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 CO_2 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

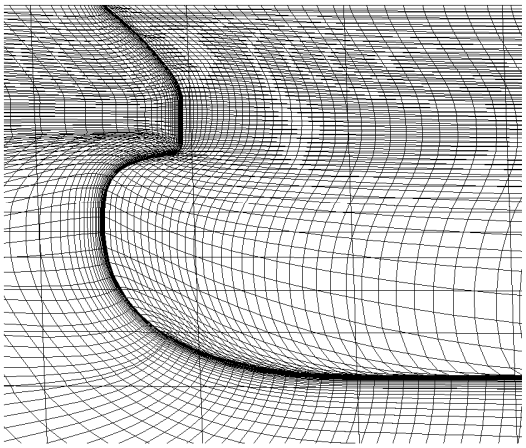
5. Conclusion

Principal Dimensions

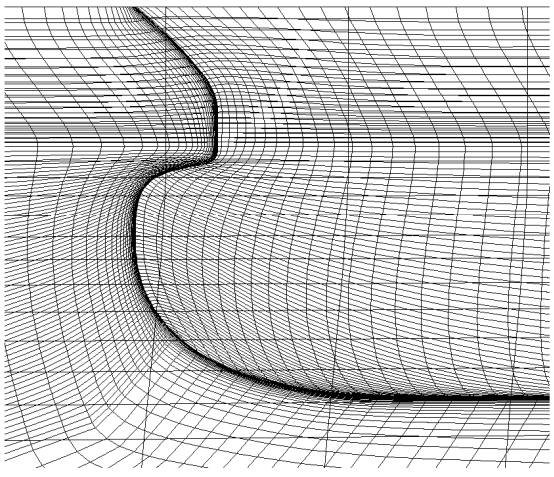
	82DWT BC	33DWT ChemicalTanker
Lwl [m]	225.0	173.0
Lpp [m]	222.0	170.5
B [m]	32.26	27.7
d [m]	12.2	10.0
Cb [-]	0.871	0.795
Dp [m]	6.40	6.60
Vs [knot]	14.2	14.5
Design Fr (Lwl)	0.15	0.18

