

Hull Form Design Utilizing CFD for Improvement of EEDI

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International Workshop on Ship Technologies Related to Energy Efficiency Design Index (EEDI)

Outline

1. EEDI places restriction on CO₂ emissions
 - Required EEDI reviewed every other 5-years
2. Refine ship form and brush up energy saving devices
3. Utilizing CFD is essential for them
 - 3.1 Resistance computation
 - 3.2 Self-propulsion computation
 - 3.3 Energy saving devices computation
4. Apply the grid-blending method to hull form design
5. Conclusion

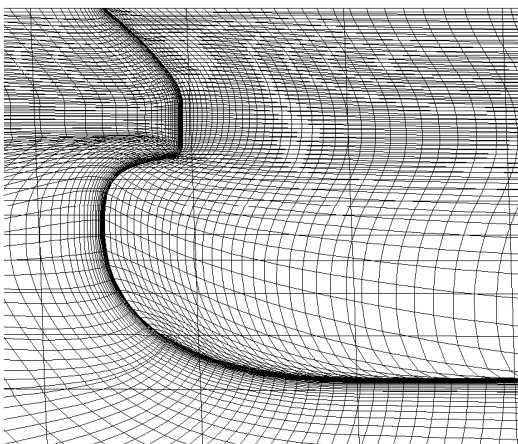
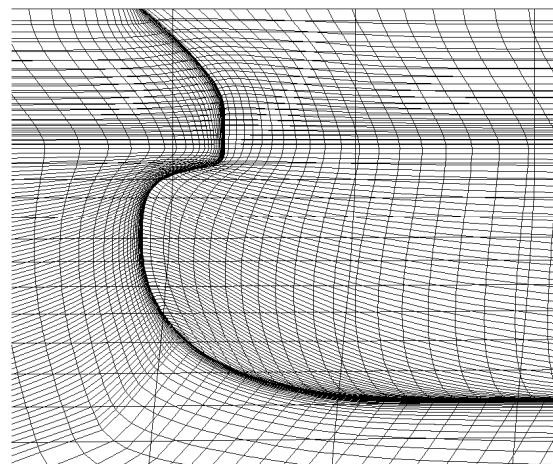
Principal Dimensions

	82DWT BC	33DWT ChemicalTanker
Lwl [m]	225.0	173.0
Lpp [m]	222.0	170.5
B [m]	32.26	27.7
d [m]	12.2	10.0
Cb [-]	0.871	0.795
Dp [m]	6.40	6.60
Vs [knot]	14.2	14.5
Design Fr (Lwl)	0.15	0.18

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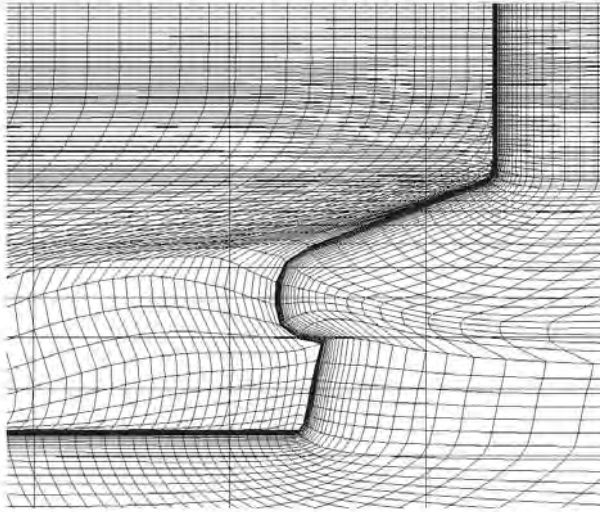
Comparison of Grid Fore-Part
HullDes & GRIDGEN[®]

HullDes

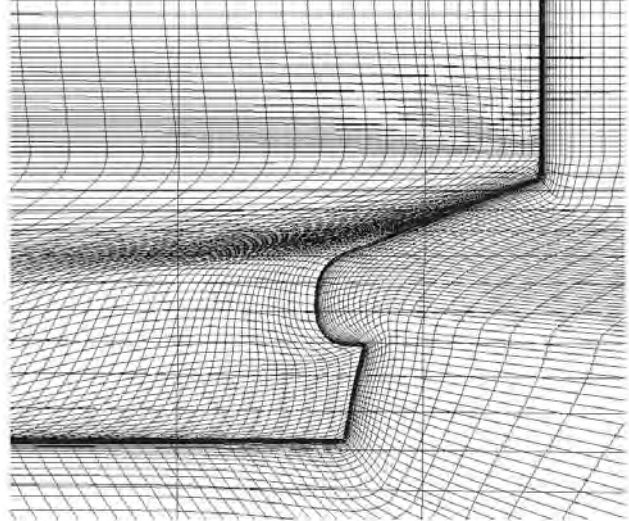
GRIDGEN[®]

Comparison of Grid Aft-Part HullDes & GRIDGEN[®]

