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Analysis of total resistance for different ship speeds

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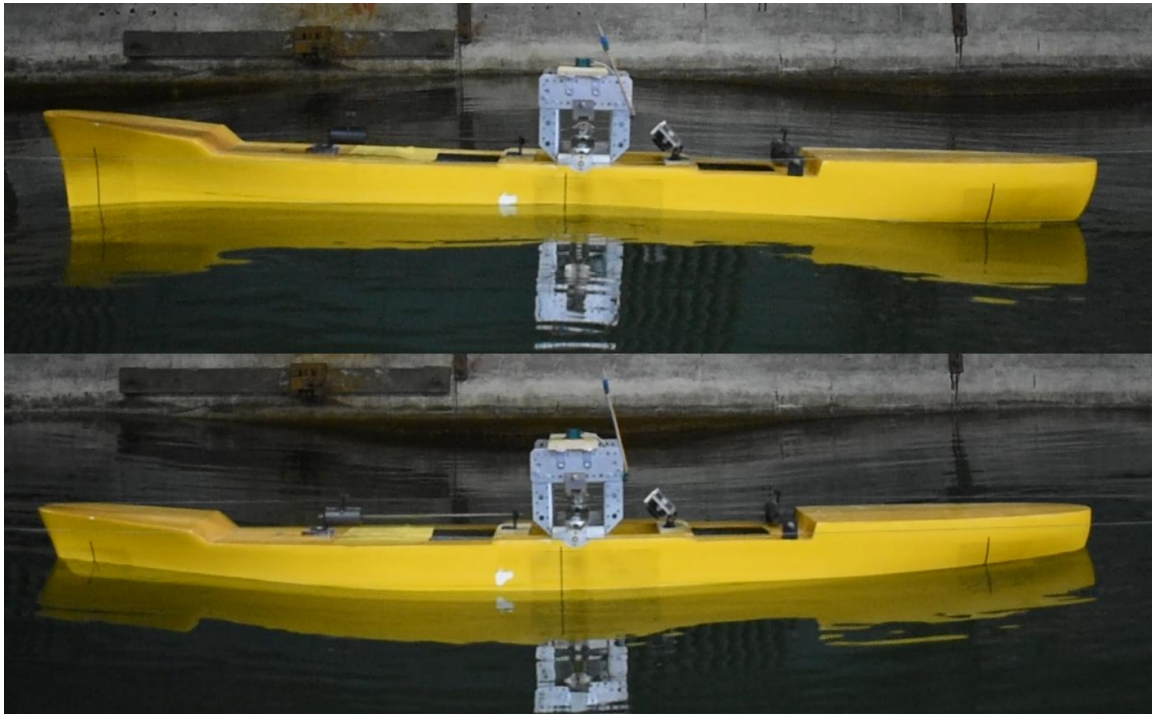
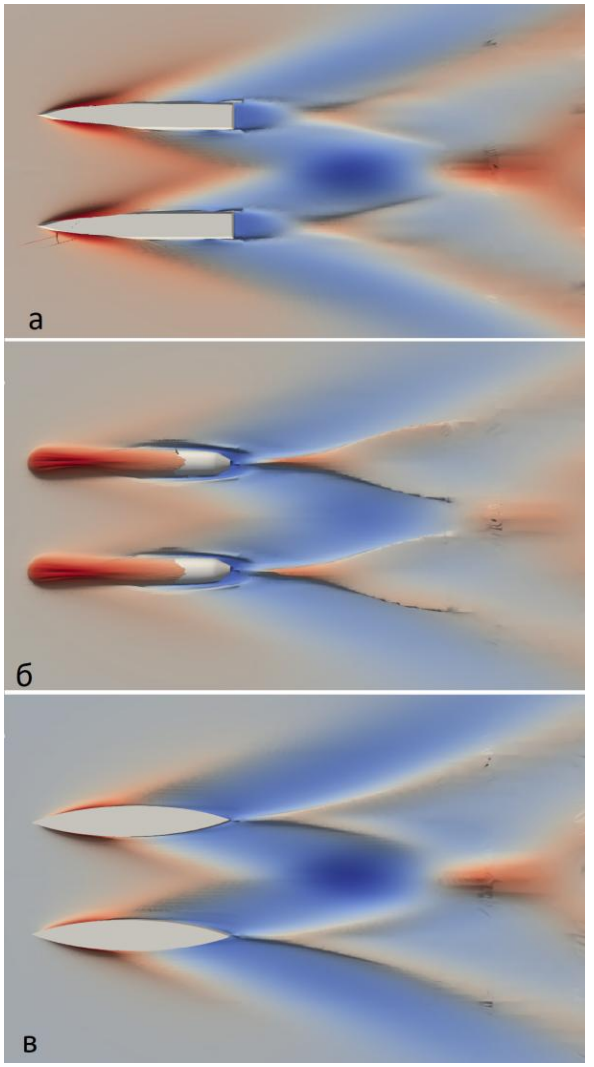
Introduction