Comparison of Grid Fore-Part HullDes & GRIDGEN ®

HullDes

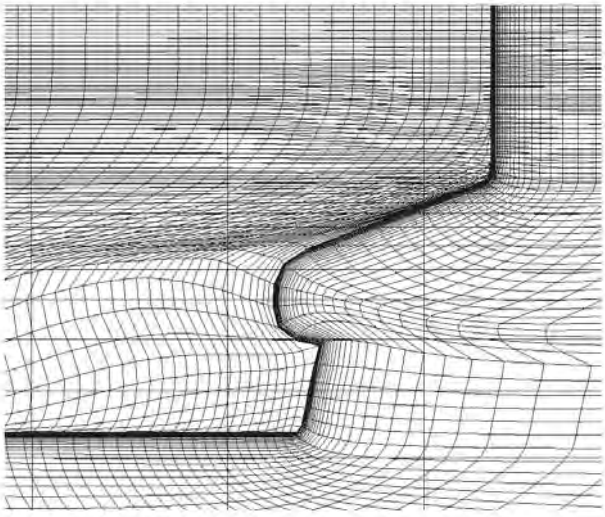


GRIDGEN ®

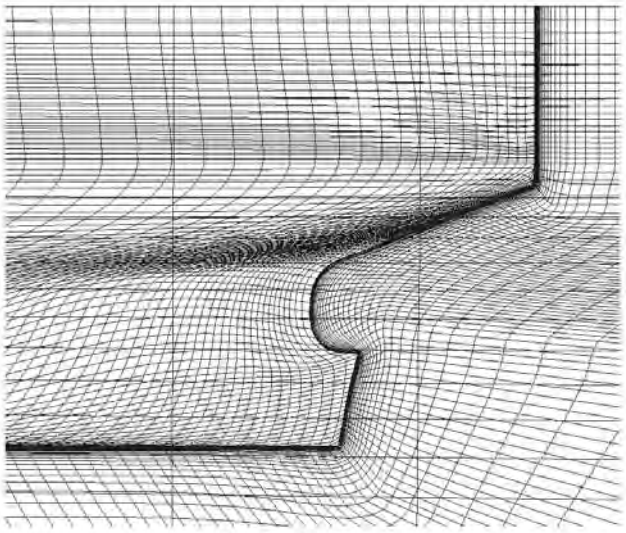


Comparison of Grid Aft-Part HullDes & GRIDGEN ®

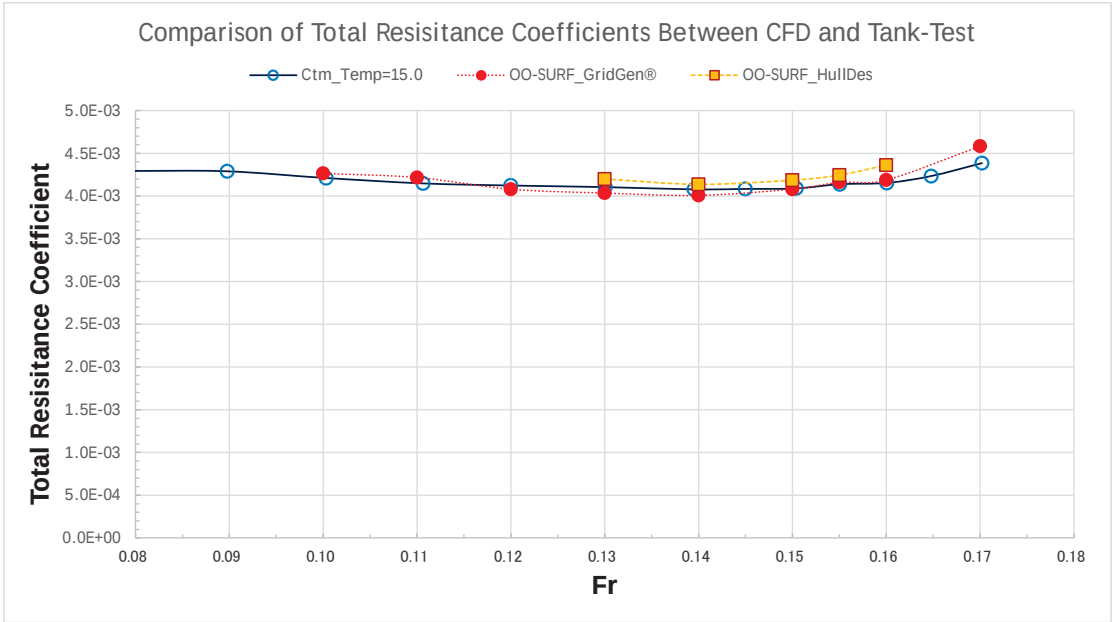
HullDes



GRIDGEN ®



3.1 Total Resistance Computing (1) 82DWT BC



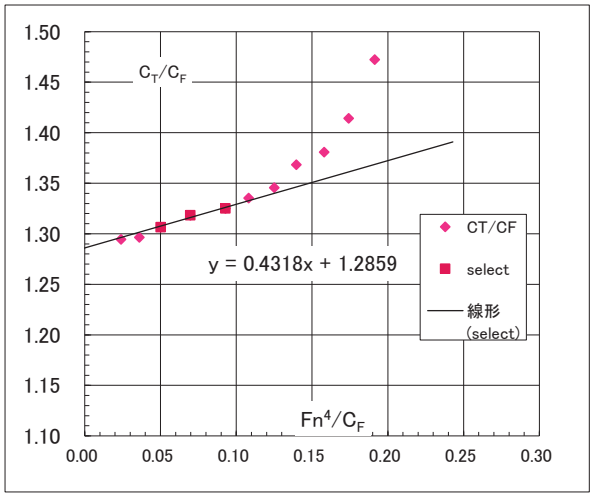
