CONFIDENTIAL

NepTech
Intelligent sea mobility

CFD VALIDATION STUDY :

KCS_CASE_2.1 - CALM WATER - MEDIUM_MESH

OCTOBER 2024

Informations

Context : This presentation aims to detail the results obtained through Computational Fluid Dynamics (CFD), as part of a validation study comparing experimental data with the digital test basin developed by NepTech, to validate the expected performance of the KRISO Container Ship (KCS) model, using an intermediate mesh, which was employed as a benchmark in the Tokyo 2015 Workshop on CFD in Ship Hydrodynamics.

Abbreviations :

- AGR = « Adaptive Grid Refinement »
- CFD = « Computational Fluid Dynamics »
- ITTC = « International Towing Tank Conference »
- LCG / TCG / VCG = Longitudinal / Transverse / Vertical Position of the Center of Gravity
- QS = « Quasi-Static »
- URANS = « Reynolds-averaged Navier-Stokes »
- VoF = « Volume of Fluid »
- SST = « Shear-Stress Transport »

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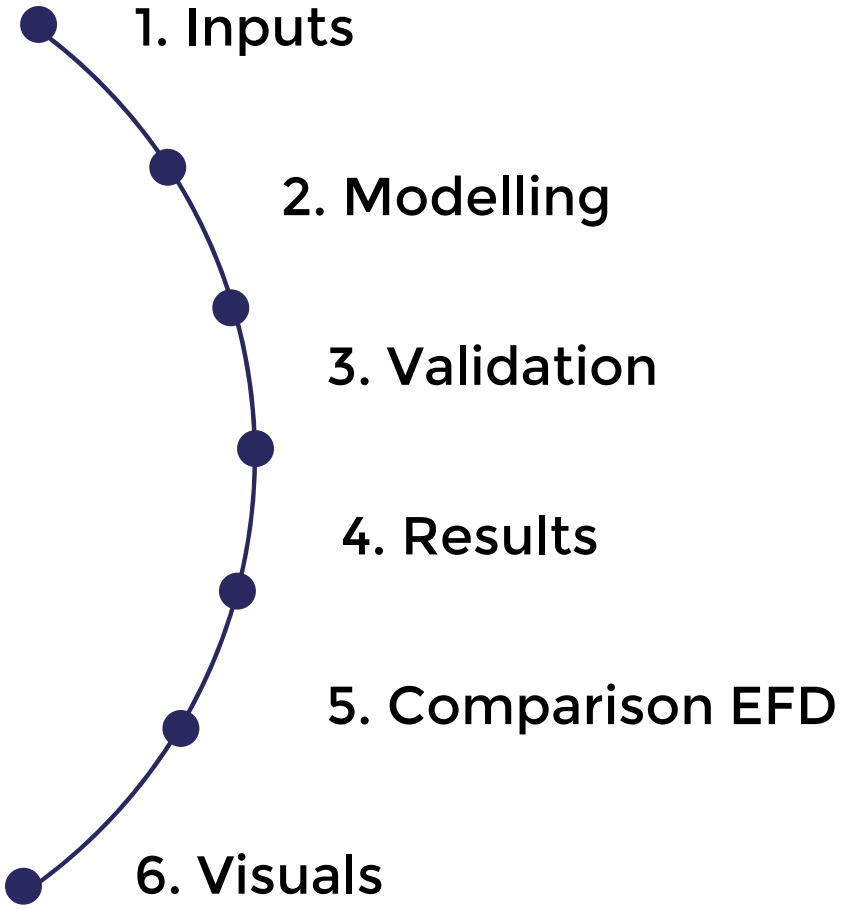
Summary


1. Inputs
2. Modelling
3. Validation
4. Results
5. Comparison EFD
6. Visuals

1. INPUTS

Hull geometry :

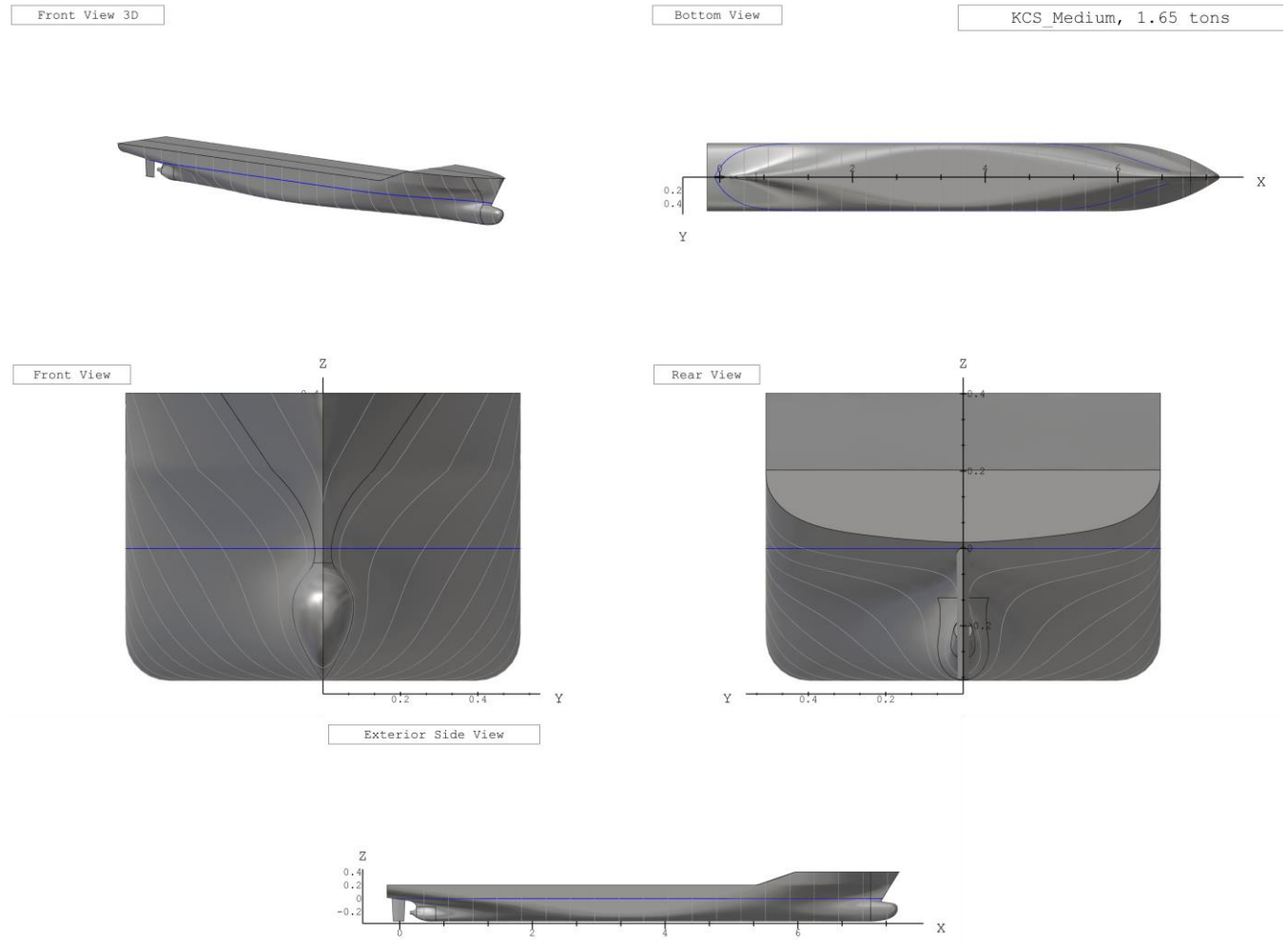
- Type : Hull with fixed rudder
- NepTech hull reference : KCS_Case_2.1
- Loading case : full load

	Description	KCS_Medium
0	Mass, Δ [t]	1.65
1	Immerged volume, ∇ [m^3]	1.65
2	Overall length, LOA [m]	7.72
3	Waterline length, L_{WL} [m]	7.39
4	Waterline beam, B_{WL} (1 float if catamaran) [m]	1.02
5	Draft, D [m]	0.34
6	Flotation surface, S_f [m^2]	6.16
7	Hydrostatic wetted surface, S_w [m^2]	9.68
8	Flotation center [m ; m ; m]	3.23, 0.00, 0.00
9	Buoyancy center [m ; m ; m]	3.53, 0.00, -0.15

Detailed characteristics of the hull

	Description	KCS_Medium
0	$\frac{L_{WL}}{B_{WL}}[-]$	7.24
1	$\frac{B_{WL}}{D}[-]$	2.98
2	$\frac{L_{WL}}{\nabla^{1/3}}[-]$	6.25
3	$C_B[-]$	0.64
4	LCB [%]	47.76

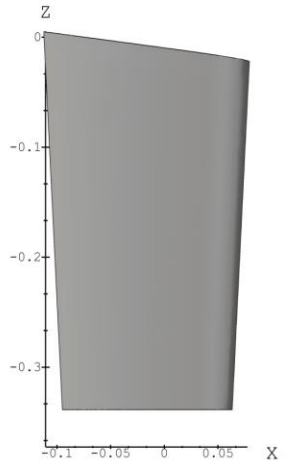
Global characteristics of the hull



Hull

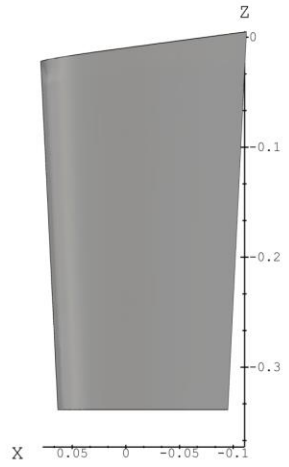
1. Inputs

Interior Side View, portside

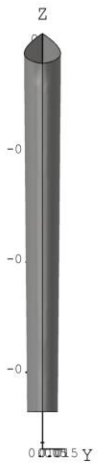


Exterior Side View, portside

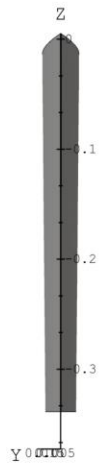
KCS_Medium, 1.65 tons



Front View, portside



Rear View, portside



Appendice(s)

2. MODELLING

a. Sign convention
b. Softwares
c. Hypothesis
d. Environmental conditions
e. Numerical models

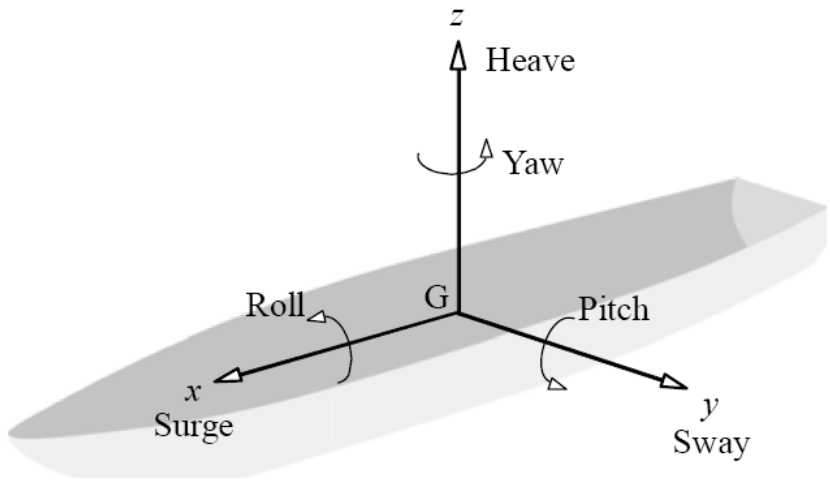
a. Sign convention

Heave

The heave values correspond to the dynamic elevation of the vessel at the center of gravity, relative to its hydrostatic position, in the absolute reference frame with the vertical axis Z oriented upwards. A positive heave value thus corresponds to a hull rise, while a negative value indicates the hull sinking.

Pitch

The pitch values correspond to the dynamic trim of the vessel at the center of gravity, relative to its hydrostatic position, in the absolute reference frame where the transverse axis is Y. A positive trim corresponds to a bow-up attitude of the hull.



2. Modelling

b. Softwares

Mesh : Hexpress™, version 12.1 developed by CADENCE

Resolution : Fidelity Fine Marine, version 12.1 developed by CADENCE

Solver : ISIS-CFD developed by CNRS and Centrale Nantes

Computing infrastructure : 2 virtual machines with 32 cores « STANDARD_F32S_V2 », optimized for computation on the Microsoft Azure cloud computing platform.

Post-processing :

- CFView™, version 12.1 developed by CADENCE
- Programming language Python version 3.11.6

**NepTech has automated the entire process, from mesh creation to post-processing of the results, to eliminate any risk of human errors.*

c. Hypothesis

Modeling scale : model scale (1/31.6), with a symmetry plane along the vessel's median axis. This approach helps reduce computation time while maintaining identical results.

Domain : the dimensions of the simulation domain are conformed to ITTC recommendations, ensuring that the boundaries are positioned sufficiently far from the vessel to avoid any influence on the solution. It is crucial, especially for the exit boundary, to place it in a way that prevents the reflection of the wave field generated by the vessel.

Hydrostatic equilibrium : the coordinates of the center of gravity are defined as follows

LCG = 3.53 m ; TCG = 0.00 m ; VCG = 0.01 m

d. Environmental conditions

Water : corresponds to fresh water, which is

$$\rho_{water} = 995.5\ kg/m^3$$
$$\mu_{water} = 1.269 * 10^{-3}\ Pa.s$$

Air : corresponds to air at a temperature of $15°C$, which is

$$\rho_{air} = 1.2256\ kg/m^3$$
$$\mu_{air} = 1.788 * 10^{-5}\ Pa.s$$

e. Numerical models

Dynamic equilibrium

- The Quasi-Static (QS) method is used since we are interested in the vessel's dynamic equilibrium state. This method relies on a succession of predictions of the vessel's physical attitude to reach the dynamic equilibrium state in record time.
- Two movements of the vessel, heave and pitch, are left free to ensure convergence toward the vessel's dynamic equilibrium position.

Flow

The Reynolds-Averaged Navier-Stokes (URANS) equations are used to describe the flow, and they are coupled with the $k-\omega\ SST$ turbulence model as the closure model.

Free surface

The air-water interface is modeled using the Volume of Fluid (VoF) method. Adaptive Grid Refinement (AGR), developed by CNRS (French National Center for Scientific Research) and Ecole Centrale de Nantes (French Engineering school), is used to model the free surface. This iterative process allows for dynamic adjustment of the mesh according to the solution's needs during the calculation, making refinement decisions based on the physics of the flow.

3. VALIDATION

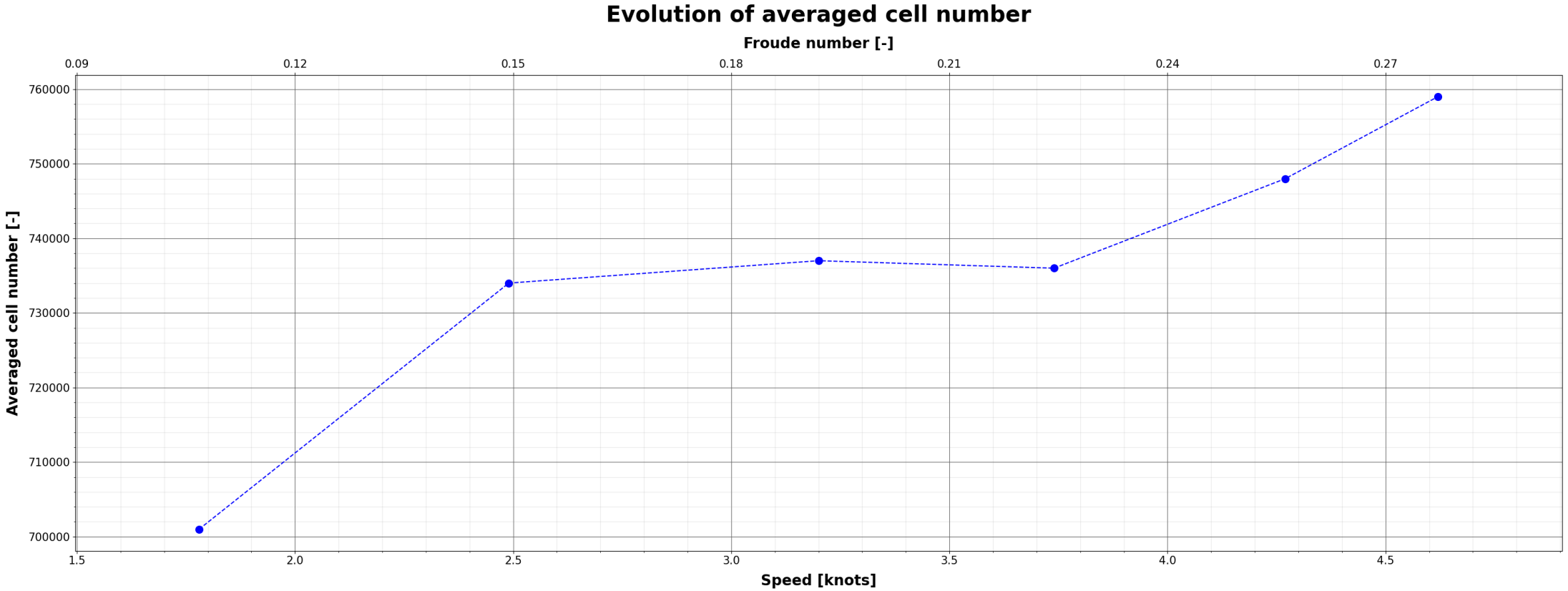
a. Mesh

1. Number of cells
2. Free surface
3. Hull

b. Courant number

c. Y+

a. Mesh (Number of cells : total)



	Speed [knots]	Froude number [-]	● Averaged cell number [-], KCS_Medium
0	1.78	0.11	7.01e+05
1	2.49	0.15	7.34e+05
2	3.20	0.19	7.37e+05
3	3.74	0.23	7.36e+05
4	4.27	0.26	7.48e+05
5	4.62	0.28	7.59e+05

3. VALIDATION

a. Mesh

1. Number of cells
2. Free surface
3. Hull

b. Courant number

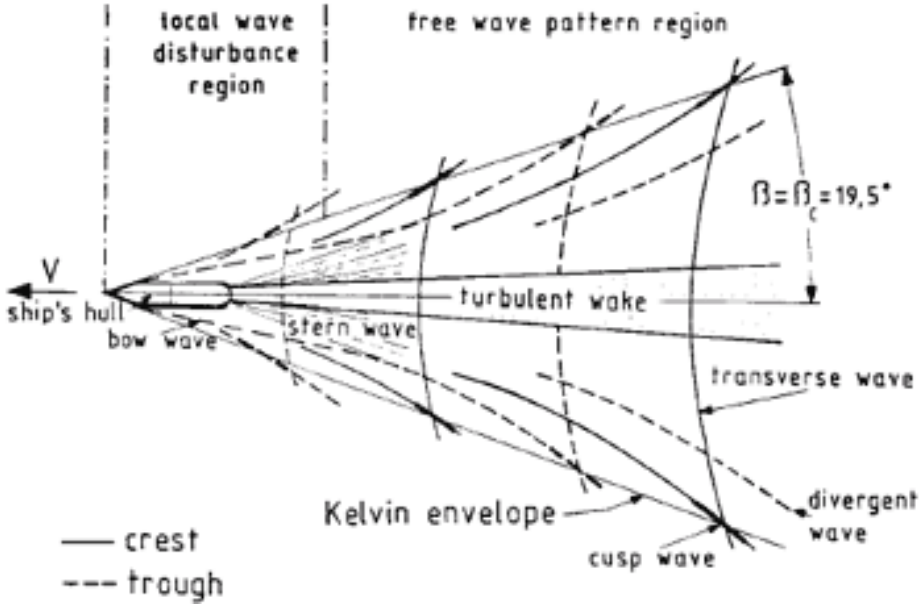
c. Y+

a. Mesh (Free surface)

The accuracy of the results regarding pressure resistance mainly depends on how the air-water interface (i.e., the free surface) is captured during the simulation. This resistance is induced by the wave field generated by the vessel, and the quality of the mesh for the latter plays a crucial role in this accuracy.

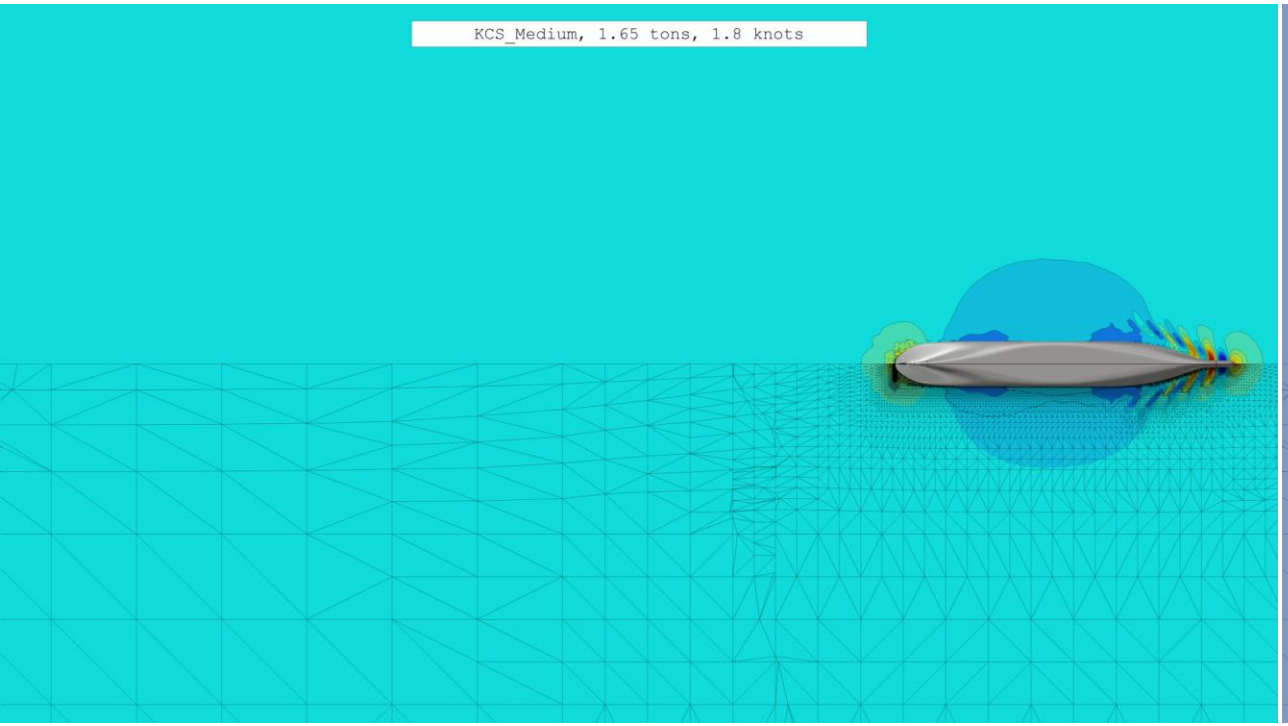
The AGR allows :

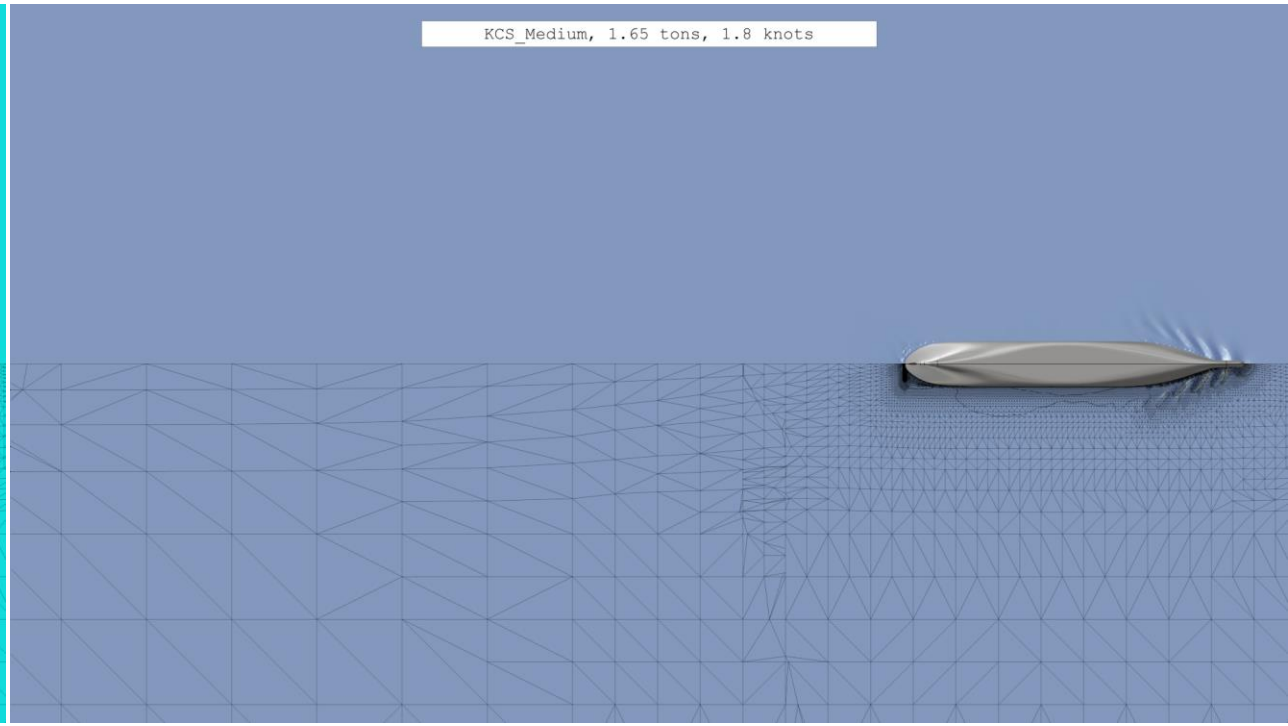
- Dynamically adapting the mesh based on the generated wave field.
- Achieving maximum precision, as it is one of the most advanced and reliable methods to date.
- Reducing computation time by converging more quickly toward the dynamic equilibrium state.



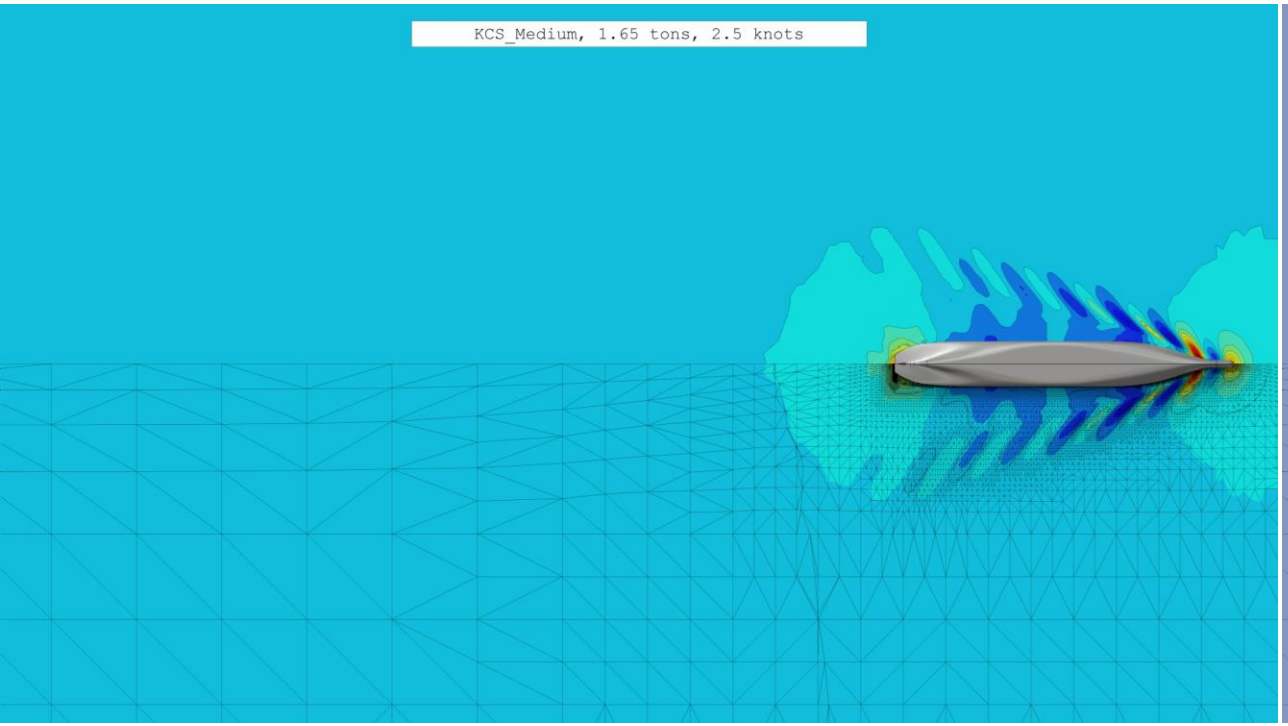
3. Validation

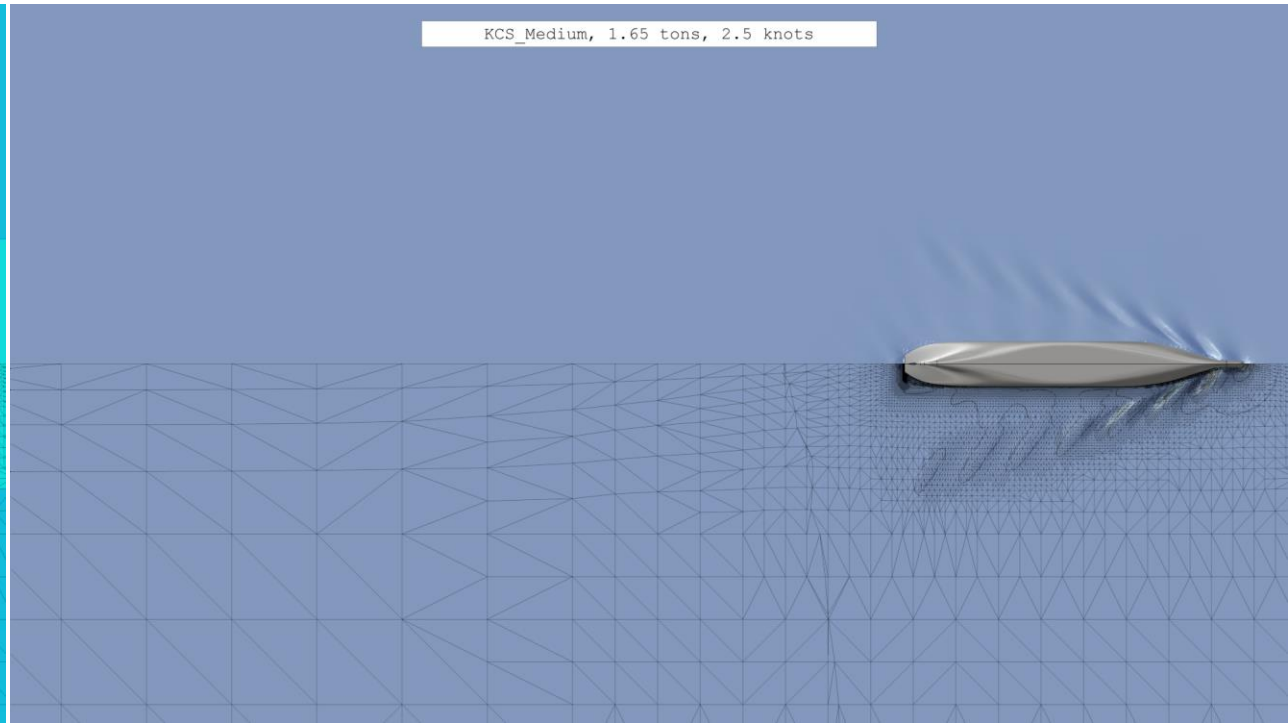
a. Mesh (Free surface)





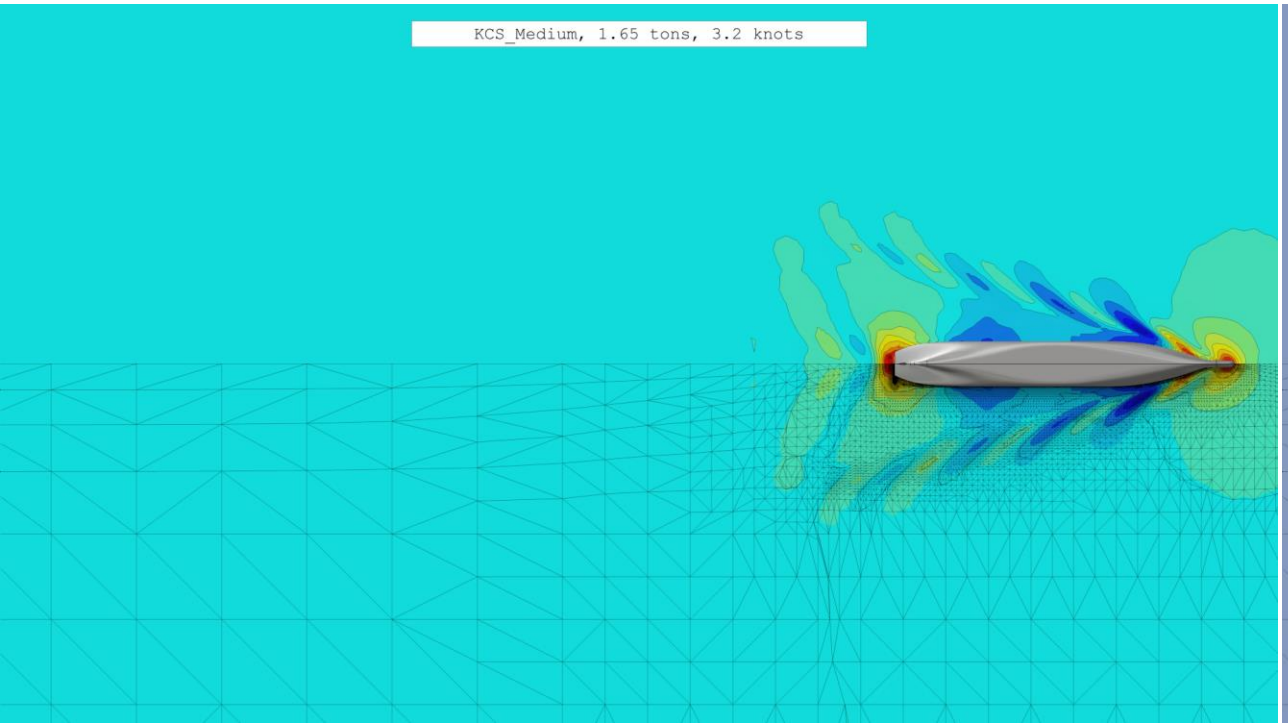
a. Mesh (Free surface)