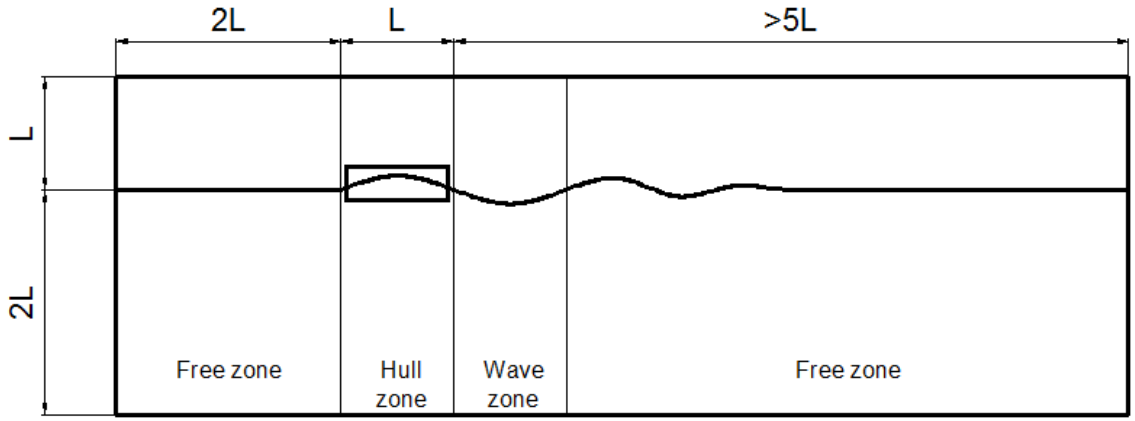
Hull resistance calculation:
- Empirical methods;
- Statistical methods;
- Model tests series results;
- Experiment;
- Numerical simulations.