Computation Conditions

	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

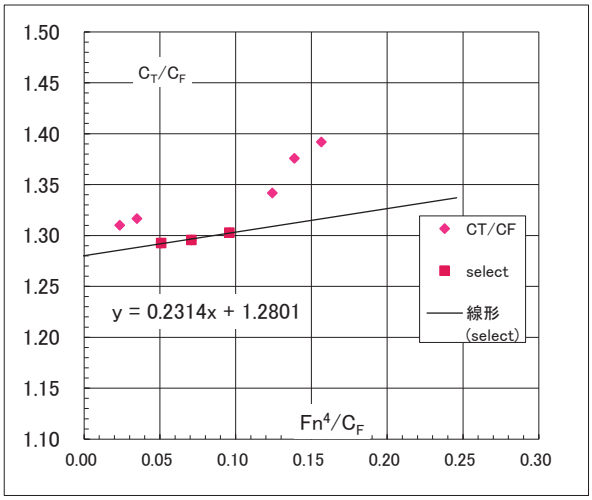
Form Factor

Prohaska's Method

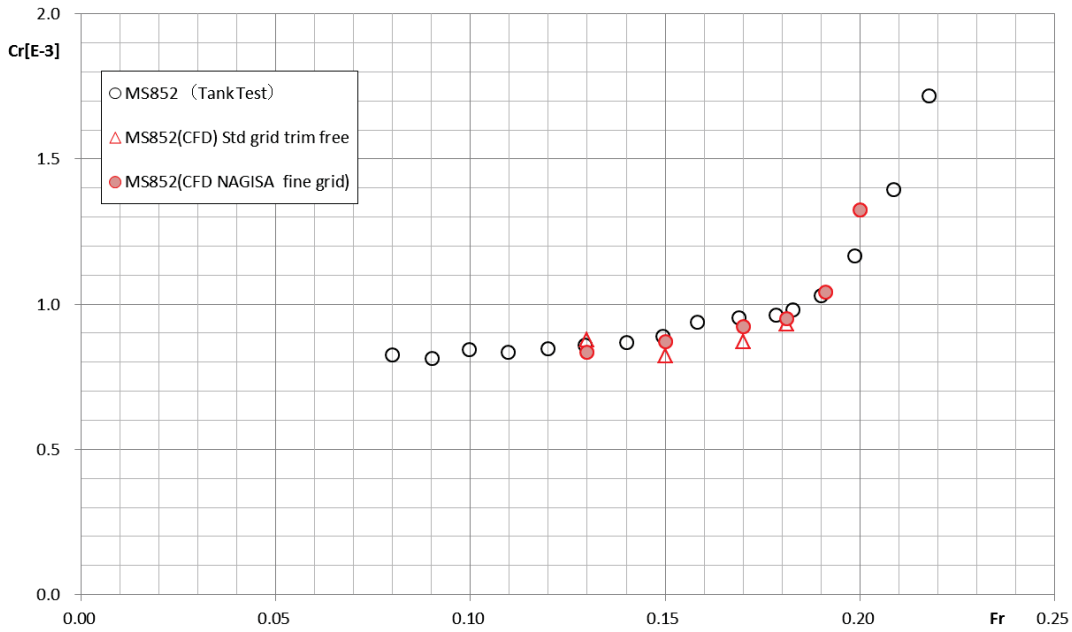
Tank Result 1+k= 1.286



CFD Result 1+k= 1.280



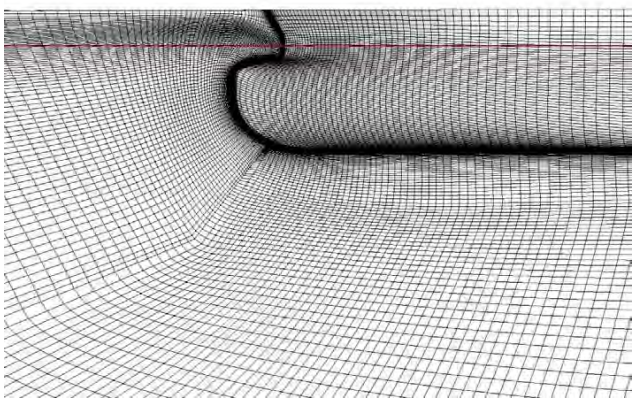
Comparison of Residual Resistance between Fine-grid CFD and Tank Test Results