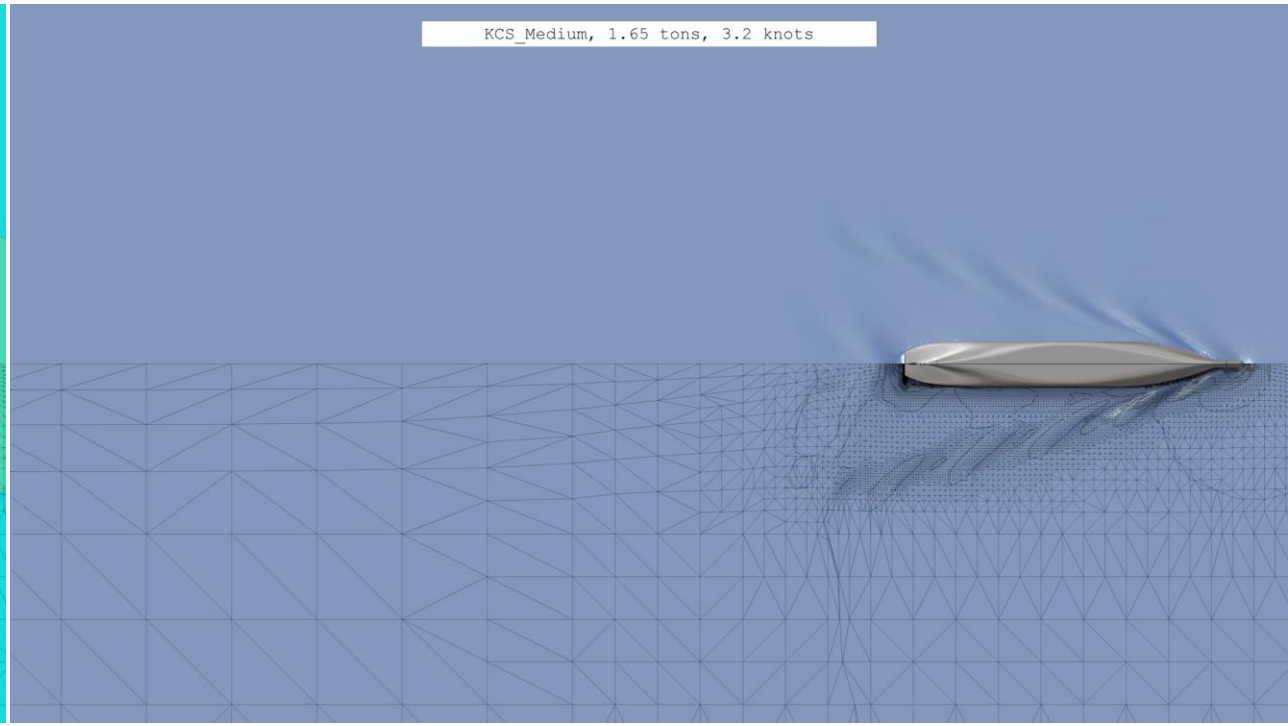




3. Validation

a. Mesh (Free surface)





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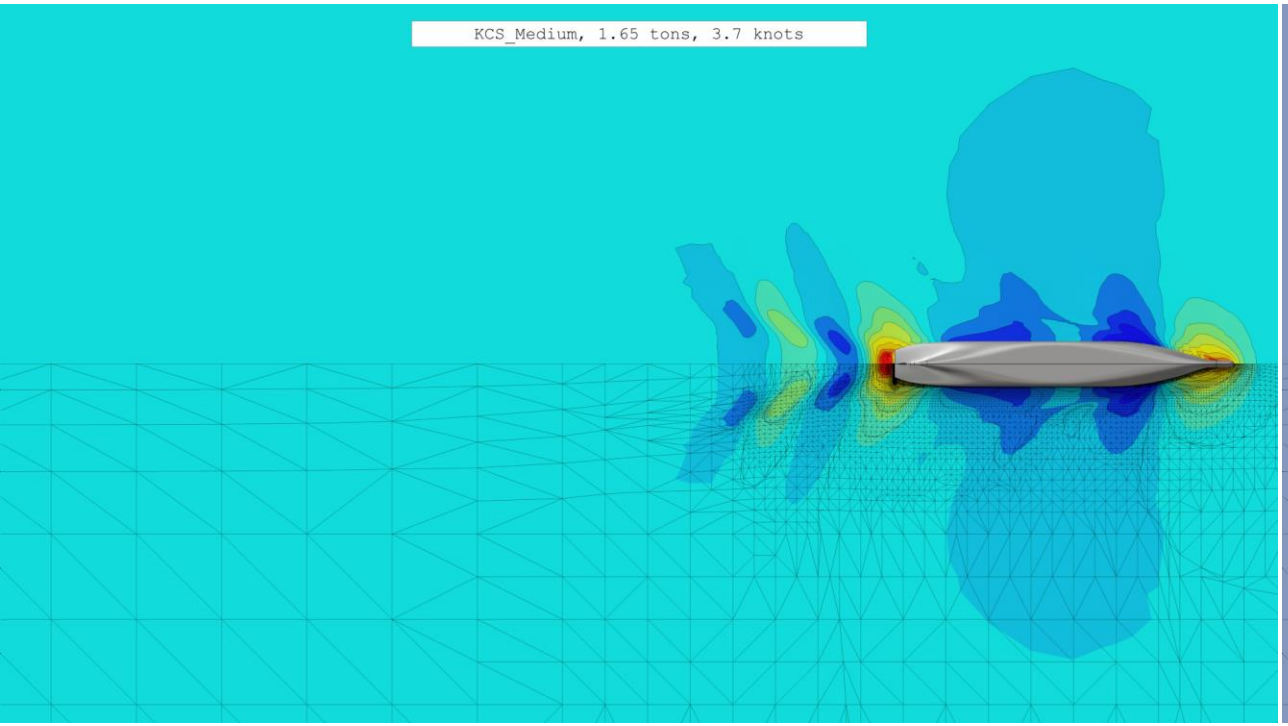
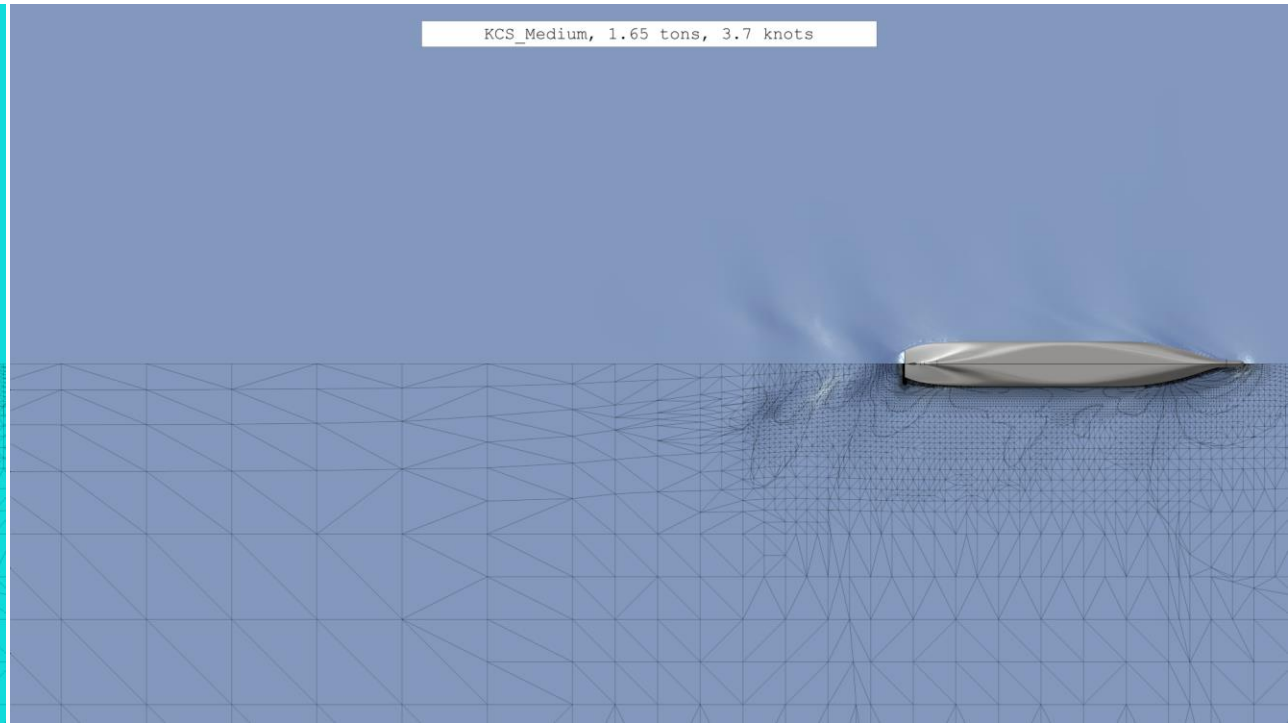
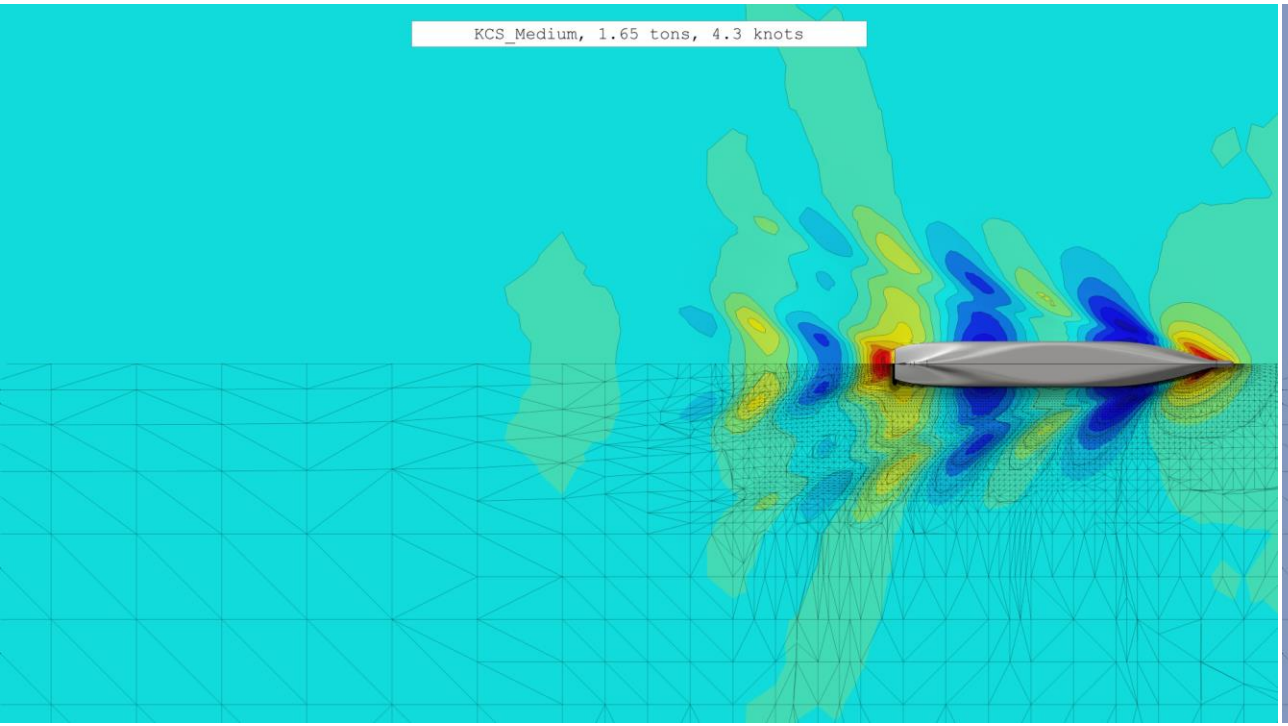
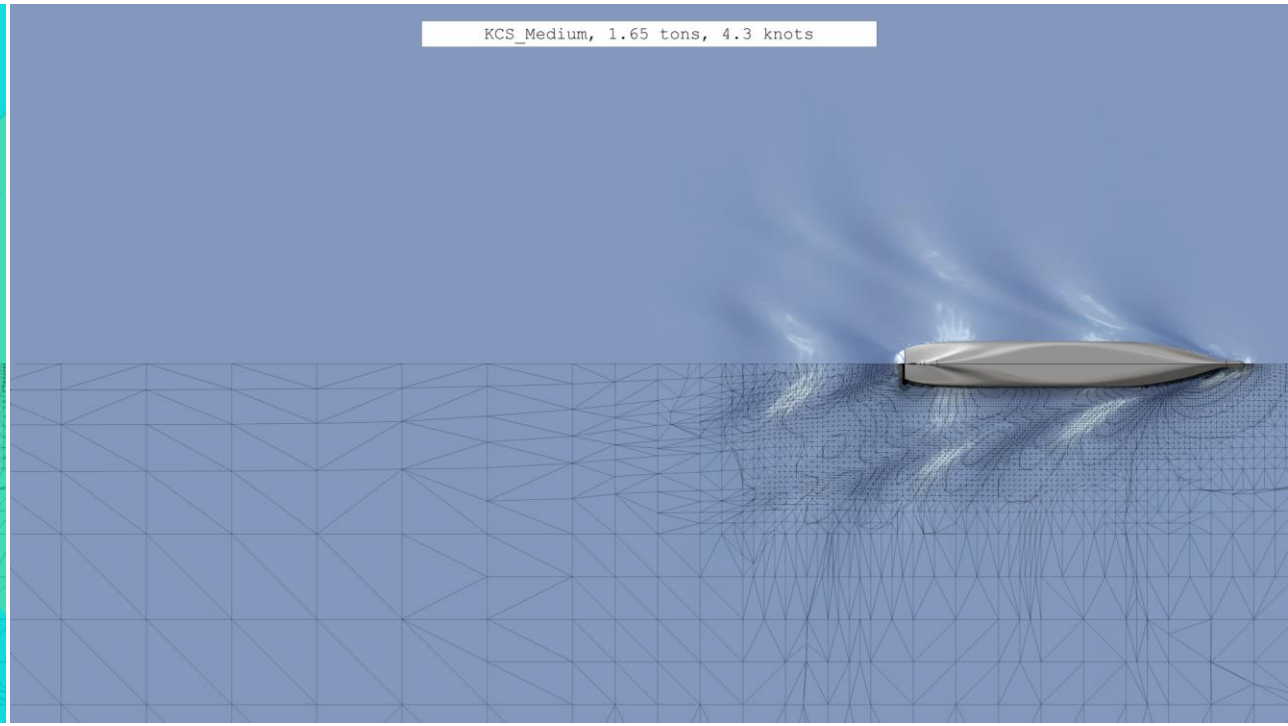




3. Validation

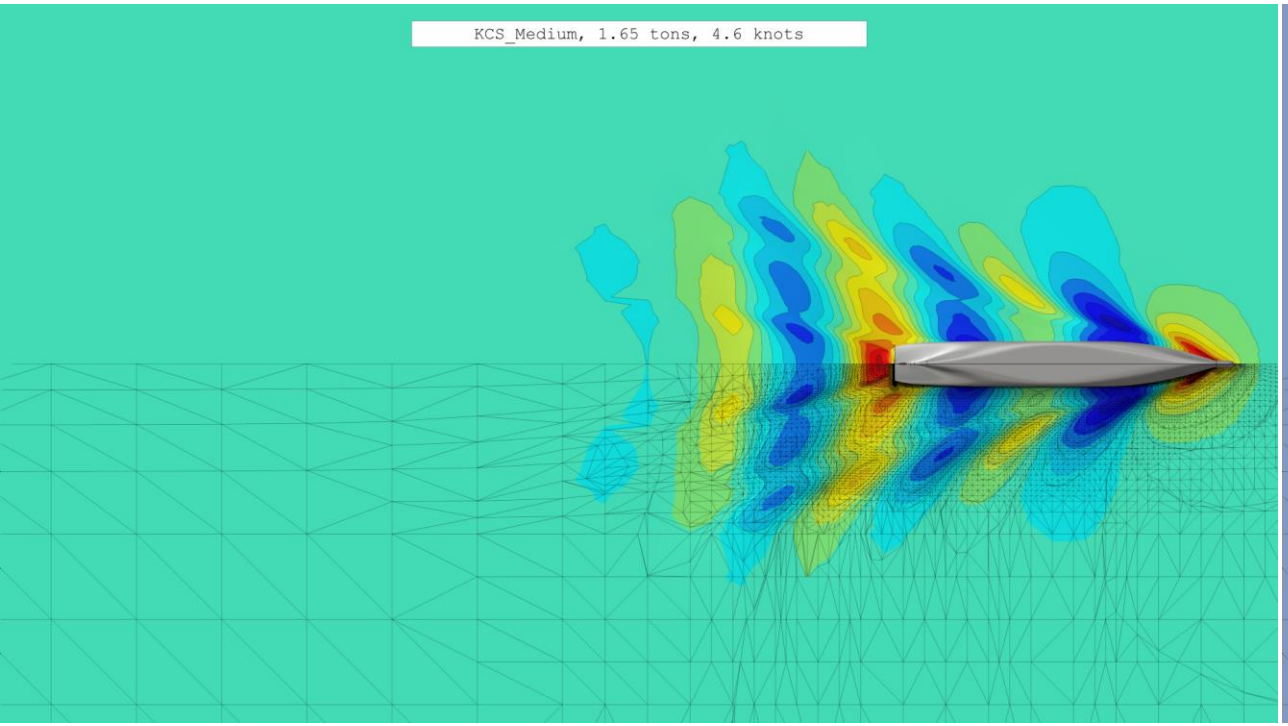
a. Mesh (Free surface)

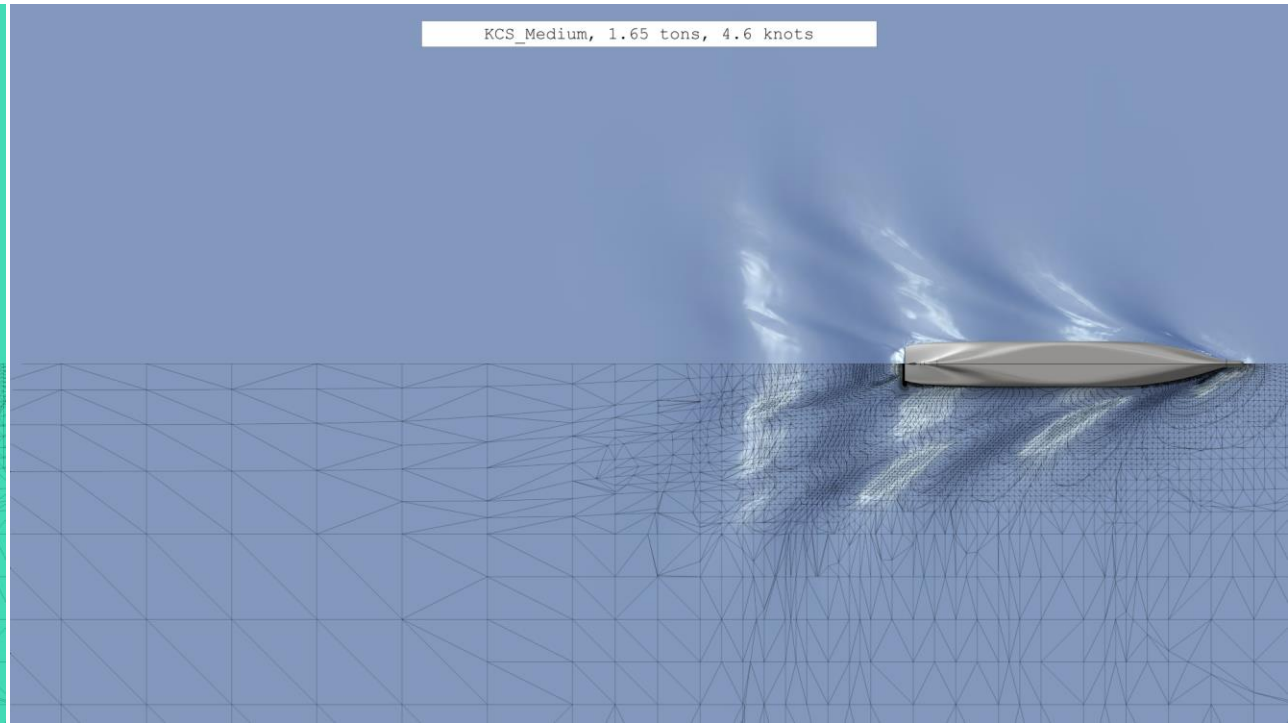




3. Validation

a. Mesh (Free surface)





3. VALIDATION

a. Mesh

1. Number of cells
2. Free surface
3. Hull

b. Courant number

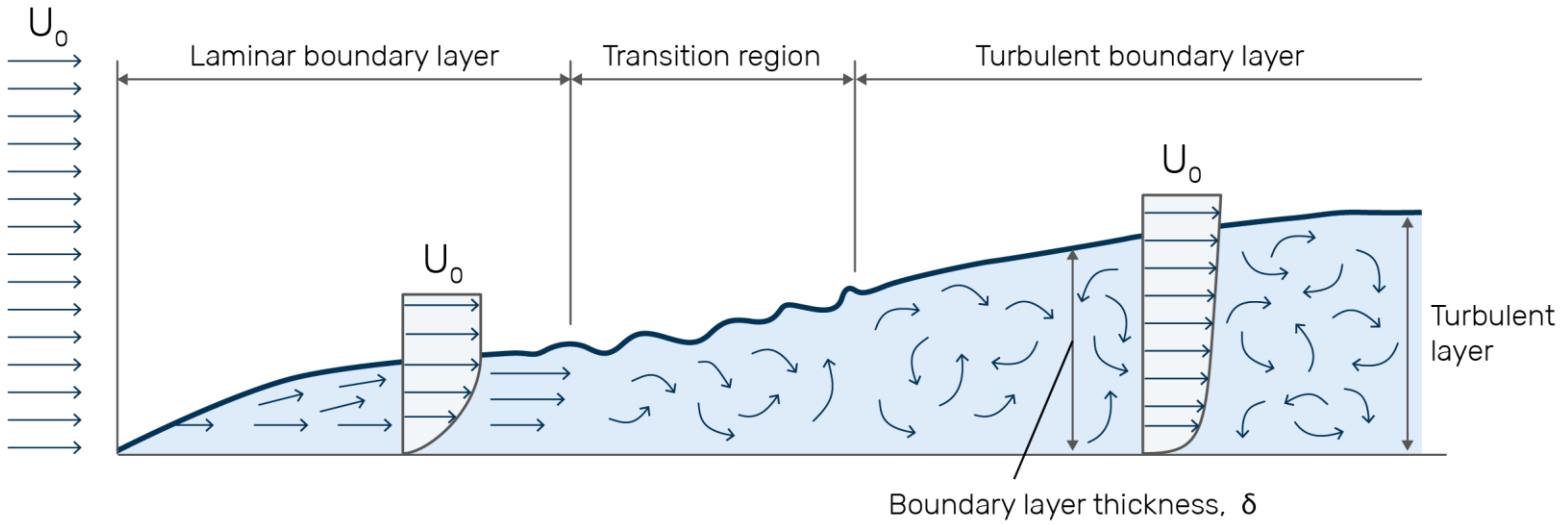
c. Y+

a. Mesh (Hull)

The accuracy of the results regarding viscous resistance mainly depends on the mesh of the hull. This resistance is caused by the entrainment of a thin fluid film: the boundary layer.

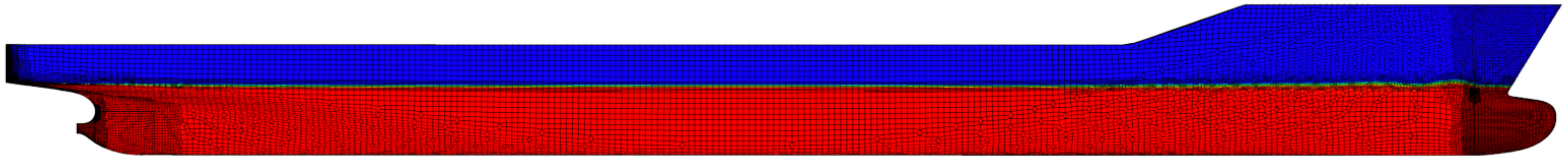
An appropriate mesh of the boundary layer is essential to correctly capture local phenomena such as viscous effects and rapid variations in fluid properties near the surface. It also allows for better capture and resolution of turbulent phenomena if they are present.

The quality of the hull mesh also affects the fidelity of the 3D model representation. A clean and regular mesh improves the reliability of the simulation, making the simulated model more representative of the actual vessel.

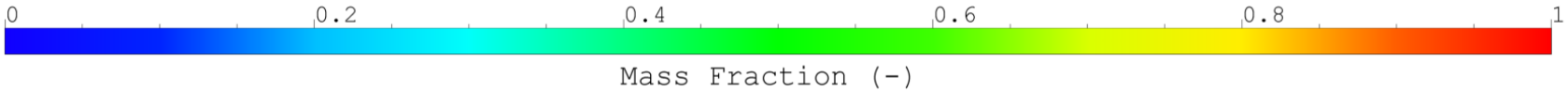


a. Mesh (Hull)

KCS_Medium, 1.65 tons, 1.8 knots

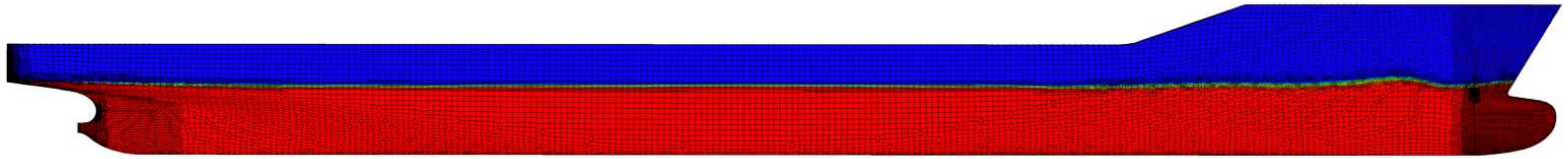


Exterior Side View



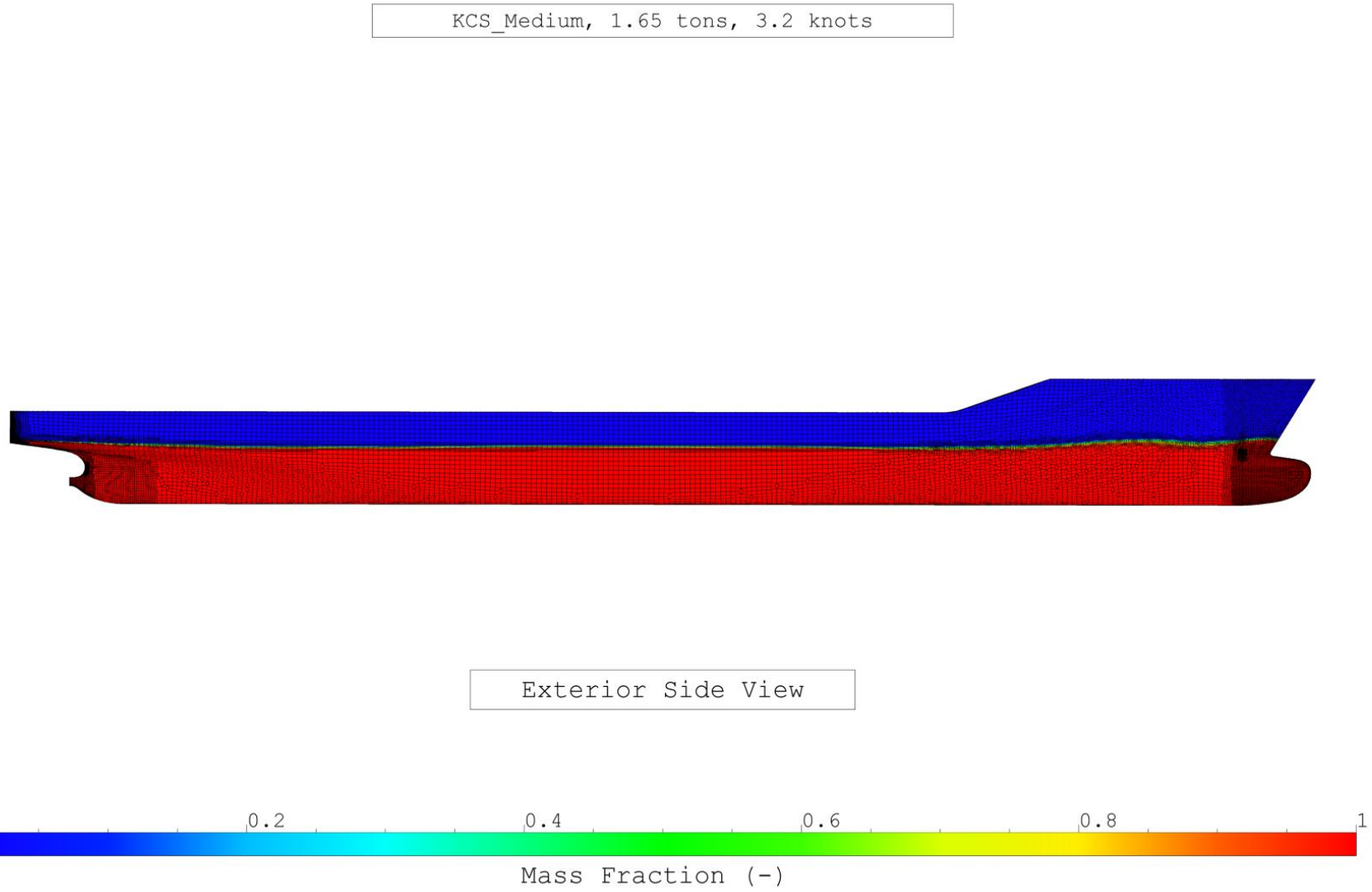
a. Mesh (Hull)

KCS_Medium, 1.65 tons, 2.5 knots



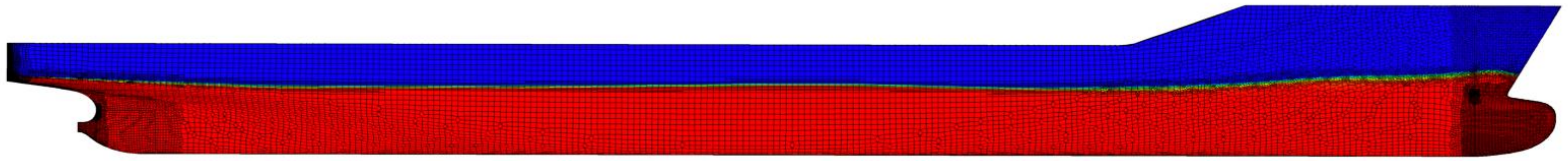
Exterior Side View

a. Mesh (Hull)

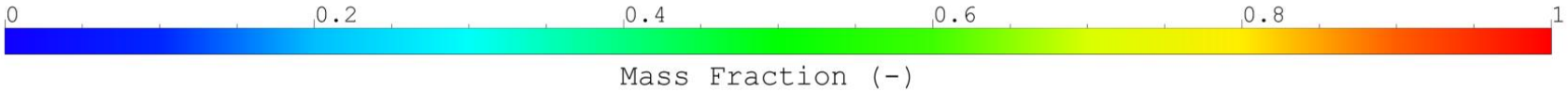


a. Mesh (Hull)

KCS_Medium, 1.65 tons, 3.7 knots

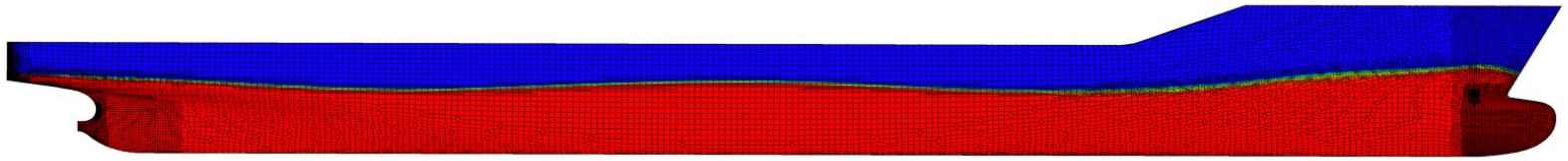


Exterior Side View

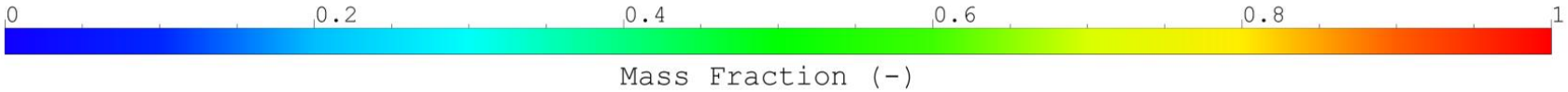


a. Mesh (Hull)

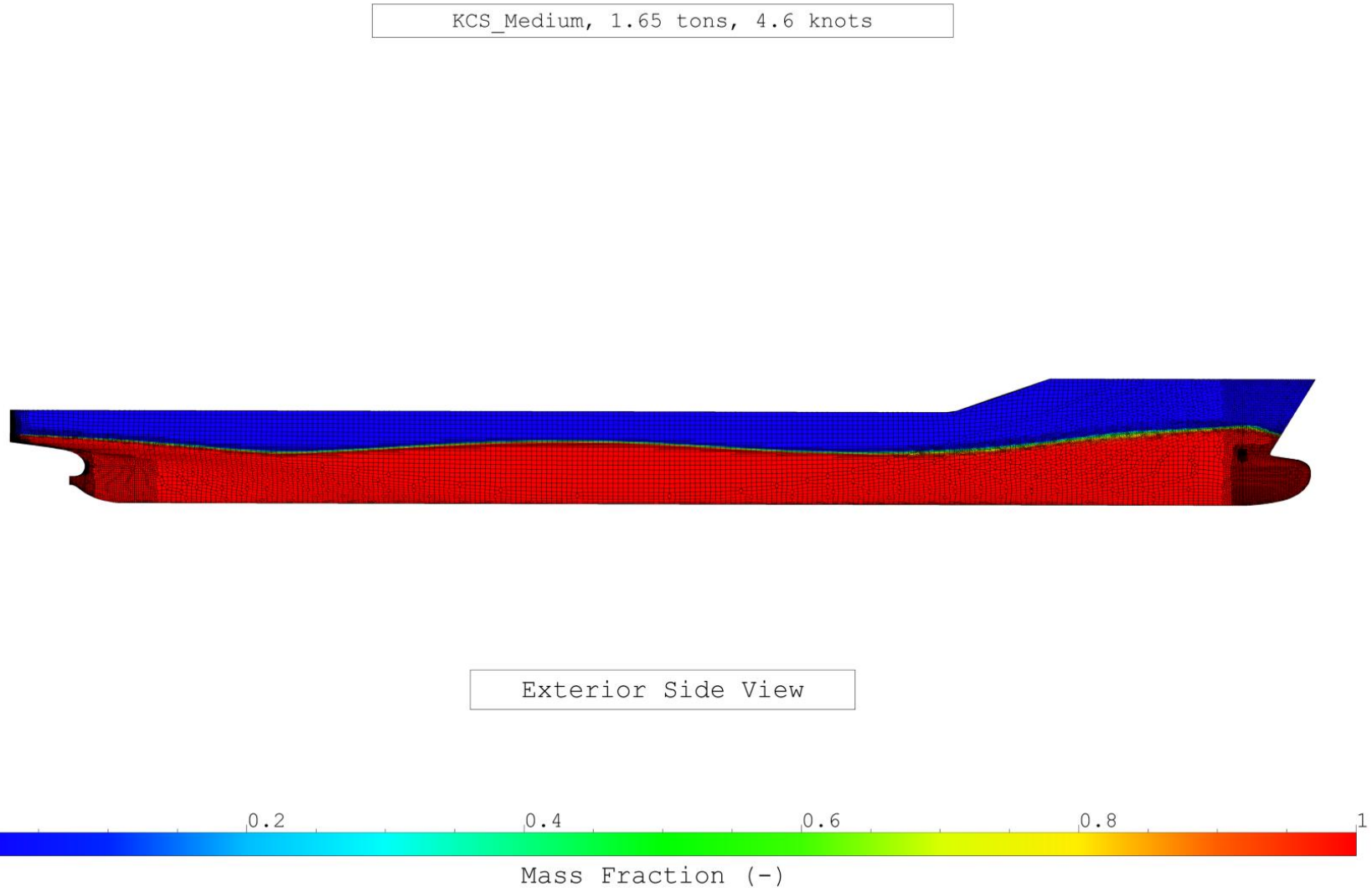
KCS_Medium, 1.65 tons, 4.3 knots



Exterior Side View

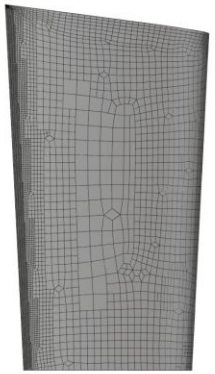


a. Mesh (Hull)



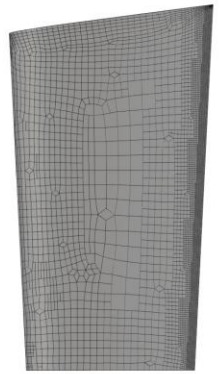
a. Mesh (Hull : appendice(s))

Interior Side View, portside



Exterior Side View, portside

KCS_Medium, 1.65 tons, 1.8 knots

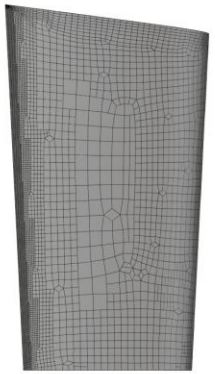


Front View, portside

Rear View, portside

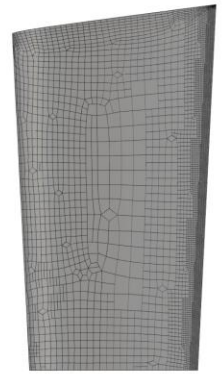
a. Mesh (Hull : appendice(s))

Interior Side View, portside



Exterior Side View, portside

KCS_Medium, 1.65 tons, 2.5 knots

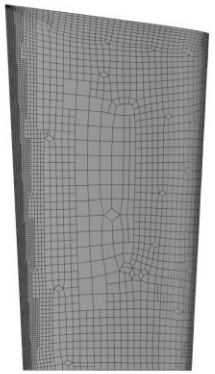


Front View, portside

Rear View, portside

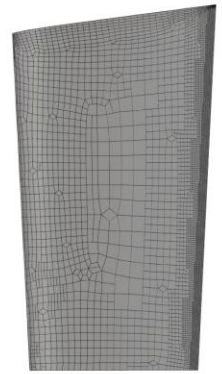
a. Mesh (Hull : appendice(s))

Interior Side View, portside



Exterior Side View, portside

KCS_Medium, 1.65 tons, 3.2 knots

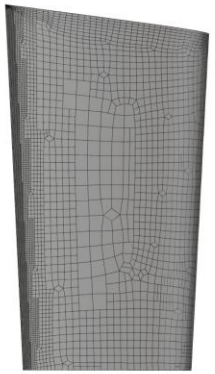


Front View, portside

Rear View, portside

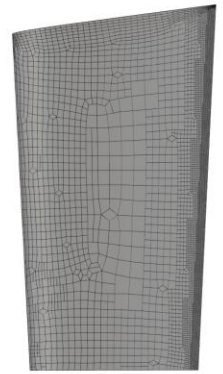
a. Mesh (Hull : appendice(s))

Interior Side View, portside



Exterior Side View, portside

KCS_Medium, 1.65 tons, 3.7 knots

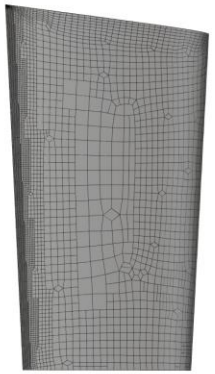


Front View, portside

Rear View, portside

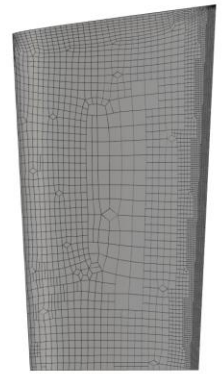
a. Mesh (Hull : appendice(s))

Interior Side View, portside



Exterior Side View, portside

KCS_Medium, 1.65 tons, 4.3 knots

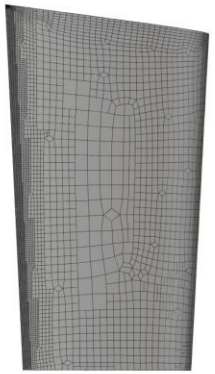


Front View, portside

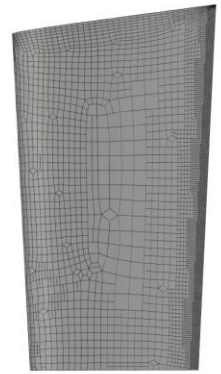
Rear View, portside

a. Mesh (Hull : appendice(s))

Interior Side View, portside



Exterior Side View, portside



KCS_Medium, 1.65 tons, 4.6 knots

Front View, portside

Rear View, portside

3. VALIDATION

a. Mesh

1. Number of cells
2. Free surface
3. Barehull

b. Courant number

c. Y+

b. Courant number

The Courant number, also called the CFL (Courant-Friedrichs-Lewy) number, is a crucial parameter in computational fluid dynamics (CFD). It measures the numerical stability of the discretization scheme used in the simulation.

