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7th EMship cycle: September 2016 – February 2018

Master Thesis

Development Of Flap Rudder Systems For Large Container Vessels

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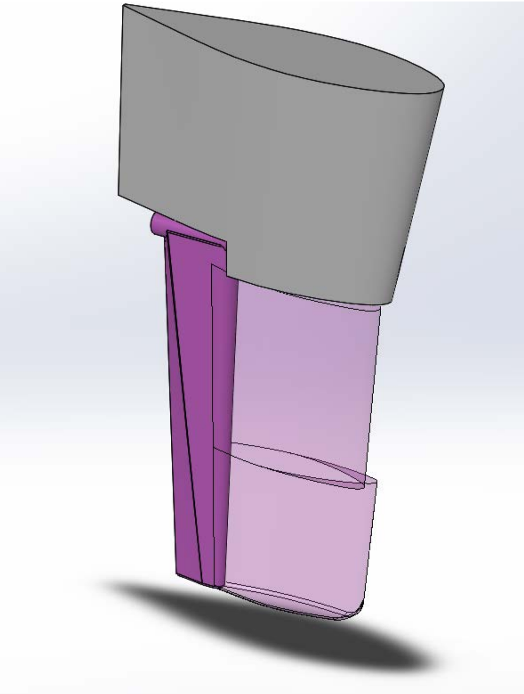
La spezia, February 2018

Why Flap Rudder For Containership Operation?

- Higher safety and higher side force compared to conventional rudders
- Better maneuvering ability
- Compared to conventional rudder lesser rudder area required to provide same side force
- Improved course keeping with reduced rudder angle.
- Reduced tug assistance for small feeder vessels



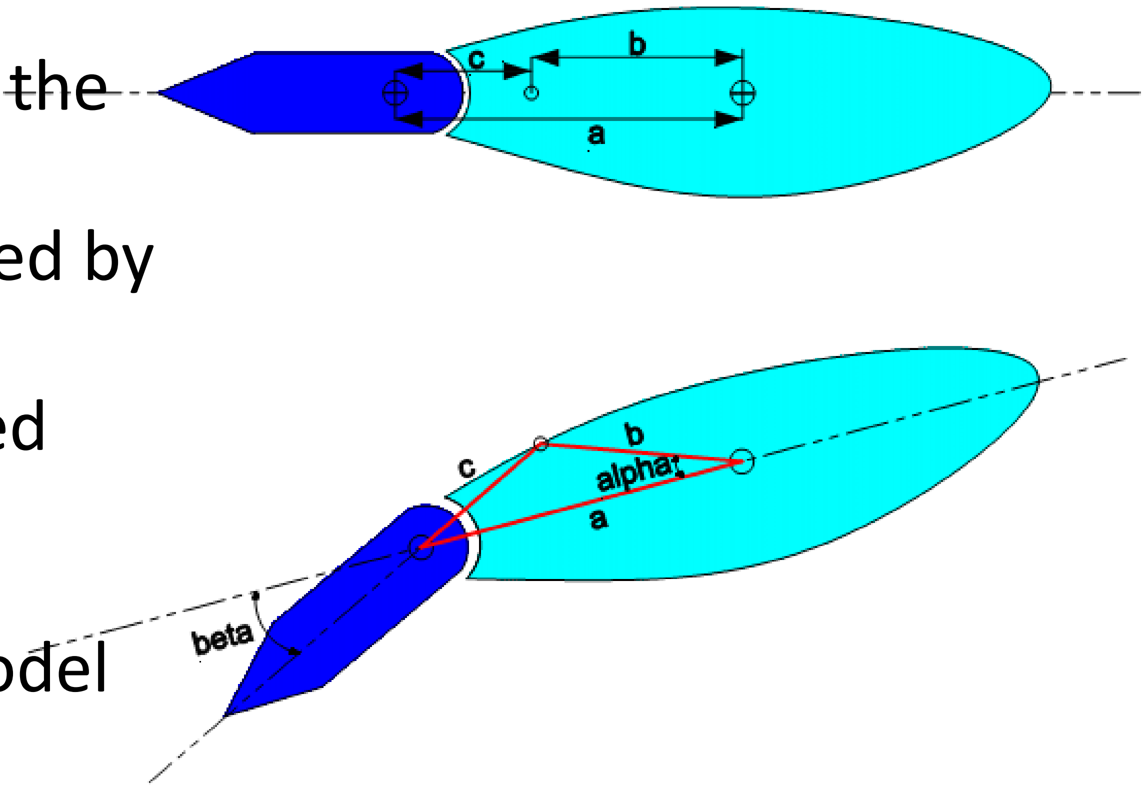
Objectives of the Study

- Feedback from large containership owners regarding the low maneuvering problem in shallow water
- Previous CFD analyses indicates that flow separation starts from the flap rather than the leading edge
- Existing linkage mechanism means relatively aggressive flap operation at small rudder angles
- Initial project aim to develop new flap actuation ratios

Becker Flap Rudder CFD Analysis

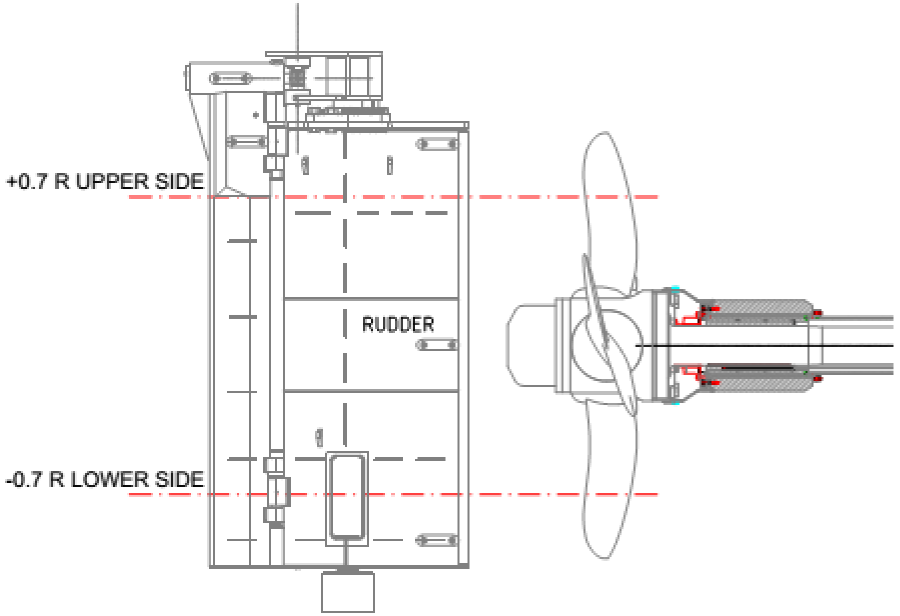
- **Two dimensional analysis**

1. New flap ratios find out by changing the value of a/b ratios.
2. a/b values from 1.5 to 1.7 incremented by 0.05
3. Flow analysis conducted at slow speed (8 knot) and cruise speed (23 knot) conditions.
4. Wake values are derived from the model test result at 14.5 m draft (V_A).