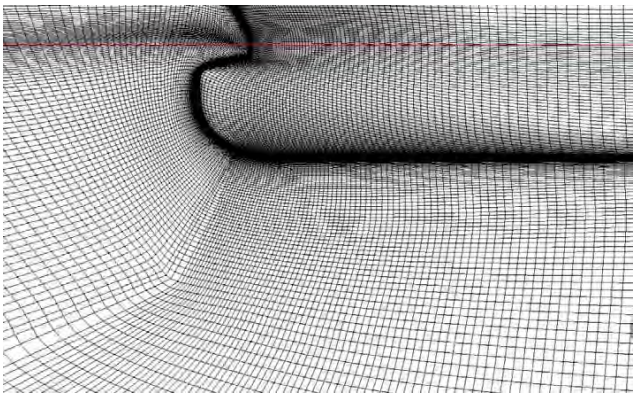


Comparison of Computation Grid between Standard and Fine Grid

Standard grid
131*77*81=817,047 cells

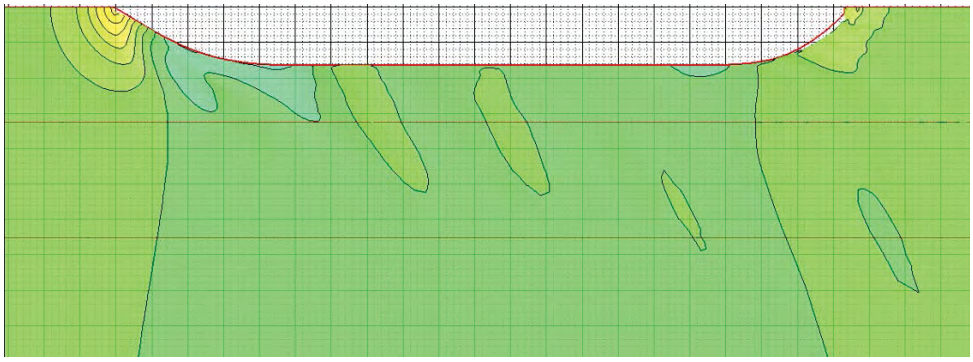
Fine grid
225*89*145=2,903,625 cells



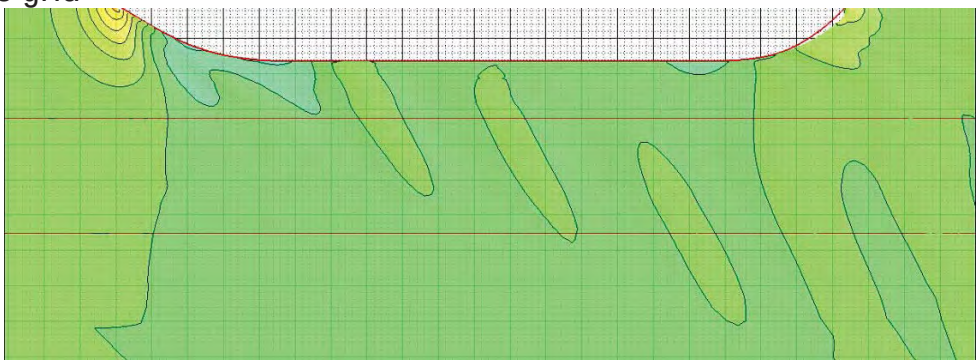


Comparison of Wave Pattern between CFD Standard Grid and CFD Fine Grid

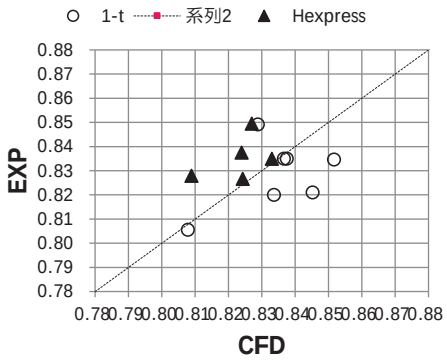
standard grid

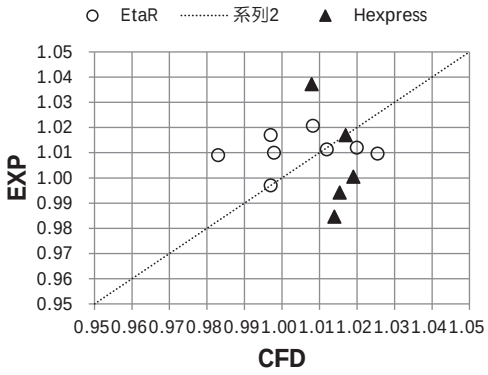


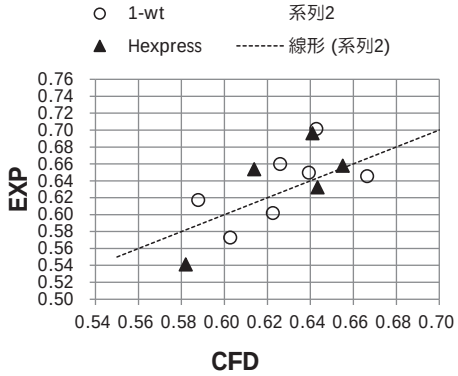
fine grid



3.2 Self-Propulsion Computing







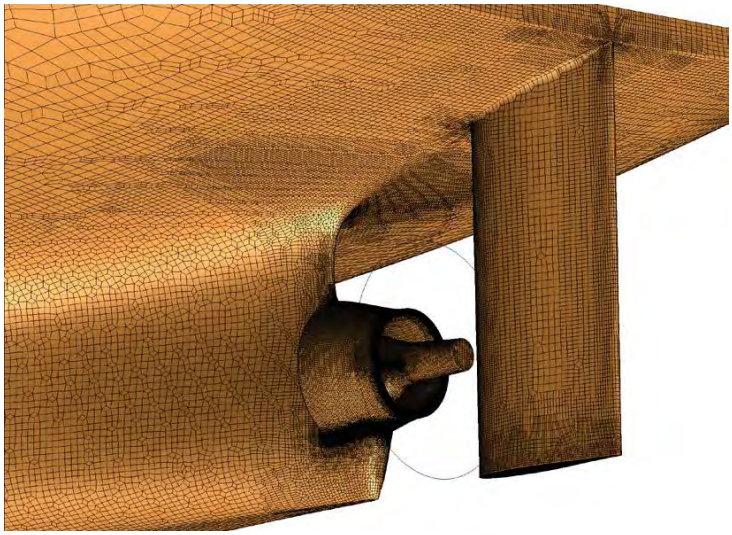
○ : Solver：Neptune
Grid ：HULDES, 931,840 cells

▲ : Solver：Surf
Grid ：HEXPRESS@, 3,930,000 cells

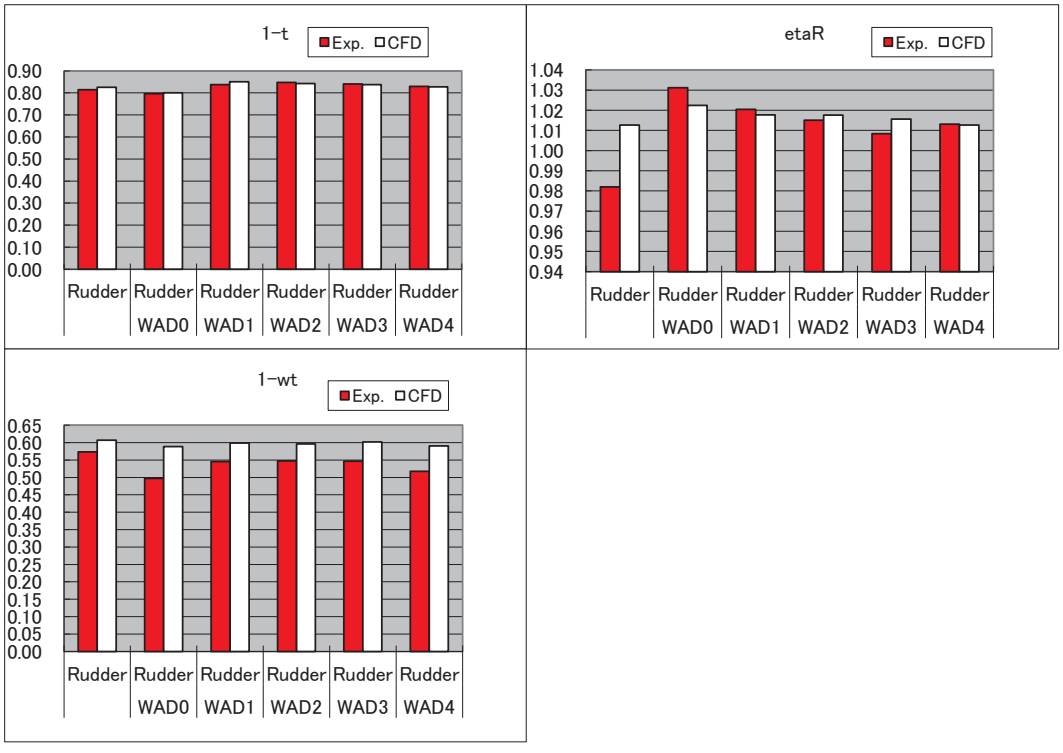
3.3 Energy Saving Devices Computation

Grid (Hull + Rudder + Energy Saving Device)