An inappropriate Courant number can lead to numerical instabilities, compromising both convergence and the accuracy of the results. In CFD, the Courant number is related to the size of the numerical time steps. It is calculated by comparing the speed of fluid particles with the size of the cells in the simulation domain.

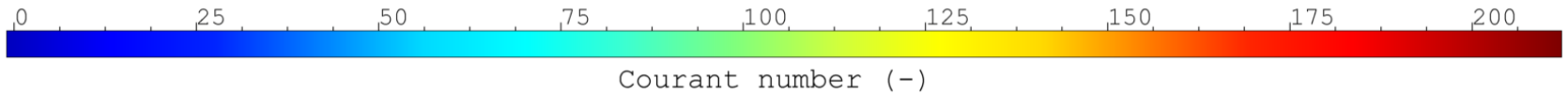
Recommended values : For typical resistance simulations, it is recommended to keep the Courant number below or close to 1 to ensure maximum accuracy and reliability. Local spikes in this parameter may occur, but it is essential to control them to maintain numerical stability and the quality of the results.

b. Courant number

Min value = 0.19 (-)
Max value = 212.23 (-)
Mean value = 1.16 (-)

KCS_Medium, 1.65 tons, 1.8 knots

Exterior Side View

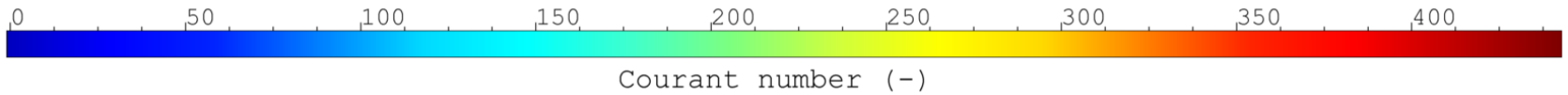


b. Courant number

Min value = 0.21 (-)
Max value = 442.71 (-)
Mean value = 1.17 (-)

KCS_Medium, 1.65 tons, 2.5 knots

Exterior Side View

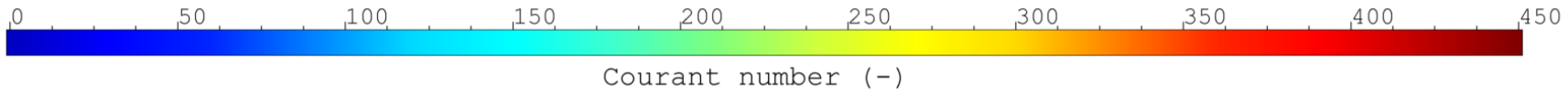


b. Courant number

Min value = 0.11 (-)
Max value = 451.05 (-)
Mean value = 1.20 (-)

KCS_Medium, 1.65 tons, 3.2 knots

Exterior Side View

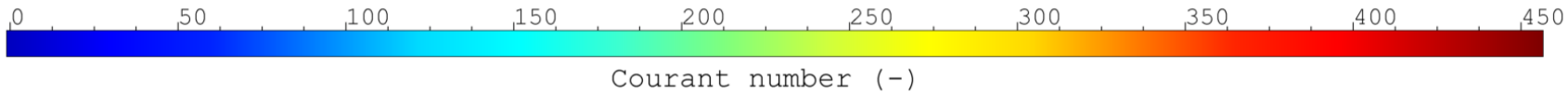


b. Courant number

Min value = 0.03 (-)
Max value = 456.48 (-)
Mean value = 1.22 (-)

KCS_Medium, 1.65 tons, 3.7 knots

Exterior Side View

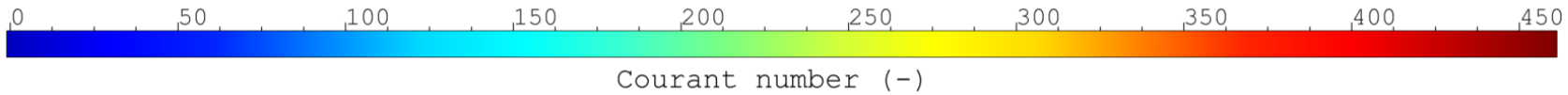


b. Courant number

Min value = 0.09 (-)
Max value = 461.13 (-)
Mean value = 1.24 (-)

KCS_Medium, 1.65 tons, 4.3 knots

Exterior Side View

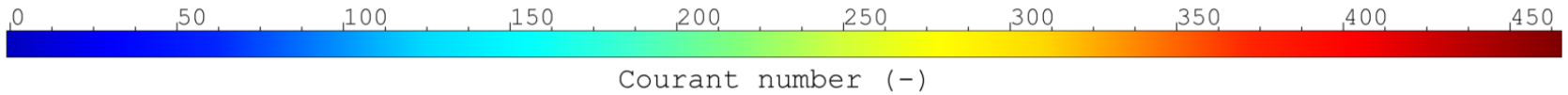


b. Courant number

Min value = 0.06 (-)
Max value = 465.40 (-)
Mean value = 1.26 (-)

KCS_Medium, 1.65 tons, 4.6 knots

Exterior Side View



3. VALIDATION

a. Mesh

1. Number of cells
2. Free surface
3. Barehull

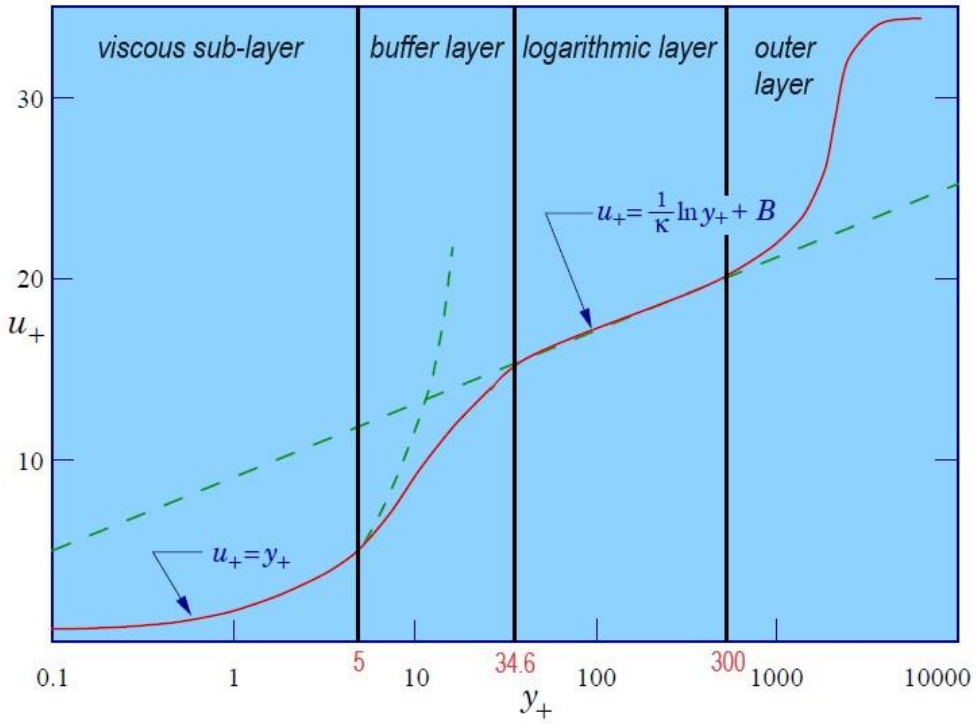
b. Courant number

c. Y+

c. Y+

In the naval field, managing the Y+ parameter is crucial in computational fluid dynamics (CFD) simulations. Y+ measures the quality of the boundary layer resolution along the submerged surfaces of ship hulls by evaluating the distance between the first mesh point and the wall relative to the boundary layer thickness. Maintaining an appropriate Y+ is essential to ensure reliable results in predicting resistance, drag, lift, and other critical hydrodynamic phenomena. An improper Y+ can lead to significant errors in the prediction of forces, drag coefficients, and other key parameters.

Recommended values : For typical resistance simulations, it is recommended that the Y+ value be between 30 and 300. This value may be lower depending on the choice of boundary layer modeling. Local spikes in this parameter may occur, but it is essential to control them to maintain numerical stability and the quality of the results.

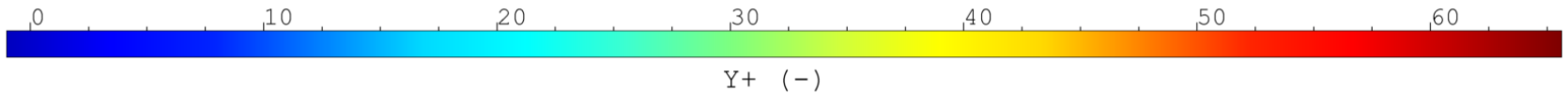


c. Y+

Min value = -0.05 (-)
Max value = 65.61 (-)
Mean value = 37.17 (-)

KCS_Medium, 1.65 tons, 1.8 knots

Exterior Side View

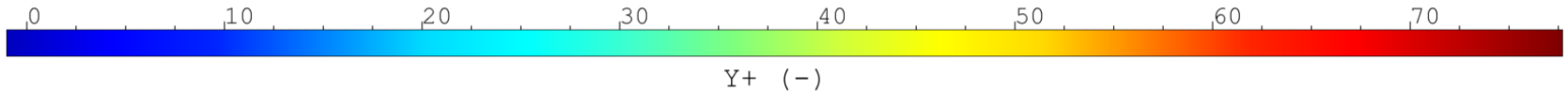


c. Y+

Min value = -0.02 (-)
Max value = 77.70 (-)
Mean value = 43.62 (-)

KCS_Medium, 1.65 tons, 2.5 knots

Exterior Side View

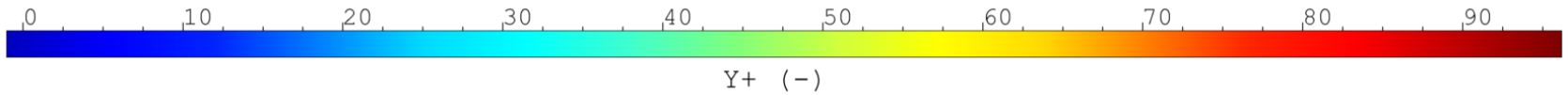


c. Y+

Min value = -0.02 (-)
Max value = 96.16 (-)
Mean value = 55.02 (-)

KCS_Medium, 1.65 tons, 3.2 knots

Exterior Side View

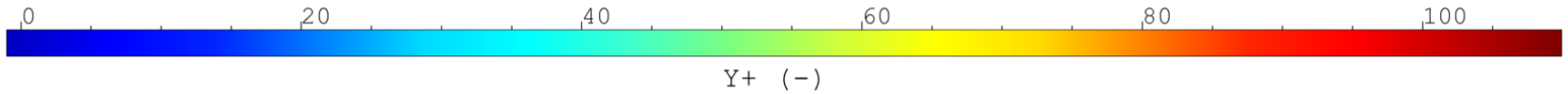


c. Y+

Min value = -0.02 (-)
Max value = 109.90 (-)
Mean value = 63.45 (-)

KCS_Medium, 1.65 tons, 3.7 knots

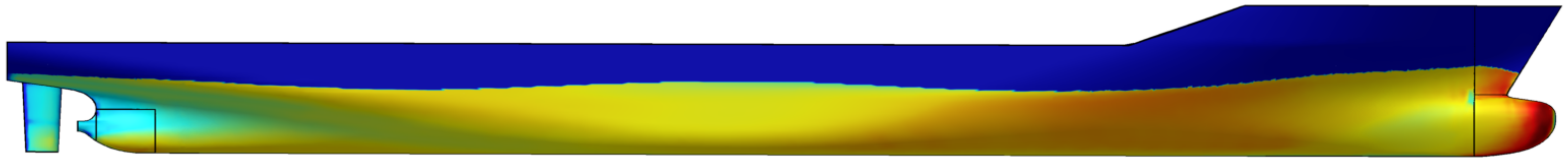
Exterior Side View



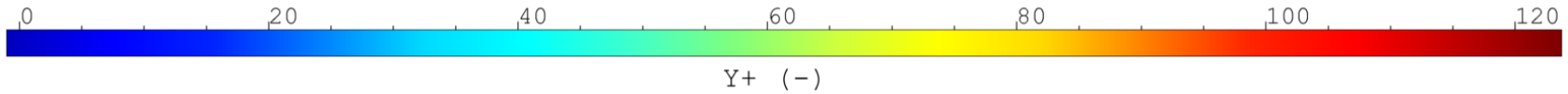
c. Y+

Min value = -0.03 (-)
Max value = 123.70 (-)
Mean value = 71.65 (-)

KCS_Medium, 1.65 tons, 4.3 knots



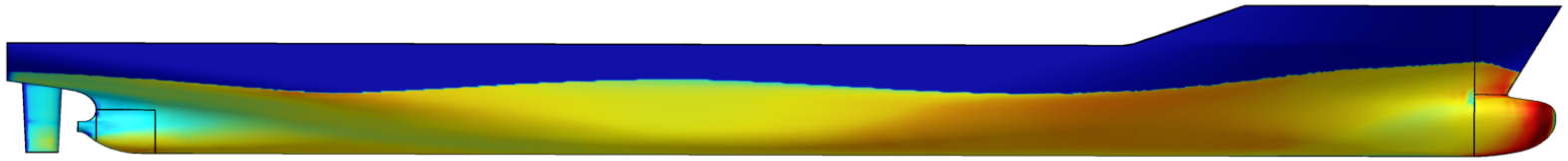
Exterior Side View



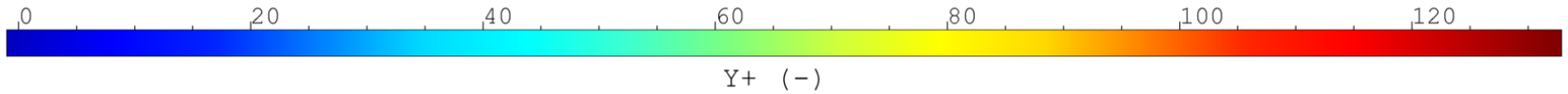
c. Y+

Min value = -0.03 (-)
Max value = 132.87 (-)
Mean value = 77.26 (-)

KCS_Medium, 1.65 tons, 4.6 knots



Exterior Side View



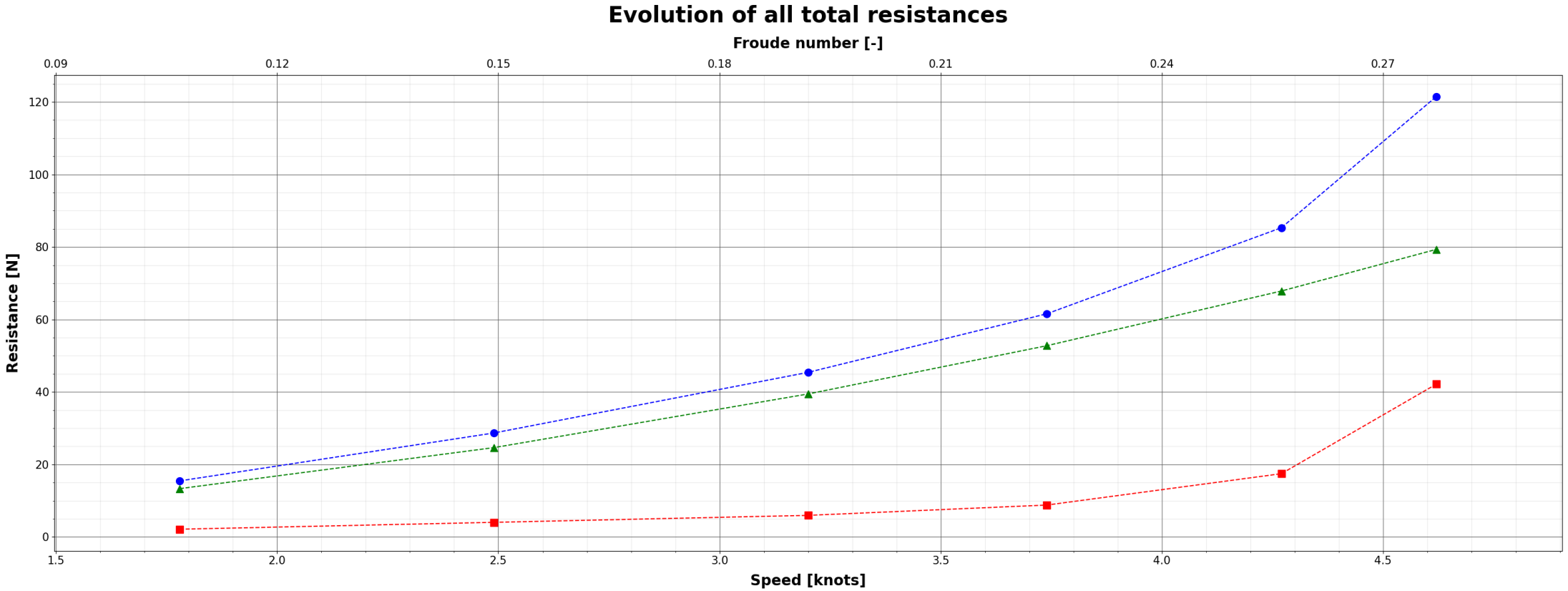
4. RESULTS

a. Forces
b. Heave
c. Pitch
d. Wetted surface

a. Forces

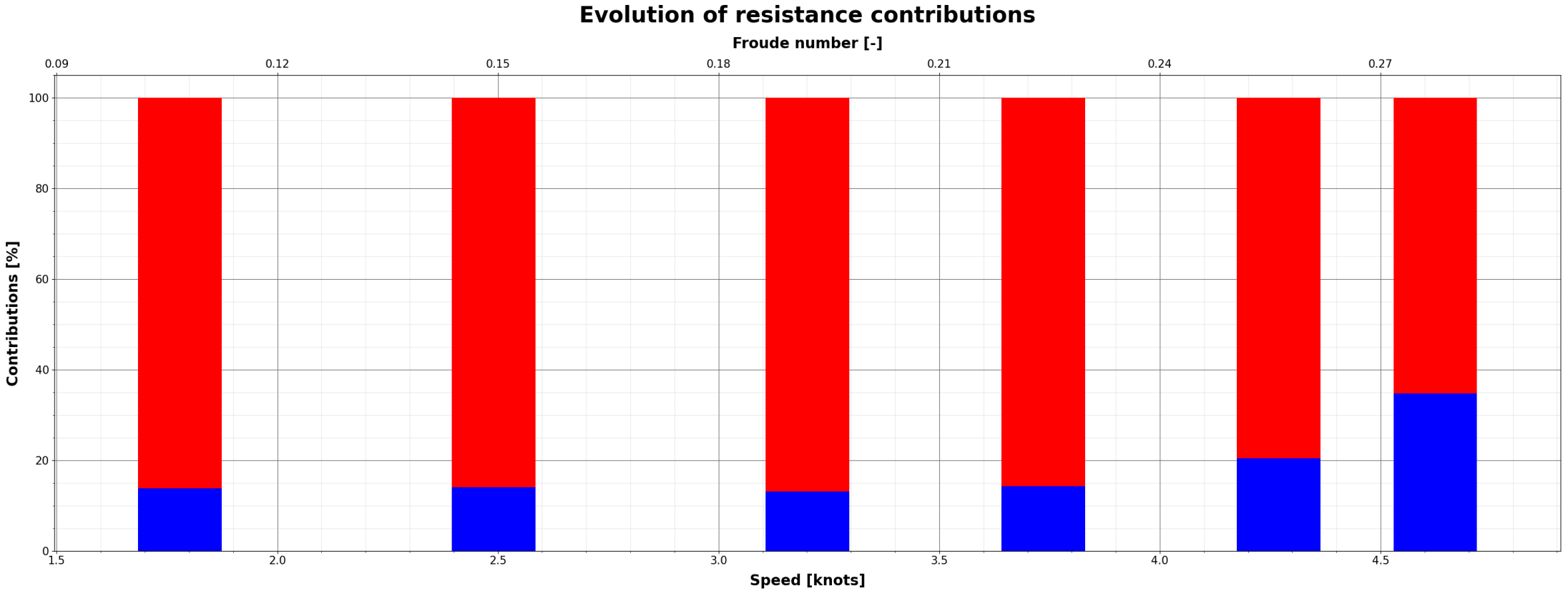
	Speed [knots]	Froude number [-]	● KCS_Coarse	■ KCS_Medium	▲ KCS_Fine	★ KCS_Extra_Fine	+ KCS_EFD
0	1.78	0.11	16.65	15.48	15.27	15.07	15.21
1	2.49	0.15	29.89	28.69	28.37	28.23	28.51
2	3.20	0.19	46.80	45.41	45.01	44.81	44.88
3	3.74	0.23	63.49	61.58	61.07	60.93	61.31
4	4.27	0.26	88.18	85.31	84.07	83.90	85.44
5	4.62	0.28	123.38	121.48	120.32	119.66	121.32

a. Forces



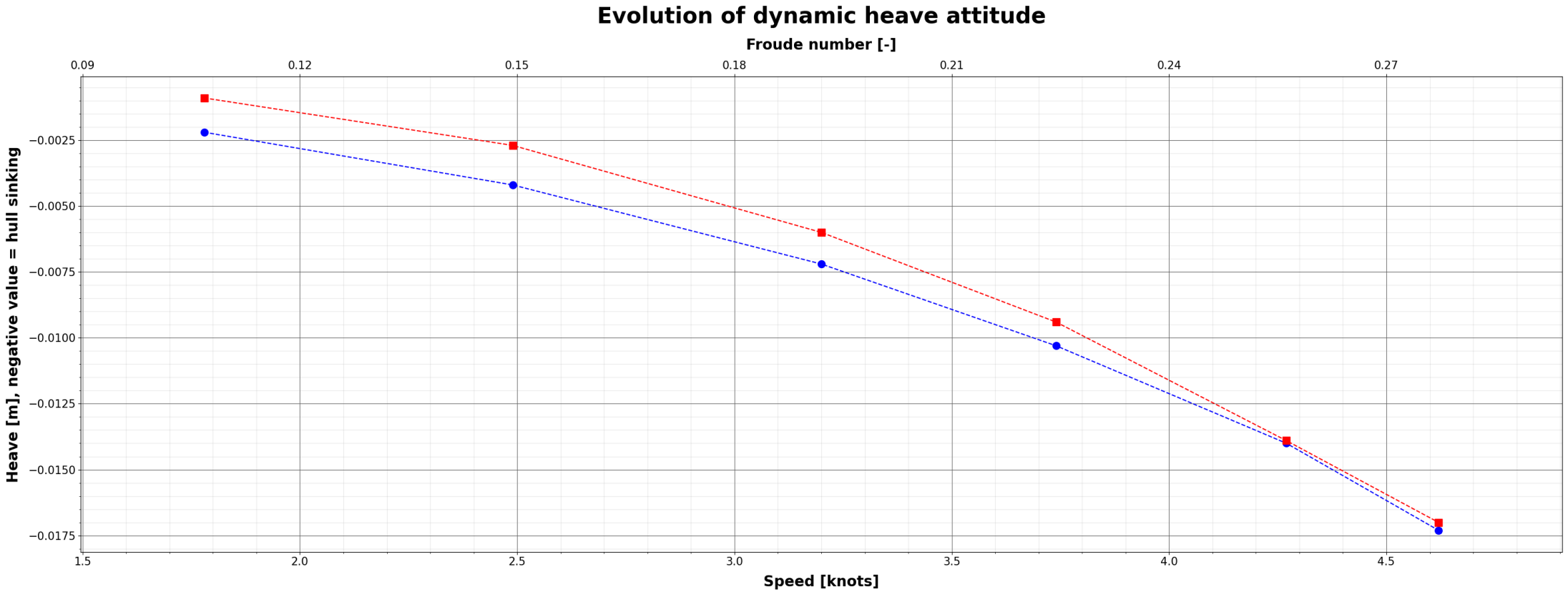
	Speed [knots]	Froude number [-]	● Total [N]	■ Pressure [N]	▲ Viscous [N]
0	1.78	0.11	15.48	2.14	13.34
1	2.49	0.15	28.69	4.04	24.65
2	3.20	0.19	45.41	5.96	39.45
3	3.74	0.23	61.58	8.81	52.77
4	4.27	0.26	85.31	17.46	67.85
5	4.62	0.28	121.48	42.15	79.33

a. Forces (contributions)



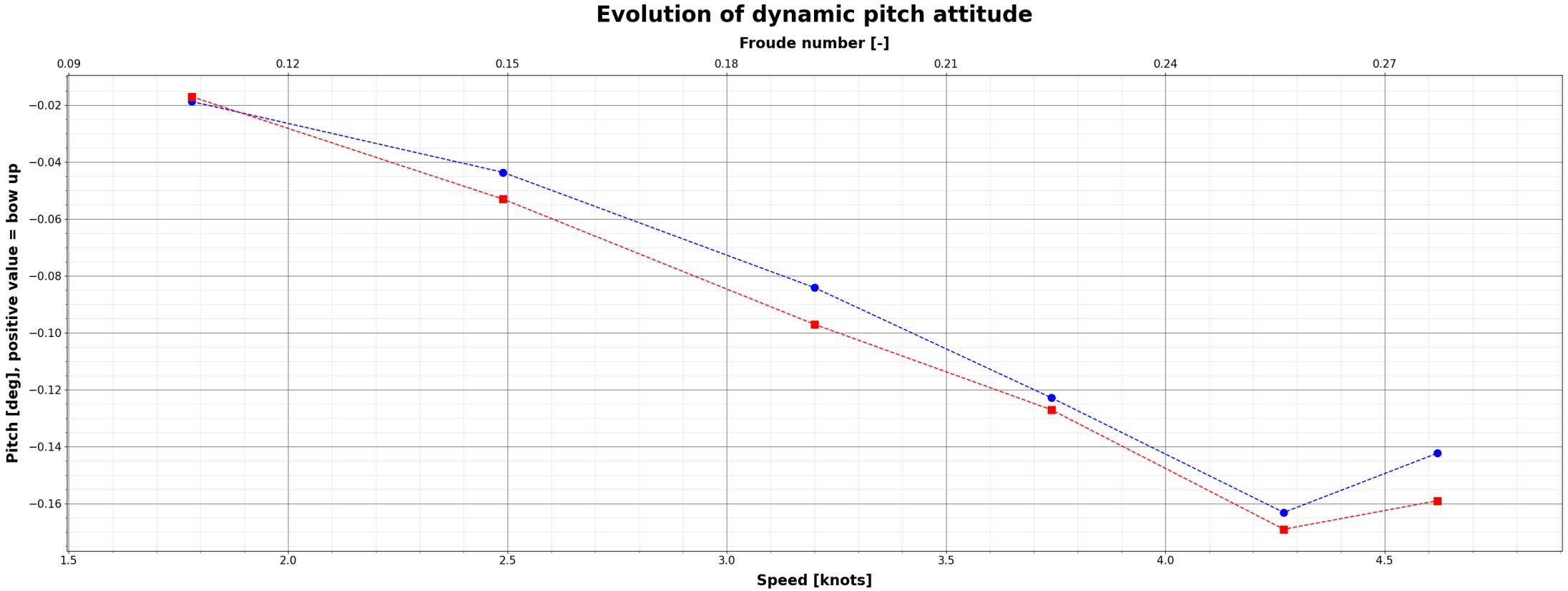
	Speed [knots]	Froude number [-]	Contribution of pressure resistance [%]	Contribution of viscous resistance [%]
0	1.78	0.11	13.82	86.18
1	2.49	0.15	14.08	85.92
2	3.20	0.19	13.12	86.88
3	3.74	0.23	14.31	85.69
4	4.27	0.26	20.47	79.53
5	4.62	0.28	34.70	65.30

b. Heave



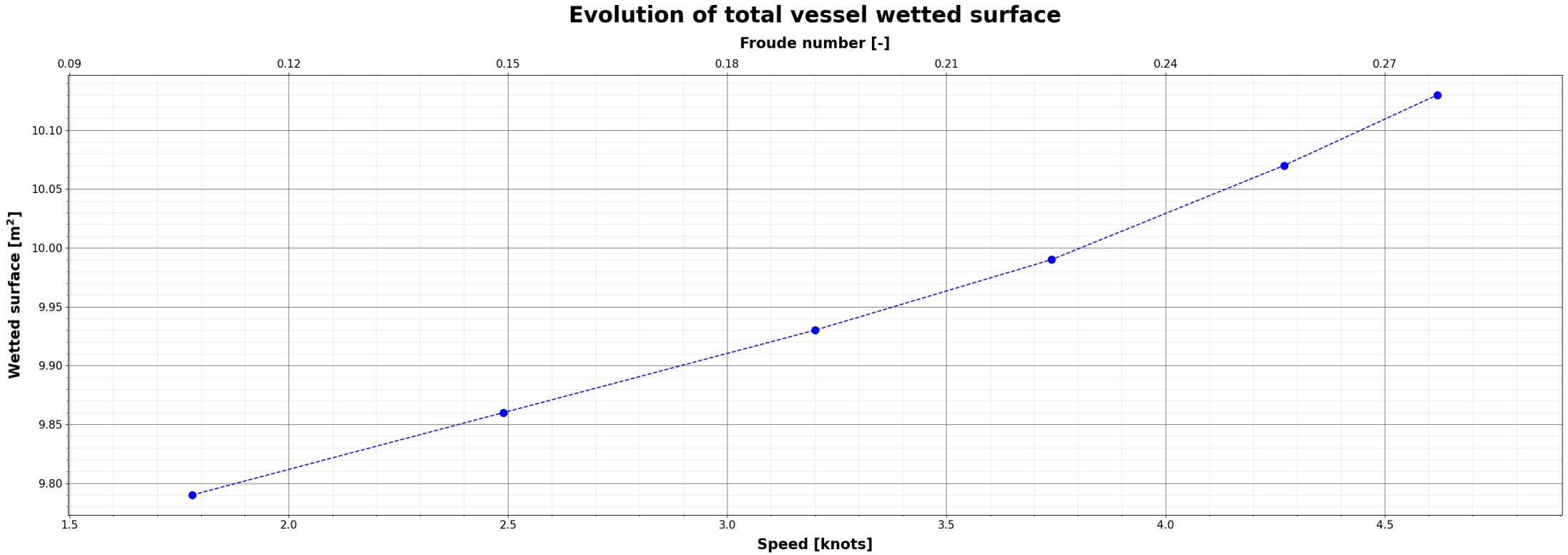
	Speed [knots]	Froude number [-]	● Heave [m], KCS_Medium	■ Heave [m], KCS_EFD
0	1.78	0.11	-0.0022	-0.0009
1	2.49	0.15	-0.0042	-0.0027
2	3.20	0.19	-0.0072	-0.0060
3	3.74	0.23	-0.0103	-0.0094
4	4.27	0.26	-0.0140	-0.0139
5	4.62	0.28	-0.0173	-0.0170