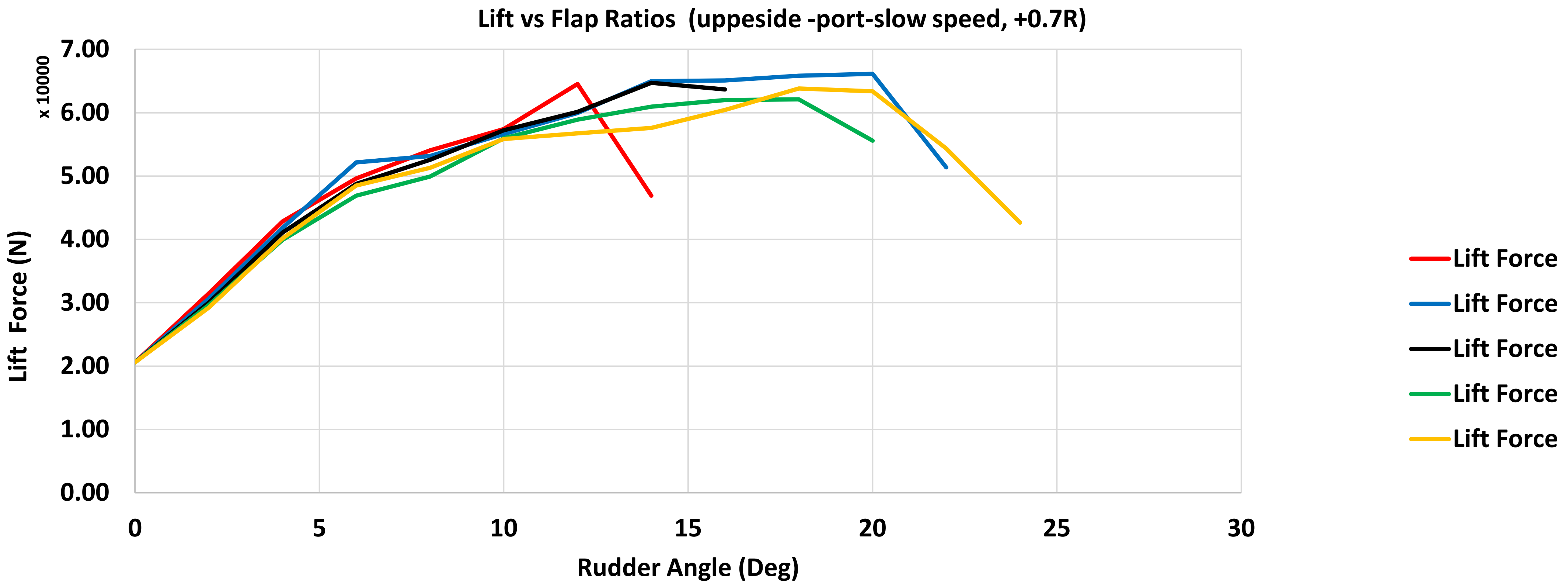


Details of 2D CFD Plan

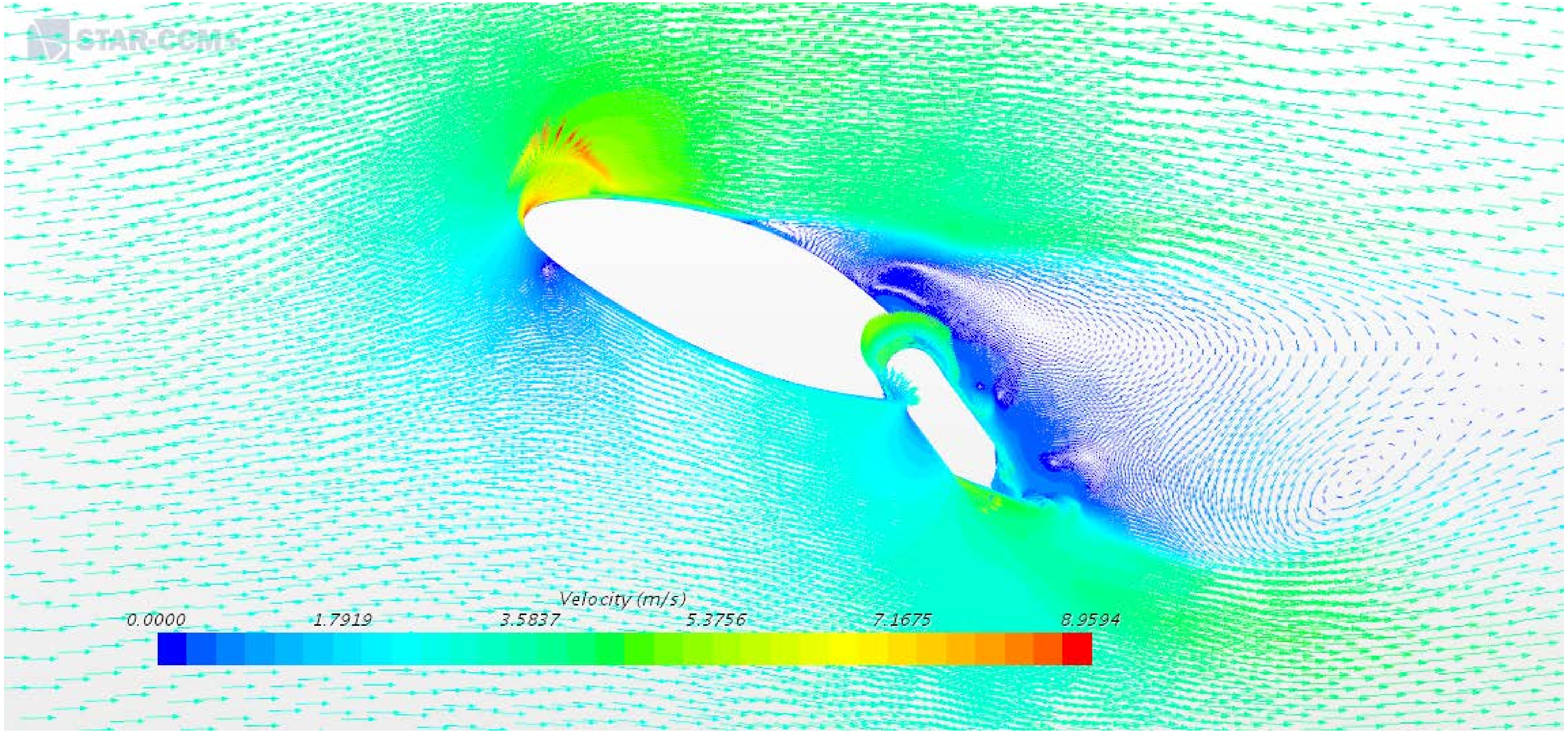
- Flow analysis conducted at +0.7R & -0.7R of the rudder horizontal section
- Domain size fixed based on chord length of rudder
- 50000 to 80000 cells used (polyhedral)
- Base size fixed at 0.9m with 1.05 times surface growth
- Prism layer count fixed at 7 with steady case & full scale rudder
- 5 to 10 minutes for meshing & analysis using 383 processor server