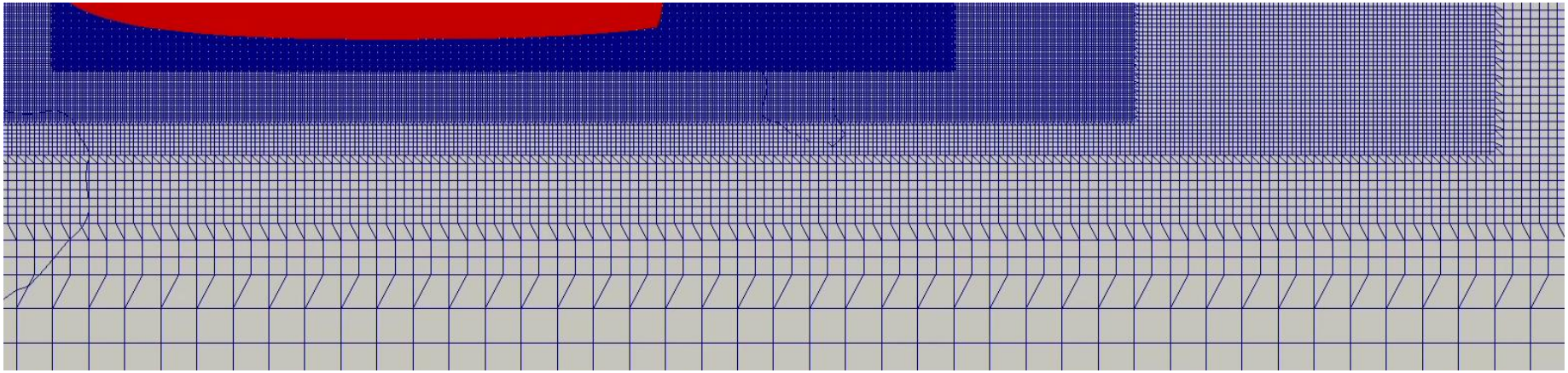


Numerical implementation in OpenFOAM

- interDyMFoam
  - k-ω SST
  - water & air
  - sixDoFRigidBodyMotion
- Mesh
  - blockMesh
  - topoSet
  - snappyHexMesh



L – ship length



Case validation

Mesh quality:
- Coarse grid (~936 000 cells);
- Medium grid (~ 2 867 000 cells);
- Good grid (~7 458 000 cells).

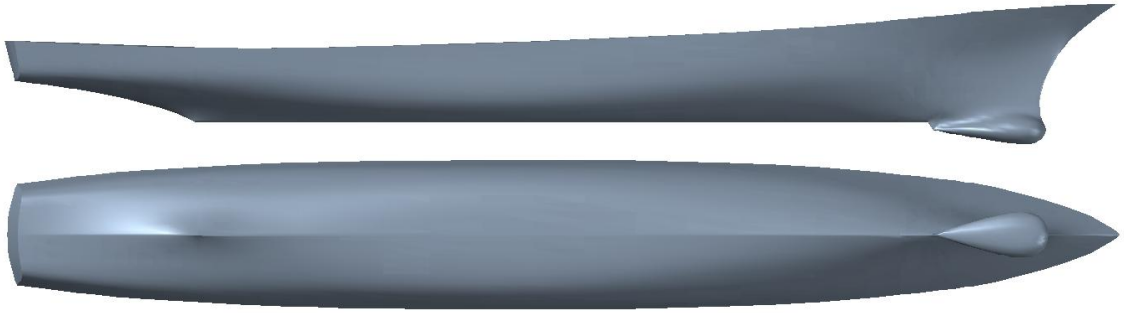
Ship speeds:
- Fr = 0.14 (friction resistance has maximum percentage in total resistance);
- Fr = 0.28 (wave-making resistance increases);
- Fr = 0.41 (wave-making resistance has main part in total resistance).

Data of model DTMB 5415[1,2,3]:
- Length L_{pp} = 3,048 m,
- Beam B = 0,409 m,
- Draft T = 0,132 m,
- Displacement D = 83,5 kg,
- Centre of gravity z_g = 0,163 m,
- Moment of inertia J_{55} = 48,5 kg·m^2.

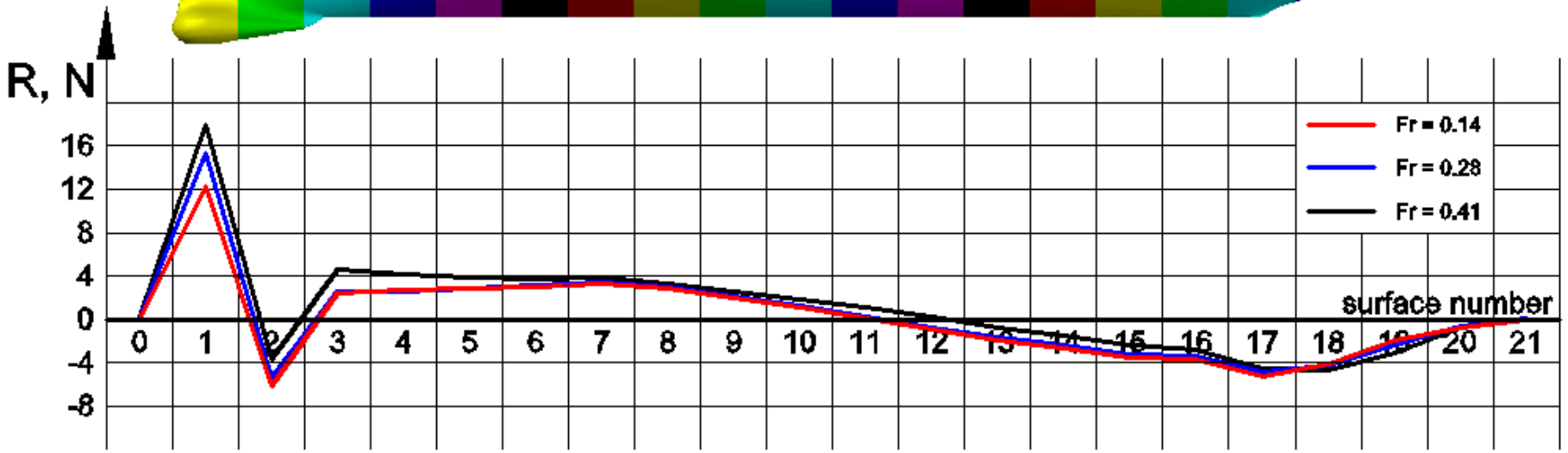
Turbulence properties[4]:
- T_u = 7,85 %;
- μ_t/μ = 540.