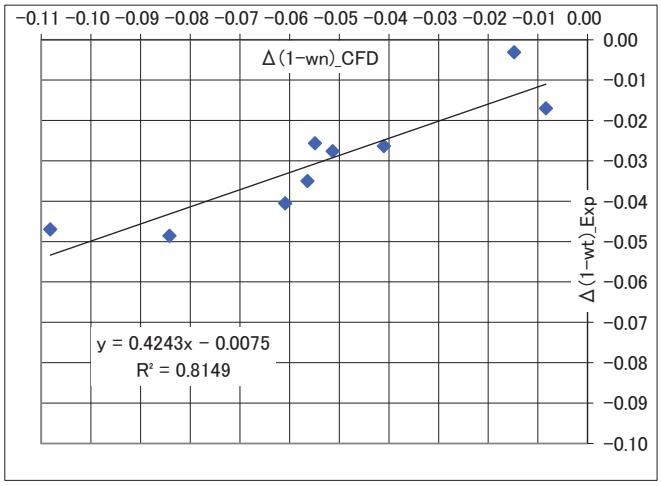
HEXPRESS ® [Total cells 5.76~7.84 Million]



Self-Propulsion Computing with ESD



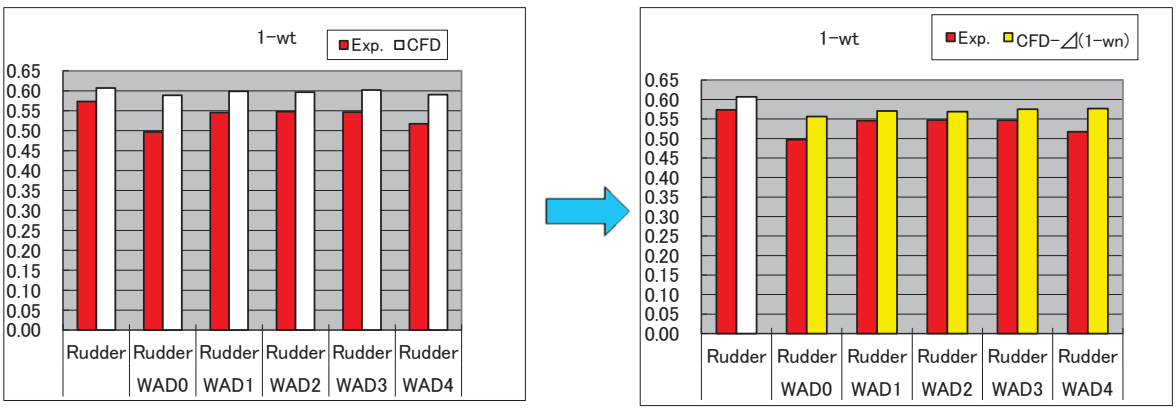
Estimation of Wake-gain by ESD



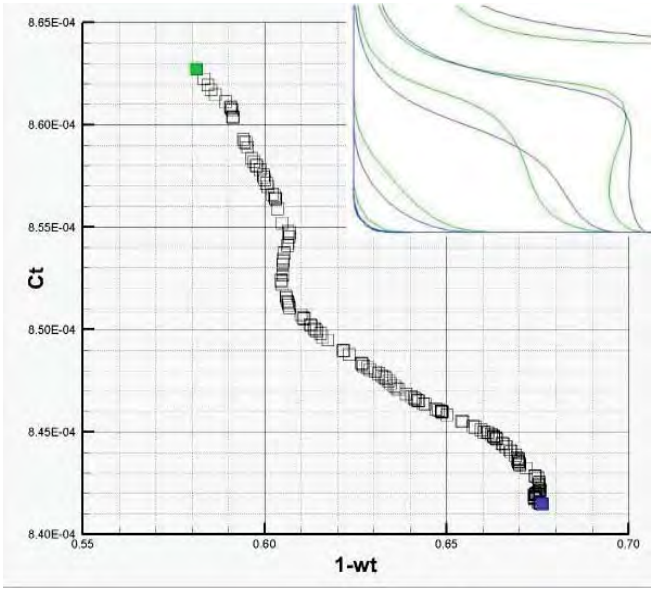
$$(1-w_T)_{ESD} = (1-w_T)_{without} + \Delta(1-w_T)_{ESD}$$

$$\Delta(1-w_T)_{ESD} = 0.4243 \times \{(1-w_n)_{without\_CFD} - (1-w_n)_{ESD\_CFD}\} - 0.0075$$