Results of Two Dimensional Analysis

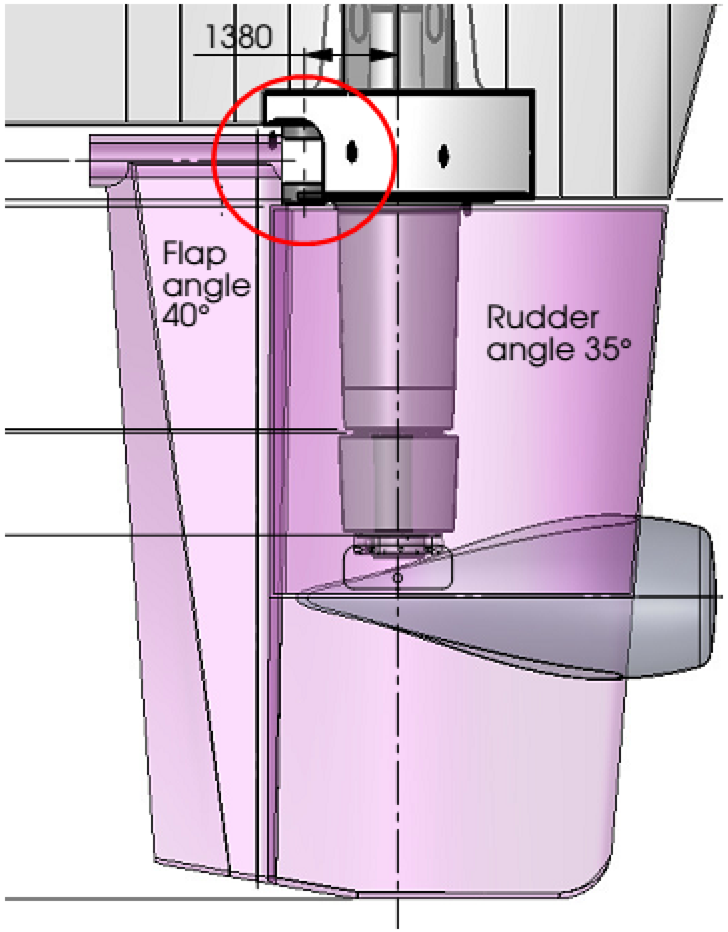


Flow Separation at 12° for Existing Flap Rudder



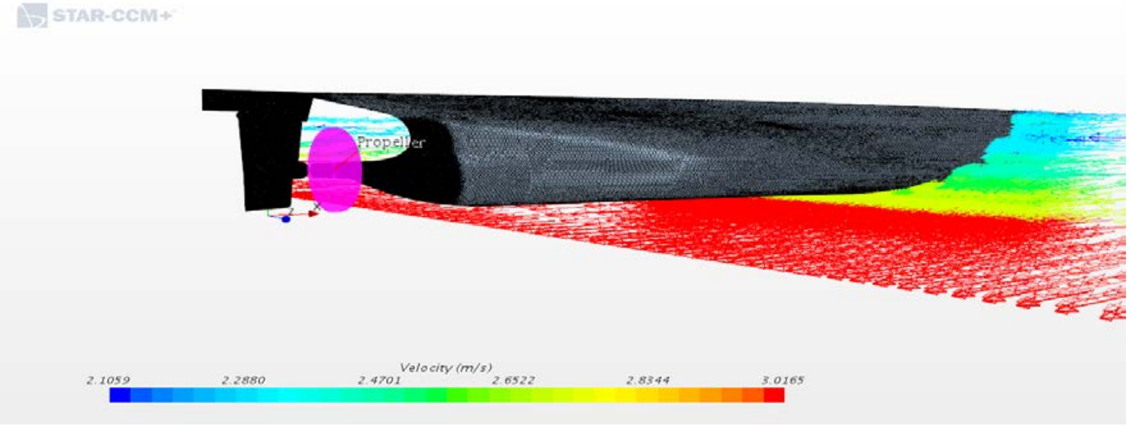
Result of Two Dimensional CFD Study

- Analysis result recommend that Flap Ratios D (a/b=1.7) has reduced aggressiveness in flap operation
- Stall angle delayed 6 to 8 degree for each case of Ratio D
- Further increase of a/b ratio not possible due to space limitations caused by trunk/stock dimensions
- Flow separation appears to start from the forward part of flap / end point of suction side of rudder



Three Dimensional Analysis

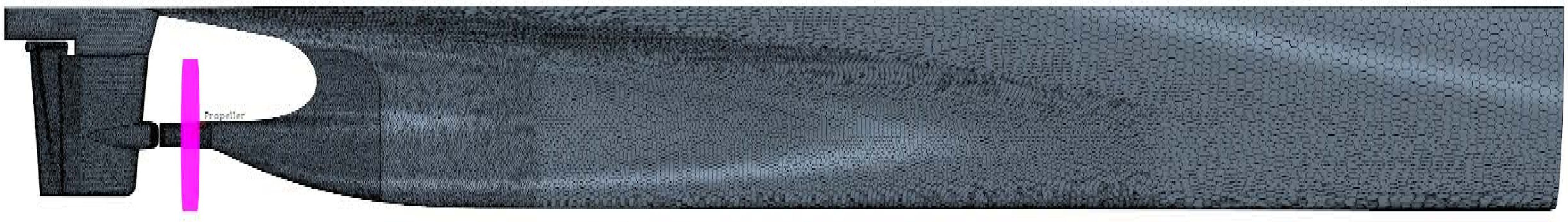
- Flow analysis done with the ship hull and virtual propeller.
- Wake calculated independently, file as table in STAR-CCM+.
- Comparison of existing ratios and optimum ratios
- Impact of water depth in rudder side force.
- Hull force in different water depth.