	Experiment[1,2,3]			Coarse grid			Medium grid			Good grid		
Fr	0,14	0,28	0,41	0,14	0,28	0,41	0,14	0,28	0,41	0,14	0,28	0,41
R_t, N	1,79	7,43	23,4	1,57	6,93	21,9	1,68	7,58	23,5	1,69	7,70	23,2
ξ, N	-	-	-	-0,22	-0,50	-1,46	-0,11	0,15	0,12	-0,10	0,27	-0,20
ζ	-	-	-	-12%	-7%	-6%	-6%	2%	1%	-6%	4%	-1%
t, h	-	-	-	2,6	4,0	6,0	10,0	15,9	31,0	23,0	57,9	147

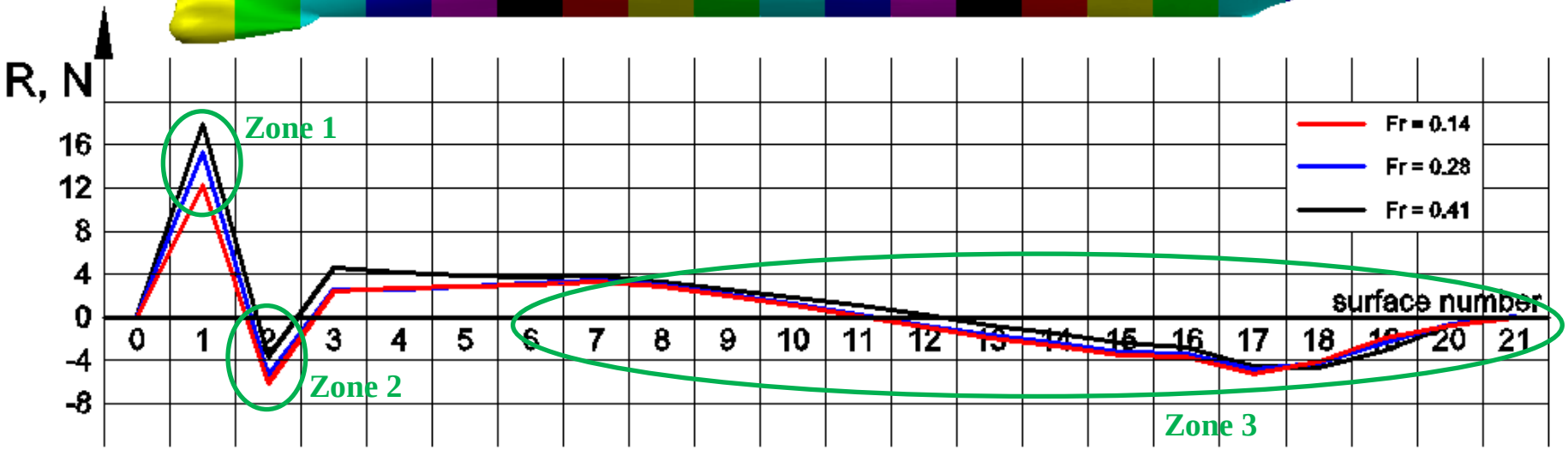
References:
1. Gui, L., Longo, J., and Stern, F., (2001), "Biases of PIV Measurement of Turbulent Flow and the Masked Correlation-Based Interrogation," Experiments in Fluids, Vol. 30, pp. 27-35.
2. Gui, L., Longo, J., and Stern, F., (2001), "Towing Tank PIV Measurement System, Data and Uncertainty Assessment for DTMB Model 5512," Experiments in Fluids, Vol. 31, pp. 336-346.
3. Longo, J. and Stern, F., (2005), "Uncertainty Assessment for Towing Tank Tests With Example for Surface Combatant DTMB Model 5415," J. Ship Research, Vol. 49, No. 1, pg. 55-68.
4. Henry Peter Piehl. Ship Roll Damping Analysis. Von der Fakultät für Ingenieurswissenschaften, Abteilung Maschinenbau und Verfahrenstechnik, der Universität Duisburg-Essen zur Erlangung des akademischen Grades eines. Doktors der Ingenieurswissenschaften Dr.-Ing. April 2016.