c. Pitch



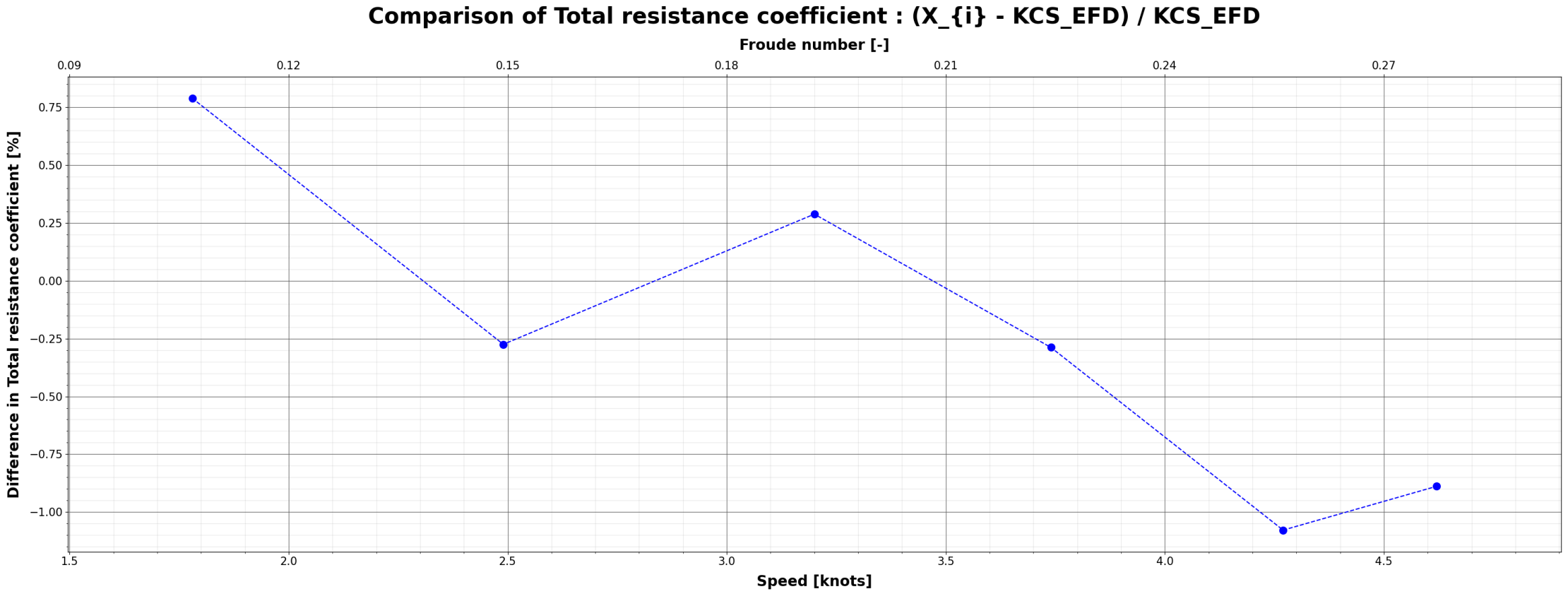
	Speed [knots]	Froude number [-]	● Pitch [deg], KCS_Medium	■ Pitch [deg], KCS_EFD
0	1.78	0.11	-0.0187	-0.0170
1	2.49	0.15	-0.0436	-0.0530
2	3.20	0.19	-0.0841	-0.0970
3	3.74	0.23	-0.1228	-0.1270
4	4.27	0.26	-0.1631	-0.1690
5	4.62	0.28	-0.1423	-0.1590

d. Wetted surface

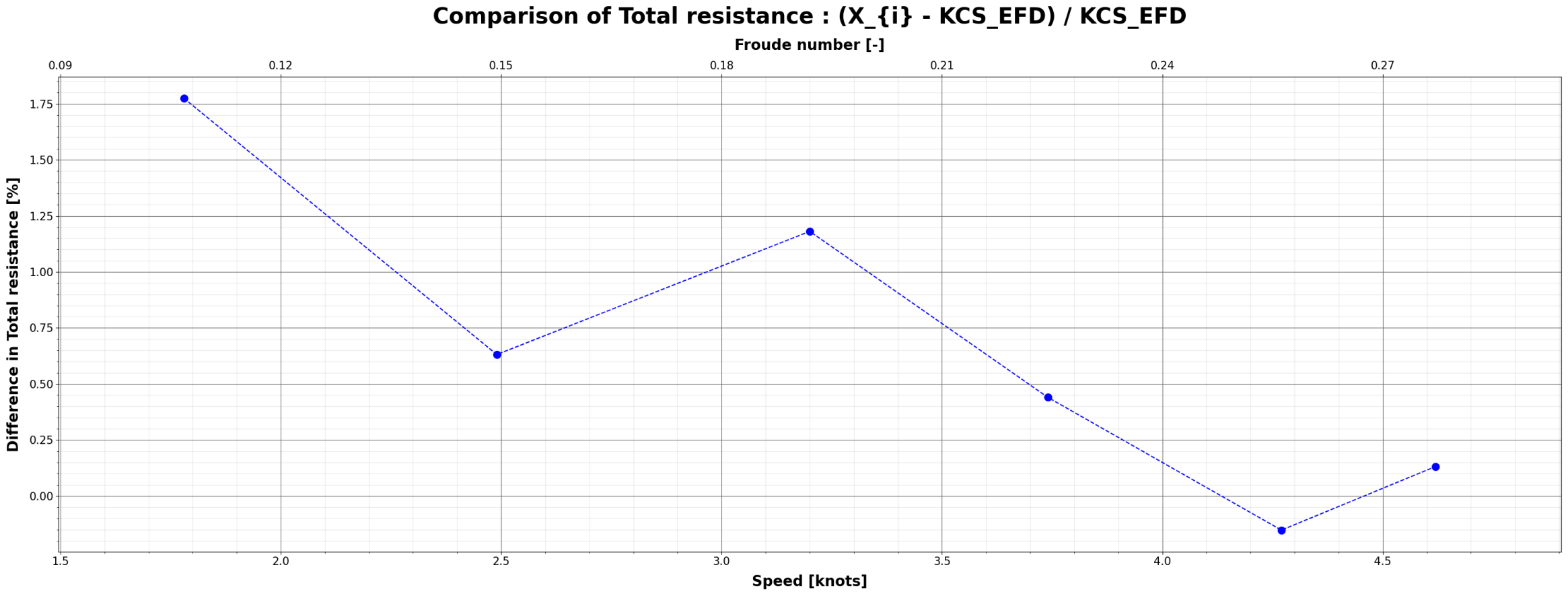


	Speed [knots]	Froude number [-]	● Wetted surface [m²], KCS_Medium
0	0.00	0.00	9.68
1	1.78	0.11	9.79
2	2.49	0.15	9.86
3	3.20	0.19	9.93
4	3.74	0.23	9.99
5	4.27	0.26	10.07
6	4.62	0.28	10.13

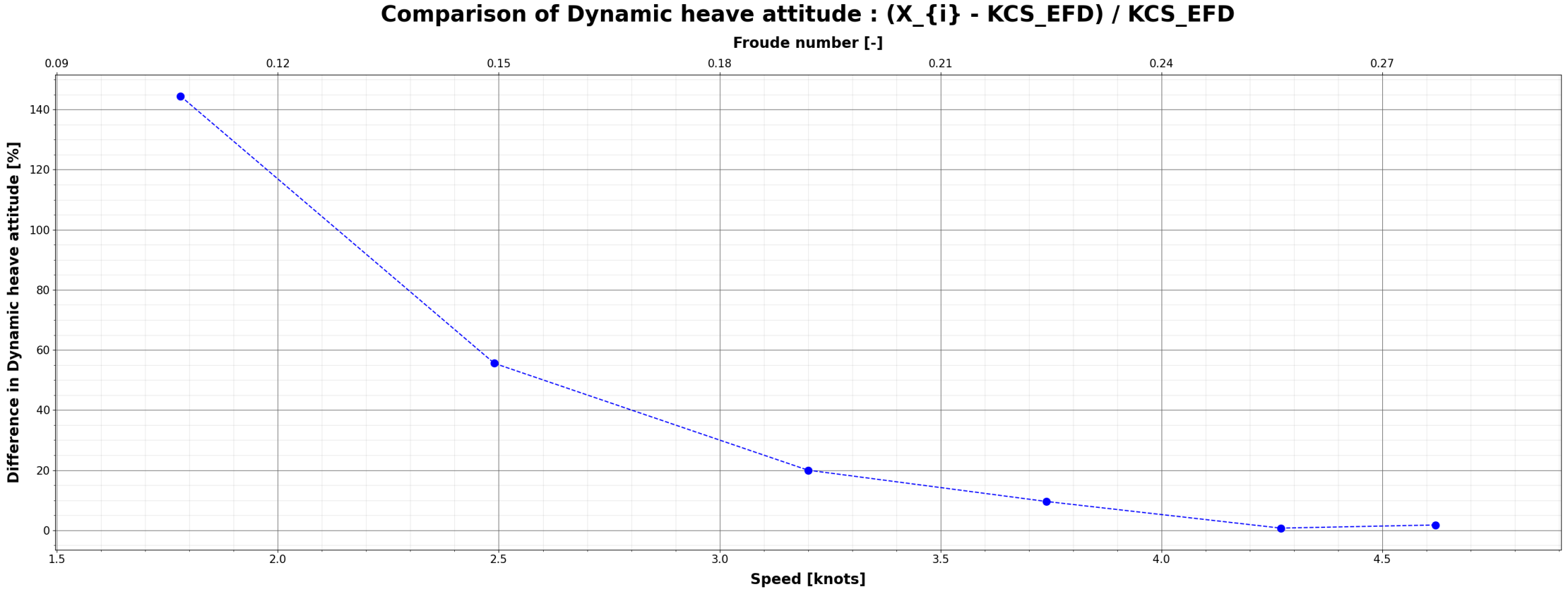
5. COMPARISON EFD



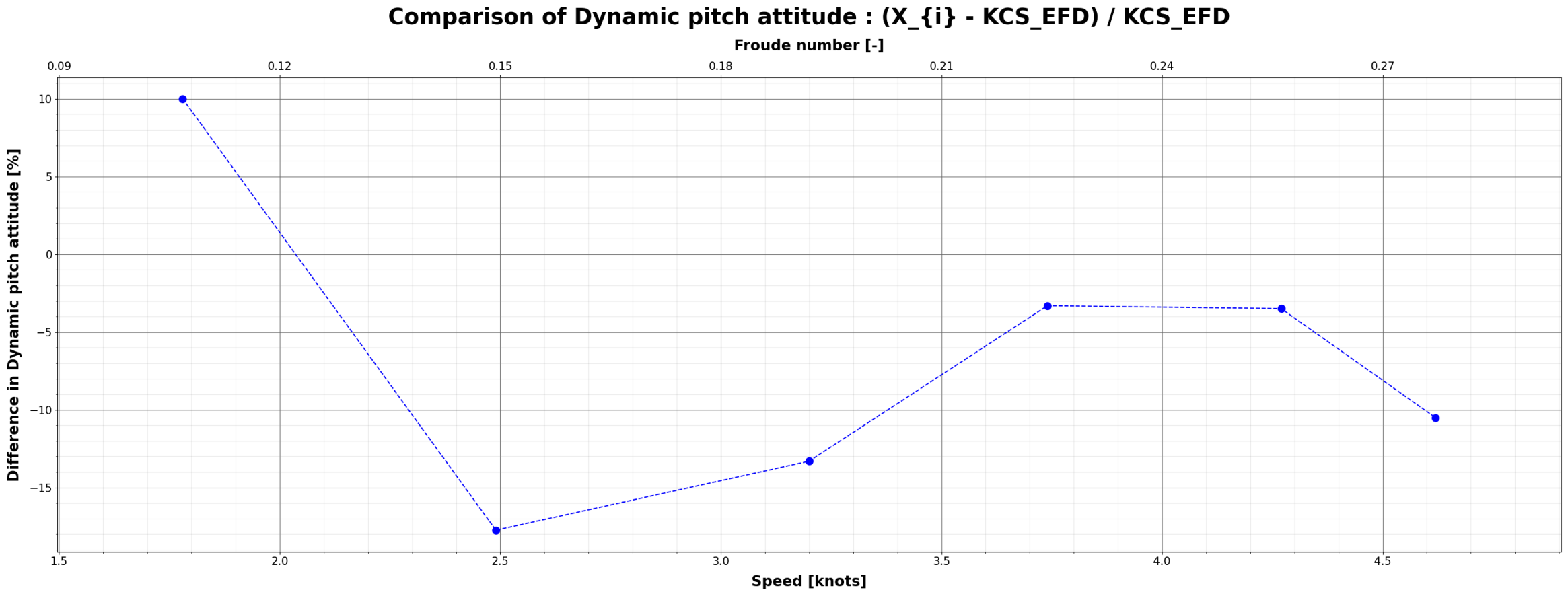
	Speed [knots]	Froude number [-]	X_0 = KCS_Medium, [%]
0	1.78	0.11	0.79
1	2.49	0.15	-0.27
2	3.20	0.19	0.29
3	3.74	0.23	-0.29
4	4.27	0.26	-1.08
5	4.62	0.28	-0.89



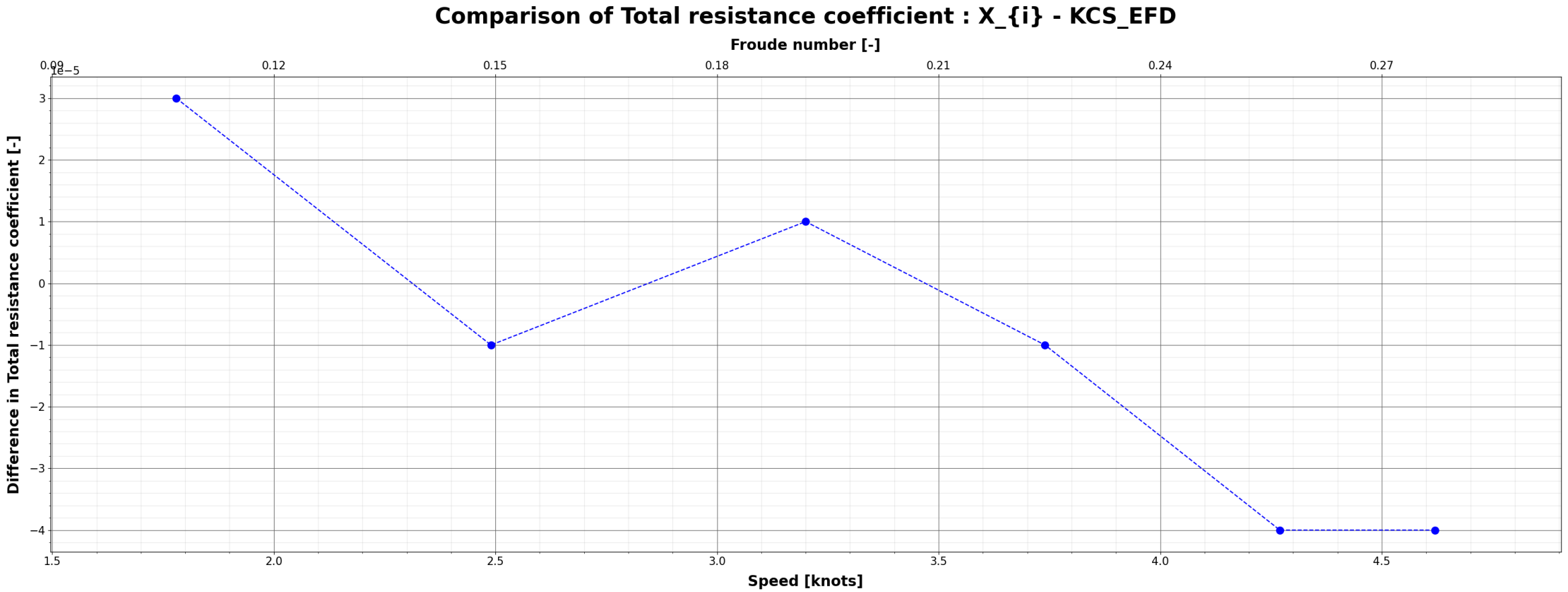
	Speed [knots]	Froude number [-]	X_0 = KCS_Medium, [%]
0	1.78	0.11	1.78
1	2.49	0.15	0.63
2	3.20	0.19	1.18
3	3.74	0.23	0.44
4	4.27	0.26	-0.15
5	4.62	0.28	0.13



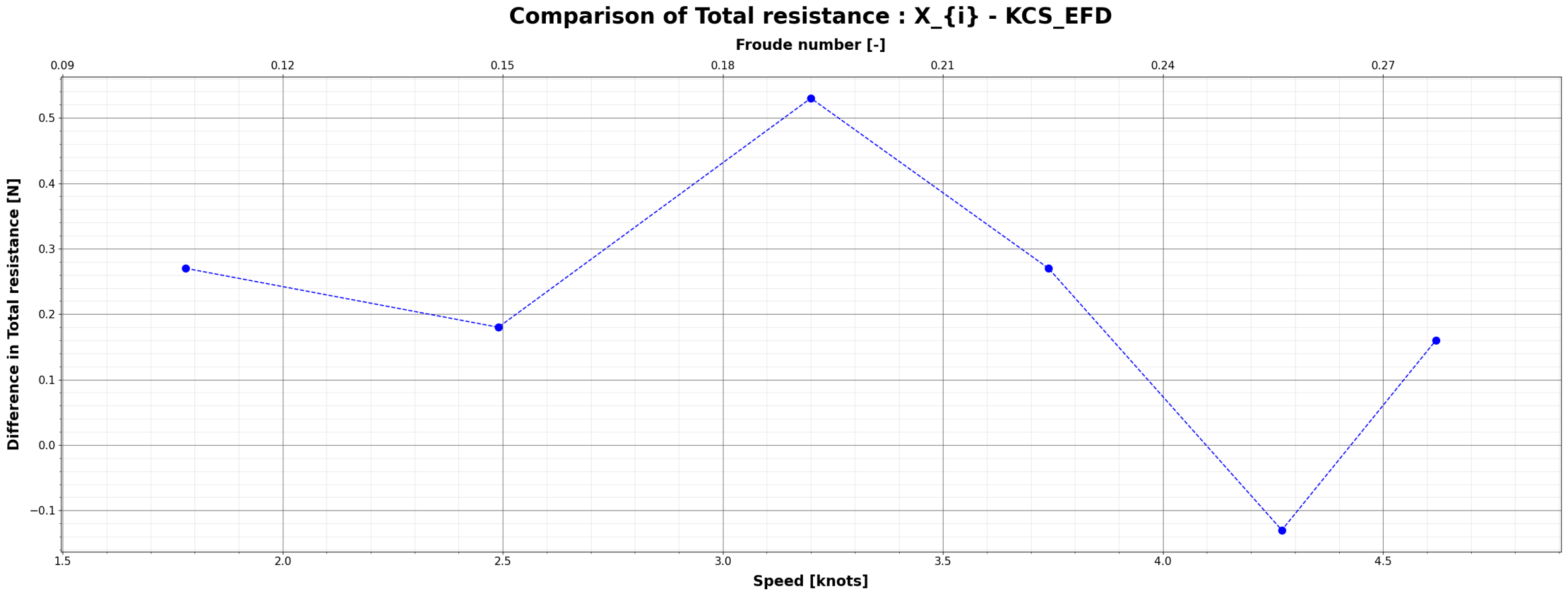
	Speed [knots]	Froude number [-]	X_0 = KCS_Medium, [%]
0	1.78	0.11	144.44
1	2.49	0.15	55.56
2	3.20	0.19	20.00
3	3.74	0.23	9.57
4	4.27	0.26	0.72
5	4.62	0.28	1.76



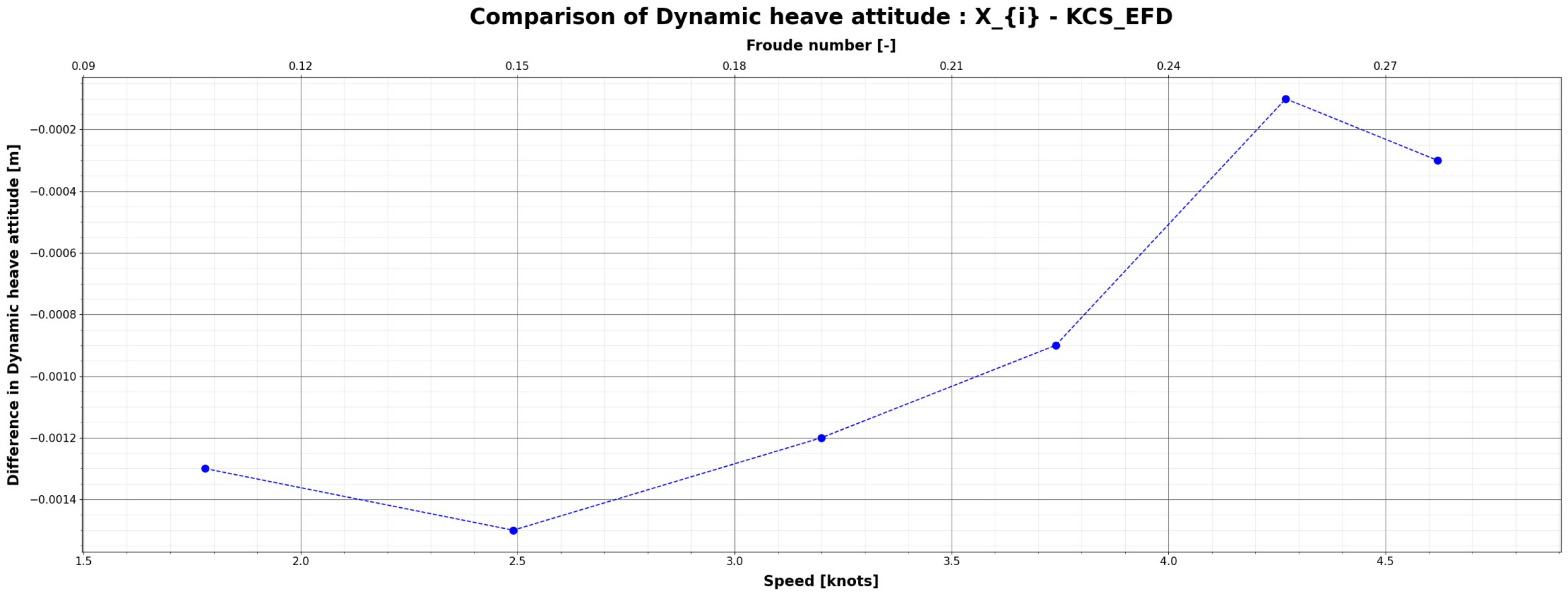
	Speed [knots]	Froude number [-]	X_0 = KCS_Medium, [%]
0	1.78	0.11	10.00
1	2.49	0.15	-17.74
2	3.20	0.19	-13.30
3	3.74	0.23	-3.31
4	4.27	0.26	-3.49
5	4.62	0.28	-10.50



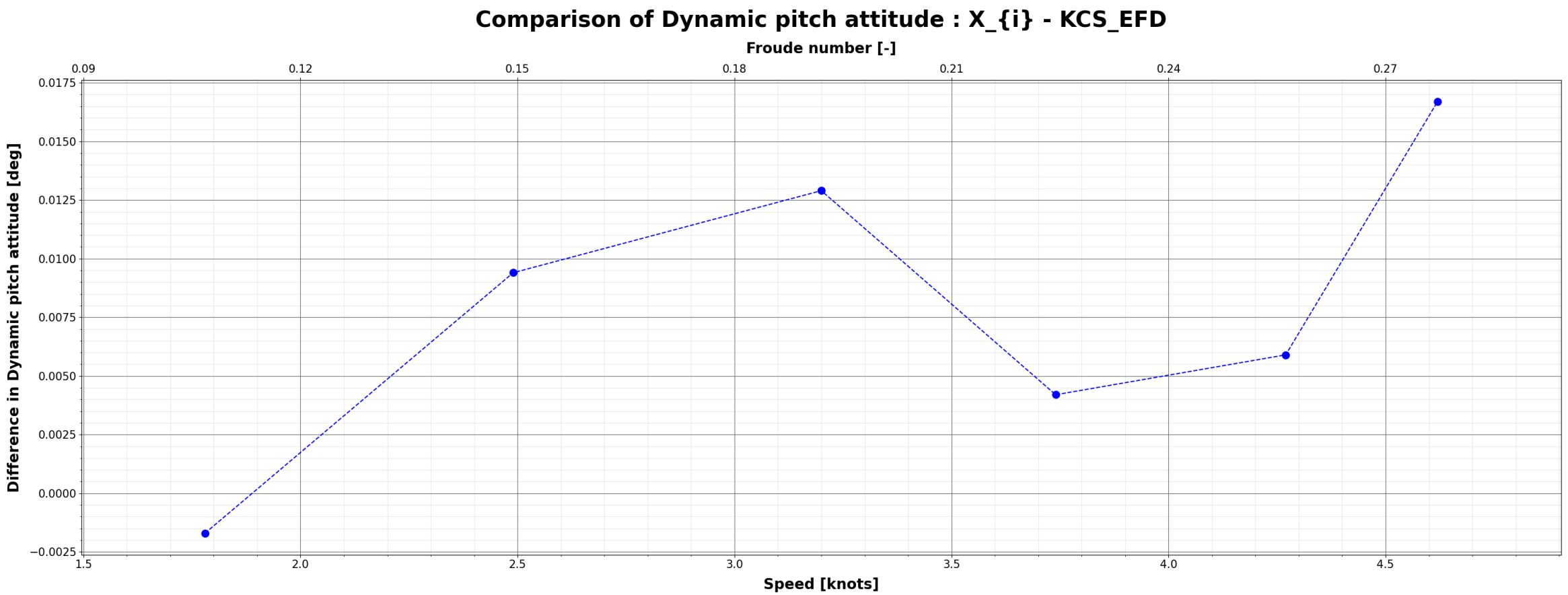
	Speed [knots]	Froude number [-]	X_0 = KCS_Medium, [-]
0	1.78	0.11	3.00e-05
1	2.49	0.15	-1.00e-05
2	3.20	0.19	1.00e-05
3	3.74	0.23	-1.00e-05
4	4.27	0.26	-4.00e-05
5	4.62	0.28	-4.00e-05



	Speed [knots]	Froude number [-]	X_0 = KCS_Medium, [N]
0	1.78	0.11	0.27
1	2.49	0.15	0.18
2	3.20	0.19	0.53
3	3.74	0.23	0.27
4	4.27	0.26	-0.13
5	4.62	0.28	0.16



	Speed [knots]	Froude number [-]	X_0 = KCS_Medium, [m]
0	1.78	0.11	-0.001
1	2.49	0.15	-0.001
2	3.20	0.19	-0.001
3	3.74	0.23	-0.001
4	4.27	0.26	-0.000
5	4.62	0.28	-0.000



	Speed [knots]	Froude number [-]	X_0 = KCS_Medium, [deg]
0	1.78	0.11	-0.002
1	2.49	0.15	0.009
2	3.20	0.19	0.013
3	3.74	0.23	0.004
4	4.27	0.26	0.006
5	4.62	0.28	0.017