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

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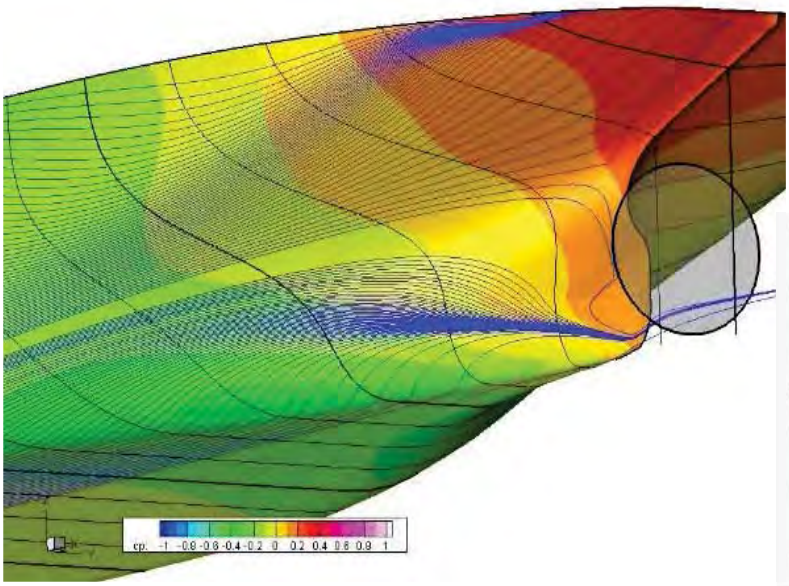
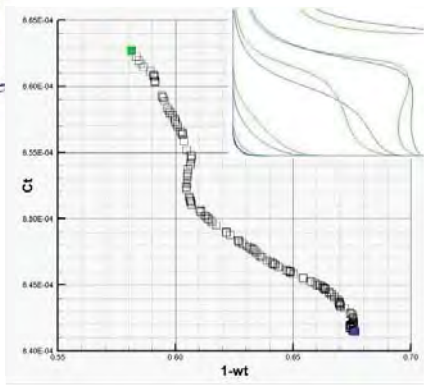
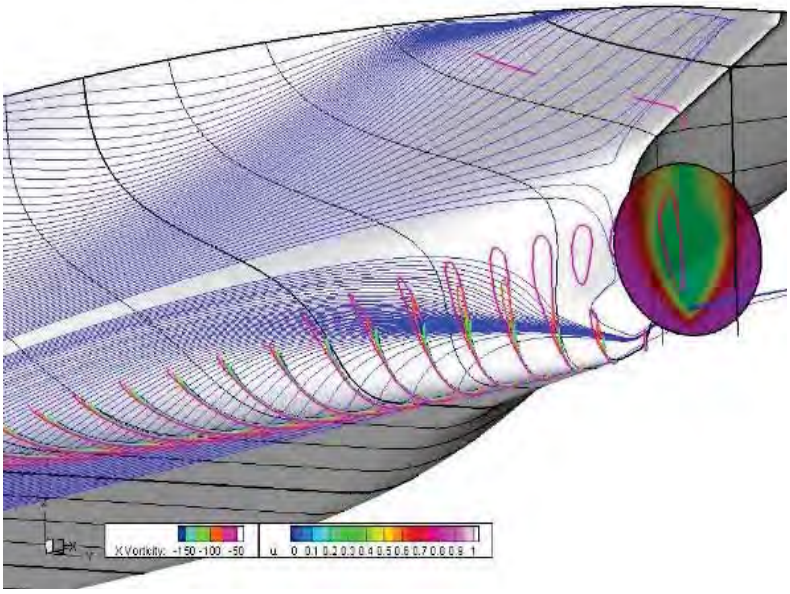
Variations in Flow Field
(Limiting Streamlines and Pressure Distribution)

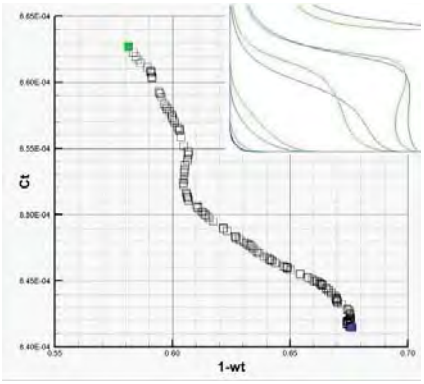
- As Aft Body become from V-type to U-type, negative pressure area moves aft and expands to upper-side.



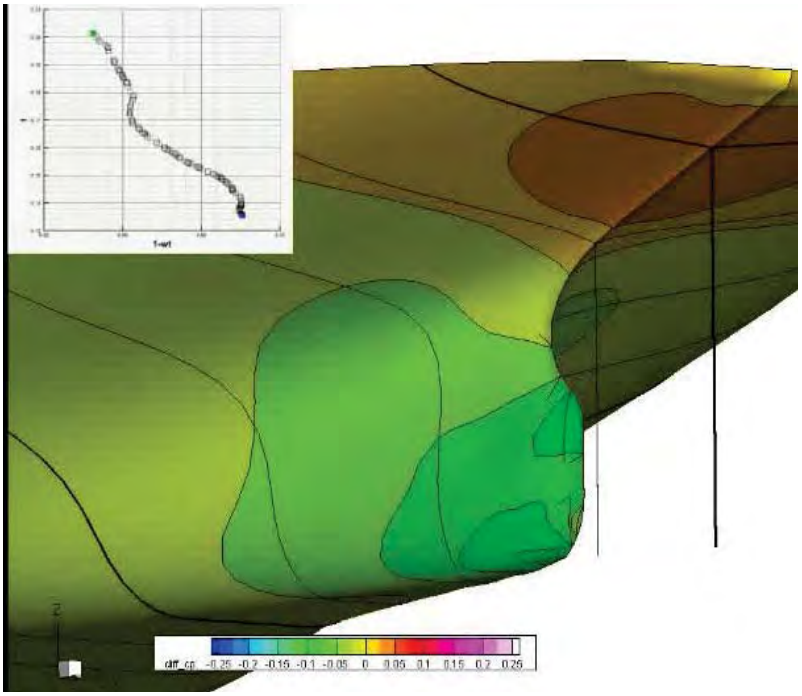


Variations in Flow Field
(Limiting Streamlines and Vortices Contours)