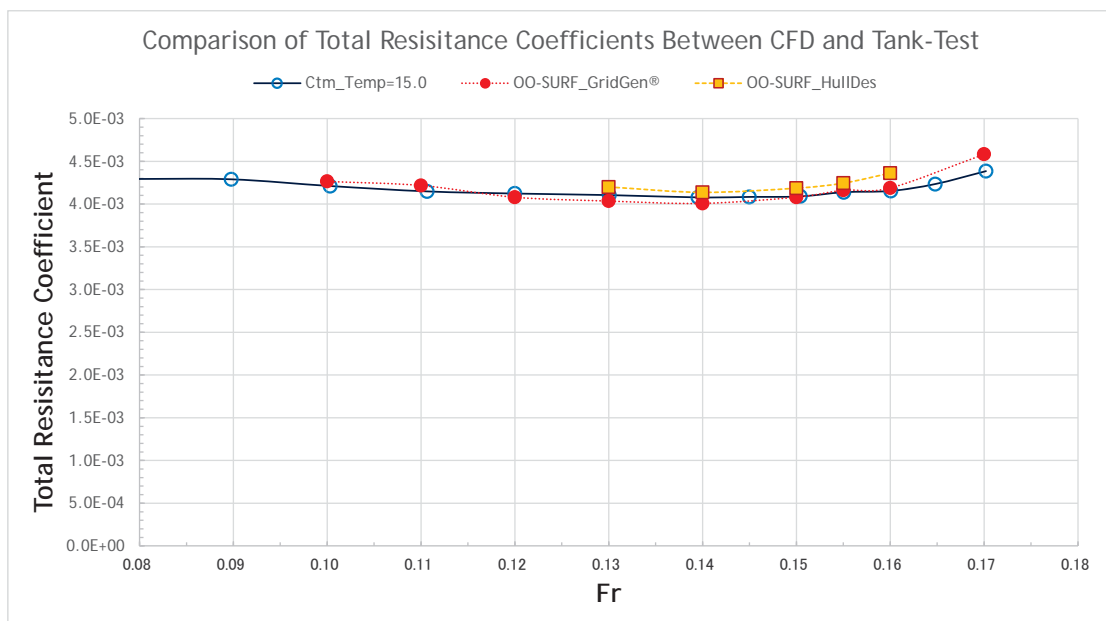
HullDes



GRIDGEN[®]



3.1 Total Resistance Computing (1) 82DWT BC



Computation Conditions

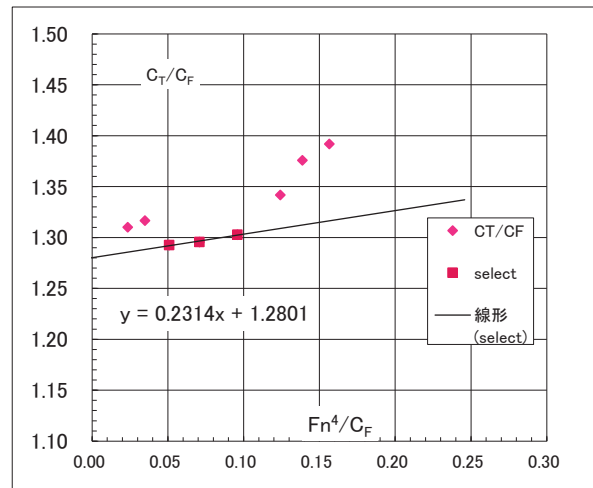
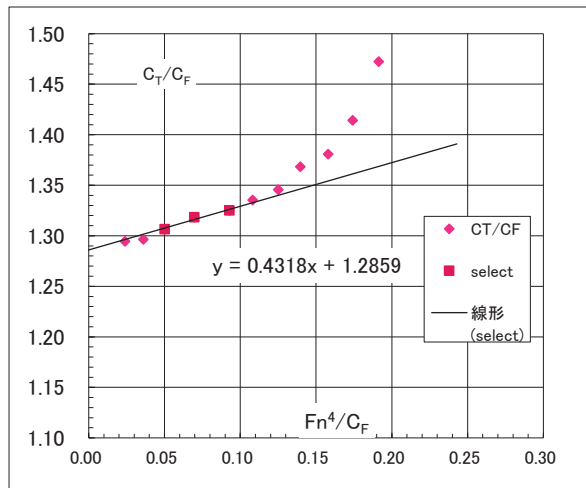
	TankTest	CFD_2	CFD_1	CFD_7	CFD_3	CFD_4	CFD_5	CFD_6
Fr	0.155	0.154	0.154	0.155	0.155	0.155	0.155	0.155
Rn×10 ⁶	8.35	9.00	9.00	8.35	8.35	8.35	8.35	8.35
Topology		H-O	O-O	O-O	O-O	O-O	O-O	O-O
Total_cell		931,840	609,280	609,280	847,000	847,000	847,000	609,280
grid		HullDes	HullDes	HullDes	Gridgen	Gridgen	Gridgen	HullDes
Min. Grid Space×10 ⁻⁶		1.69	2.36	0.301	0.301	0.301	0.301	0.301
Solver		Neptune	Neptune	Neptune	Neptune	Neptune	SURF	SURF
Free Surface Model		Tracking	Tracking	Tracking	Level Set	Level Set	Level Set	Level Set
Turbulence Model		Mod_SA	Mod_SA	SA	SA	Mod_SA	SA	SA
cvor		10	10	0	0	10	0	0
Total Resistance Coeff.×10 ⁻³	4.138	3.7617	3.8579	3.8932	4.2714	4.2506	4.1608	4.1859
CTM/TankTest	1.000	0.909	0.932	0.941	1.032	1.027	1.006	1.012