6. Visuals

a. Mass fraction

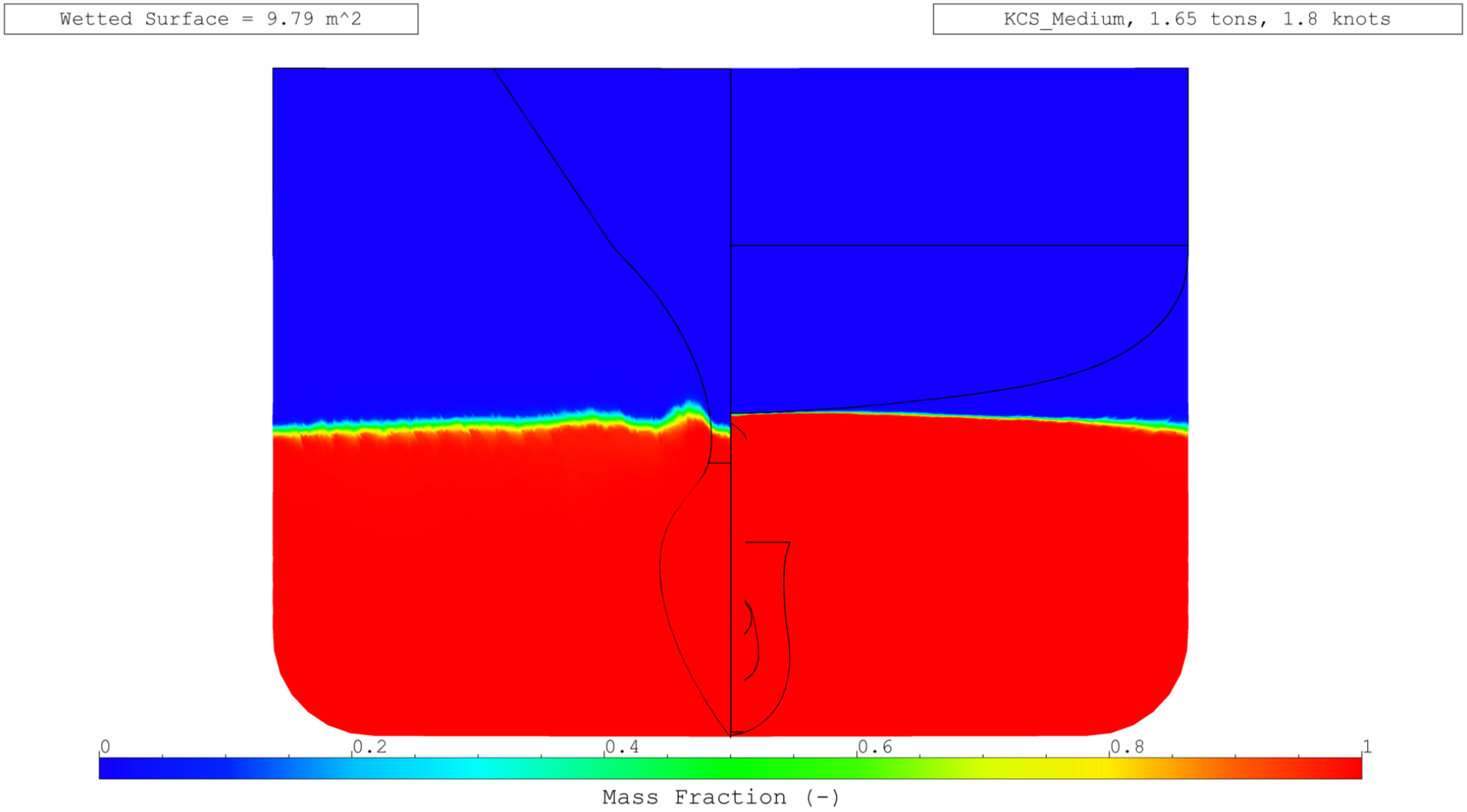
b. Pressure coefficient

c. Free surface

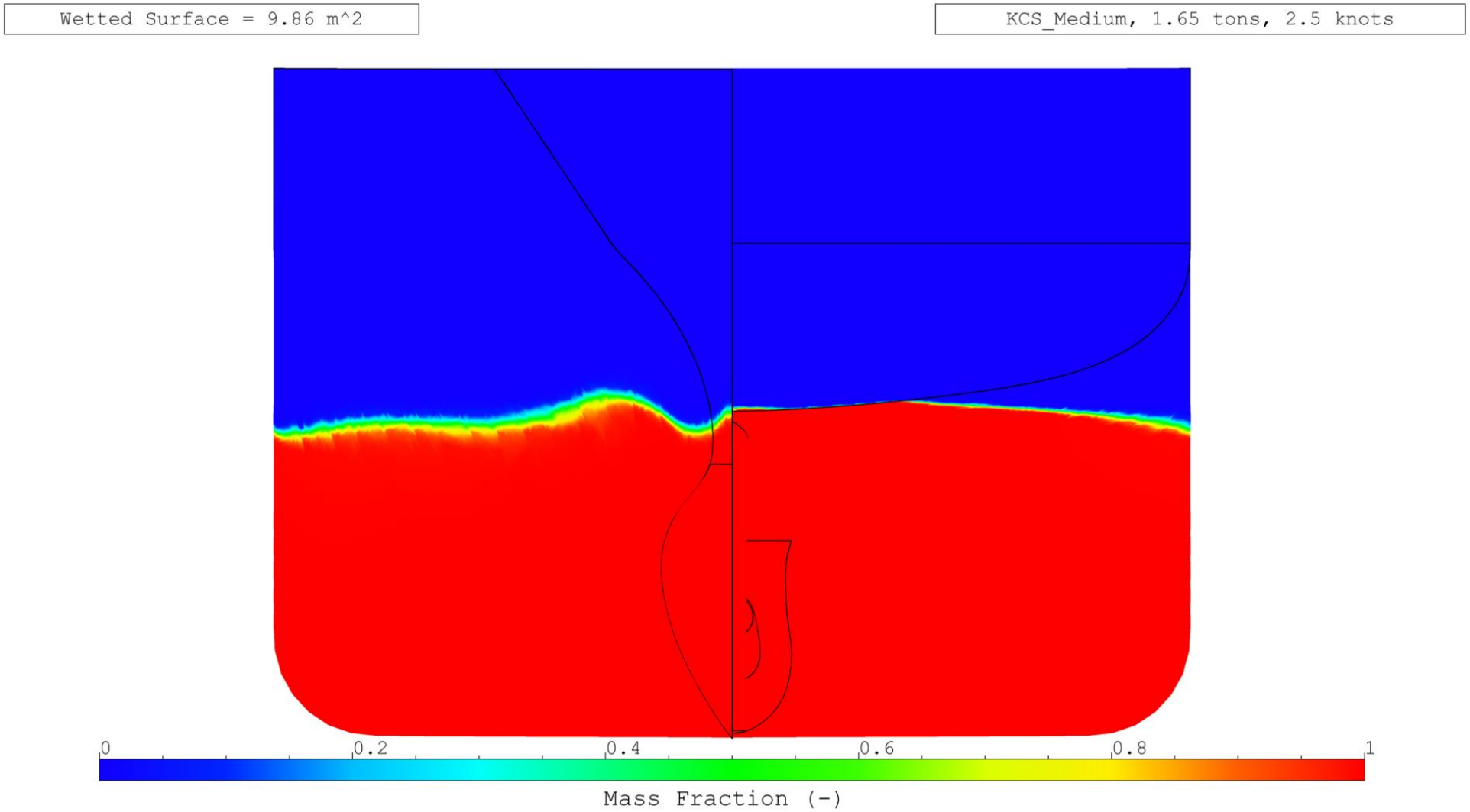
d. Streamlines

1. Surfacic
2. Volumic

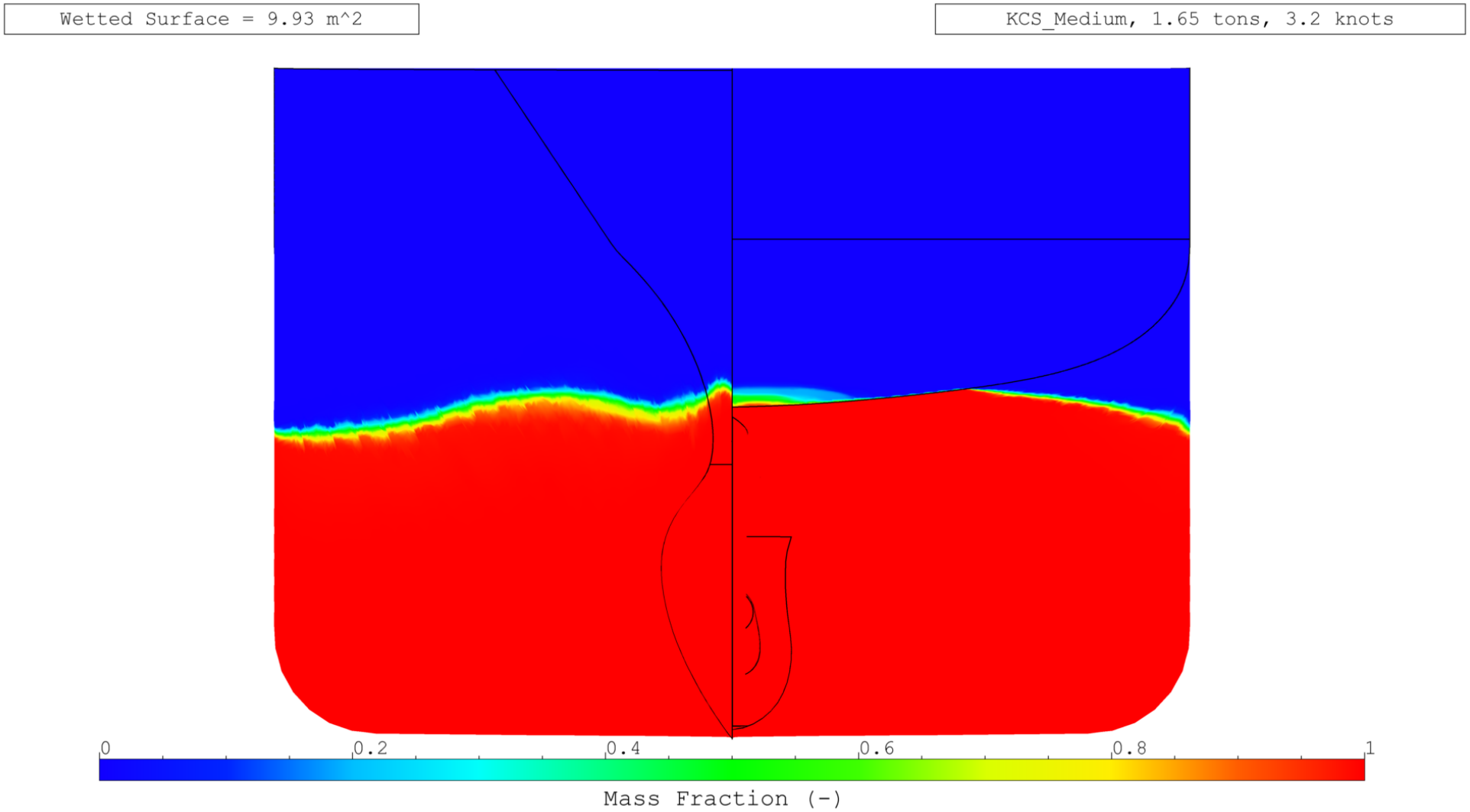
a. Mass fraction : front and rear view



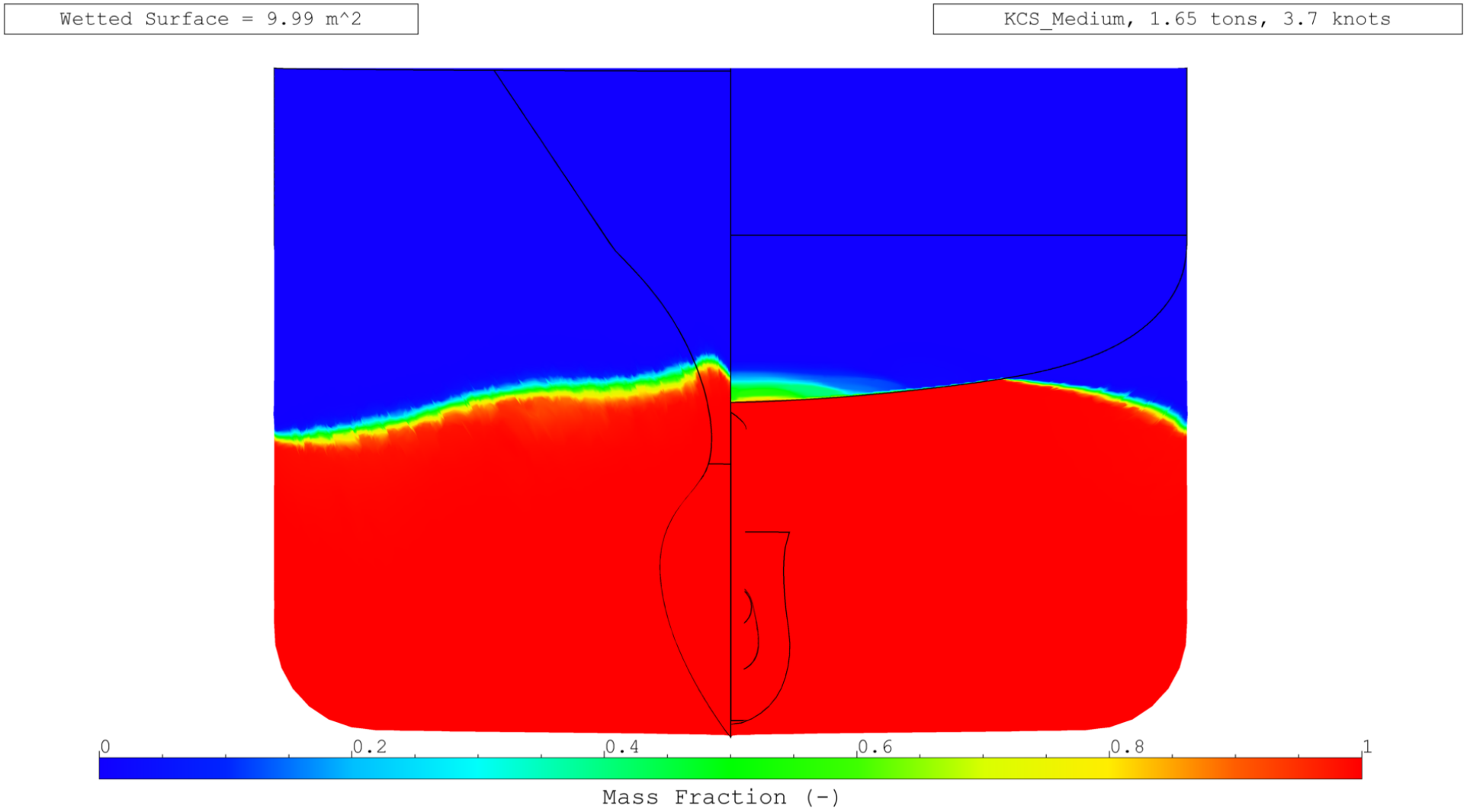
a. Mass fraction : front and rear view



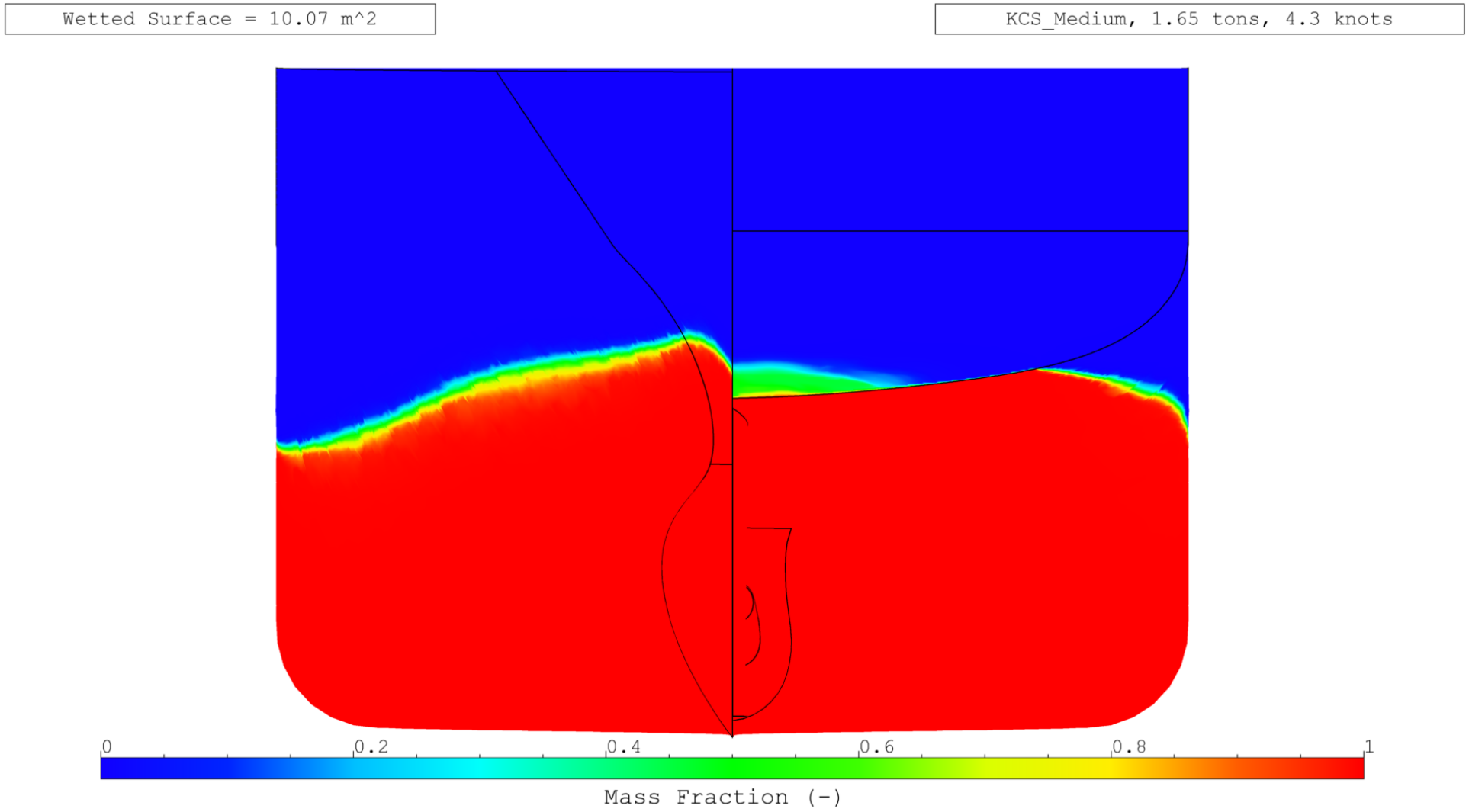
a. Mass fraction : front and rear view



a. Mass fraction : front and rear view



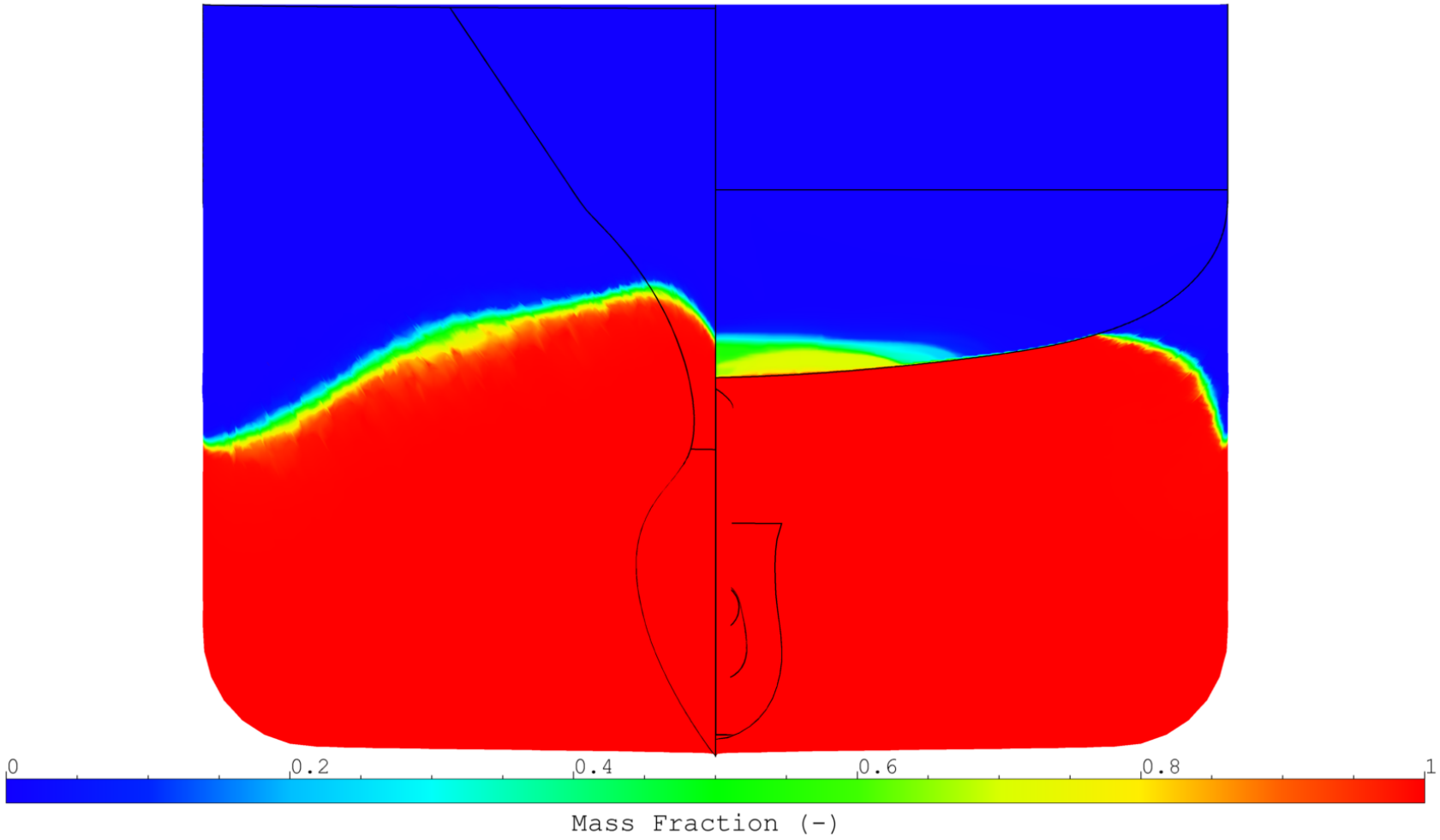
a. Mass fraction : front and rear view



a. Mass fraction : front and rear view

Wetted Surface = 10.13 m^2

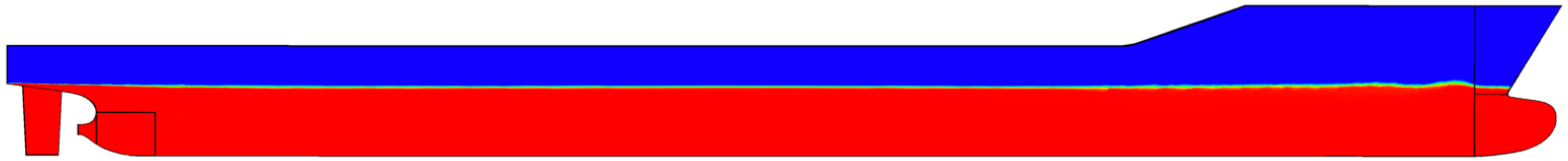
KCS_Medium, 1.65 tons, 4.6 knots



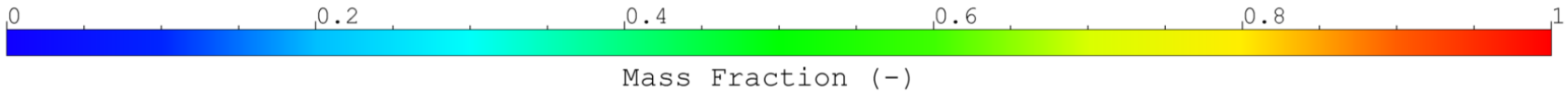
a. Mass fraction : side view(s)

Wetted Surface = 9.79 m^2

KCS_Medium, 1.65 tons, 1.8 knots



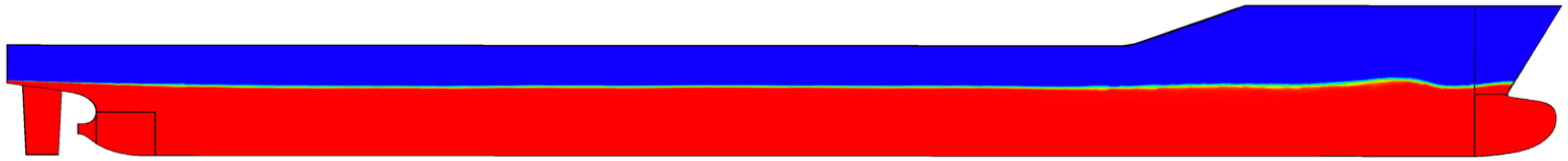
Exterior Side View



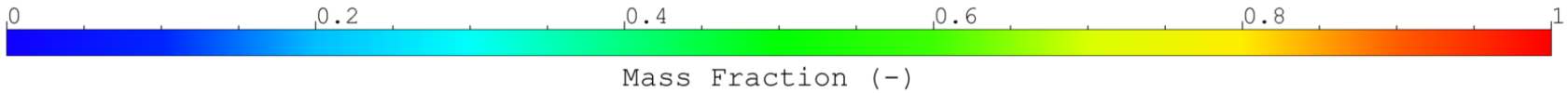
a. Mass fraction : side view(s)

Wetted Surface = 9.86 m^2

KCS_Medium, 1.65 tons, 2.5 knots



Exterior Side View

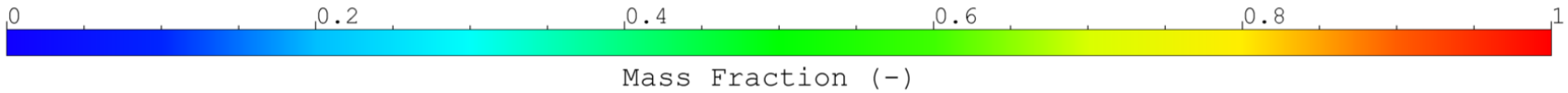


a. Mass fraction : side view(s)

Wetted Surface = 9.93 m^2

KCS_Medium, 1.65 tons, 3.2 knots

Exterior Side View

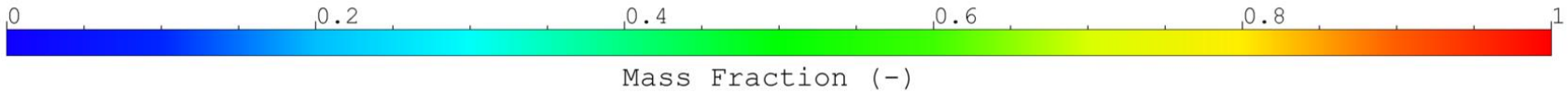


a. Mass fraction : side view(s)

Wetted Surface = 9.99 m^2

KCS_Medium, 1.65 tons, 3.7 knots

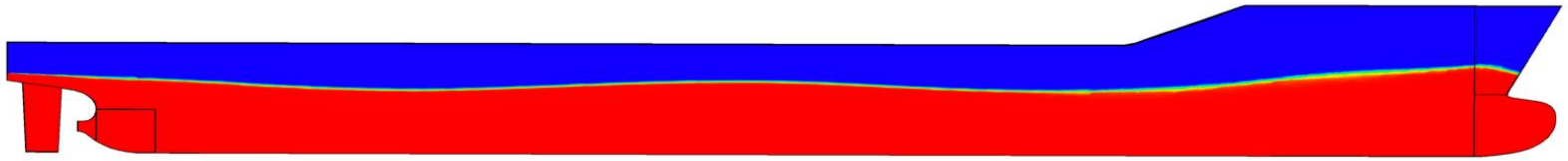
Exterior Side View



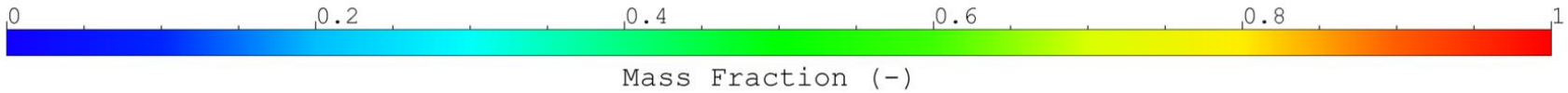
a. Mass fraction : side view(s)

Wetted Surface = 10.07 m^2

KCS_Medium, 1.65 tons, 4.3 knots



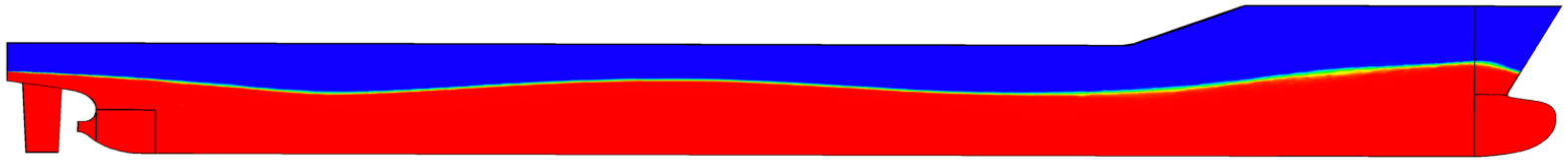
Exterior Side View



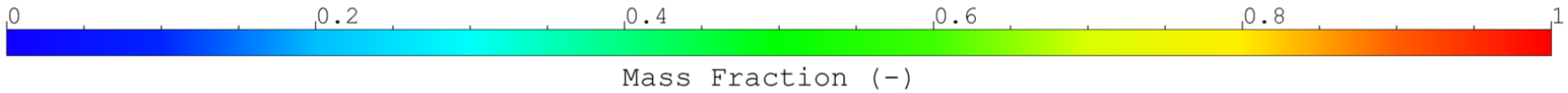
a. Mass fraction : side view(s)

Wetted Surface = 10.13 m^2

KCS_Medium, 1.65 tons, 4.6 knots



Exterior Side View



6. Visuals

a. Mass fraction

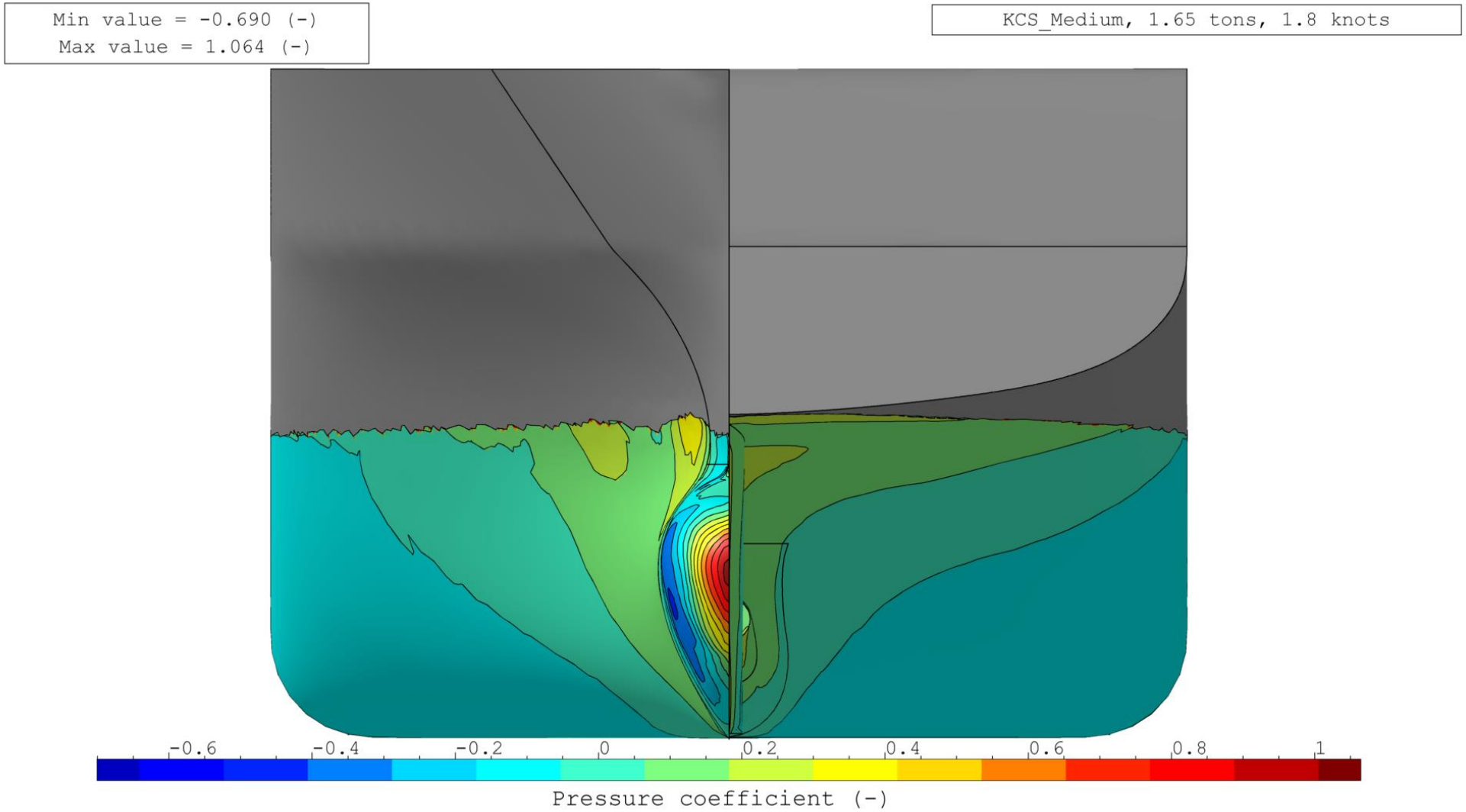
b. Pressure coefficient

c. Free surface

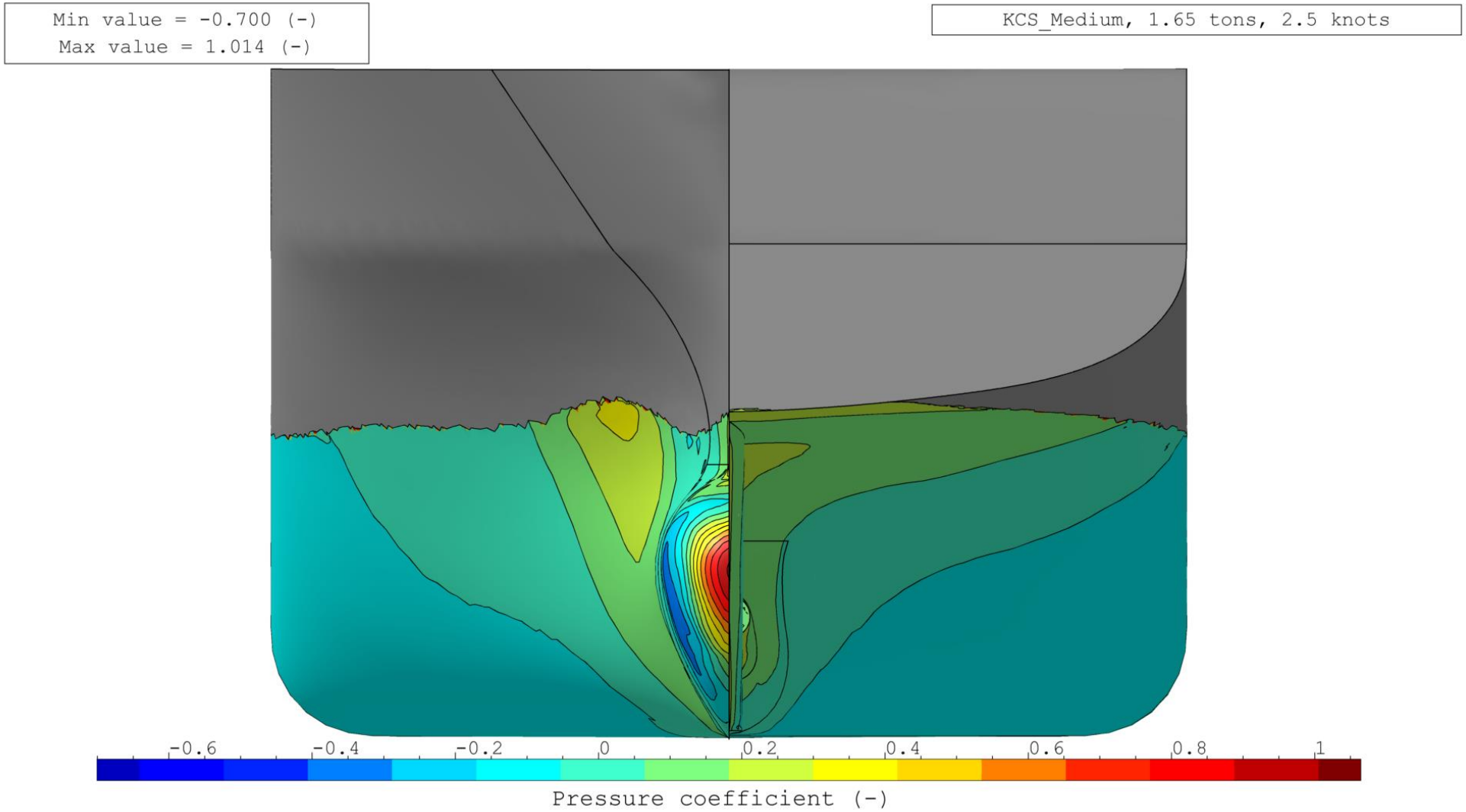
d. Streamlines

1. Surfacic
2. Volumic

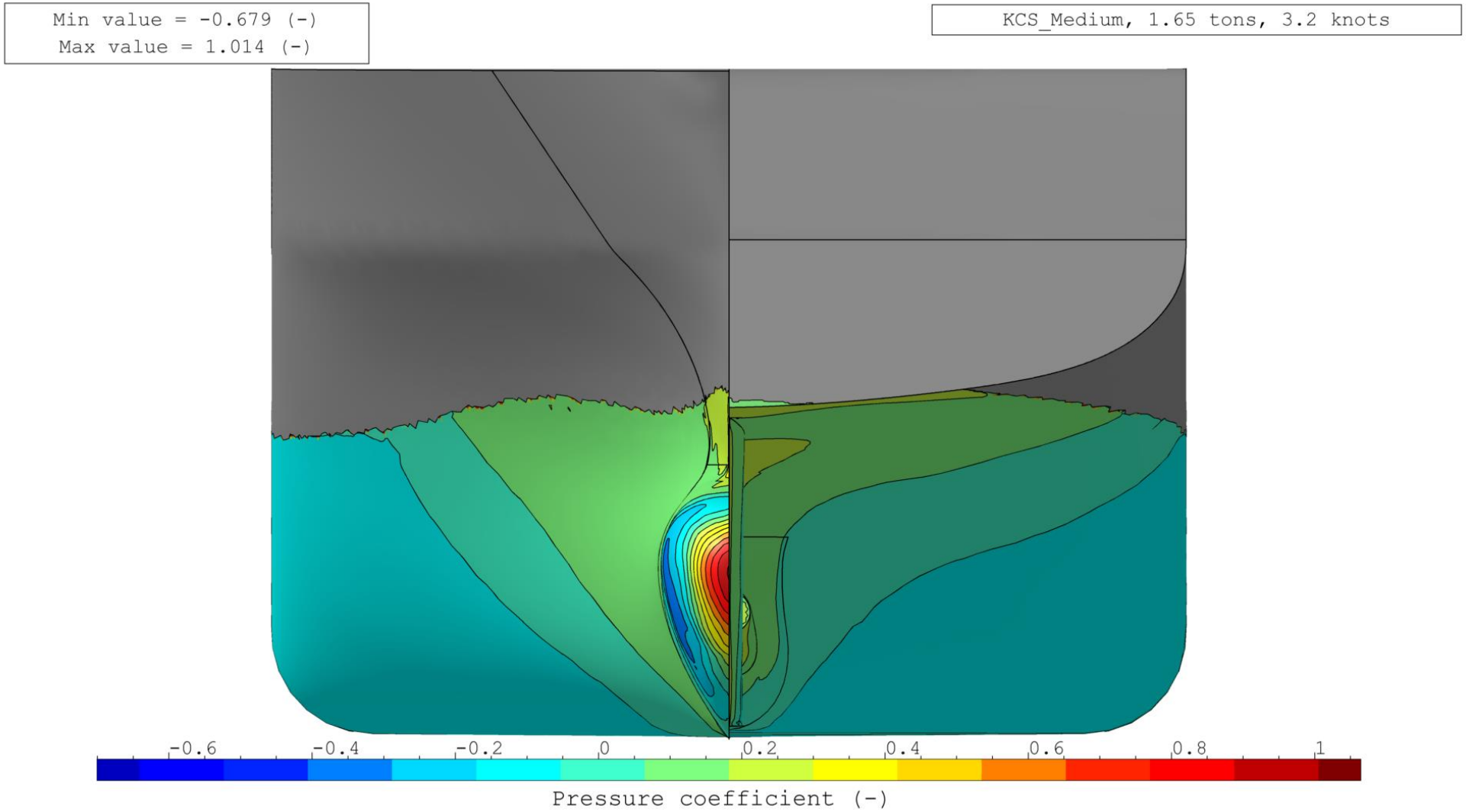
b. Pressure coefficient : front and rear view



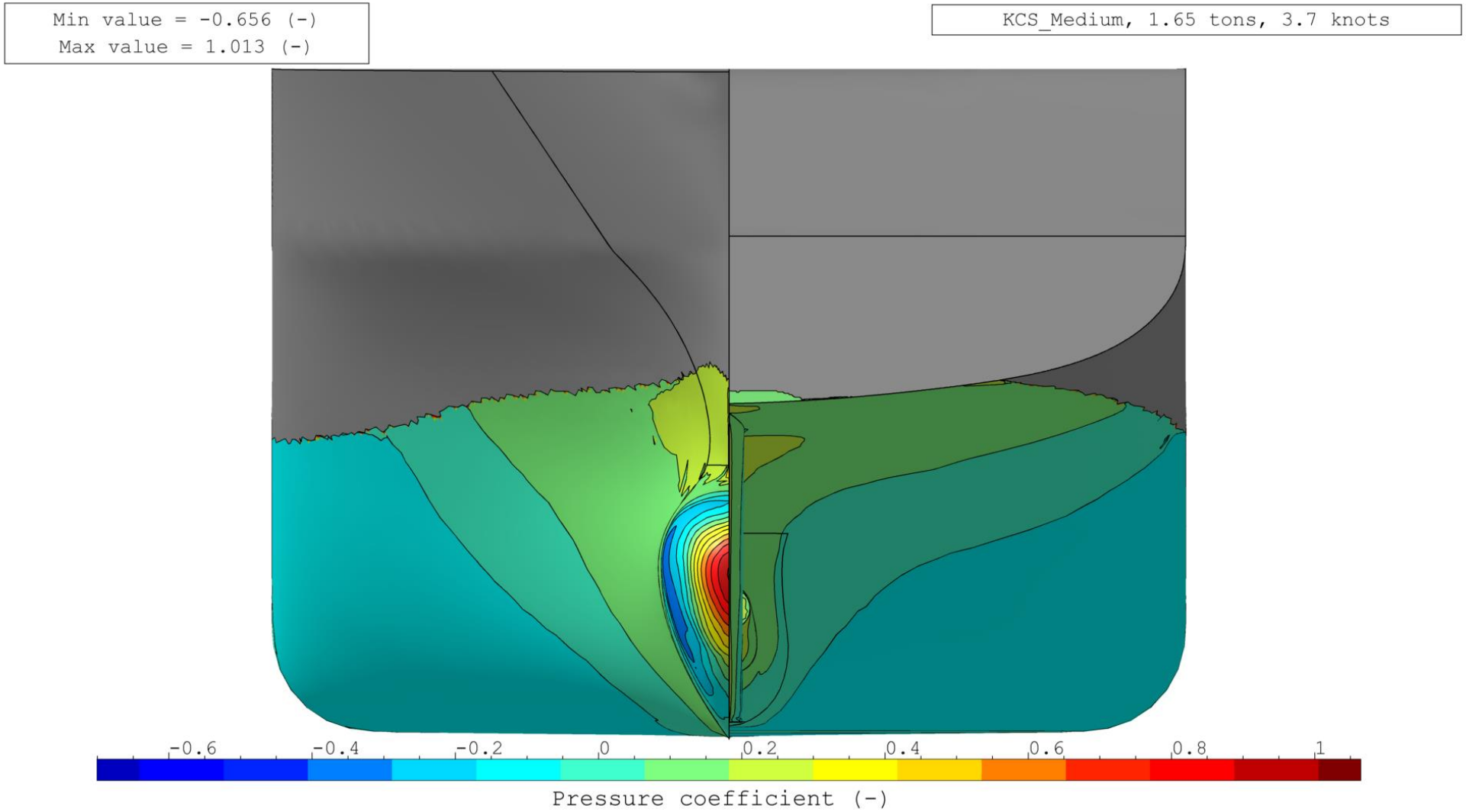
b. Pressure coefficient : front and rear view