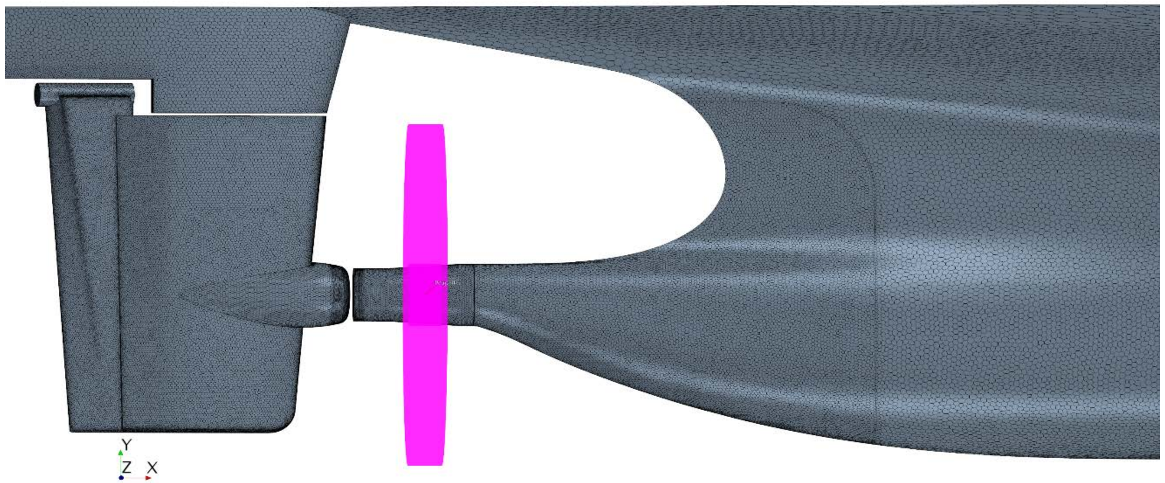


Details of Three Dimensional CFD Plan

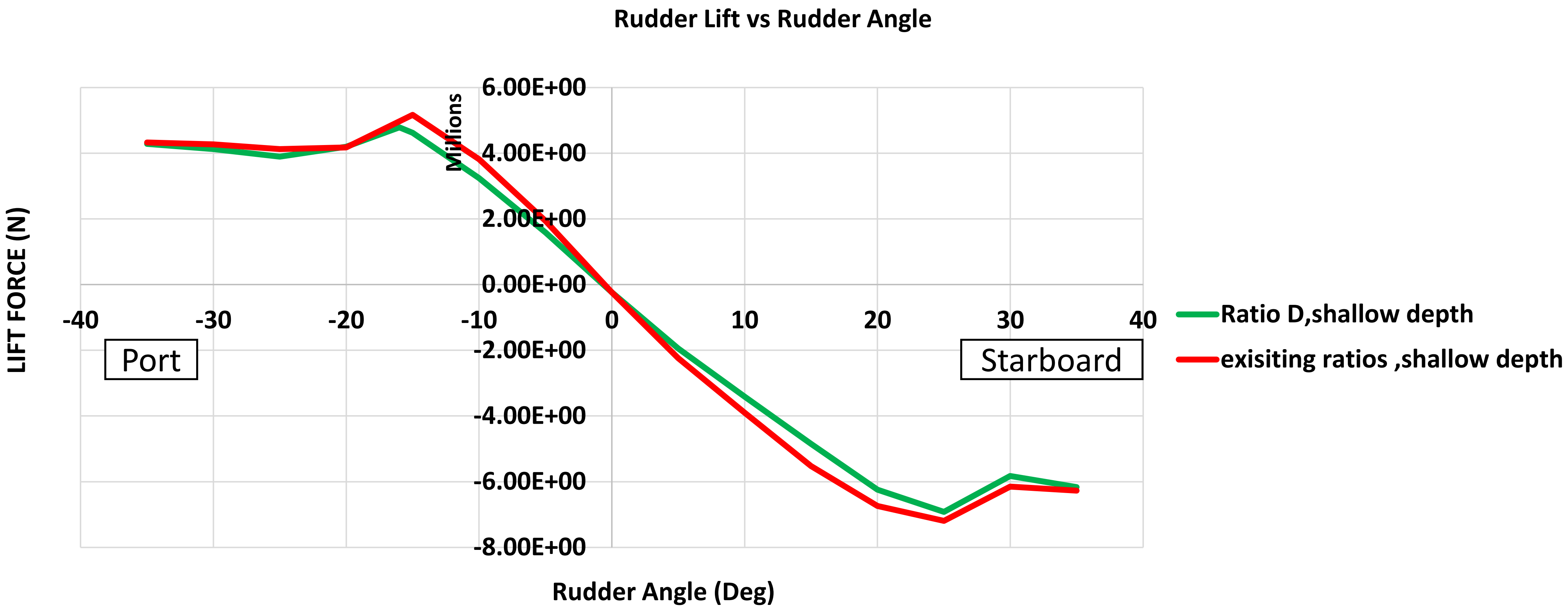
- Base size fixed 30.3 m
- 1/3 of the ship hull considered for the analysis
- Analysis done at full scale
- Steady-state
- 5 to 6 million cells used per case
- k-omega SST turbulence model used
- 383 processors
- Run time – about 2 hours per case