Resistance analysis method



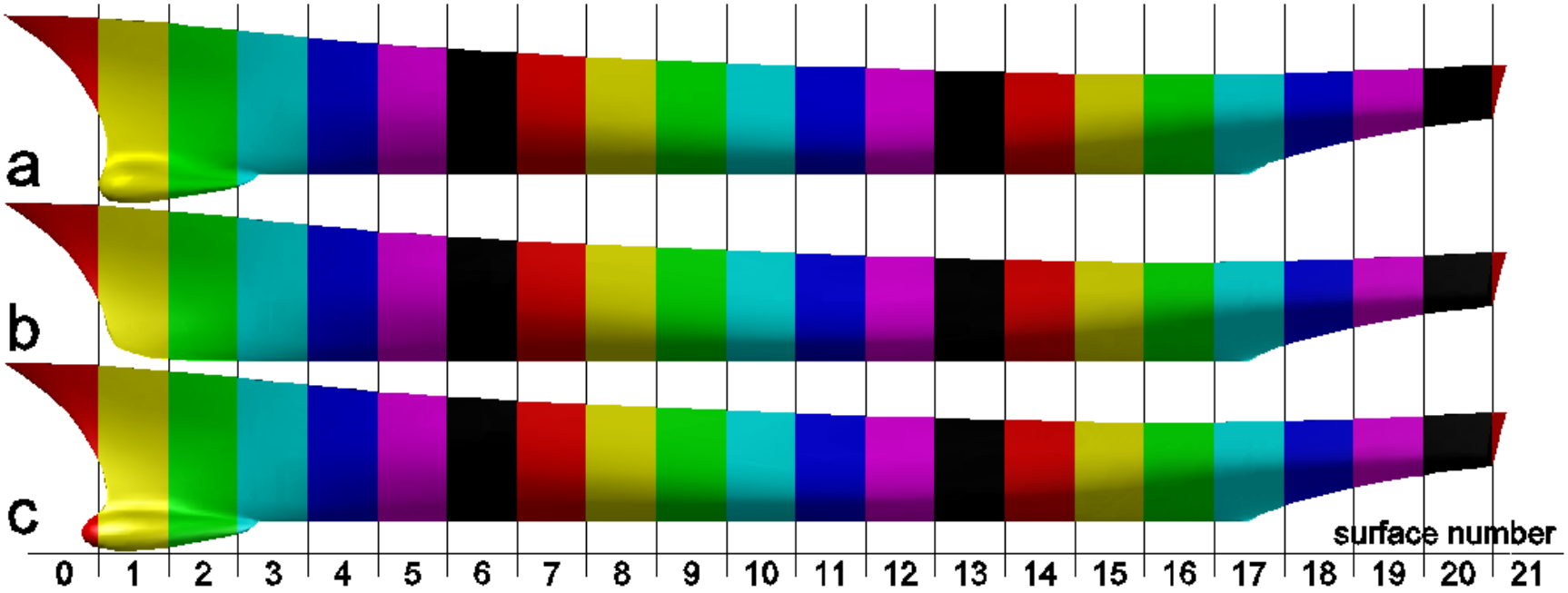
Resistance analysis method



Zone 1: Maximum peak of resistance force on the nose part of the bulb;
Zone 2: Minimum peak of resistance force on the stern part of the bulb;
Zone 3: Approximately the same value of resistance force.