Form Factor

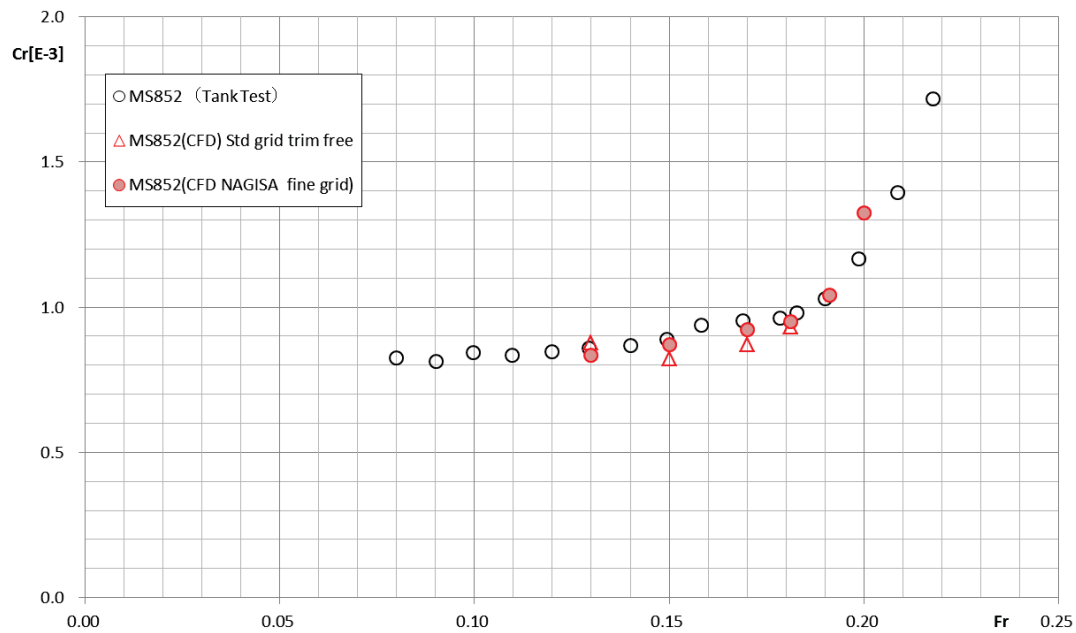
Prohaska's Method

Tank Result $1+k= 1.286$

CFD Result $1+k= 1.280$



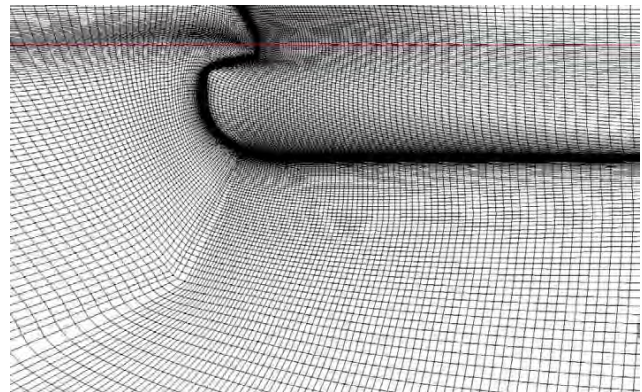
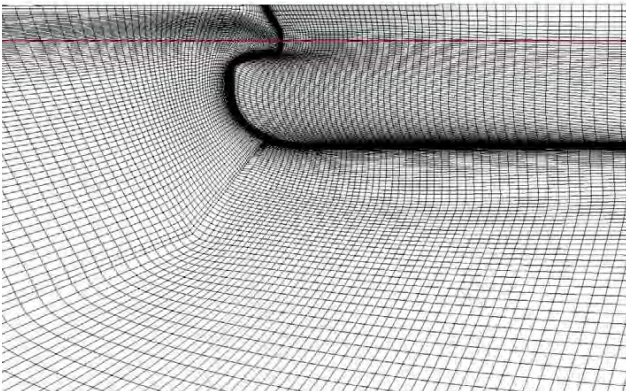
Comparison of Residual Resistance between Fine-grid CFD and Tank Test Results



Comparison of Computation Grid between Standard and Fine Grid

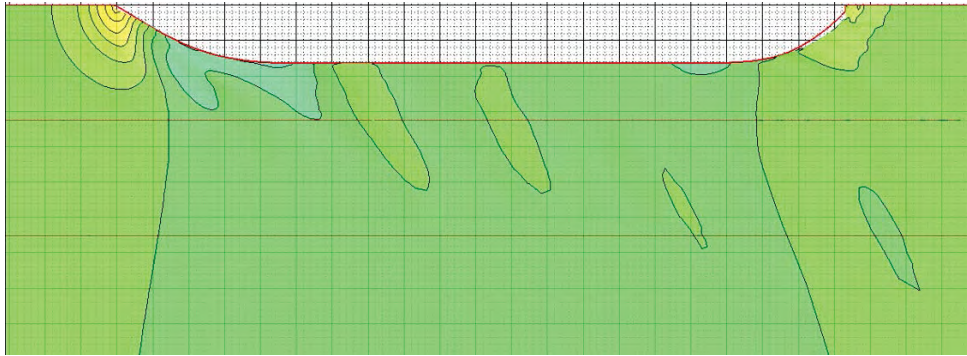
Standard grid
 $131 \times 77 \times 81 = 817,047$ cells