Details of Three Dimensional CFD Plan





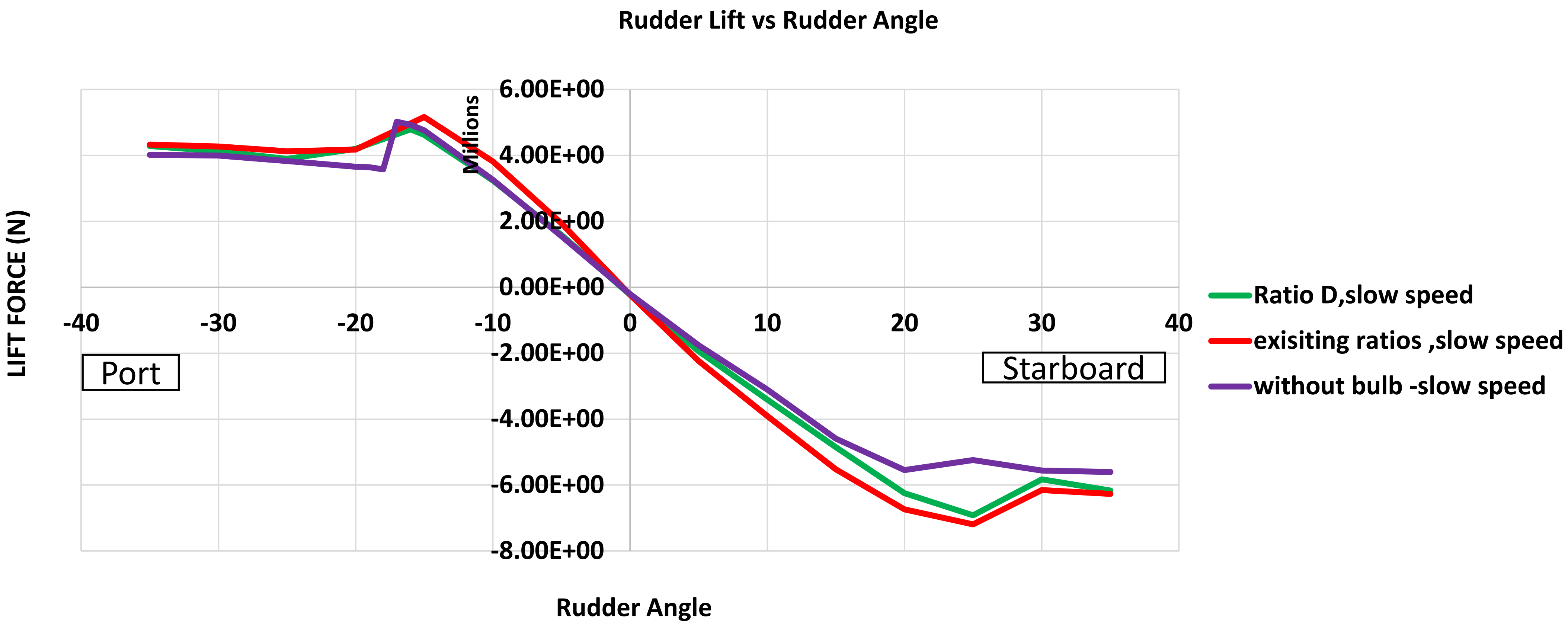
Result of Three Dimensional Analysis



Result of Three Dimensional Analysis

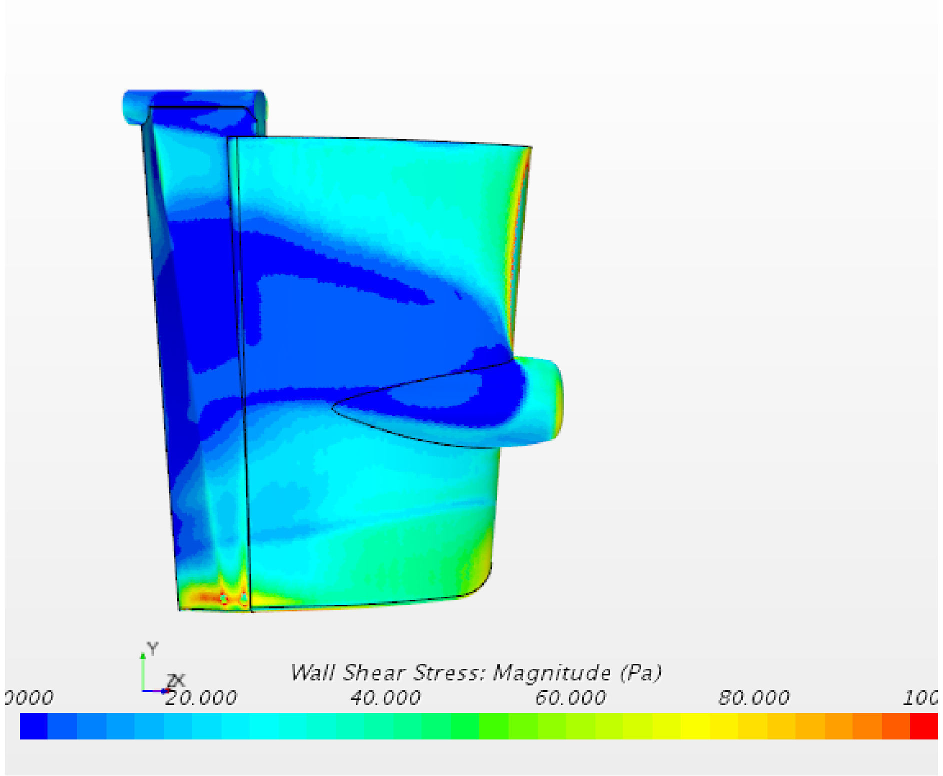
- Result from the 3D analysis are diffrent from the 2D analysis
- From the flow analysis realized that flow seperation start from the leading edge
- Rudder Bulb appear to triger flow seperation

Result Of Three Dimensional Analysis

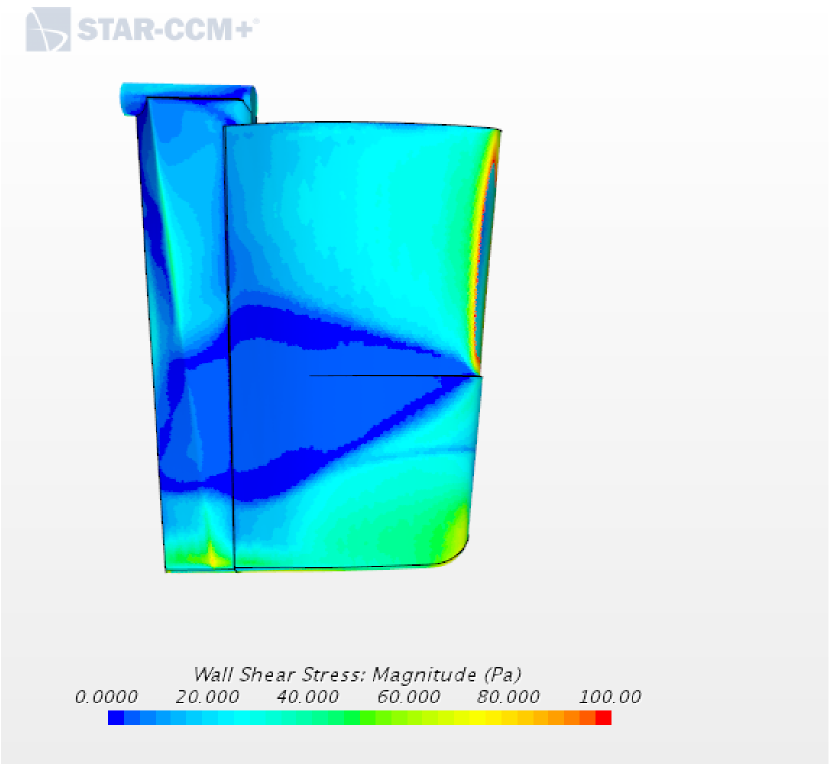


Shear Stress Distribution At 18° Rudder Angle

Rudder with normal condition



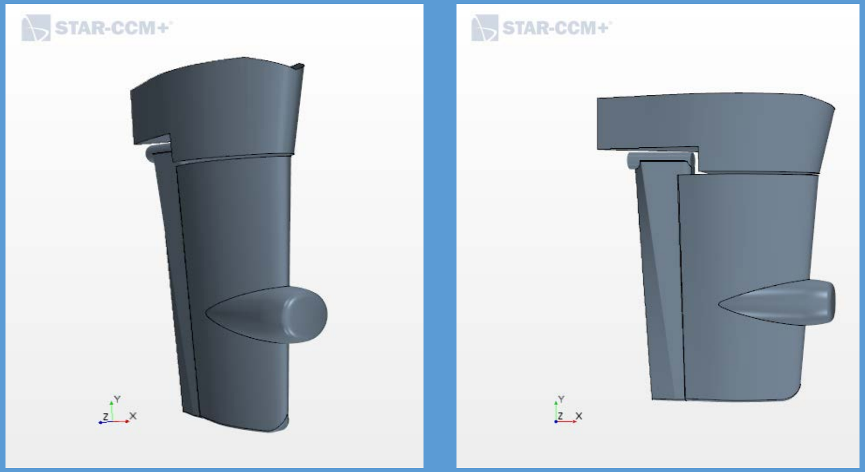
Rudder with the absence of bulb



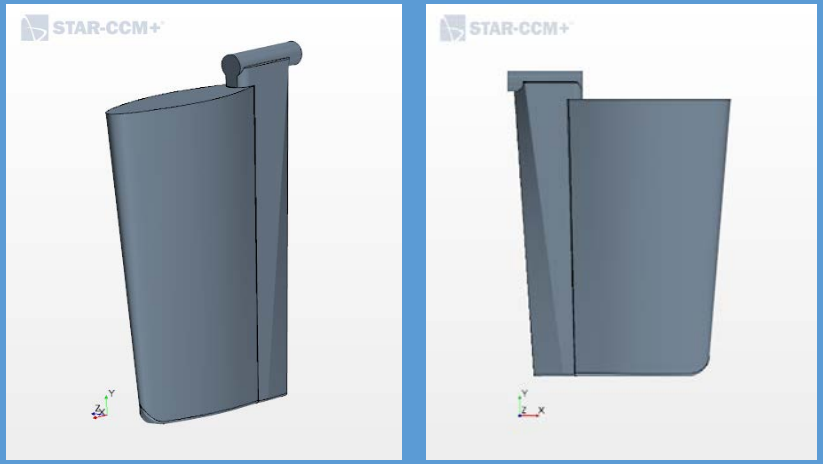
Leading Edge Flow Separation & Rudder Bulb Interaction

- Present flow analysis for the twisted flap rudder with bulb shows that flow separation starts from the leading edge of intersection of bulb and rudder geometry.
- Bulb is present to reduce fuel consumption – elimination of propeller hub vortex.
- Bulb optimized for power-saving.