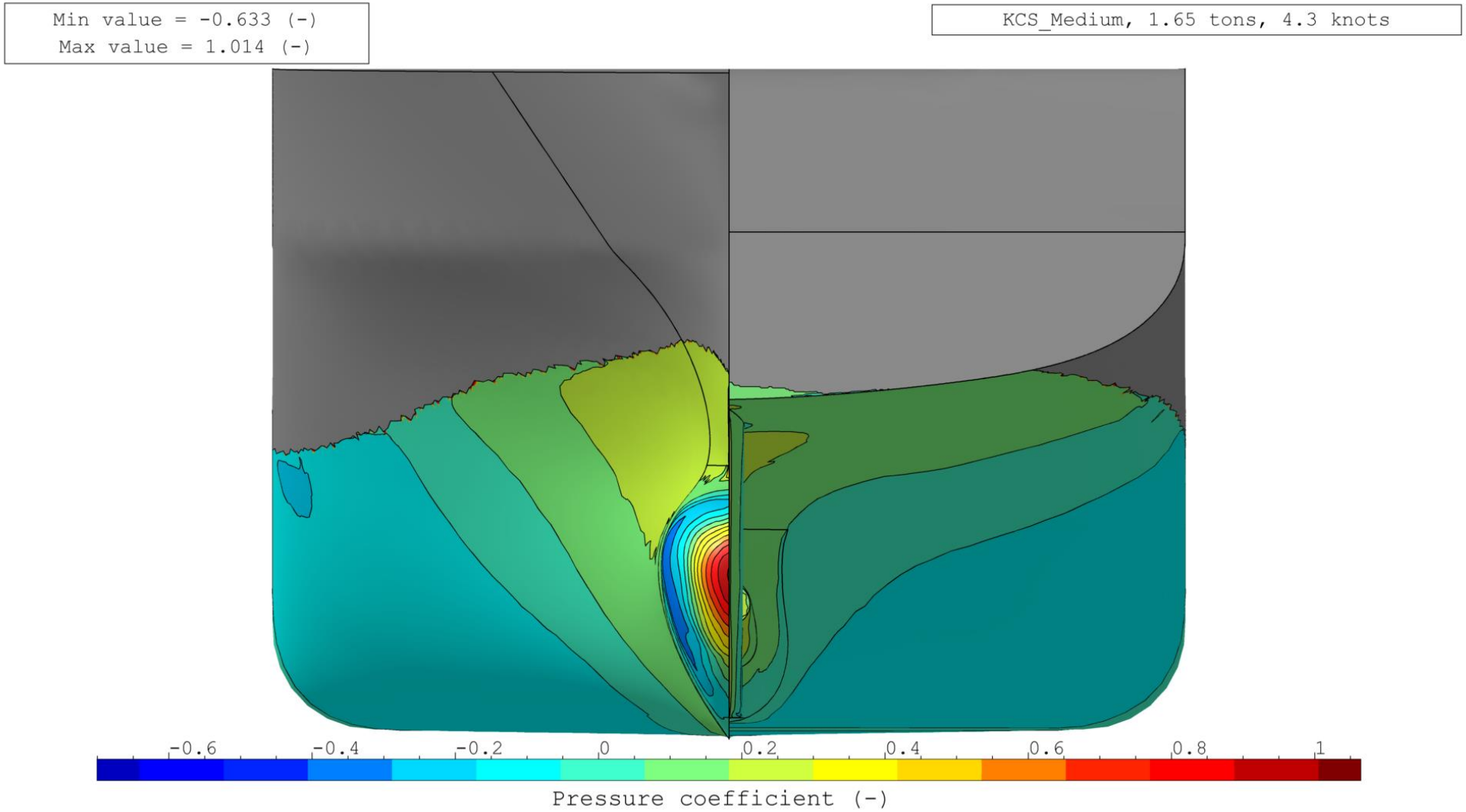
b. Pressure coefficient : front and rear view



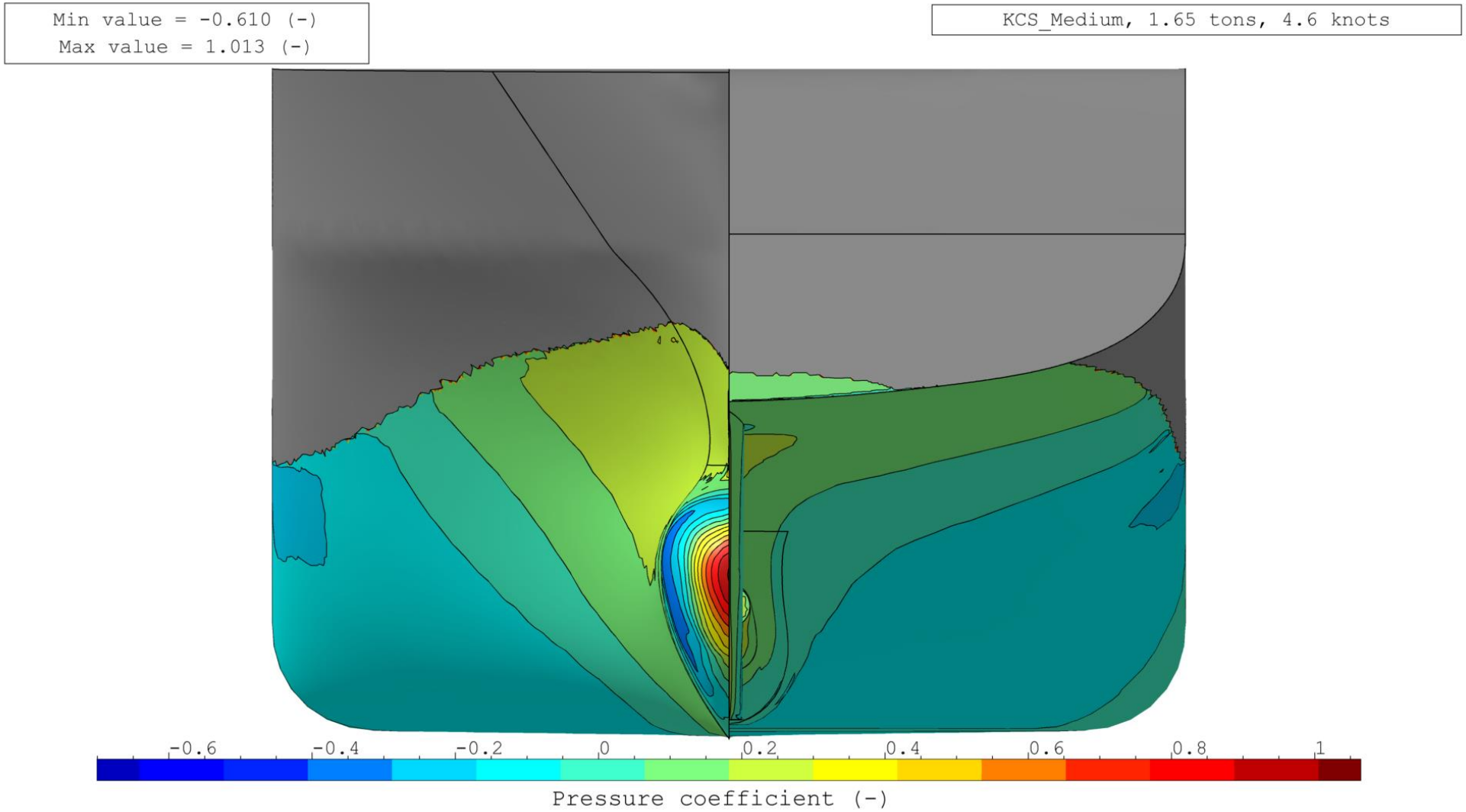
b. Pressure coefficient : front and rear view



b. Pressure coefficient : front and rear view



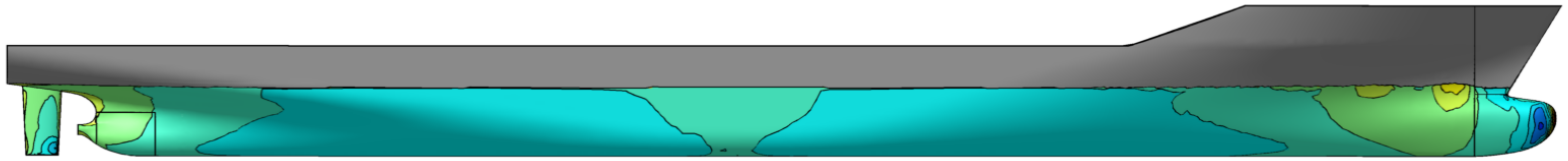
b. Pressure coefficient : front and rear view



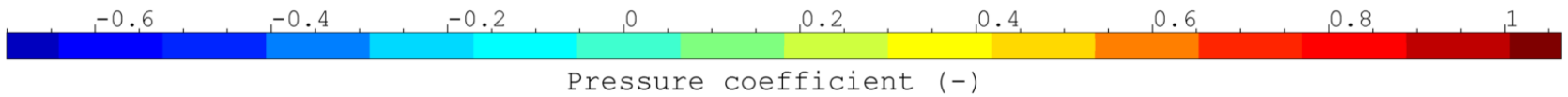
b. Pressure coefficient : side view(s)

Min value = -0.690 (-)
Max value = 1.064 (-)

KCS_Medium, 1.65 tons, 1.8 knots



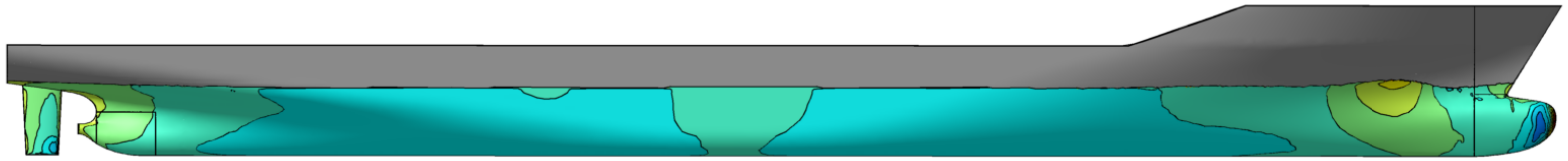
Exterior Side View



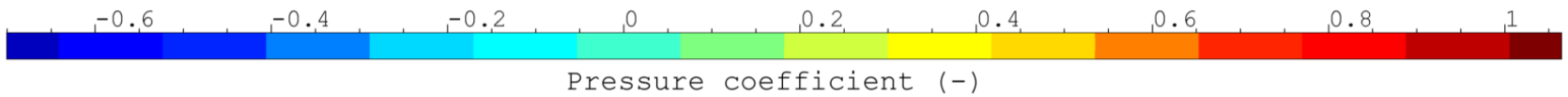
b. Pressure coefficient : side view(s)

Min value = -0.700 (-)
Max value = 1.014 (-)

KCS_Medium, 1.65 tons, 2.5 knots



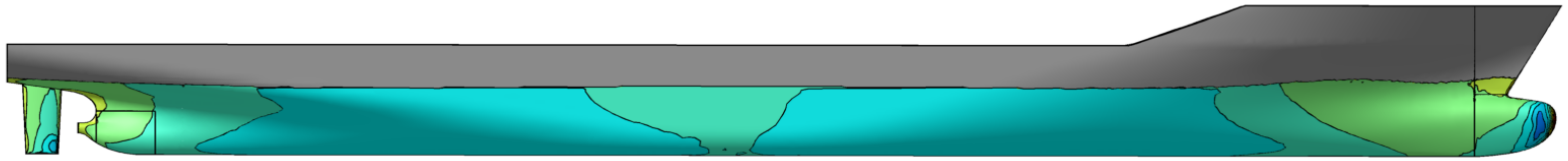
Exterior Side View



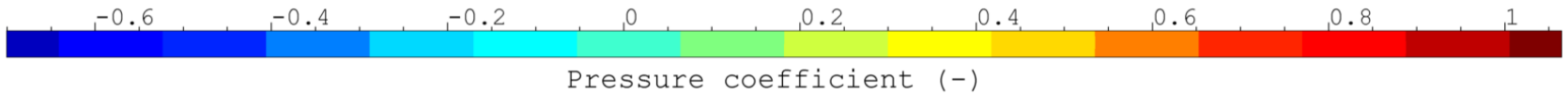
b. Pressure coefficient : side view(s)

Min value = -0.679 (-)
Max value = 1.014 (-)

KCS_Medium, 1.65 tons, 3.2 knots



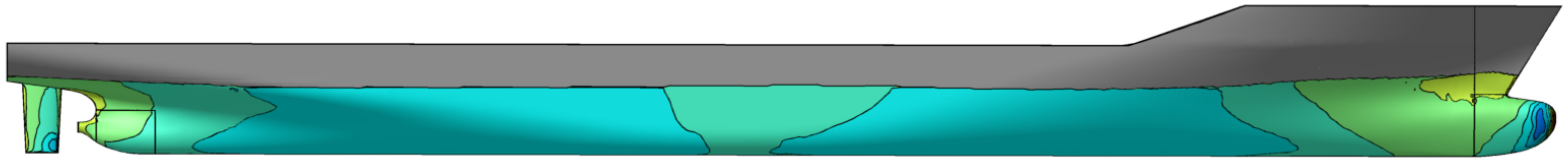
Exterior Side View



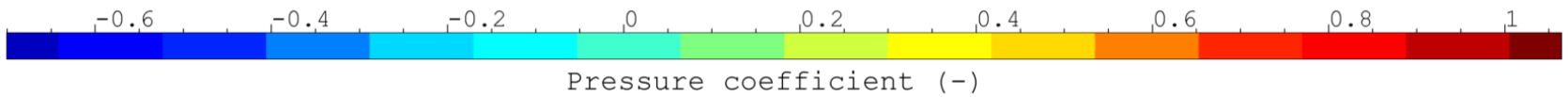
b. Pressure coefficient : side view(s)

Min value = -0.656 (-)
Max value = 1.013 (-)

KCS_Medium, 1.65 tons, 3.7 knots



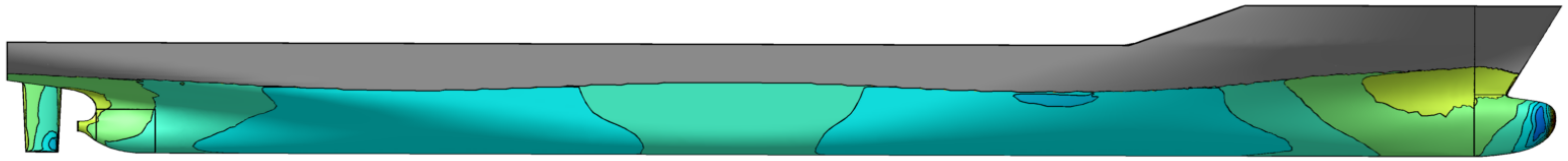
Exterior Side View



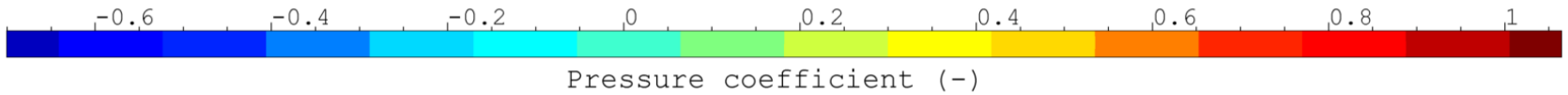
b. Pressure coefficient : side view(s)

Min value = -0.633 (-)
Max value = 1.014 (-)

KCS_Medium, 1.65 tons, 4.3 knots



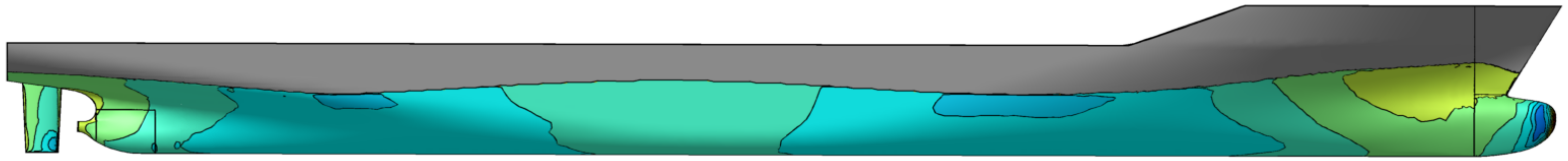
Exterior Side View



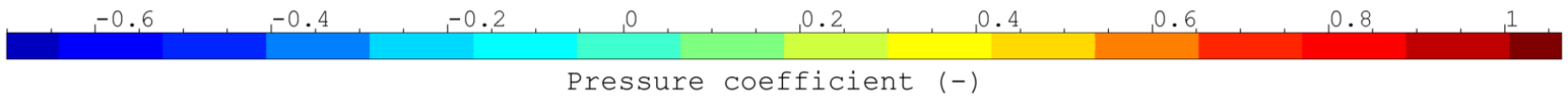
b. Pressure coefficient : side view(s)

Min value = -0.610 (-)
Max value = 1.013 (-)

KCS_Medium, 1.65 tons, 4.6 knots



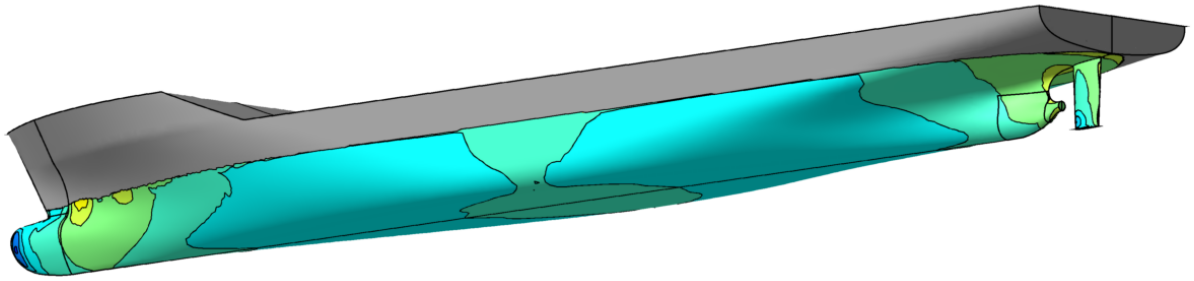
Exterior Side View

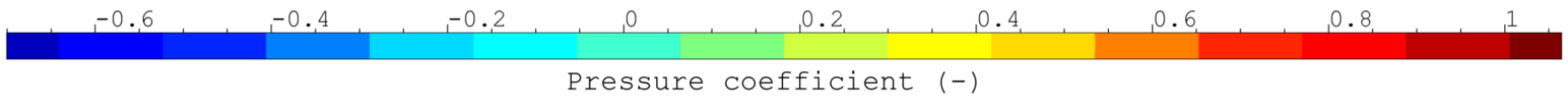


b. Pressure coefficient : ¾ rear view

Min value = -0.690 (-)
Max value = 1.064 (-)

KCS_Medium, 1.65 tons, 1.8 knots

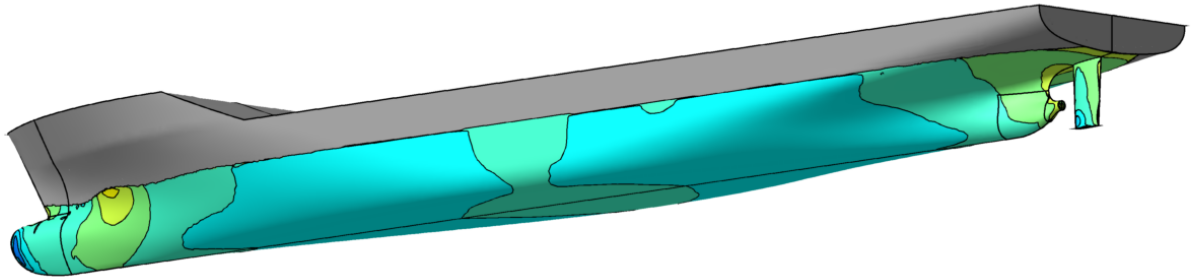


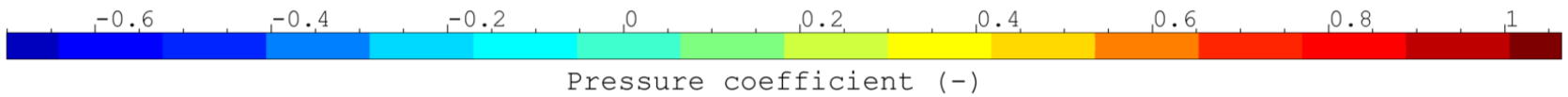


b. Pressure coefficient : ¾ rear view

Min value = -0.700 (-)
Max value = 1.014 (-)

KCS_Medium, 1.65 tons, 2.5 knots

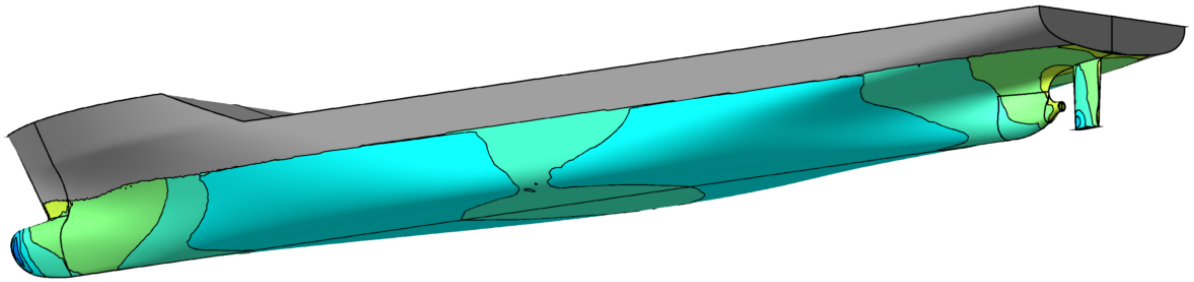


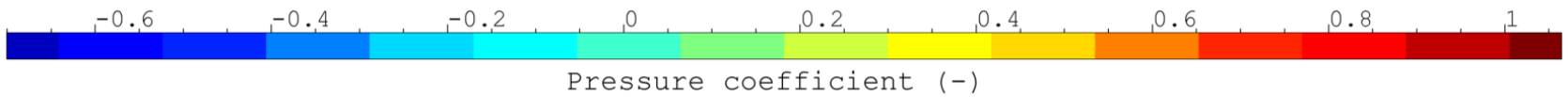


b. Pressure coefficient : ¾ rear view

Min value = -0.679 (-)
Max value = 1.014 (-)

KCS_Medium, 1.65 tons, 3.2 knots

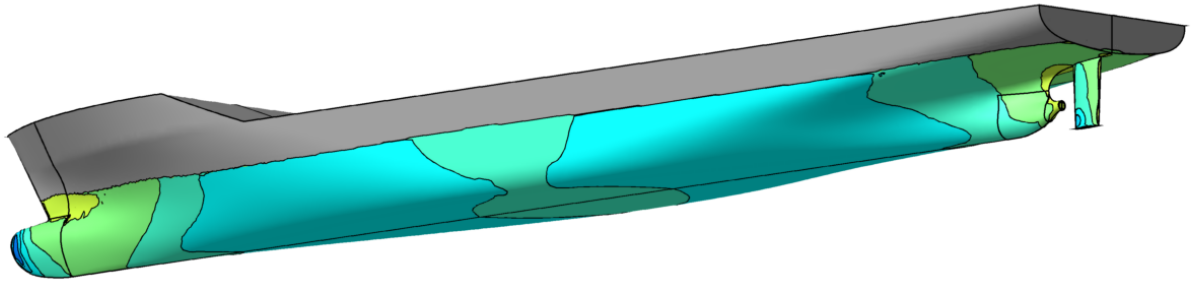


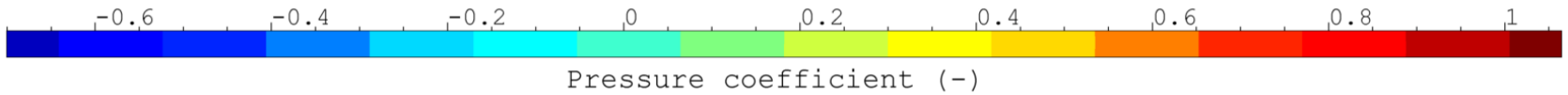


b. Pressure coefficient : ¾ rear view

Min value = -0.656 (-)
Max value = 1.013 (-)

KCS_Medium, 1.65 tons, 3.7 knots

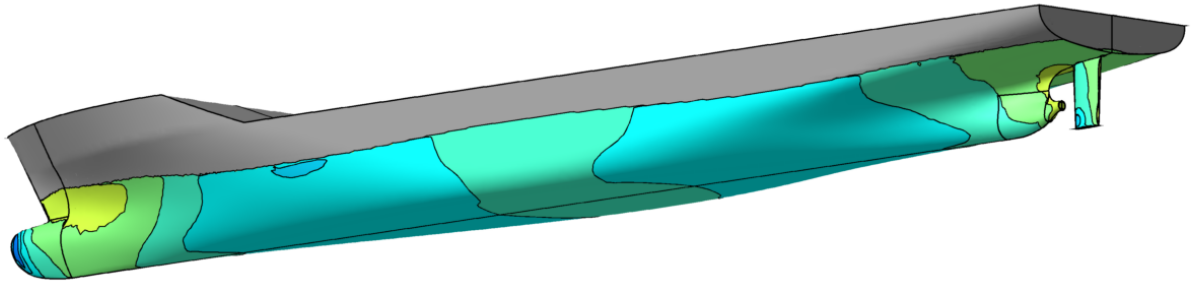


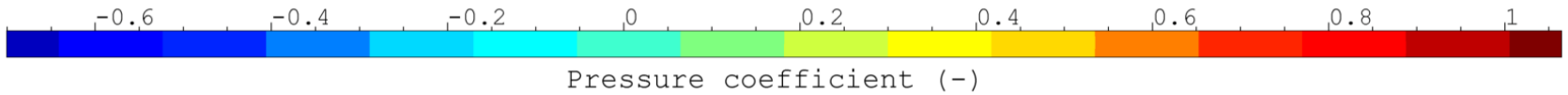


b. Pressure coefficient : ¾ rear view

Min value = -0.633 (-)
Max value = 1.014 (-)

KCS_Medium, 1.65 tons, 4.3 knots

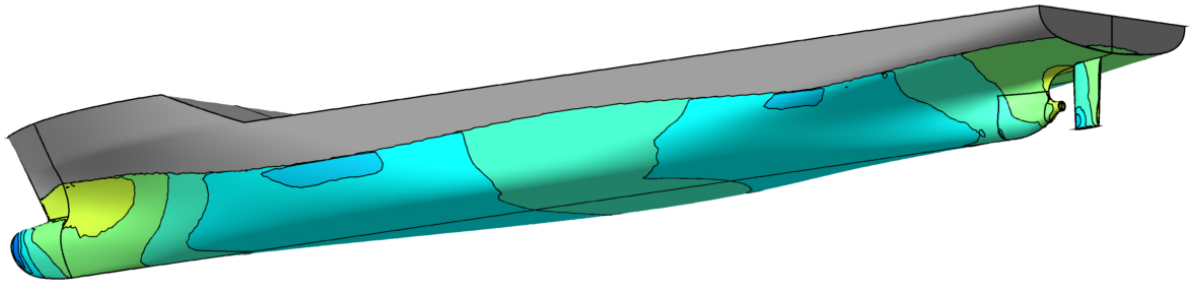


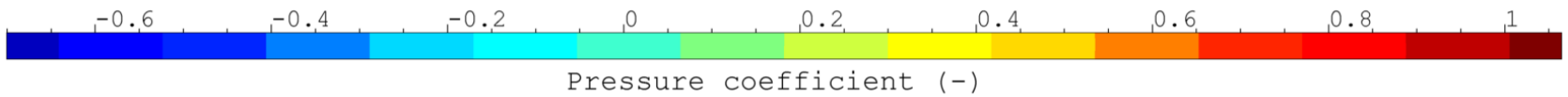


b. Pressure coefficient : ¾ rear view

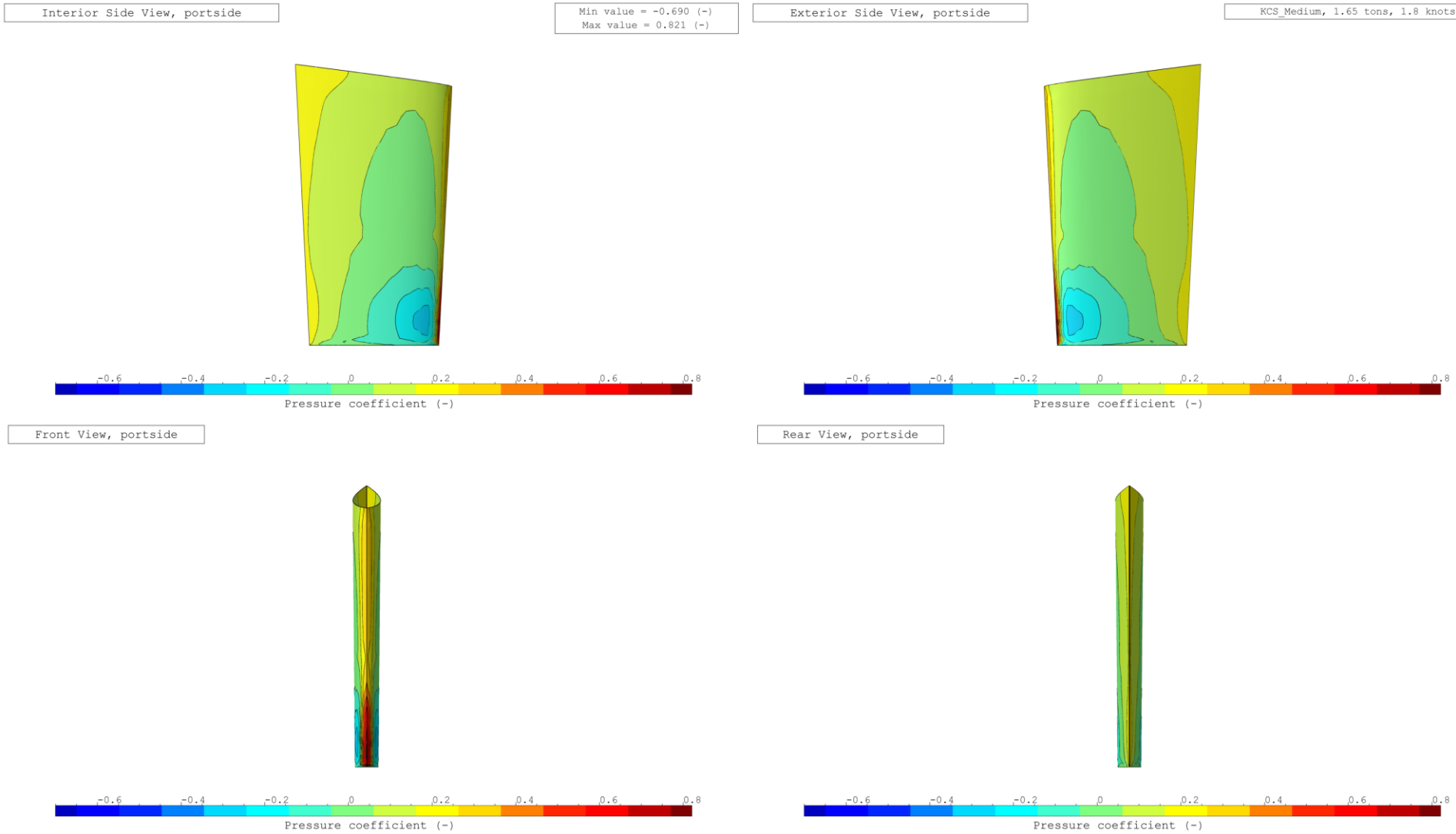
Min value = -0.610 (-)
Max value = 1.013 (-)

KCS_Medium, 1.65 tons, 4.6 knots

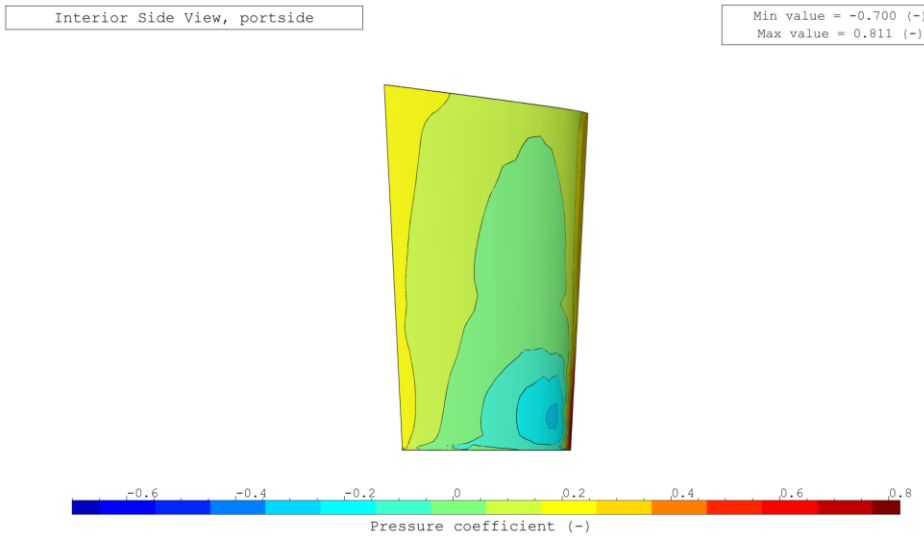


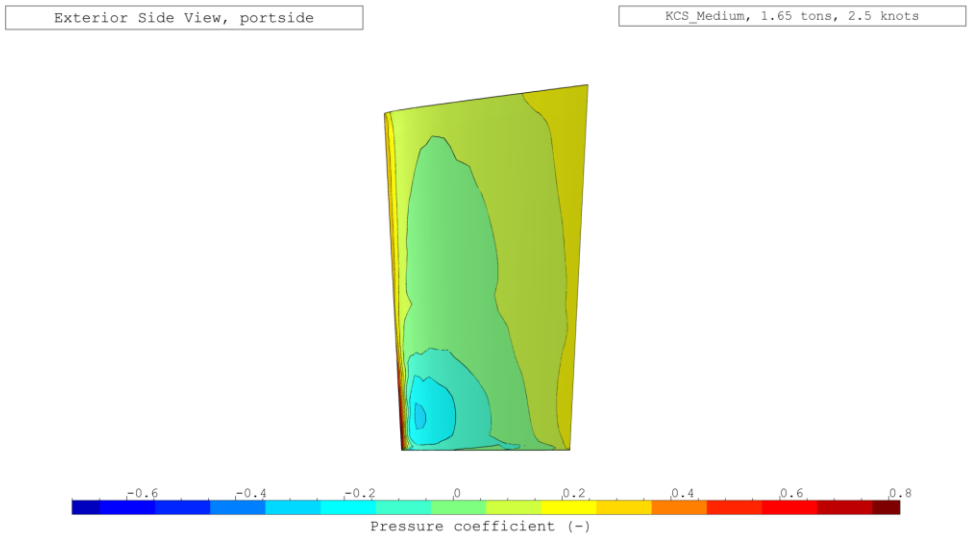


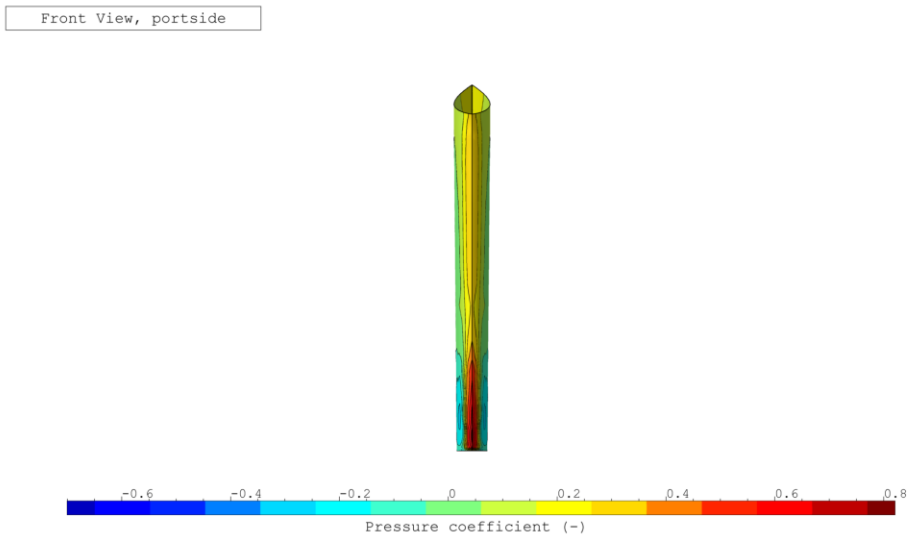
b. Pressure coefficient : appendice(s)