Fine grid
 $225 \times 89 \times 145 = 2,903,625$ cells

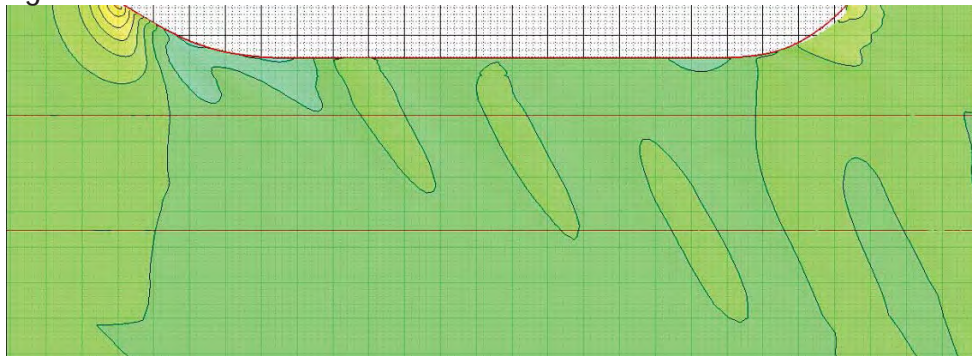


Comparison of Wave Pattern between CFD Standard Grid and CFD Fine Grid

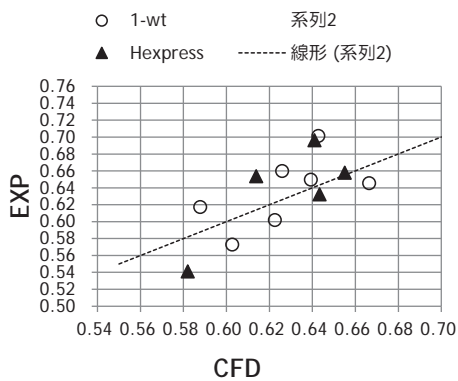
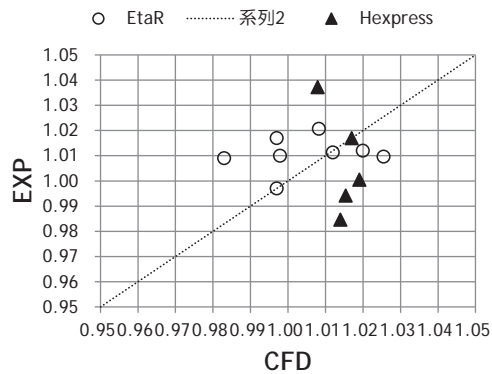
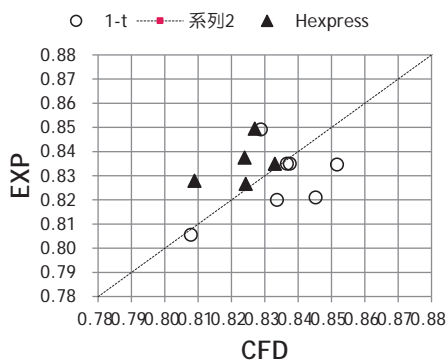
standard grid



fine grid



3.2 Self-Propulsion Computing

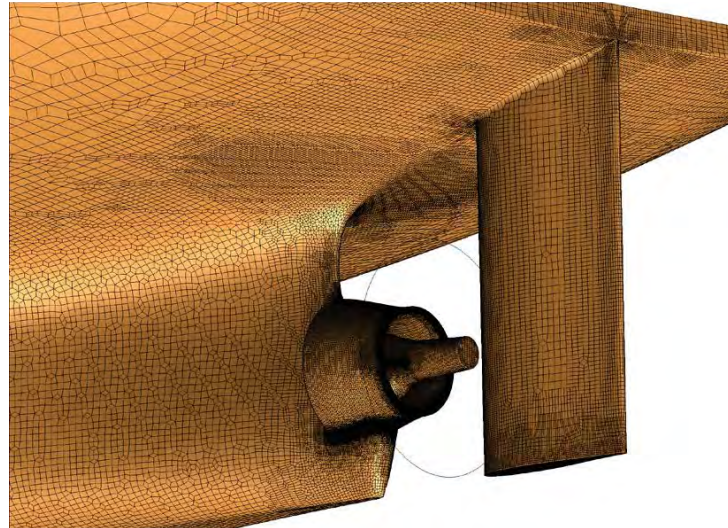


- : Solver : Neptune
Grid : HULDES, 931,840 cells
- ▲ : Solver : Surf
Grid : HEXPRESS@, 3,930,000 cells

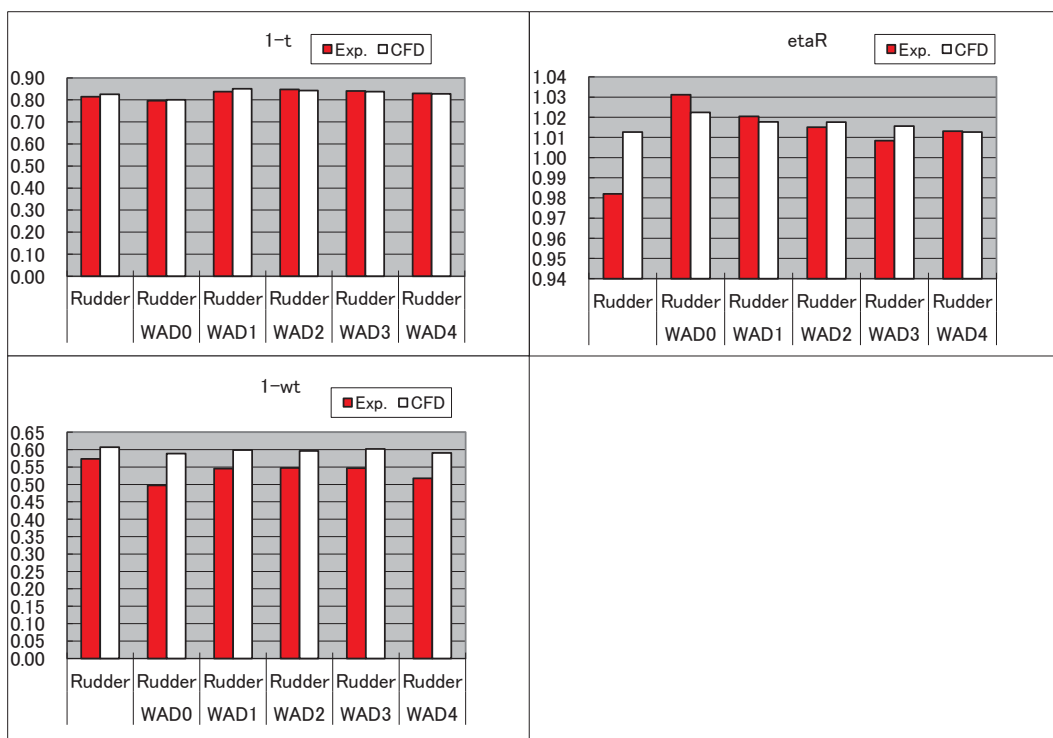
3.3 Energy Saving Devices Computation

Grid (Hull + Rudder + Energy Saving Device)

