



POLITECNICO
MILANO 1863

Study of mass and CM position impact on a ship's hull resistance

Aerodynamics of Transport Vehicles

- 1 Study Case
 - Duisburg Test Case
 - Limiting Cases
- 2 Computational model
 - Setup
 - Problem Geometry
 - Mesh Independence Test
- 3 Results
 - Performance Comparison
 - Lift and Drag Components
 - Wave-Resistance
 - Flow visualization
- 4 Conclusions

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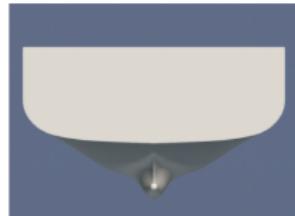
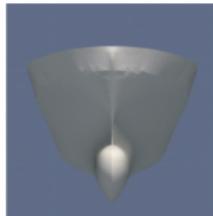
3 Results

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(a) MSC Beatrice - 14000TEU post-Panamax container vessel



(b) Bow, stern and side views of DTC

Model Scale → 1 : 59.407

Table: Main characteristics of DTC

	Ship	Model
L _{pp} [m]	355	5.976
B [m]	51	0.429
T [m]	14.5	0.244
V [m ³]	173467	0.827
C _b [-]	0.661	0.661

Problem definition

Masses:

- Normal loaded condition: 14000 TEU \approx 330000 kg \rightarrow 412.57 kg
- High loaded limiting case: 17000 TEU \approx 410000 kg \rightarrow 512.95 kg

Center of masses:

- Centered condition with the CM at half of the ship length
- CM placed 5% of the total hull's length FORWARD of the centered condition
- CM placed 5% of the total hull's length BACKWARD of the centered condition



(a) CM at 10% forward w.r.t baseline case



(b) CM at 10% behind w.r.t baseline case

Figure: Limiting cases for the displacement of the CM

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- OpenFOAM → interFOAM
- Free-surface modeling → Volume of Fluid method:

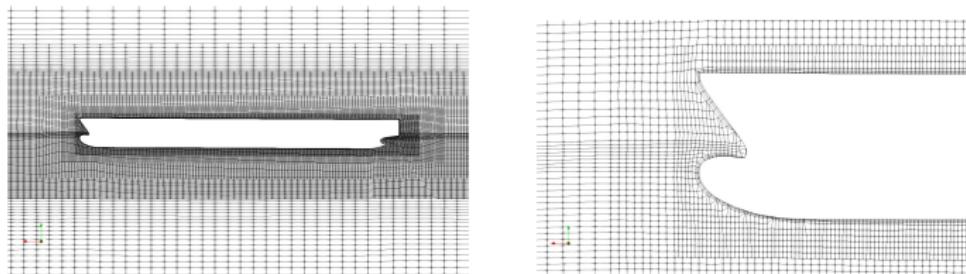
$$\alpha = \text{Volume fraction}$$

- Simulation of half of the hull (symmetry conditions)
- Assumptions: deep and calm water, no propeller, fixed trim condition and constant fluid (air and water) properties.

Table: Main Freestream conditions

Velocity	1.668 m/s
Froud Number	0.218

Grid generation → 848025 elements



Boundary Conditions (7 patches):

- Inlet, Outlet, Atmosphere → ship's velocity based
- Hull → no-slip wall condition
- Bottom, Side, MidPlane → symmetry planes

Mesh Independence Test

- **Coarse**: `refineMesh` → reduce number of divisions //
`snappyHexMesh` → `addLayers = False`
- **Medium**: `snappyHexMesh` → `addLayers = False`
- **Fine**: Baseline case

	Coarse	Medium	Fine
Number of cells	582312	766876	848025
Relative error C_L [%]	0.007	0.0068	-
Relative error C_D [%]	17.473	10.455	-

Table: Mesh Independence Test results

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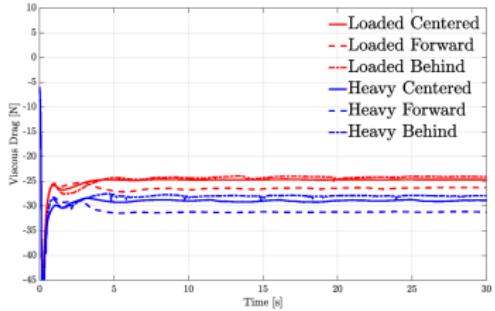
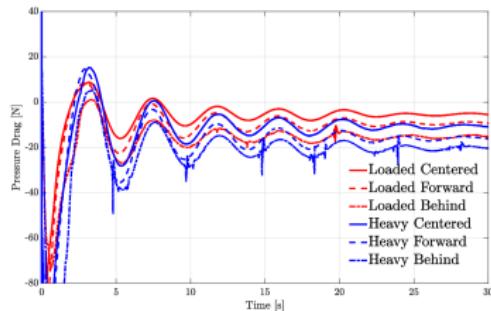
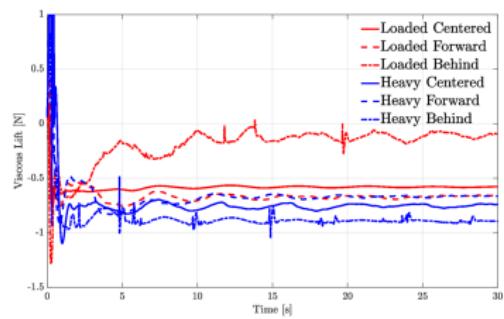
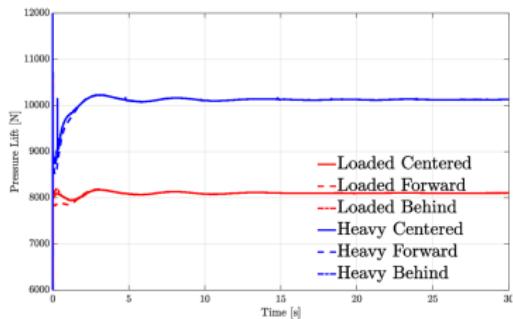
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Performance Comparison