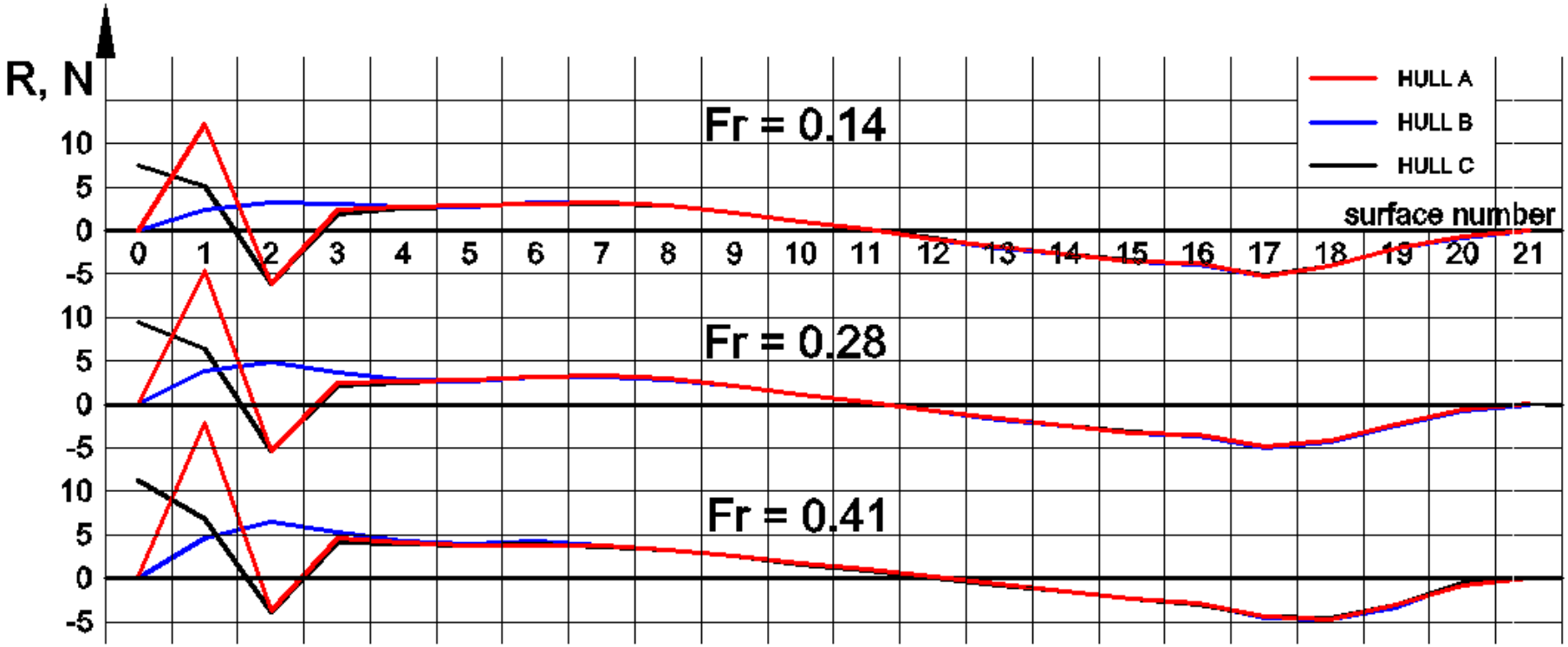
In total:
Bulbous stem should be modernized.