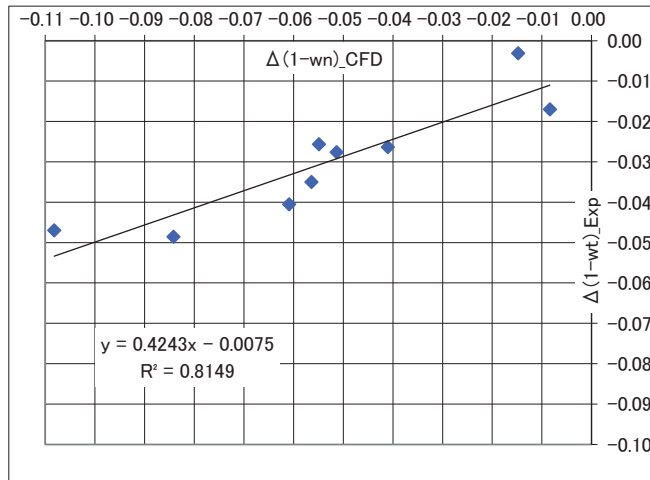
HEXPRESS ® [Total cells 5.76~7.84 Million]



Self-Propulsion Computing with ESD



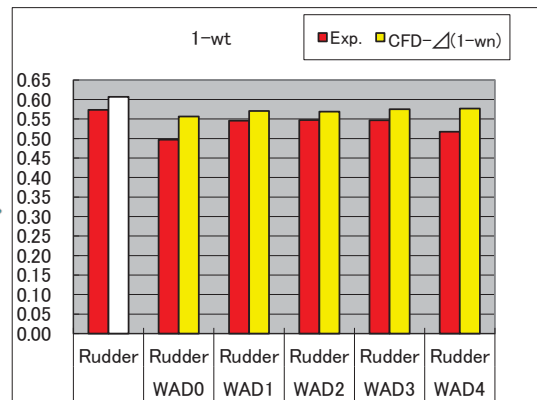
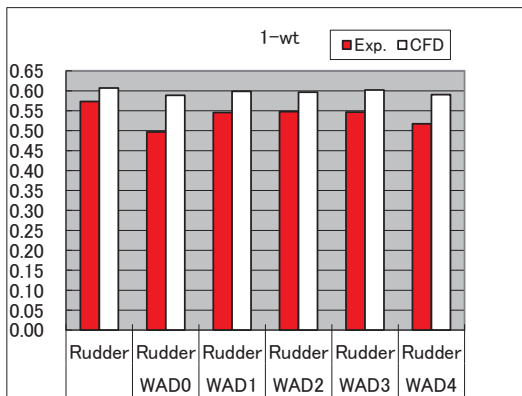
Estimation of Wake-gain by ESD



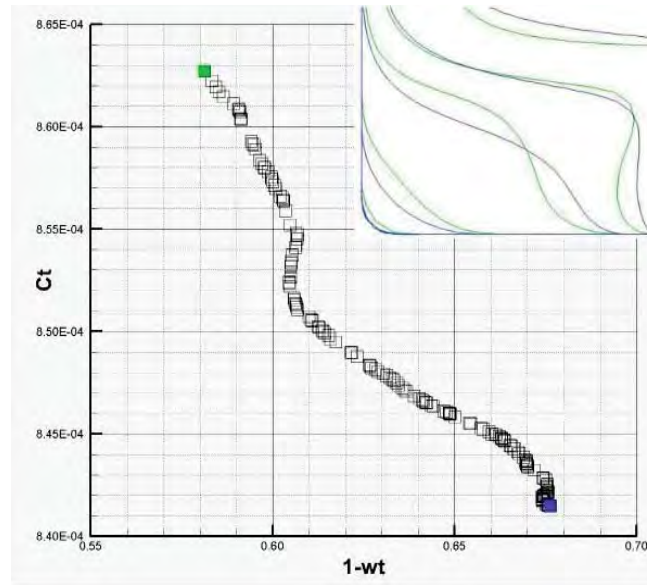
$$(1 - w_T)_{ESD} = (1 - w_T)_{without} + \Delta(1 - w_T)_{ESD}$$

$$\Delta(1 - w_T)_{ESD} = 0.4243 \times \{(1 - w_n)_{without_CFD} - (1 - w_n)_{ESD_CFD}\} - 0.0075$$

