rotative efficiency (η_R) : less than 5%
- High time consumption and computational resources
- Increase of propeller thrust due to adding rudder – ***"rudder blockage"*** phenomenon

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Key remarks

- Rotating Reference Frame method for open water simulation
- Accuracy of η_O, η_H, η_R are quite good (3-10% difference with experiment)
- Influence of rudder to propulsion simulation – ***"rudder blockage"*** phenomenon

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