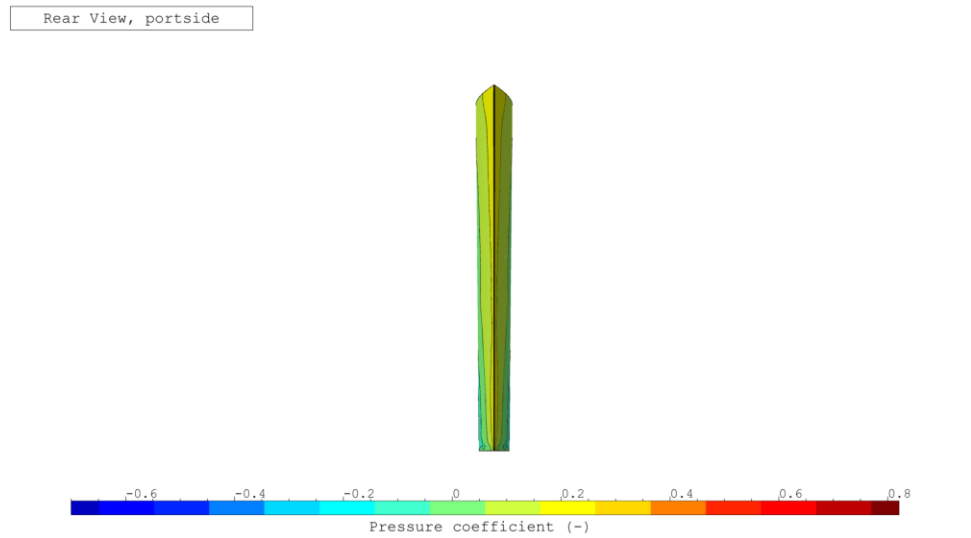


b. Pressure coefficient : appendice(s)

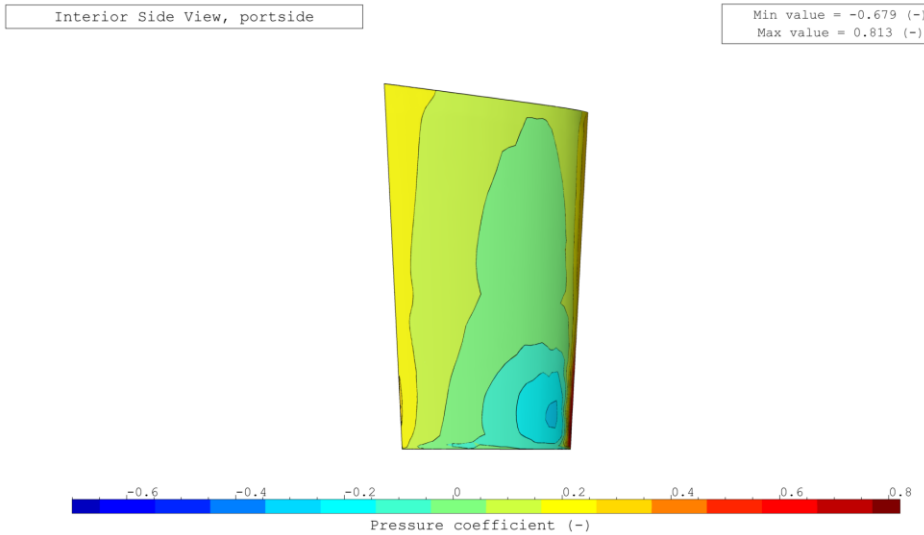


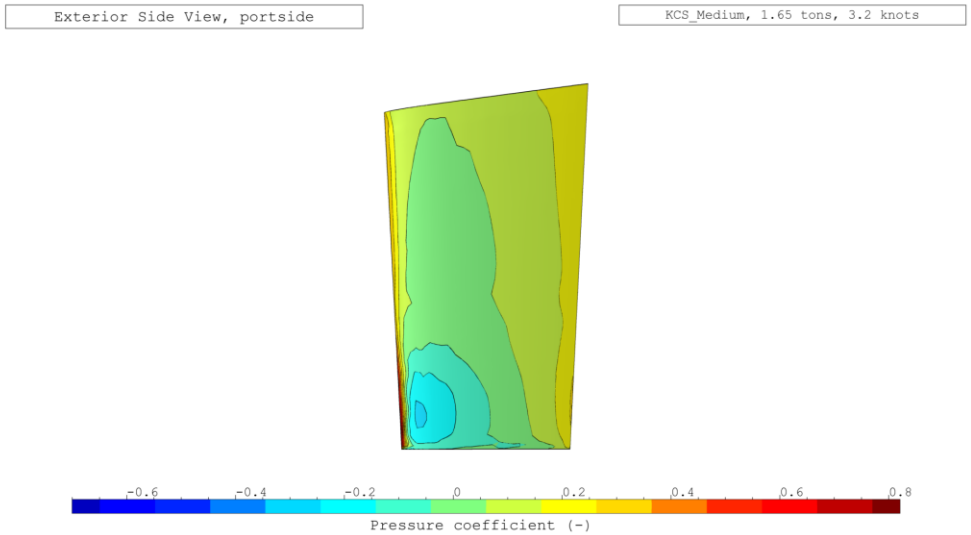


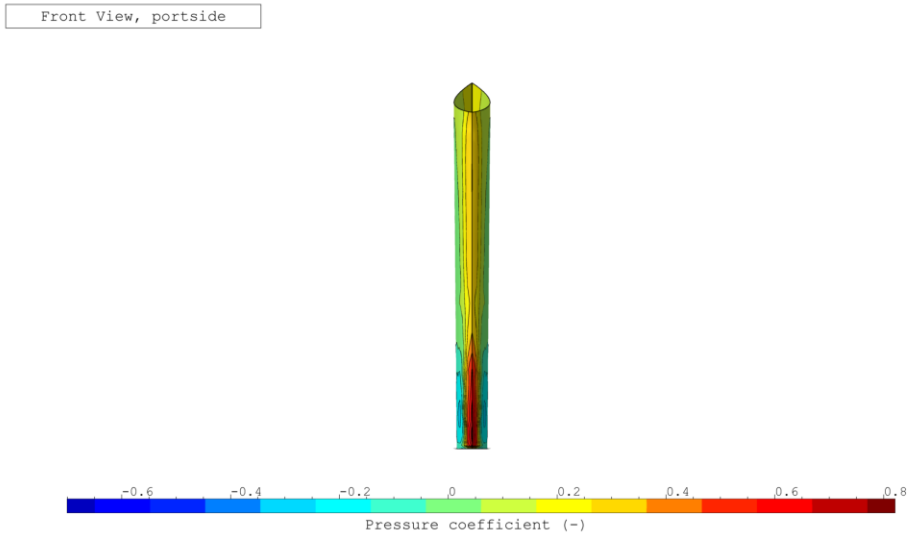


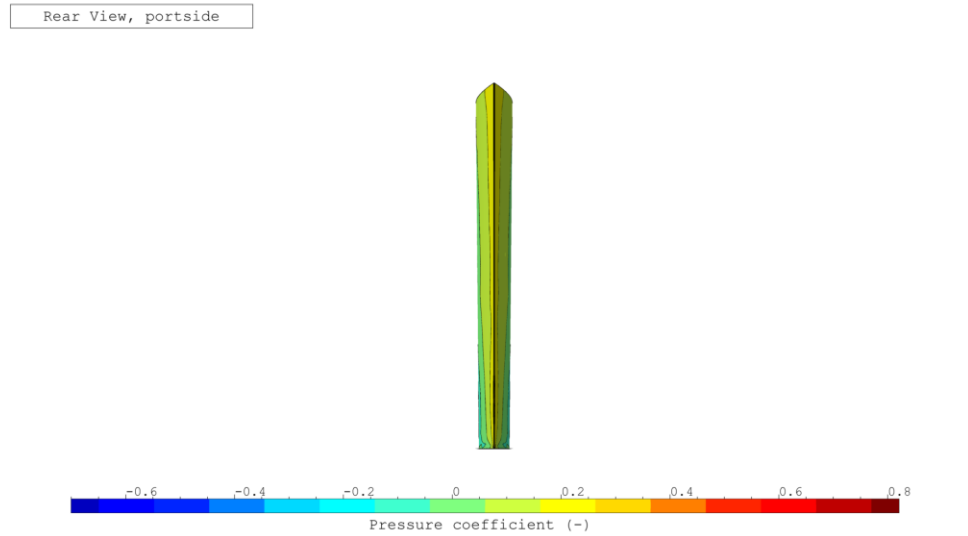


b. Pressure coefficient : appendice(s)

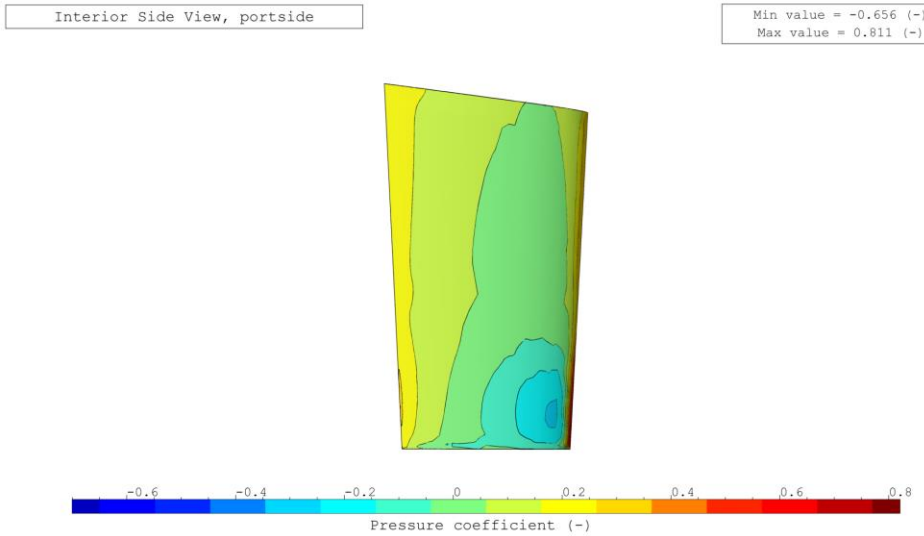


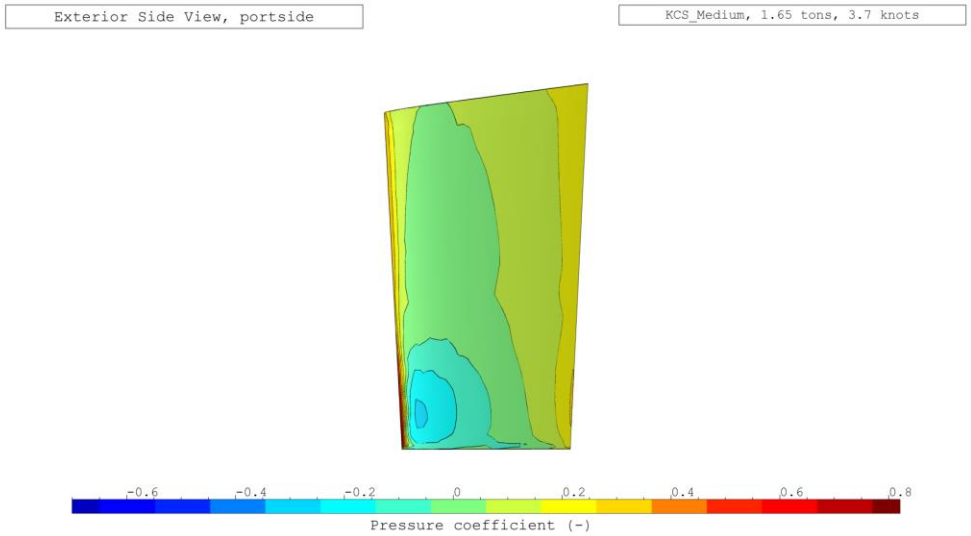


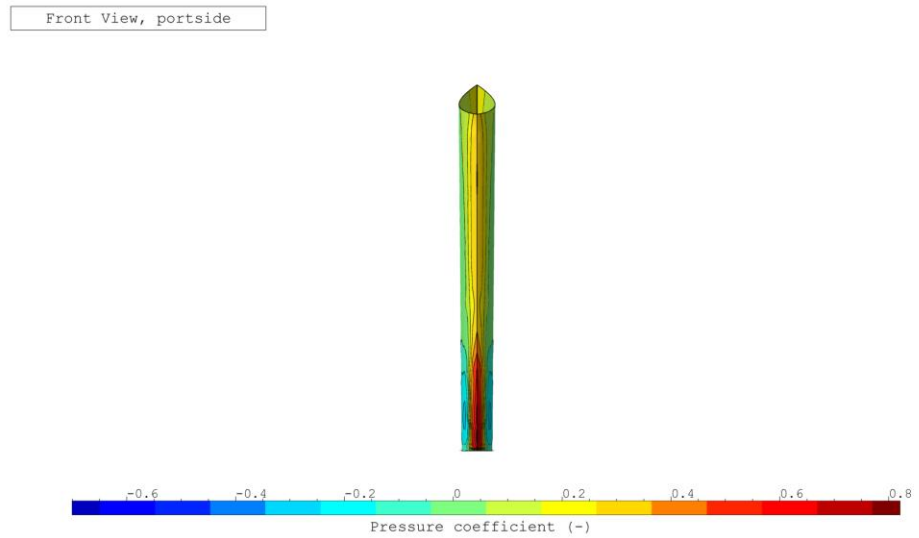


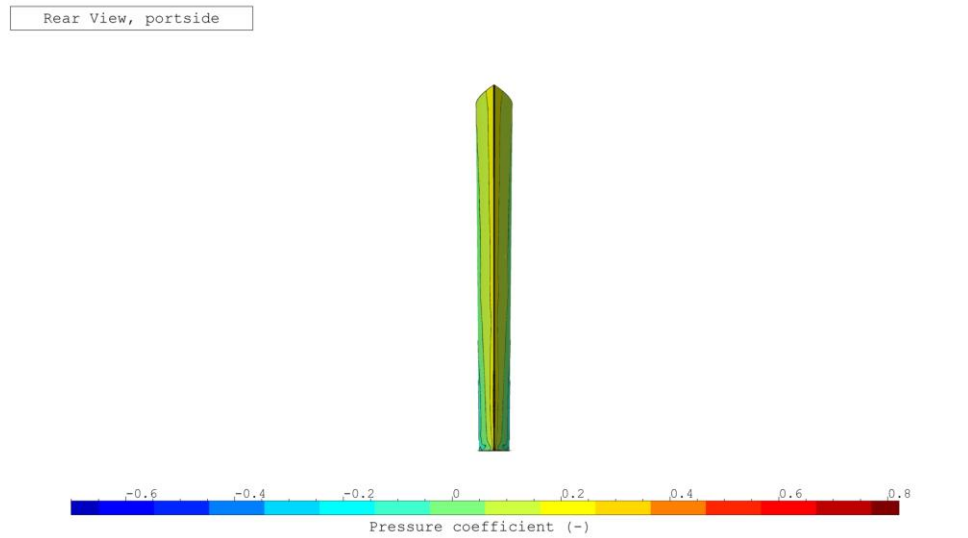


b. Pressure coefficient : appendice(s)

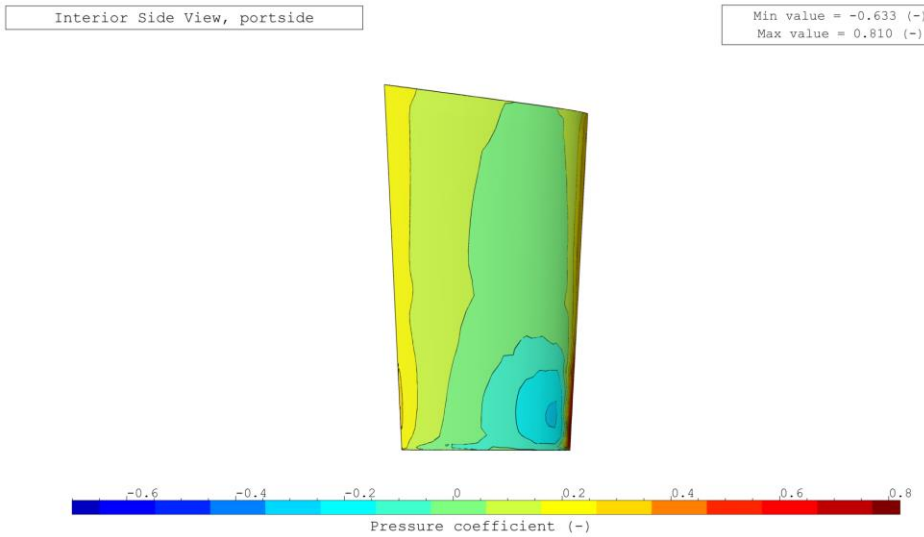


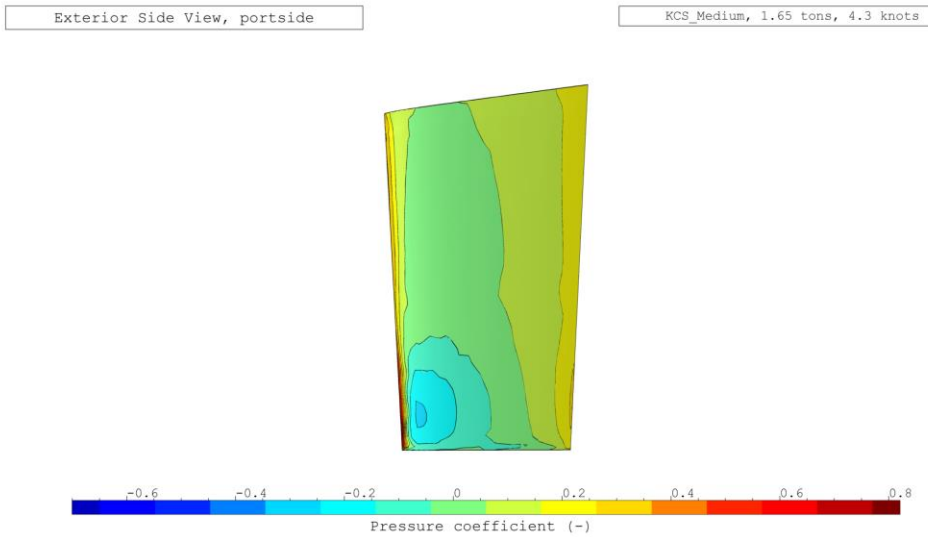


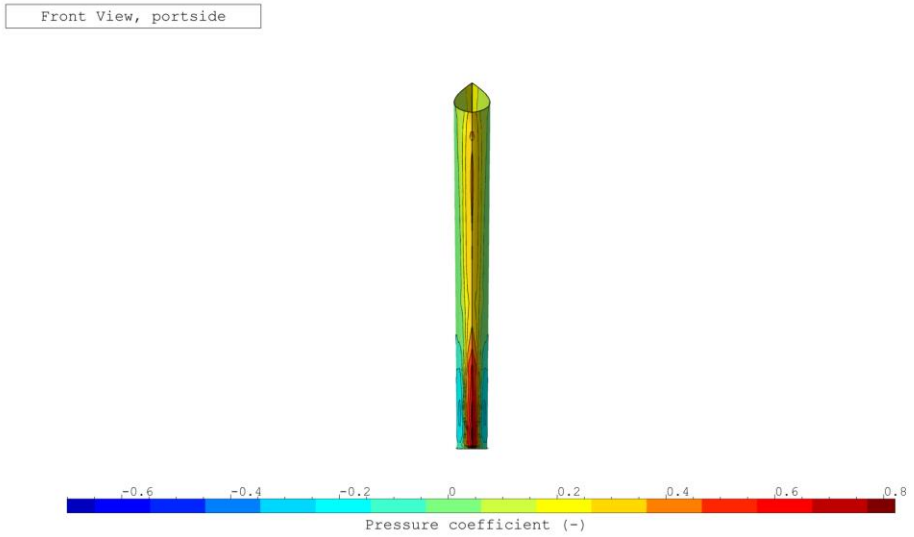


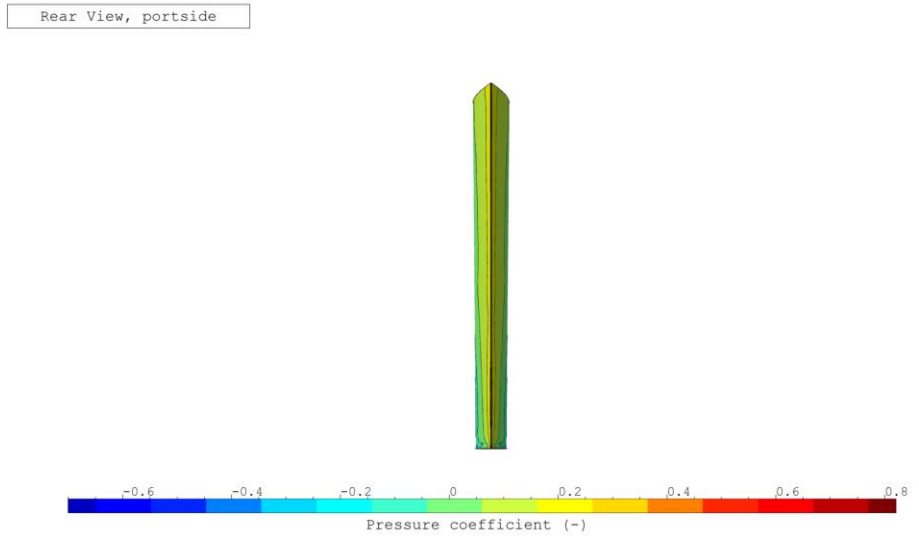


b. Pressure coefficient : appendice(s)

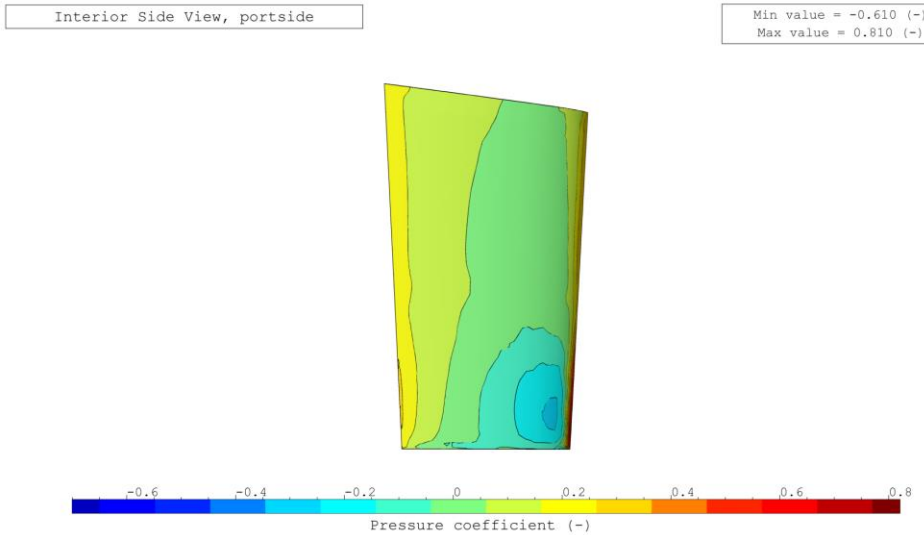


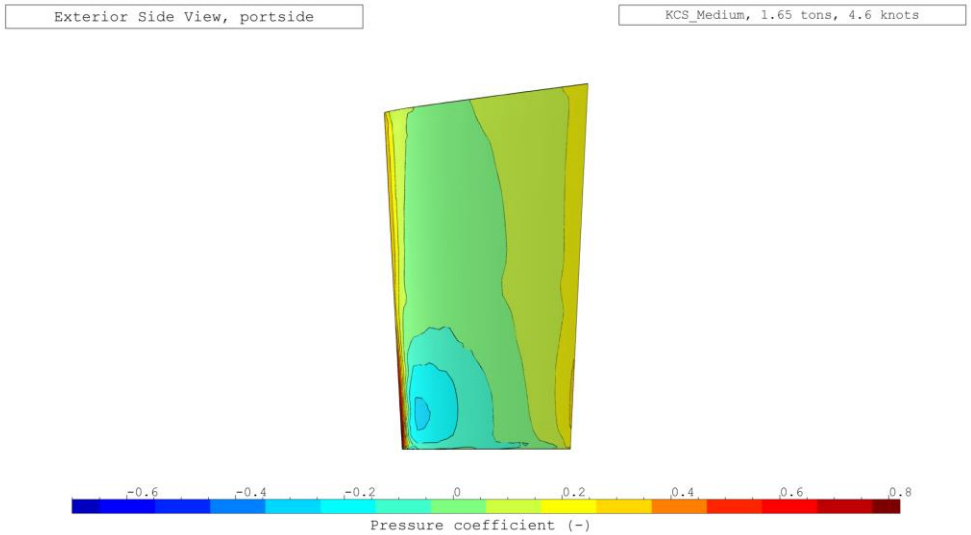


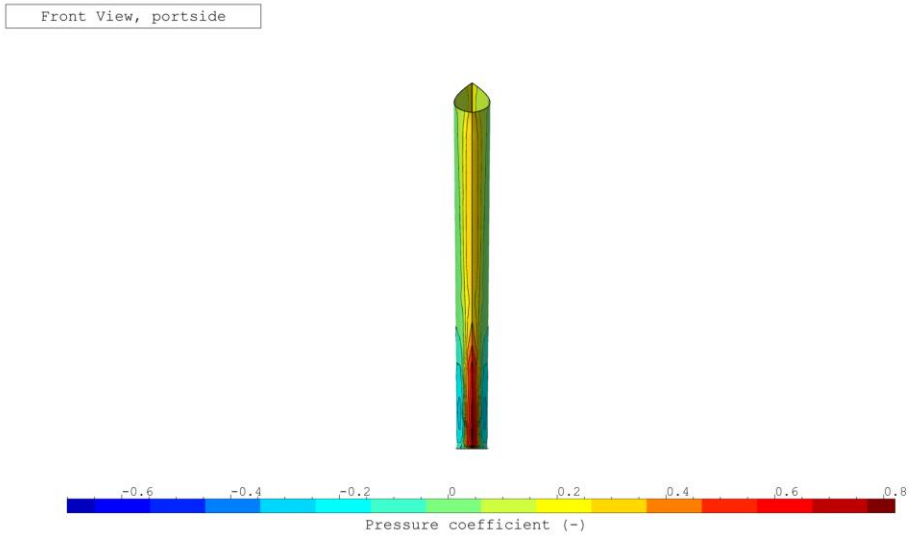


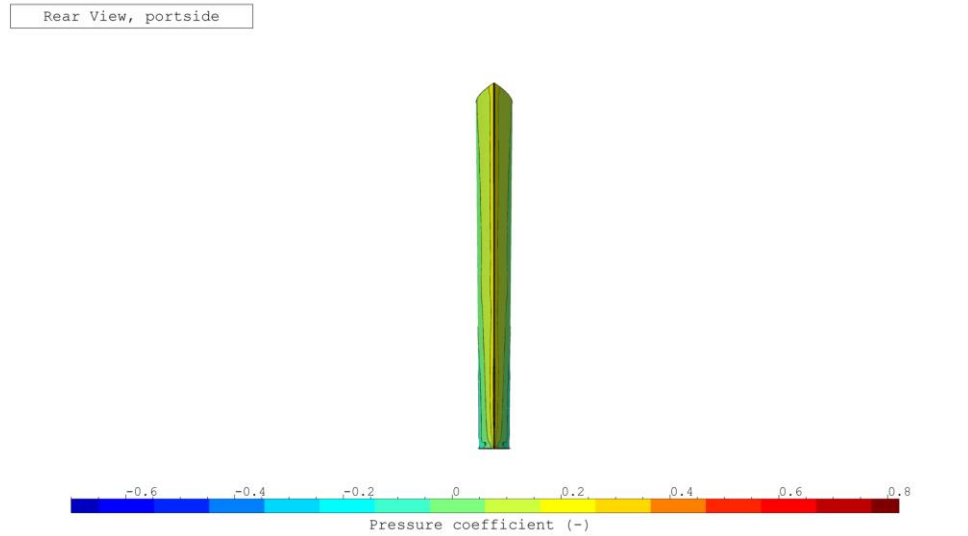


b. Pressure coefficient : appendice(s)





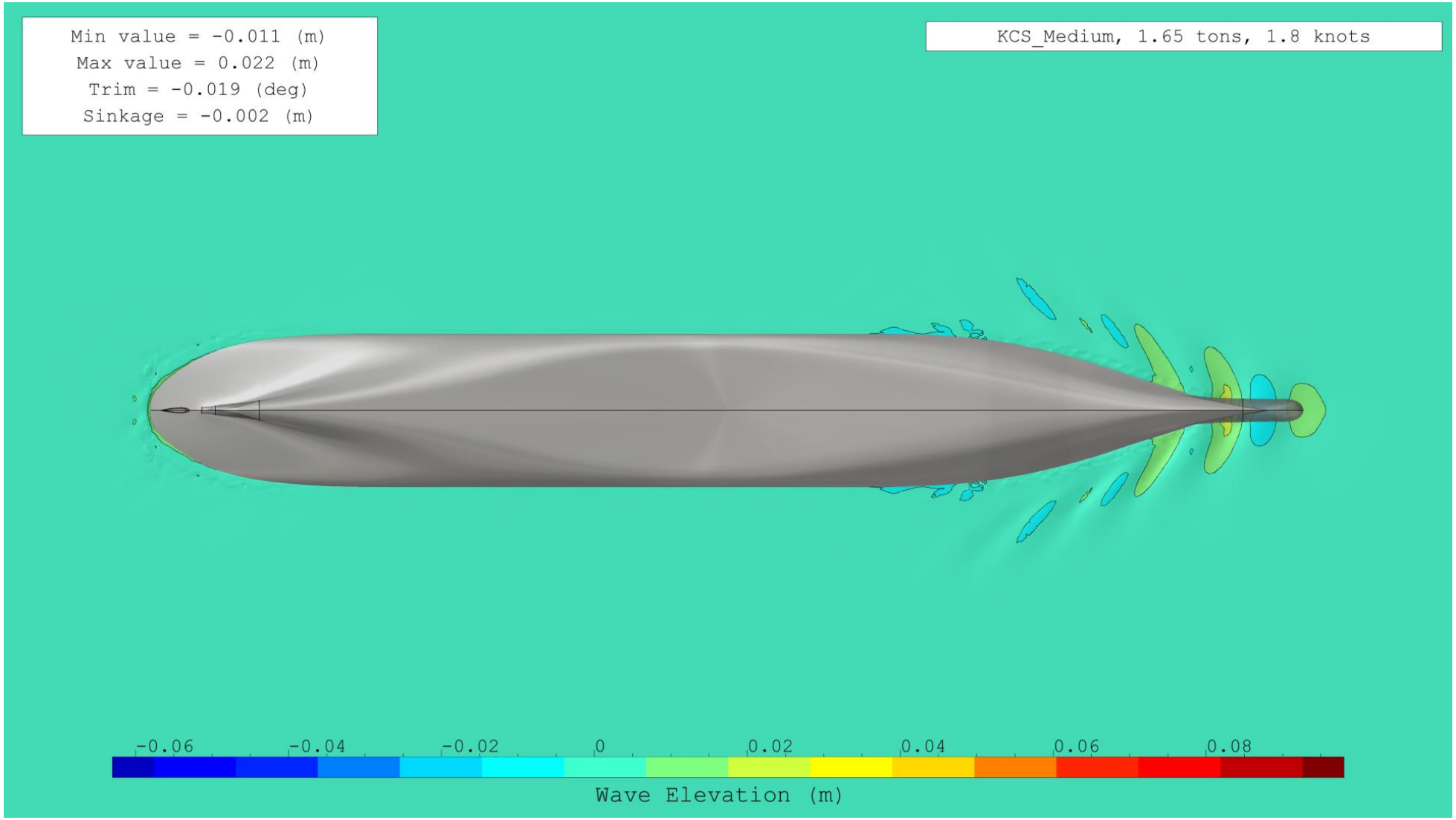




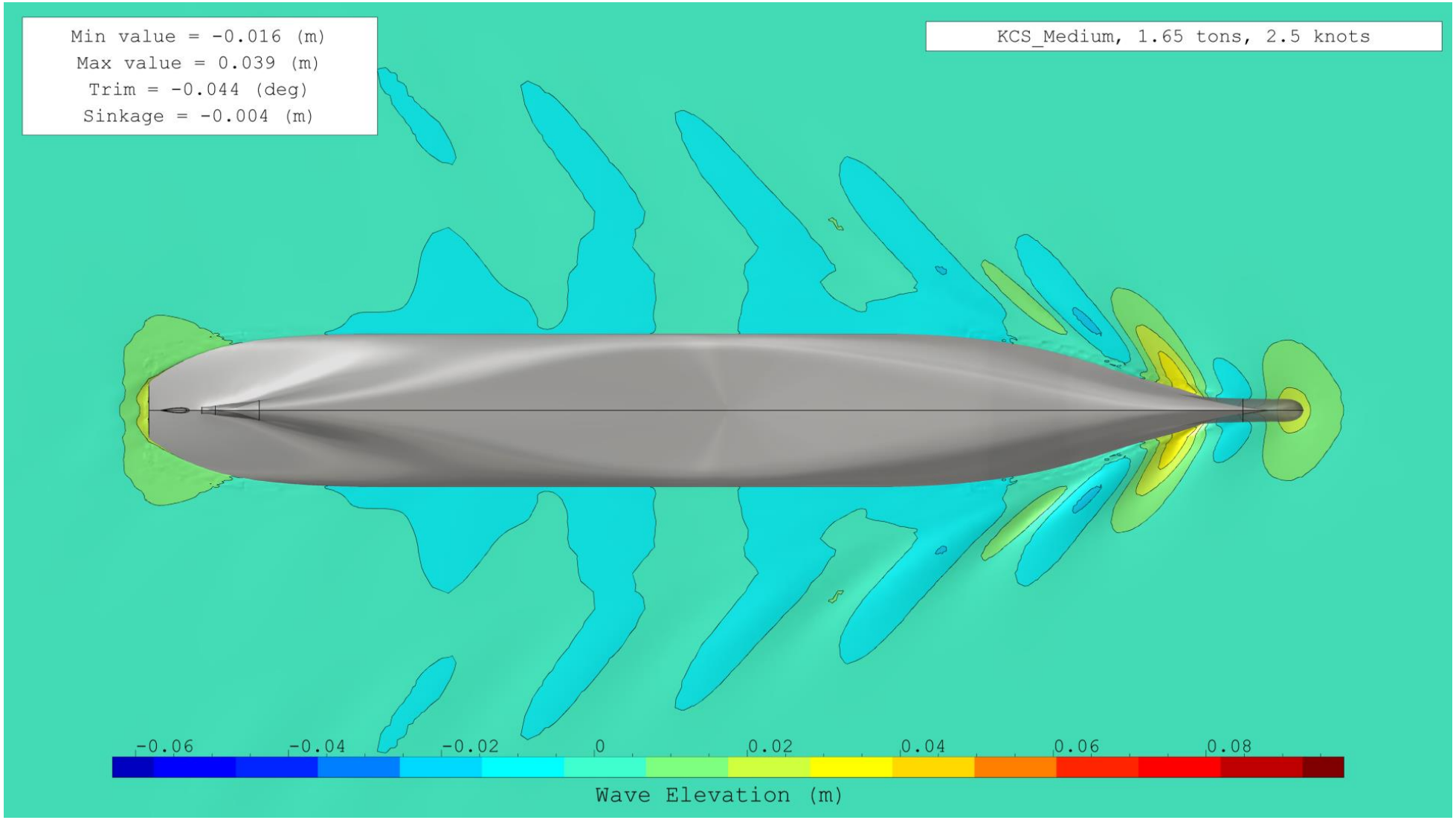
6. Visuals

a. Mass fraction
b. Pressure coefficient
c. Free surface
d. Streamlines
    1. Surfacic
    2. Volumic