Estimation of $(1-w_T)$ with ESD



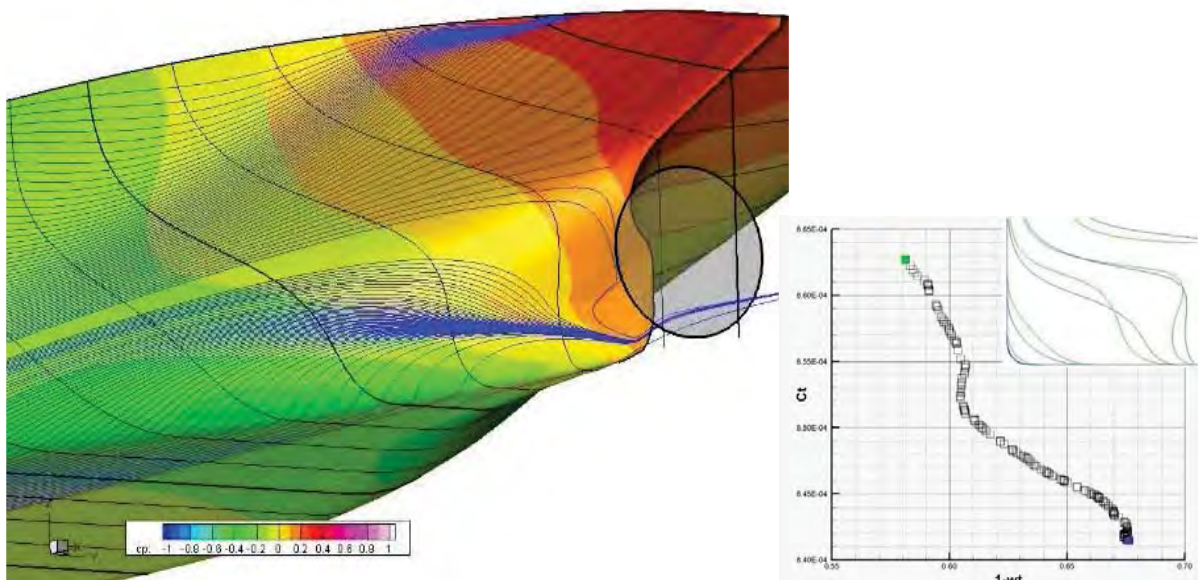
4. Apply the grid-blending method to hull form design



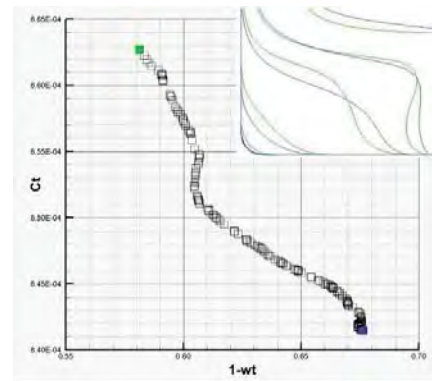
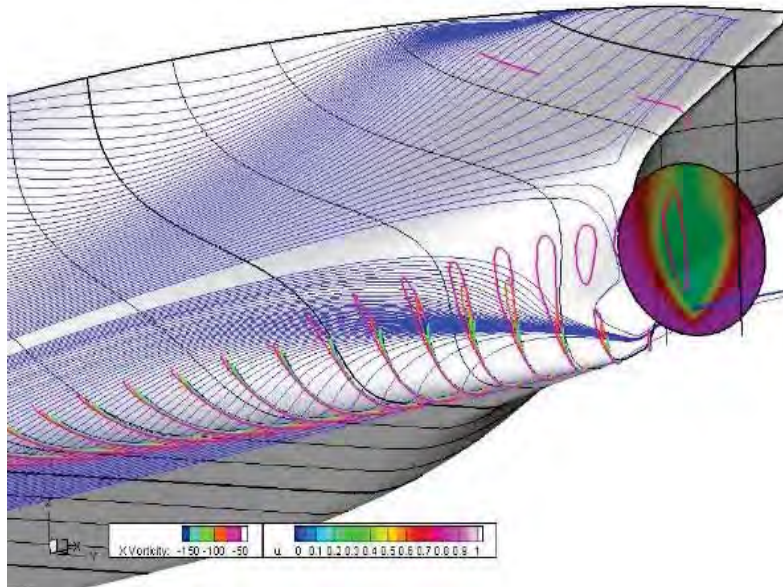
- adopt the grid-blending(morphing) method for CFD-grid
- fore-body are same.
- apply this method to variation from V-type aft-body to U-type aft-body
- 200 ships

Variations in Flow Field (Limiting Streamlines and Pressure Distribution)

- As Aft Body become from V-type to U-type, negative pressure area moves aft and expands to upper-side.

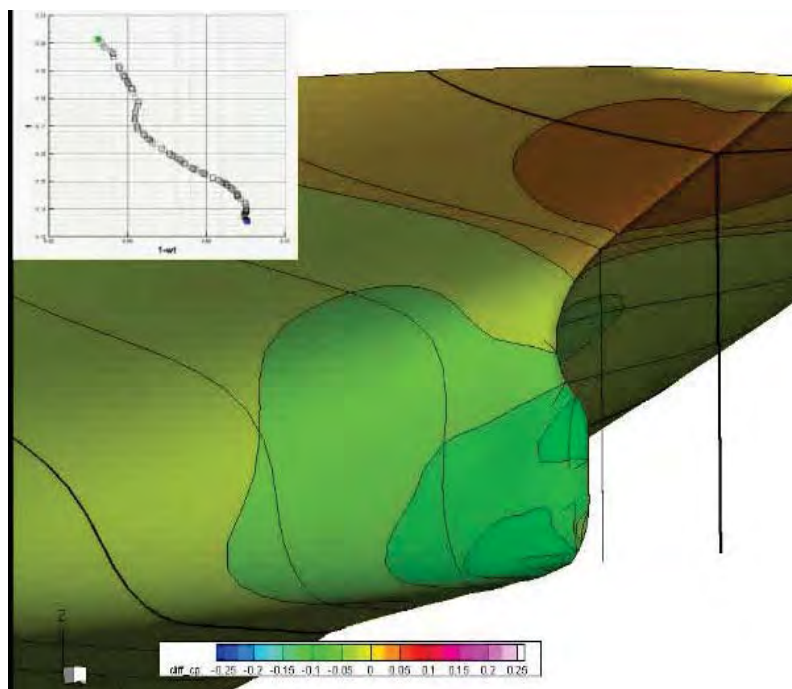


Variations in Flow Field (Limiting Streamlines and Vortices Contours)