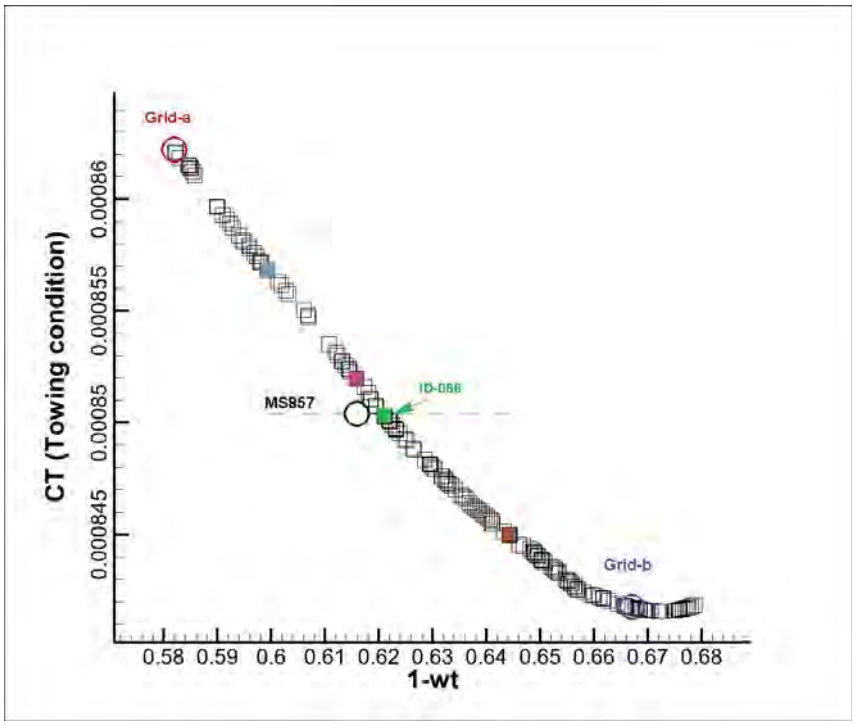




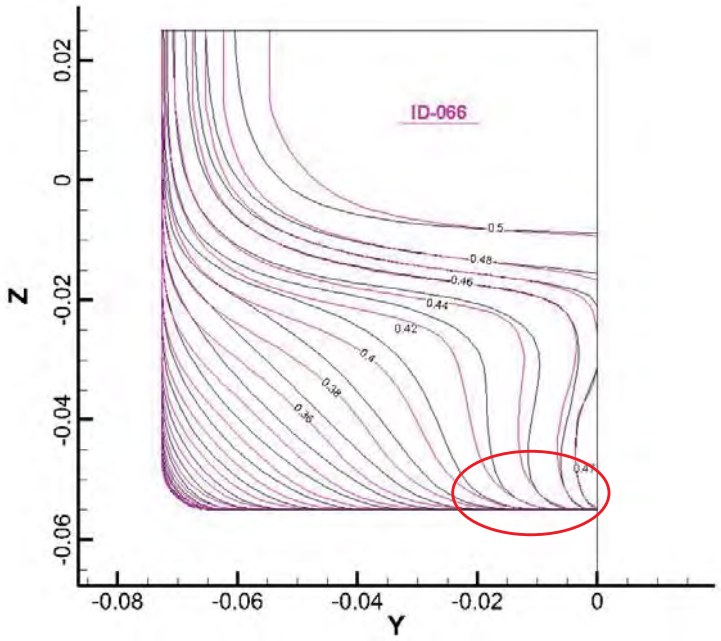
Pressure Difference Contour between Resistance and Self-Propulsion Condition