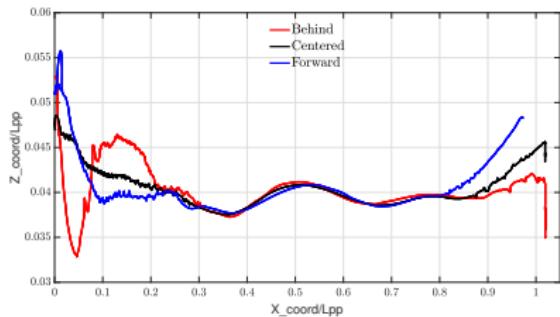
	Loaded			Heavily Loaded		
	Forward	Centered	Behind	Forward	Centered	Behind
Wetted Surface [m ²]	6.57432	6.32745	6.42725	7.10264	7.0882	6.98199
Total Lift [N]	8098.7373	8098.0481	8098.6951	10124.3678	10122.8498	10122.1400
Total Drag [N]	35.5922	30.0092	39.3558	47.2865	39.4632	48.2752
Lift coefficient	0.8223	0.9211	0.9069	1.1516	1.0278	1.0434
Drag coefficient	0.0036	0.0034	0.0044	0.0054	0.0040	0.0050

Lift and Drag Components

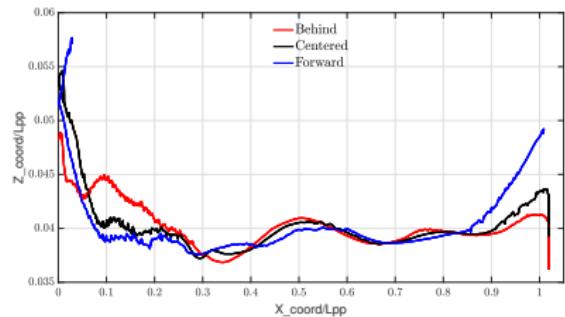


Wave-Resistance

Waterline's height for the different cases:



(a) Loaded case



(b) Heavily Loaded case

Flow visualization

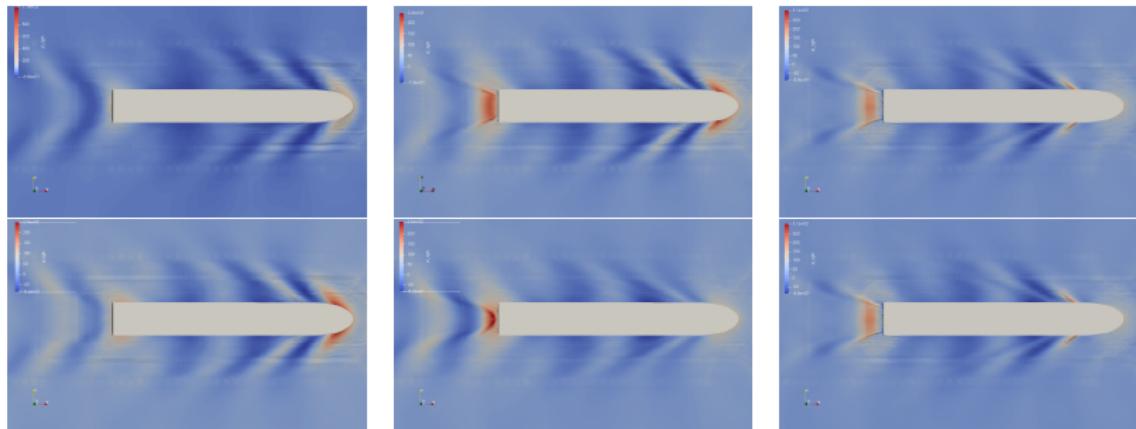


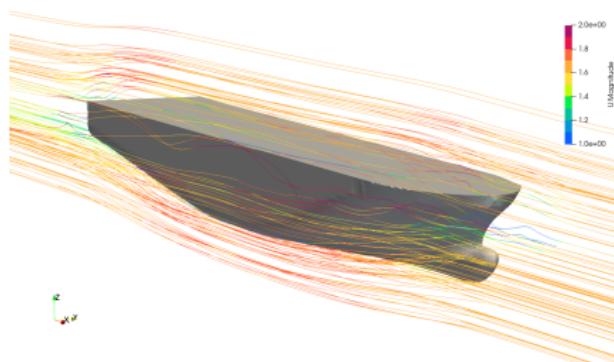
Figure: Dynamic pressure wave visualization in different configurations

Flow visualization

Waterline visualization for the high-loaded case



Water and Air streamlines



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- Optimal configuration → Centered for Loaded ($C_D = 0.0034$) and Heavily Loaded ($C_D = 0.0040$)
- Worst configuration → Forward Heavily Loaded ($C_D = 0.0054$)
- Pressure contribution dominating in the lift force
- Wave pattern captured in accordance with the theory