Resistance curves analysis

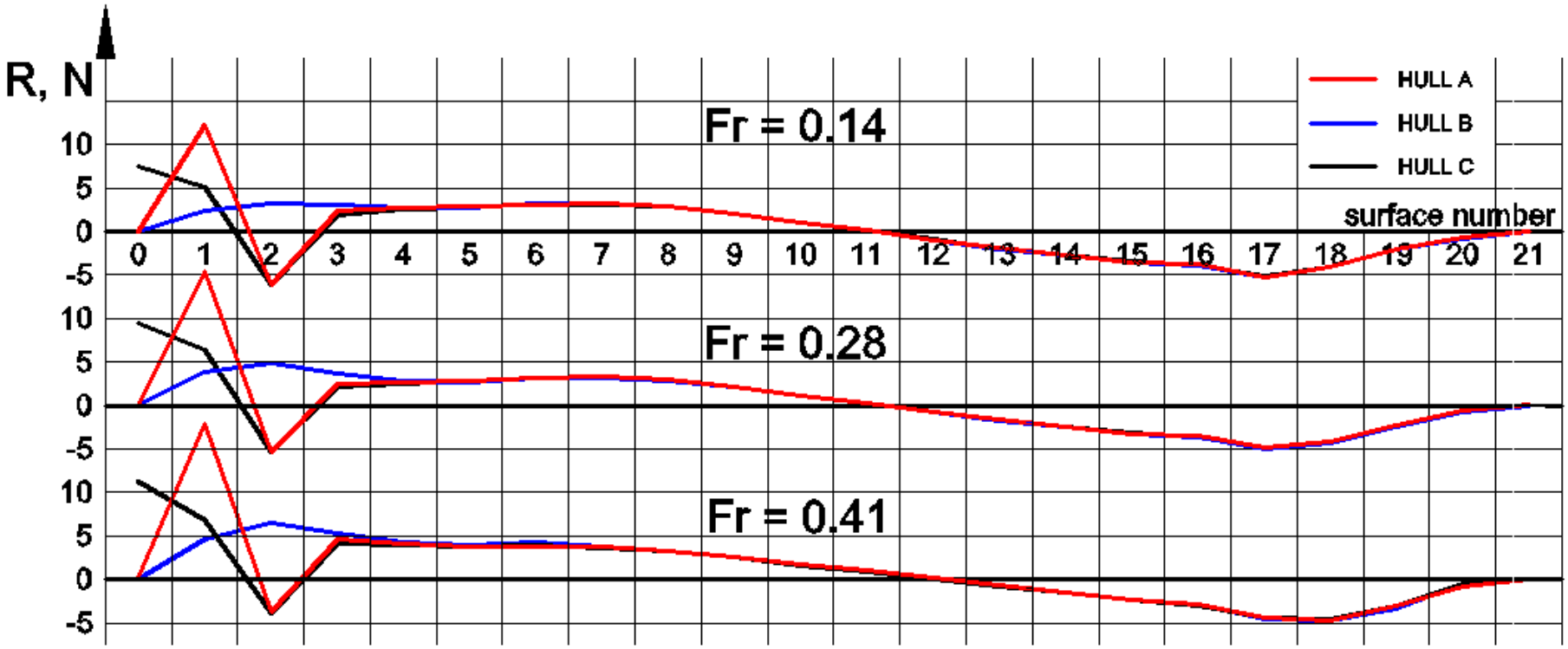


Froude number	HULL 1 (a) original	HULL 2 (b)	HULL 3 (c)
0,14	1,68	1,19	1,47
0,28	7,70	6,14	6,73
0,41	23,16	21,27	21,30

Resistance curves analysis



Resistance curves analysis



Hull B: Without bulbous bow there are not any extreme peaks;

Hull C: Maximum peak is lower than for Hull A;
Minimum peak of resistance on the 3rd surface is saved;

Resistance curves have not any changes after 4th surface.

Conclusion

Results:

• OpenFOAM software recommended to ship resistance calculations using at least medium grids. Accuracy increases with ship speed increasing due to percentage of friction resistance decreases in total resistance;

• Distributed resistance force has peaks on bulbous stem. Distributed resistance force on middle and stern parts of hull almost does not depend on ship speed (~3/4 ship length);

• Distributed resistance force on middle and stern parts of hull does not depend on stem part lines (~3/4 ship length);

• Stem part of hull has the most important influence on total resistance.

Thanks for your attention