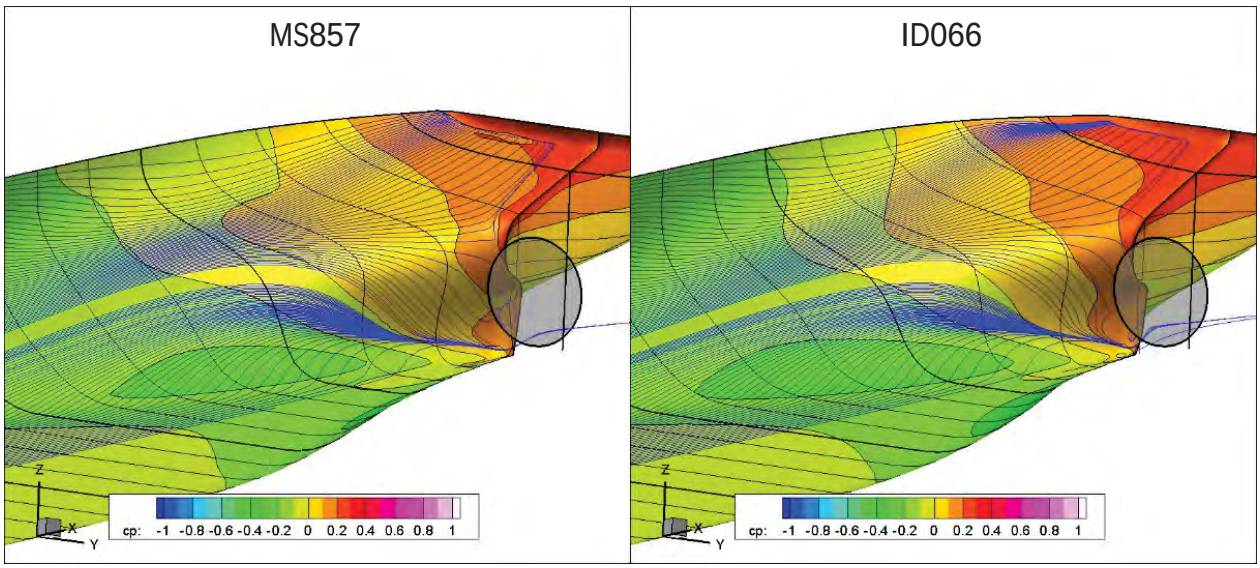
- ID-066: aft-body from grid-blending method
- MS857: tank test model
- same resistance value : MS857 and ID-066



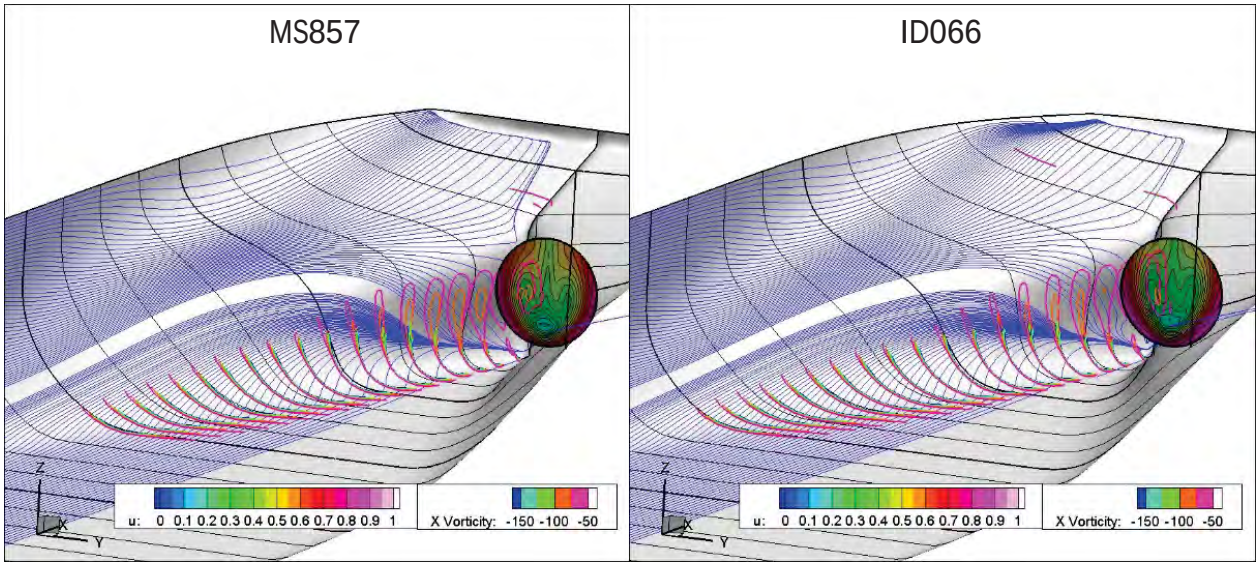
Comparison of Aft-Bodyplan between MS857 and ID066



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.

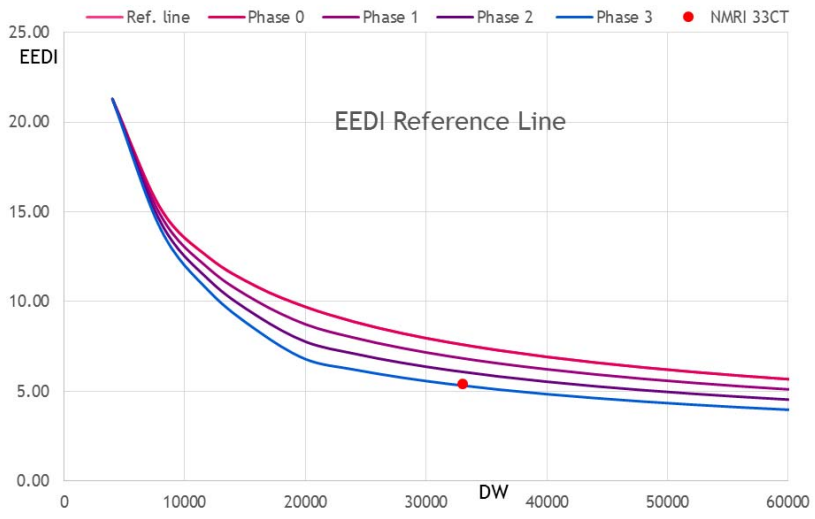
・Estimation by using CFD is carried out in comparison with tank test results carefully.

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