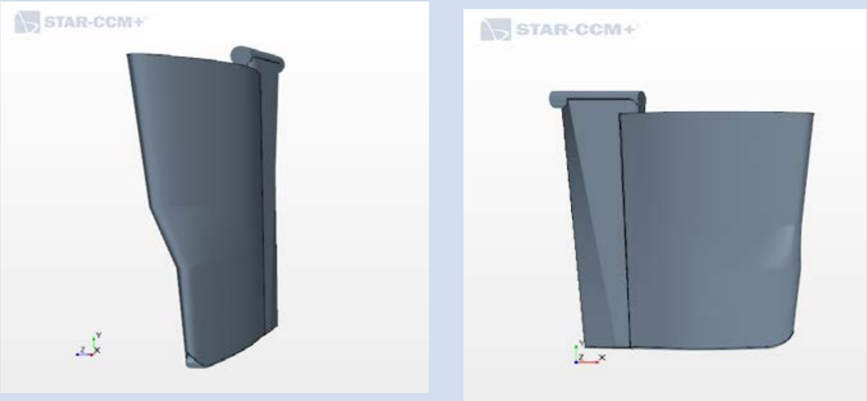
➡ Investigate effect of removing bulb



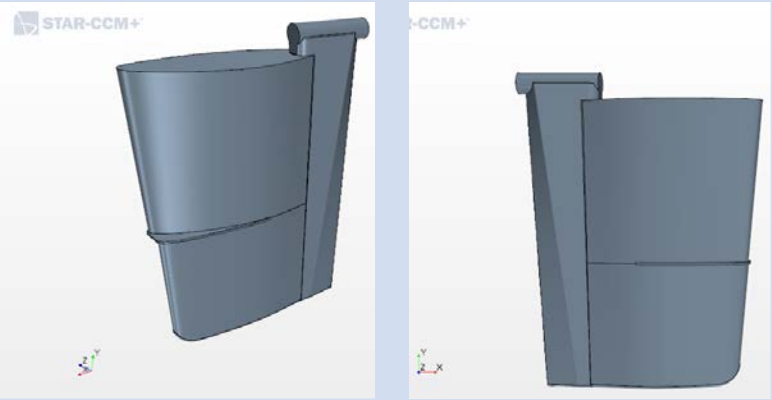
Symmetrical rudder with bulb



Symmetrical rudder without bulb

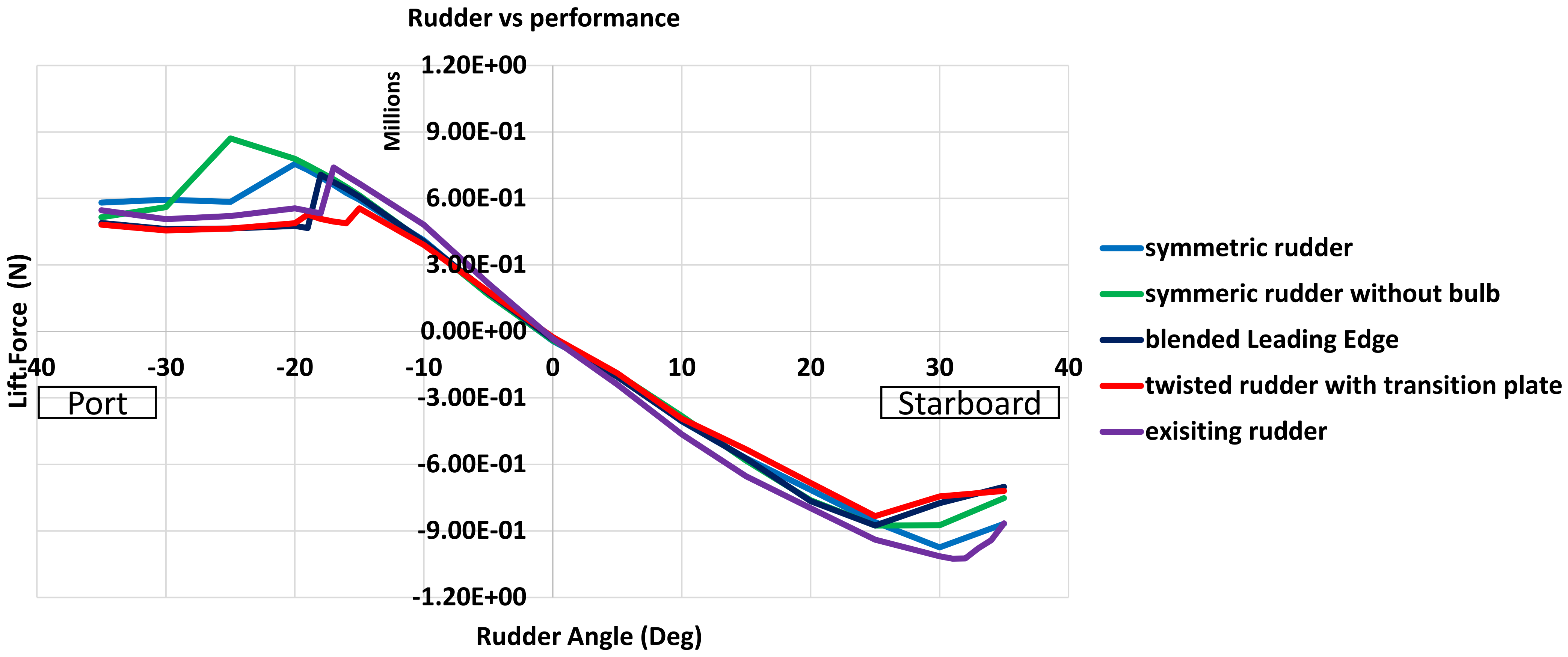


Twisted rudder with blended LE



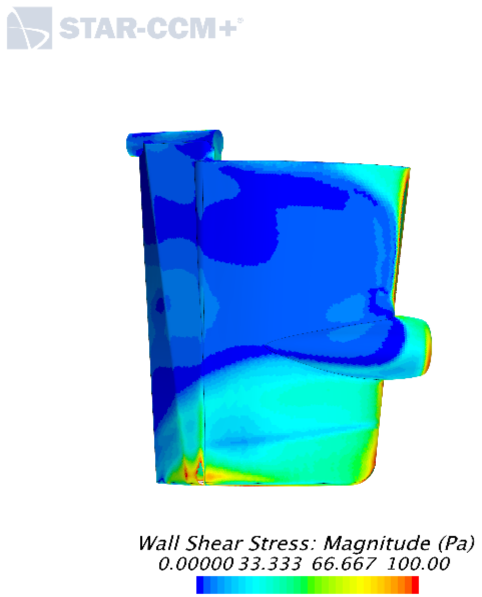
Twisted Rudder with horizontal transition plate

New Geometries Vs Existing Twisted Flap Rudder

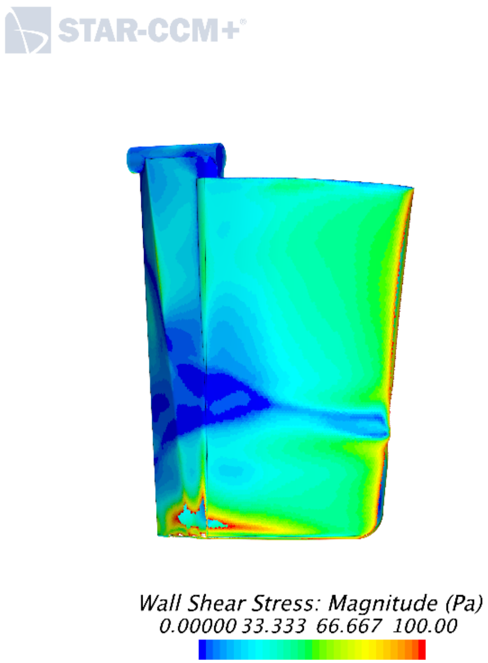


Shear Force Comparison -Existing & Symmetrical Rudder Geometry (Rudder and Flap rotate 25° towards port side)