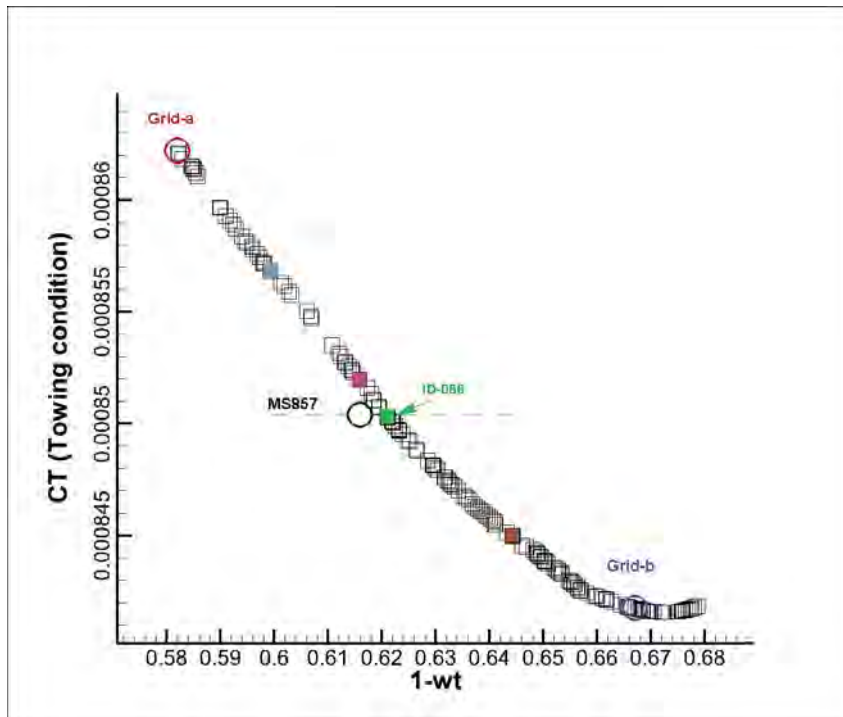
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Pressure Difference Contour between Resistance and Self-Propulsion Condition

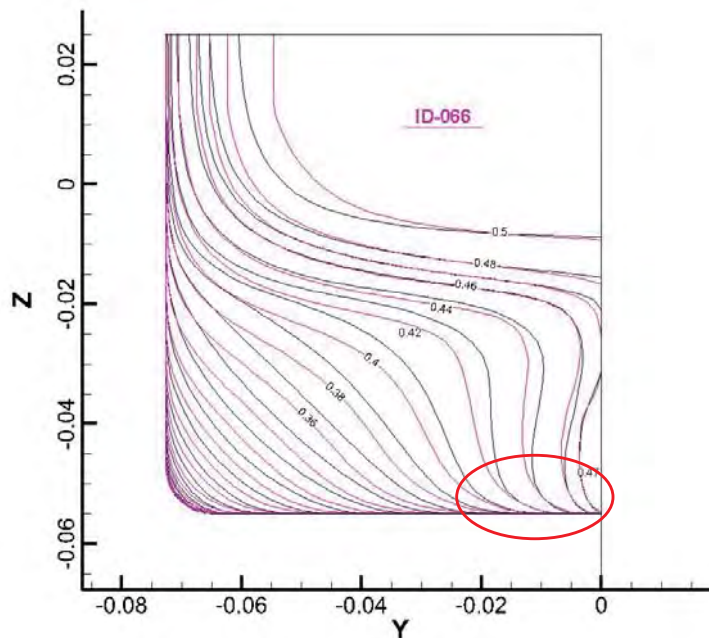


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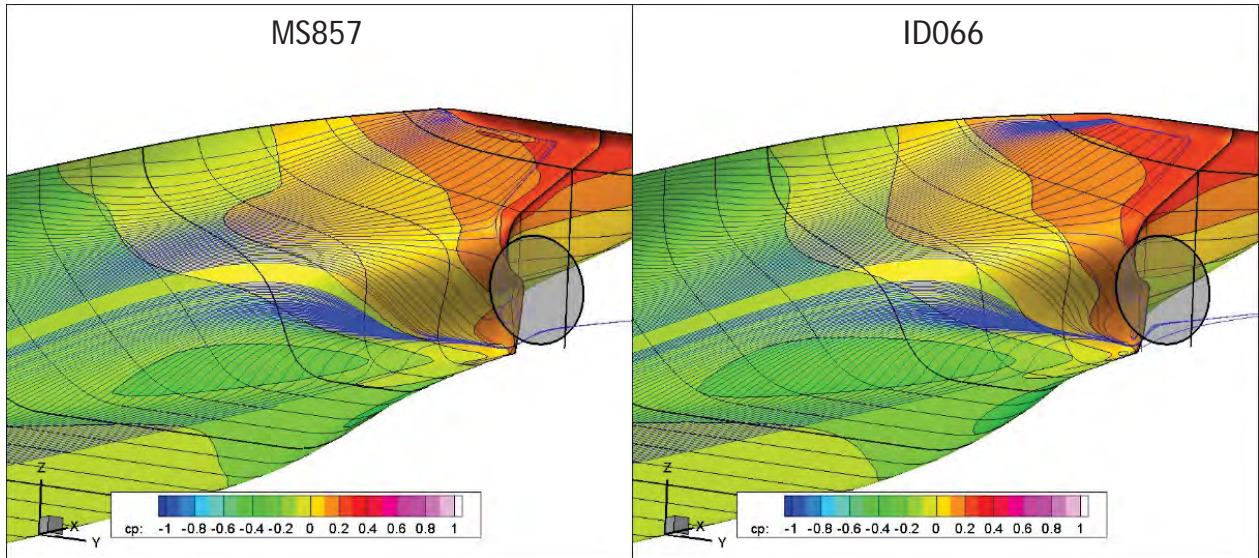
- ID-066: aft-body from grid-blending method
- MS857: tank test model
- same resistance value : MS857 and ID-066