Existing rudder with new ratio D

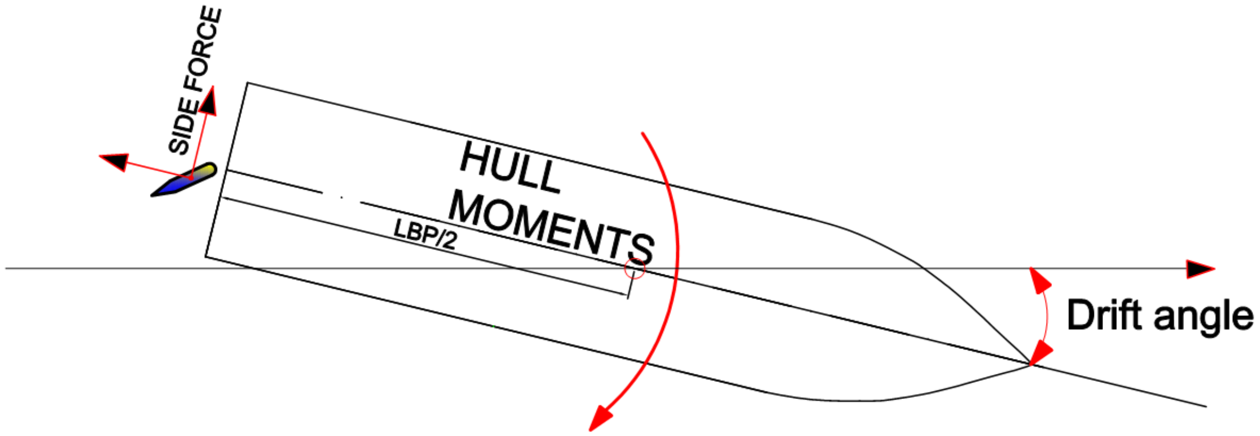


Symmetric rudder with new ratio D

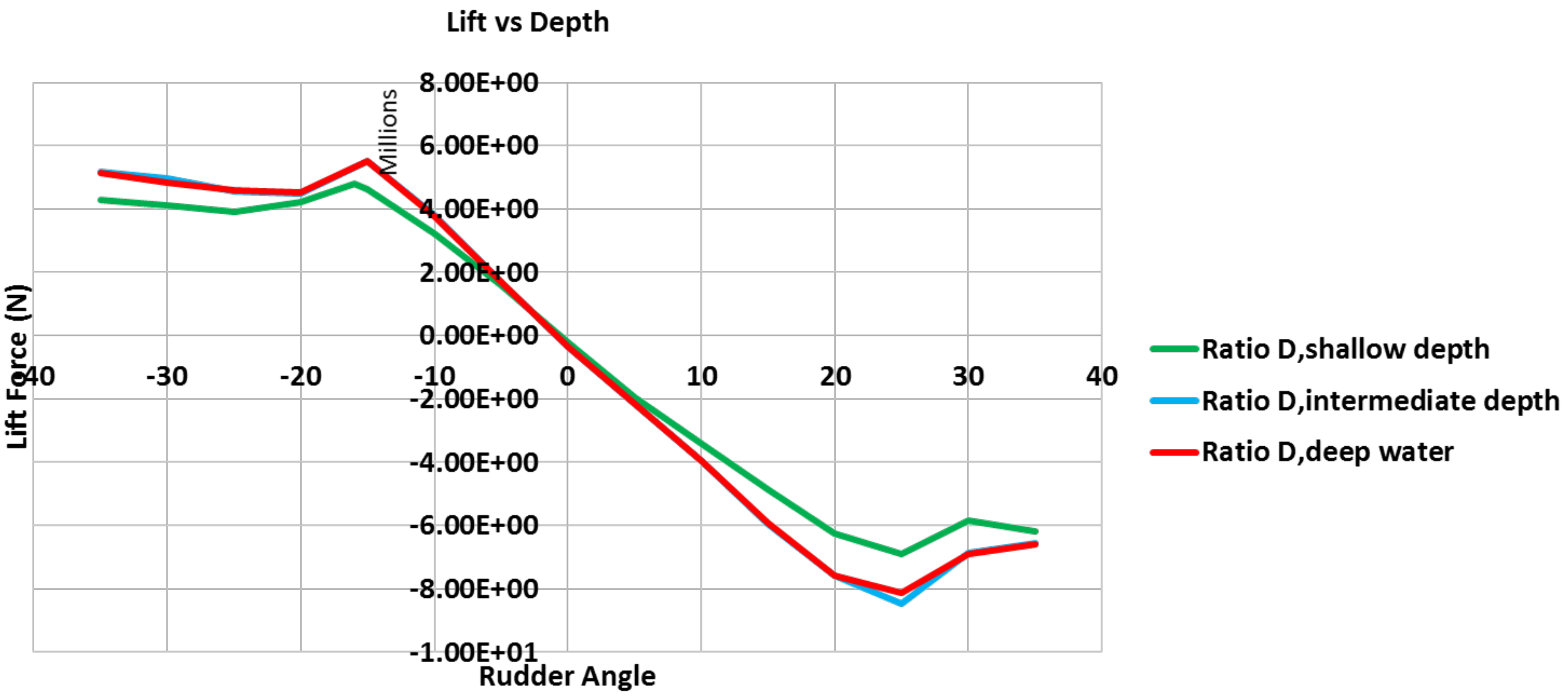


Impact of Ship Hull at Different Water Depths (8 knots)