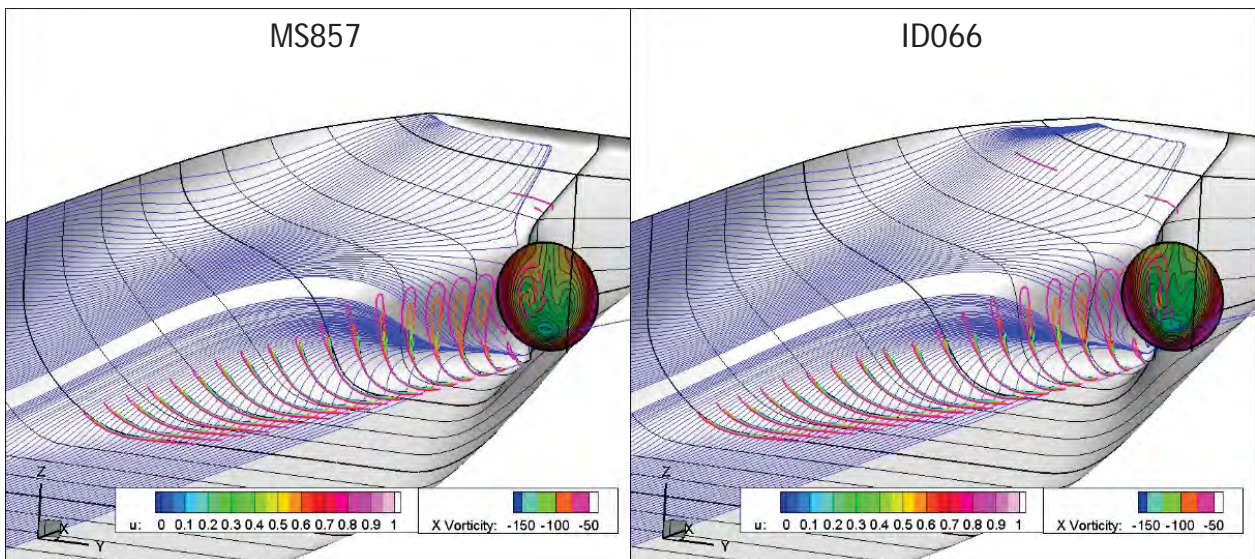
Comparison of Aft-Bodyplan between MS857 and ID066



Comparison of Limiting Streamlines and Pressure Contours between MS857 and ID066



Comparison of Limiting Streamlines and Vortices Contours between MS857 and ID066



5. Conclusion

3.1

- Resistance computational results by using CFD almost attains Numerical Towing Tank.

- The quality of computational results depend on grid generation and CFD-parameter setup.

3.2

- Self-propulsion computational results by using CFD is close to be a tool for estimating propulsion performance.

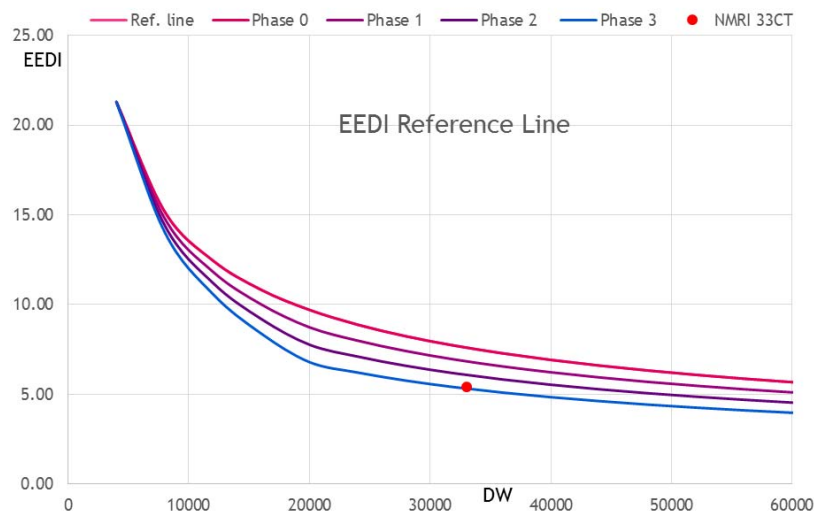
- Estimation by using CFD is carried out in comparison with tank test results carefully.

4

- The grid-blending(morphing) method is favorable tool for the hull design.

33DWT Chemical Tanker

Item	Value	Unit	Remarks
EEDI	5.43	g/(tonNM)	Attained Energy Efficiency Design Index
EEDI _{ref}	7.60	g/(tonNM)	Reference value of Energy Efficiency Design Index
R _{EEDI}	28.6	%	Reduction rate of EEDI



Thank you for your attention