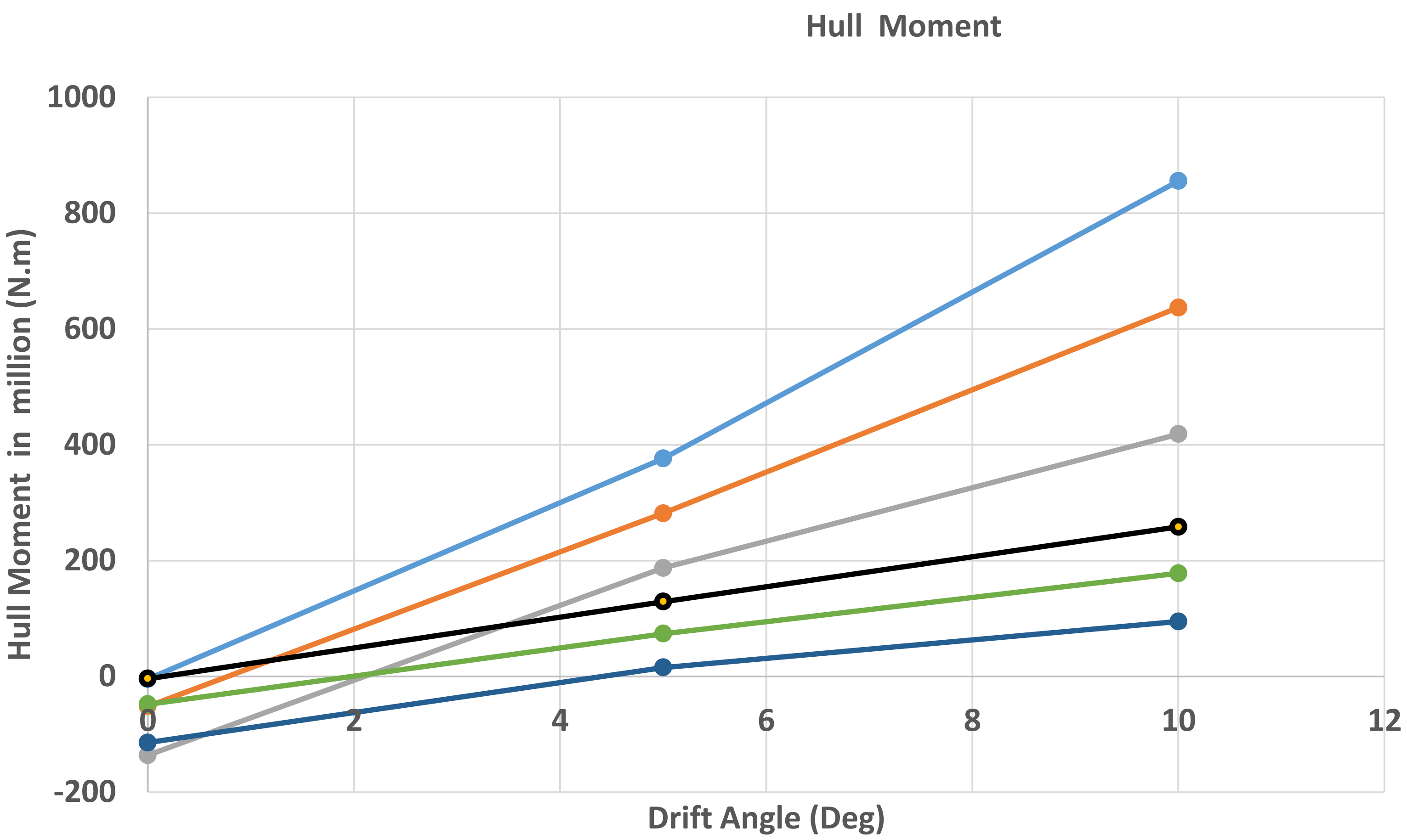
- In this section we compare the ship hull forces and moments with approximate rudder turning moment
- Ship hull force & turning moment are calculated with different turning radii to ship length ratio (R/L) and drift angle β

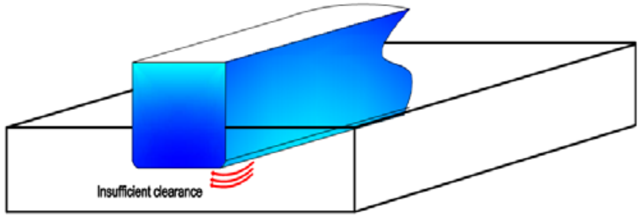


Rudder Side Force In Different Water Depths



Hull Moment &Rudder Moment –Suez Canal & Deep Depth





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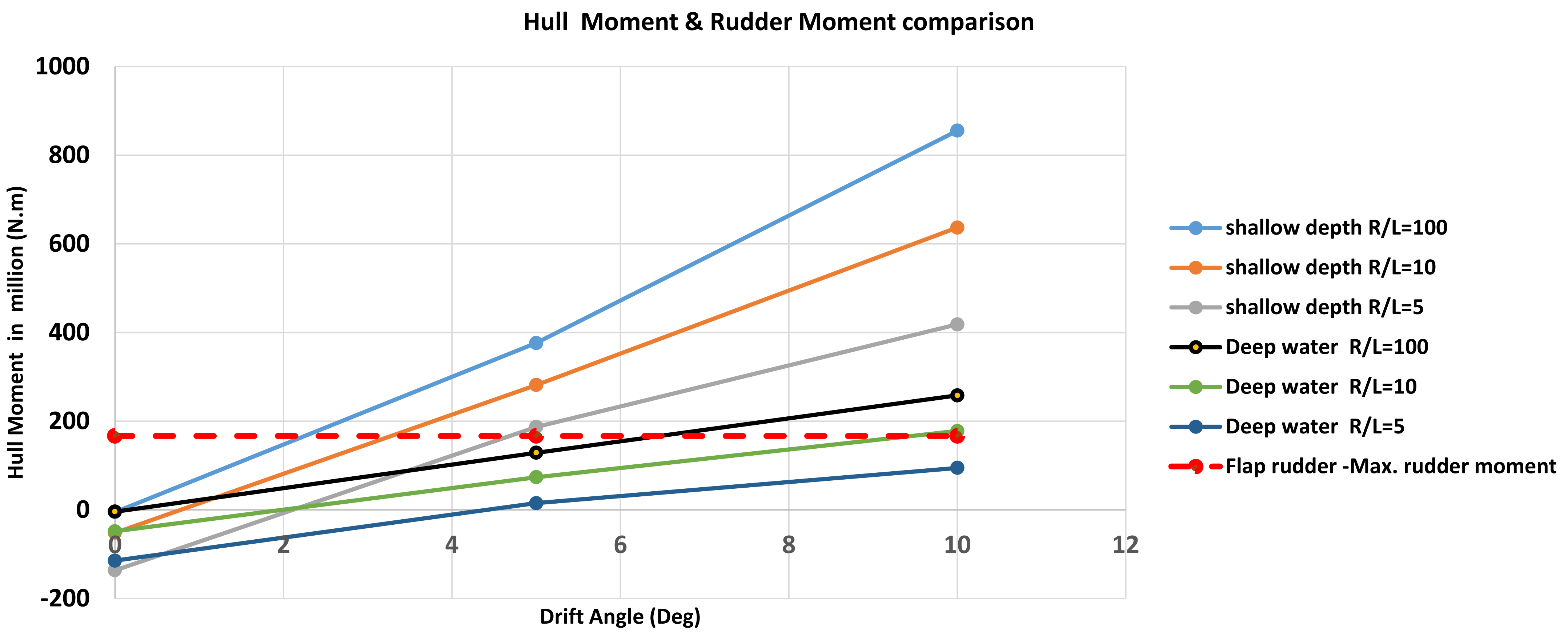

How to Overcome the Existing Problem of High Hull Force & Turning Moment

- Hull forces dominate in shallow water condition compared to deep water.

Solutions	Benefits	Penalties
Increasing rudder Area	Increasing the side force	operation difficulties
		production cost
Improving the rudder section	Improving the flow characteristics, Increasing the side force	Unlikely to provide sufficient improvement
Twin-screw propulsion	Increasing the side force in large magnitude	gain in side force vs production expense?

Conclusions

- 2D& 3D analysis results are different
- Flap ratio D has better performance
- Rudder bulb appears to start the flow separation at leading edge
- Numerical analysis of flow around rudder recommend that symmetrical rudder without bulb have improved flow separation & side forces than existing one
- Large container ships in shallow water – hull forces dominate.
- Vessel operated in shallow water require a specific recommendation of maneuvering operation

Future Works & Recommendations

- Transient analysis with explicit propeller (rotating mesh)
- Full 3D restrictions (include banking)
- Bulb details
- Model tests

Thank you