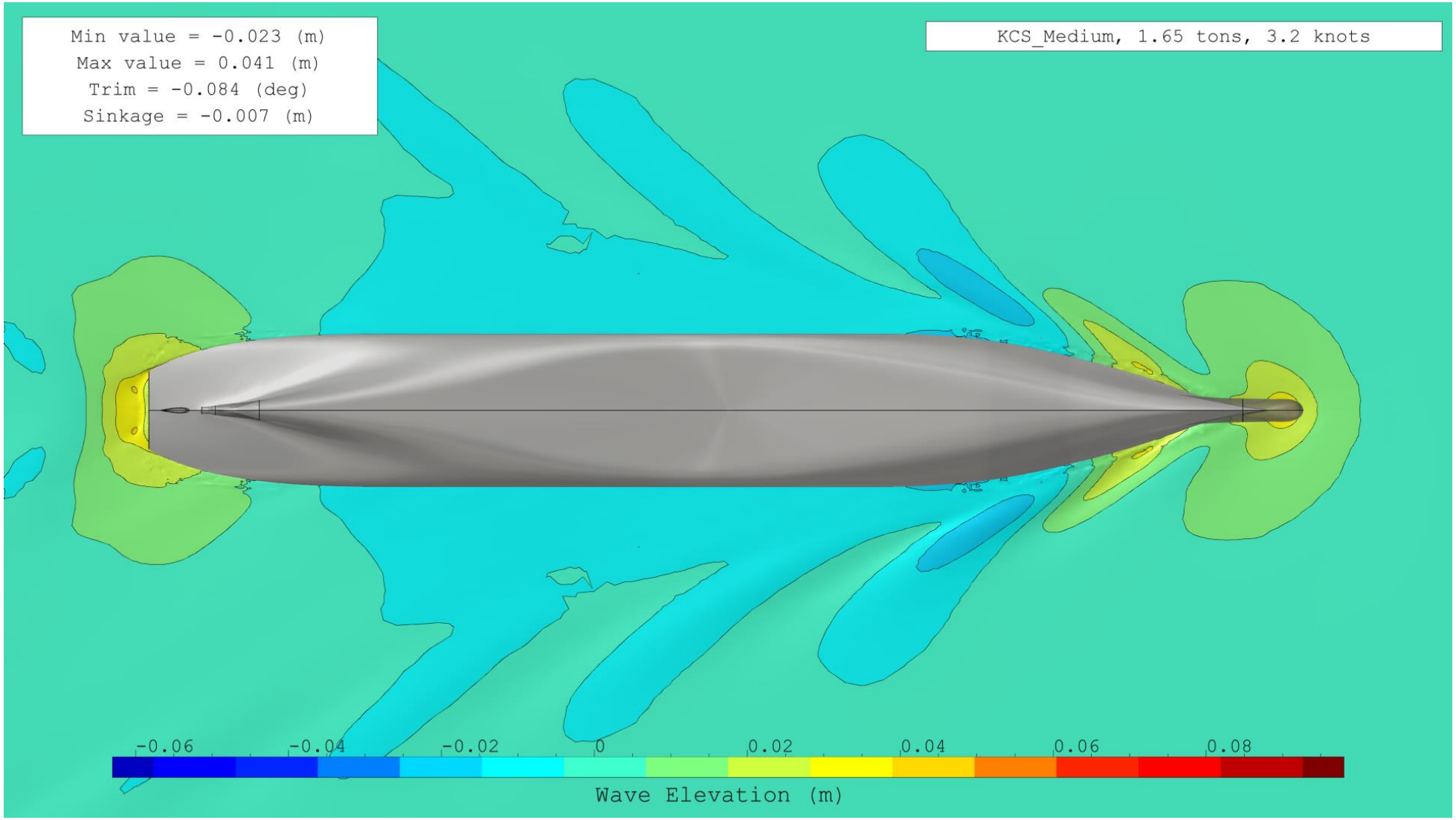
c. Free surface : near wall (common scale)



c. Free surface : near wall (common scale)



c. Free surface : near wall (common scale)



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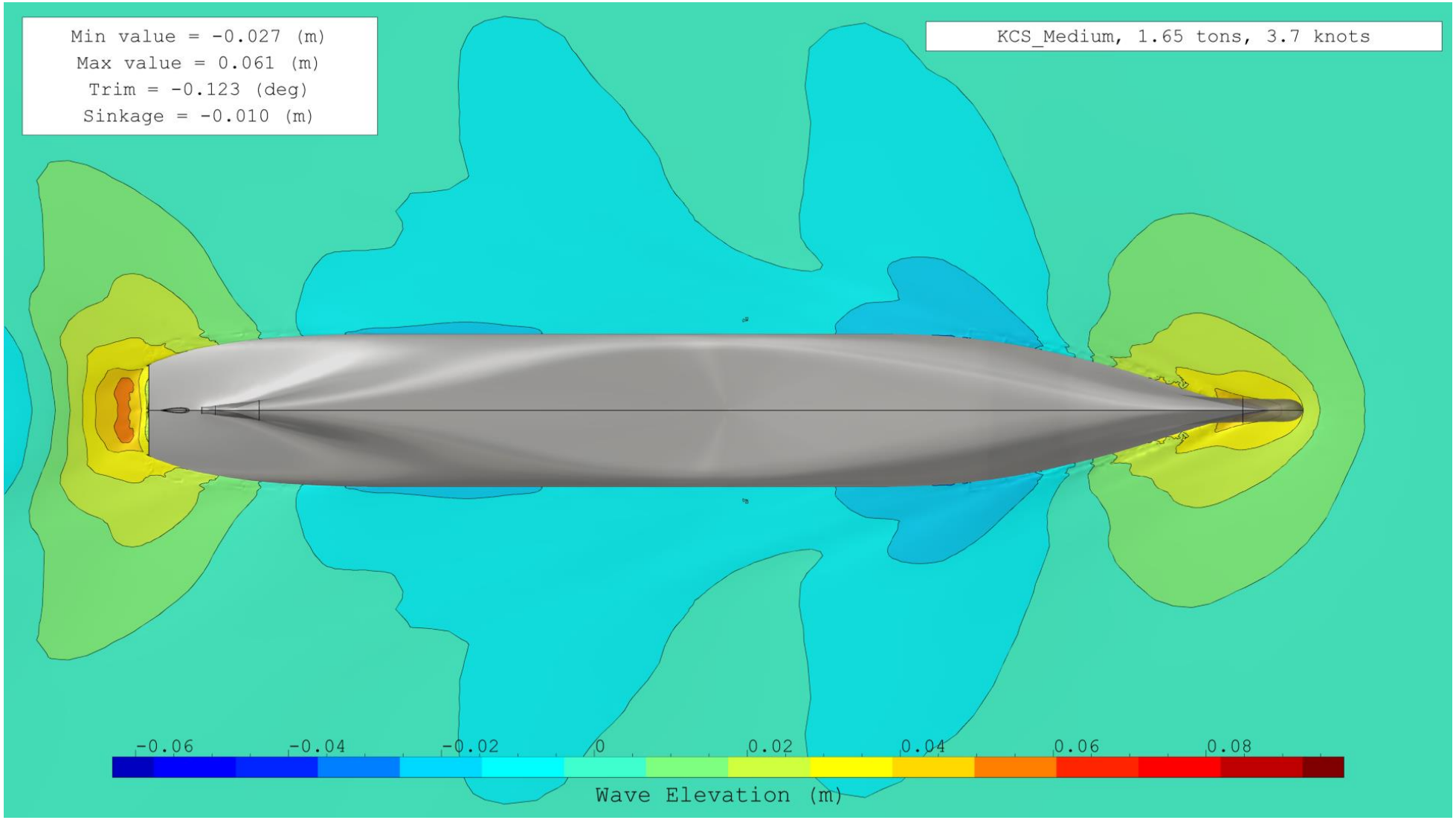
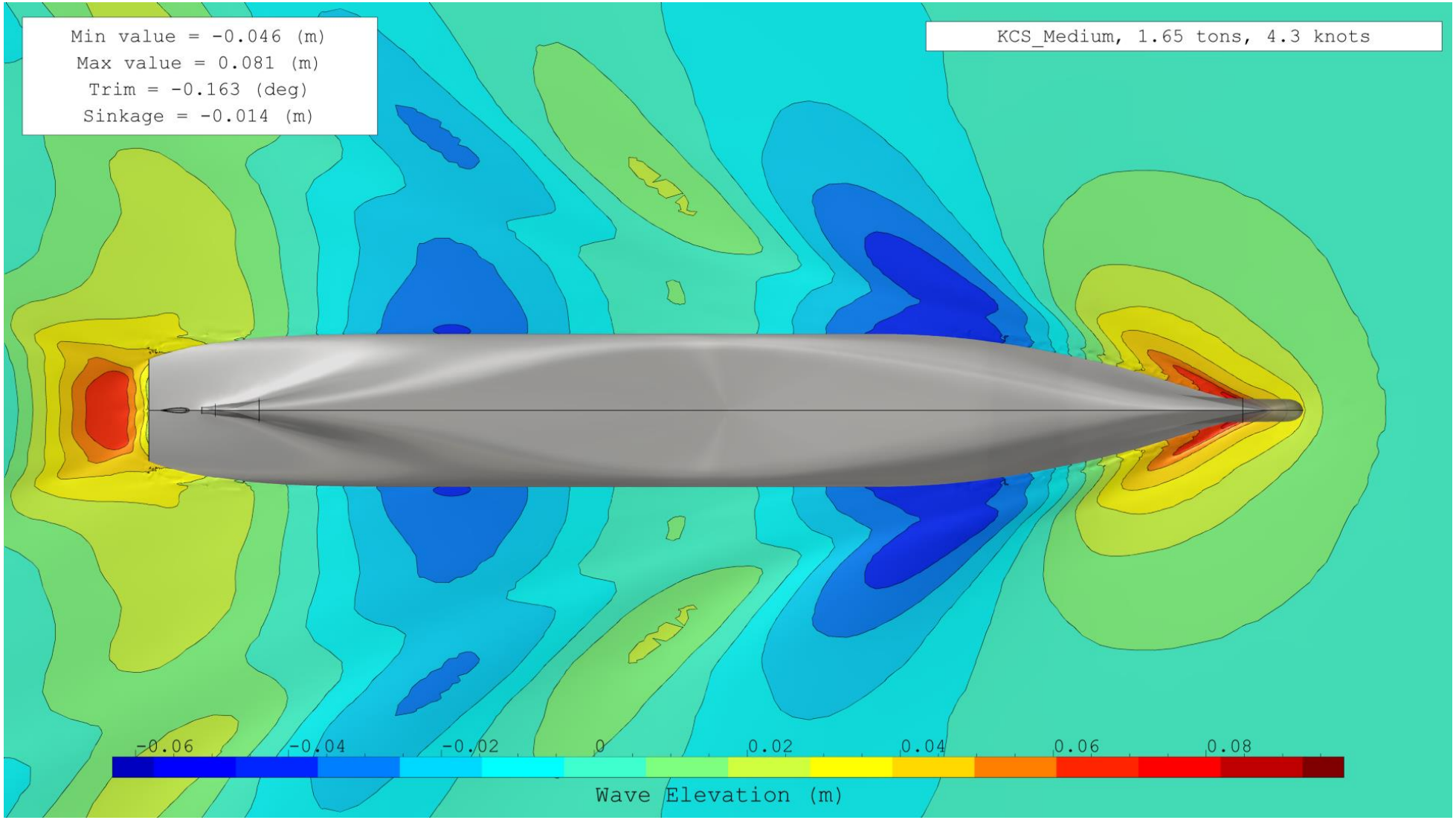
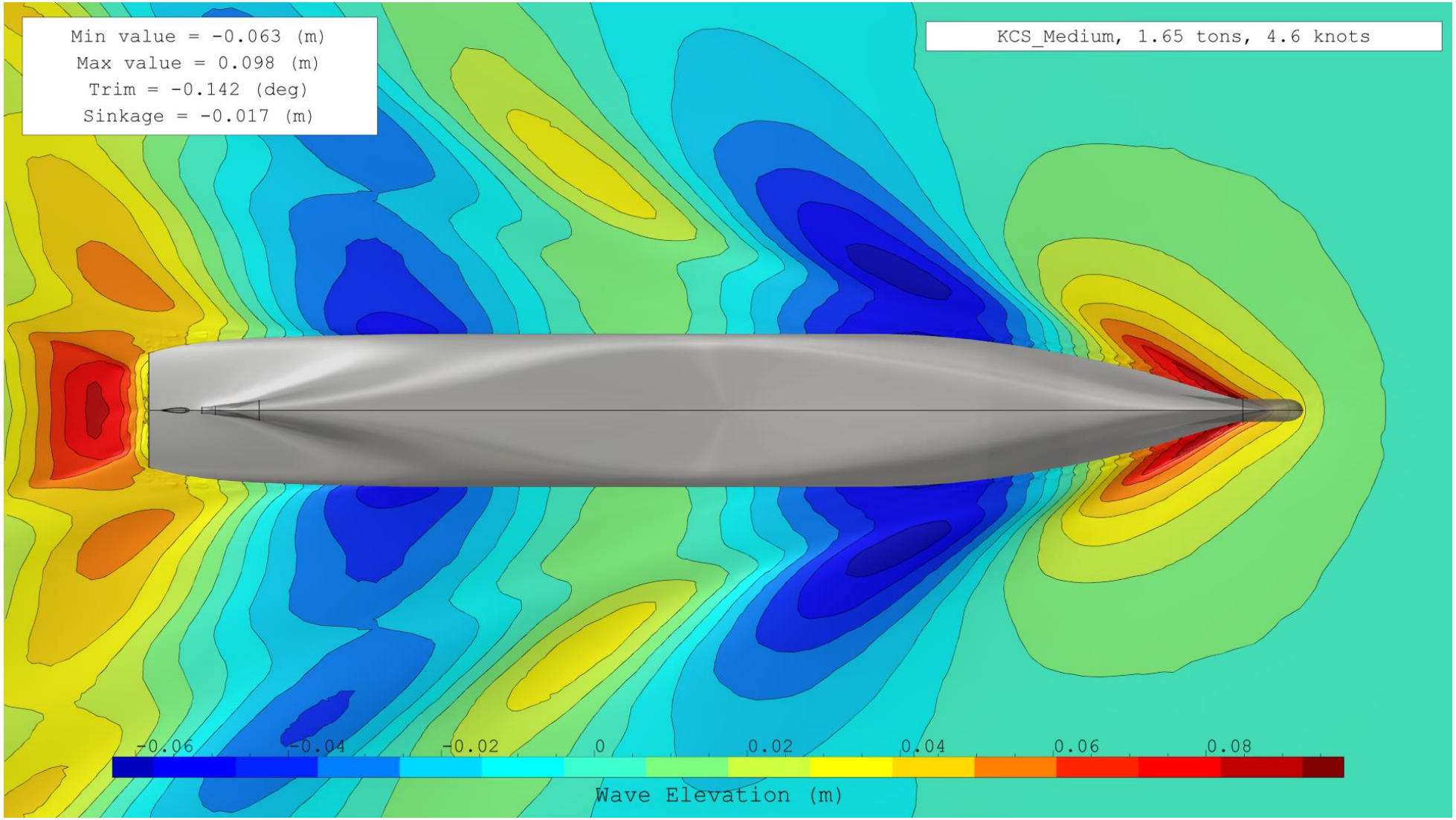


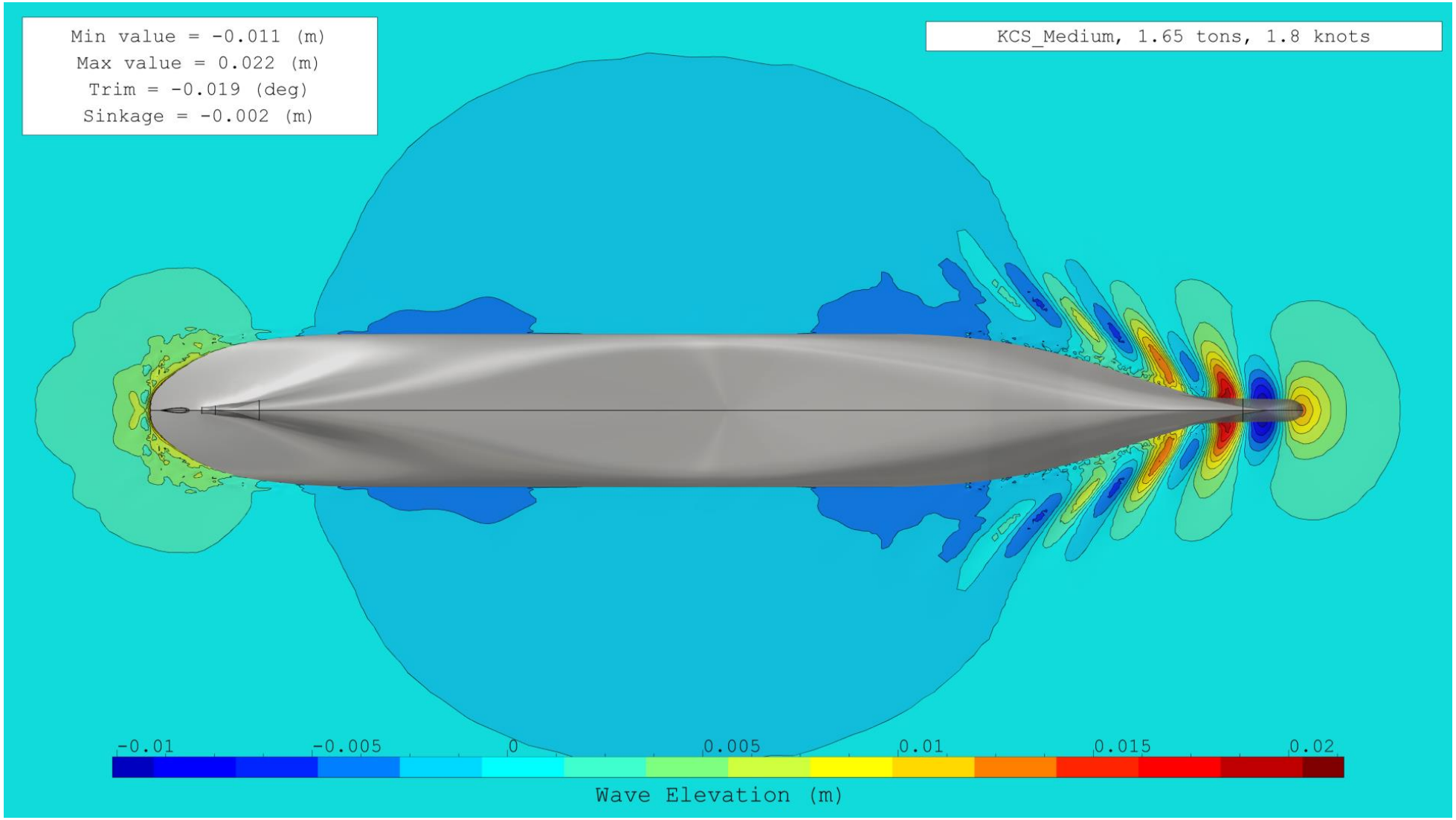
c. Free surface : near wall (common scale)



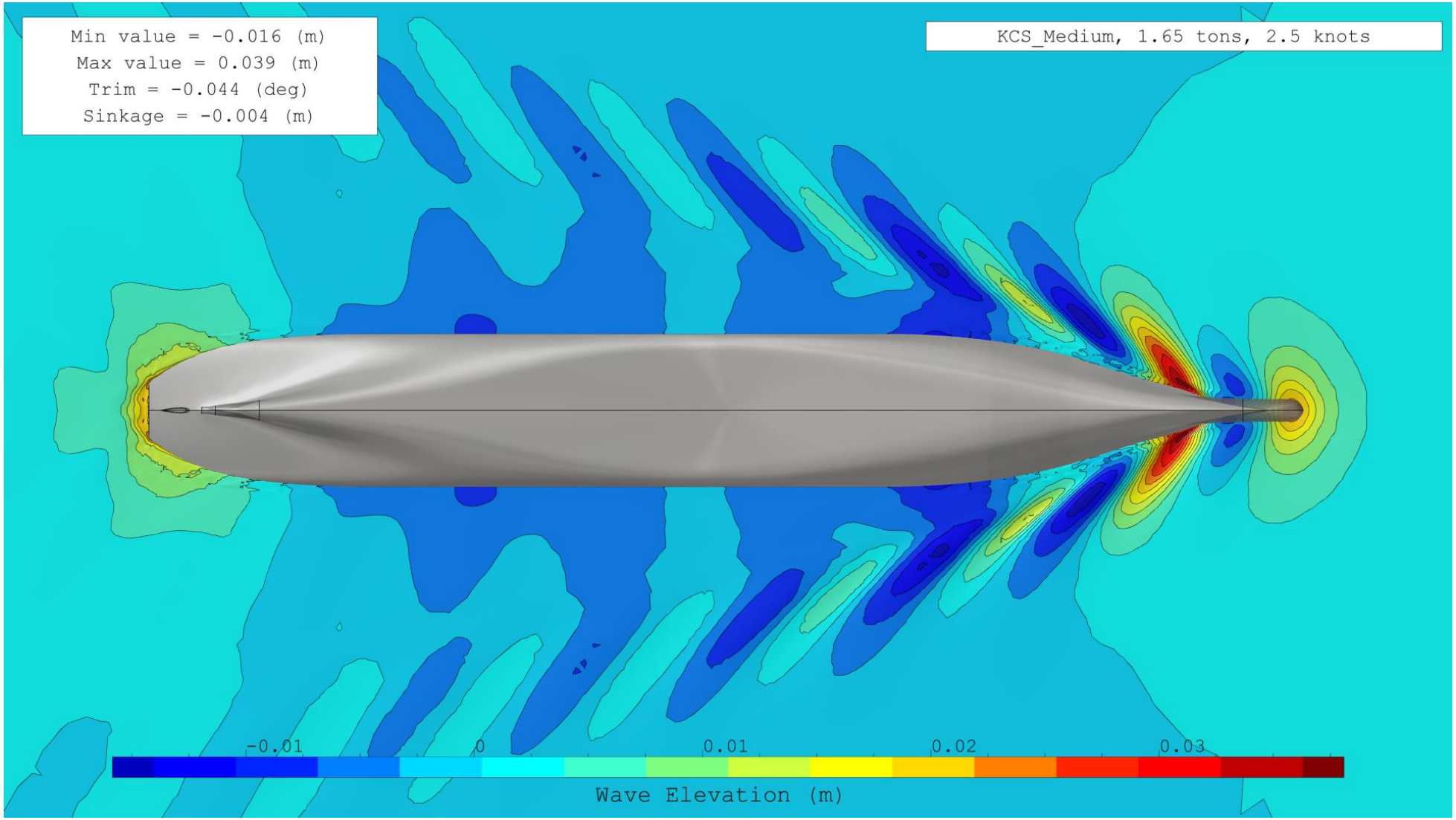
c. Free surface : near wall (common scale)



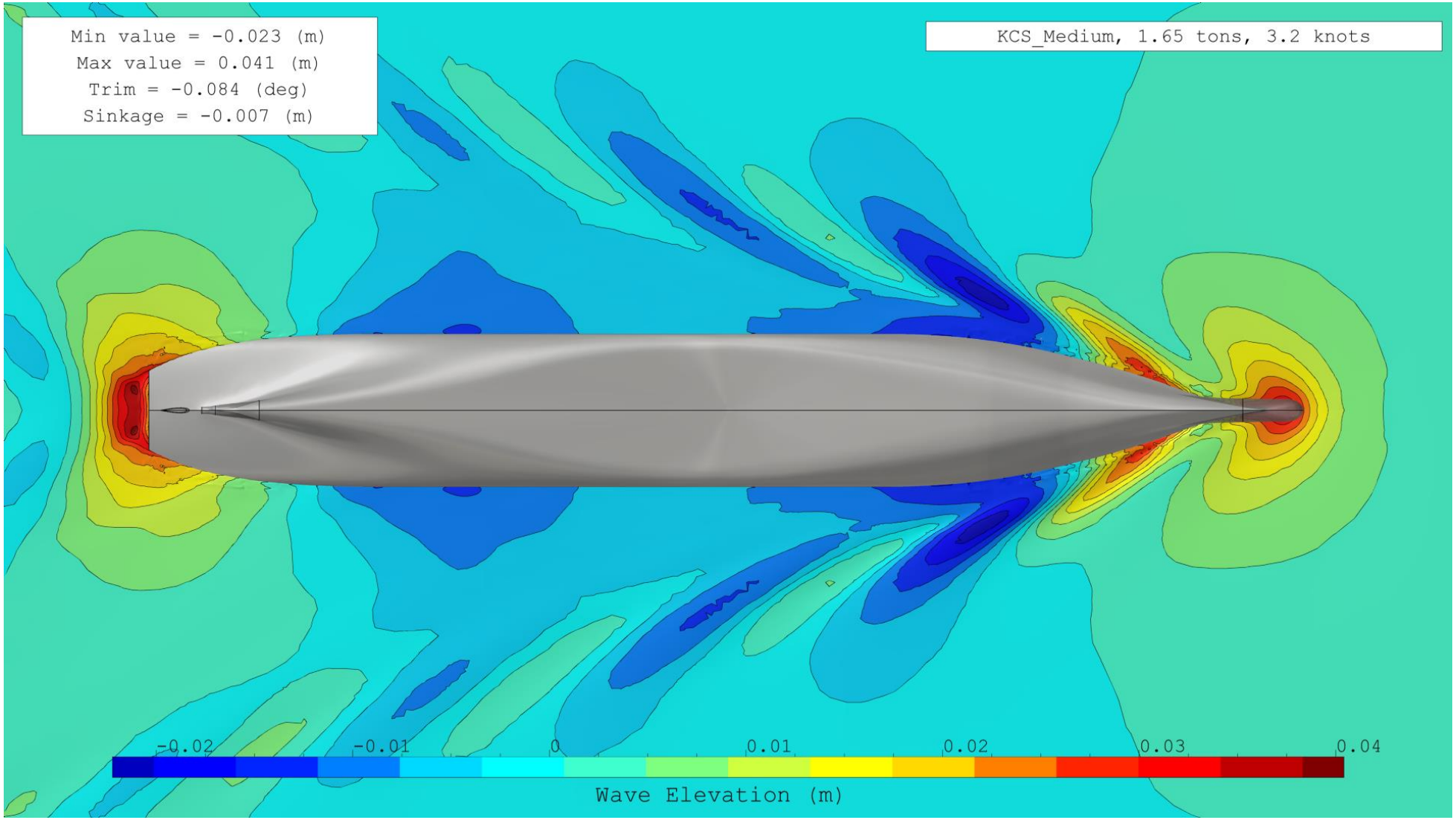
c. Free surface : near wall (independant scale)



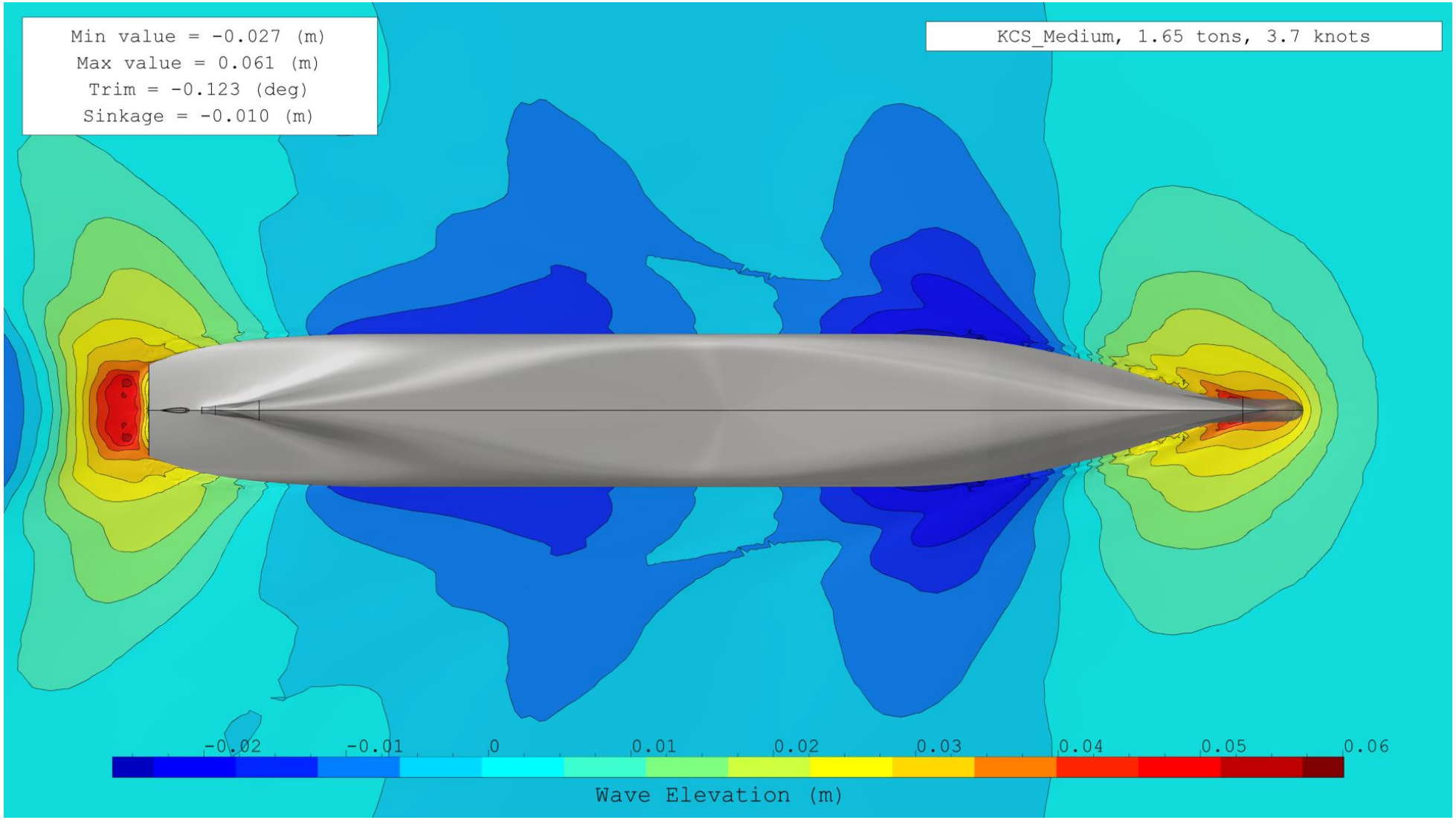
c. Free surface : near wall (independant scale)



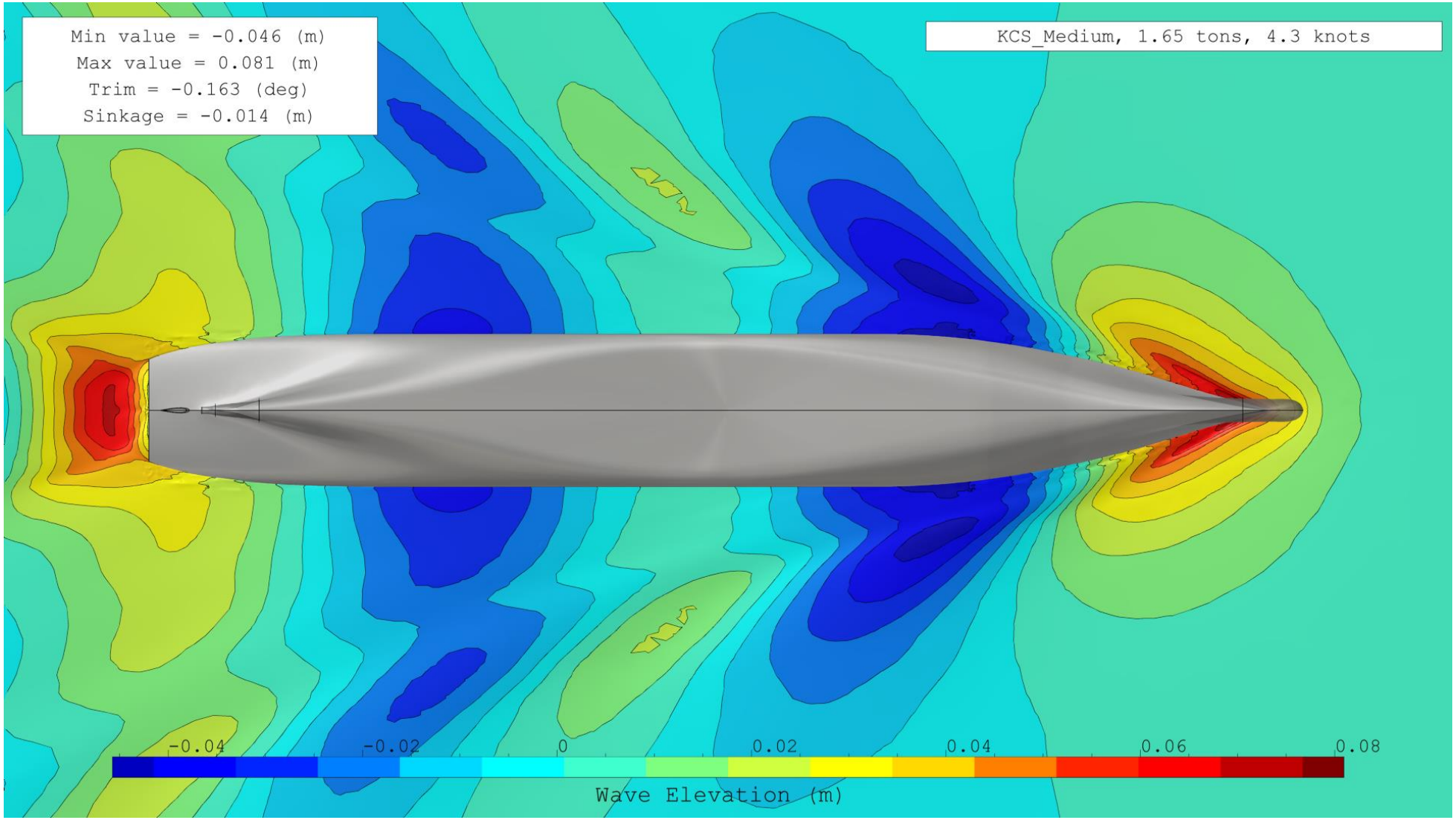
c. Free surface : near wall (independant scale)



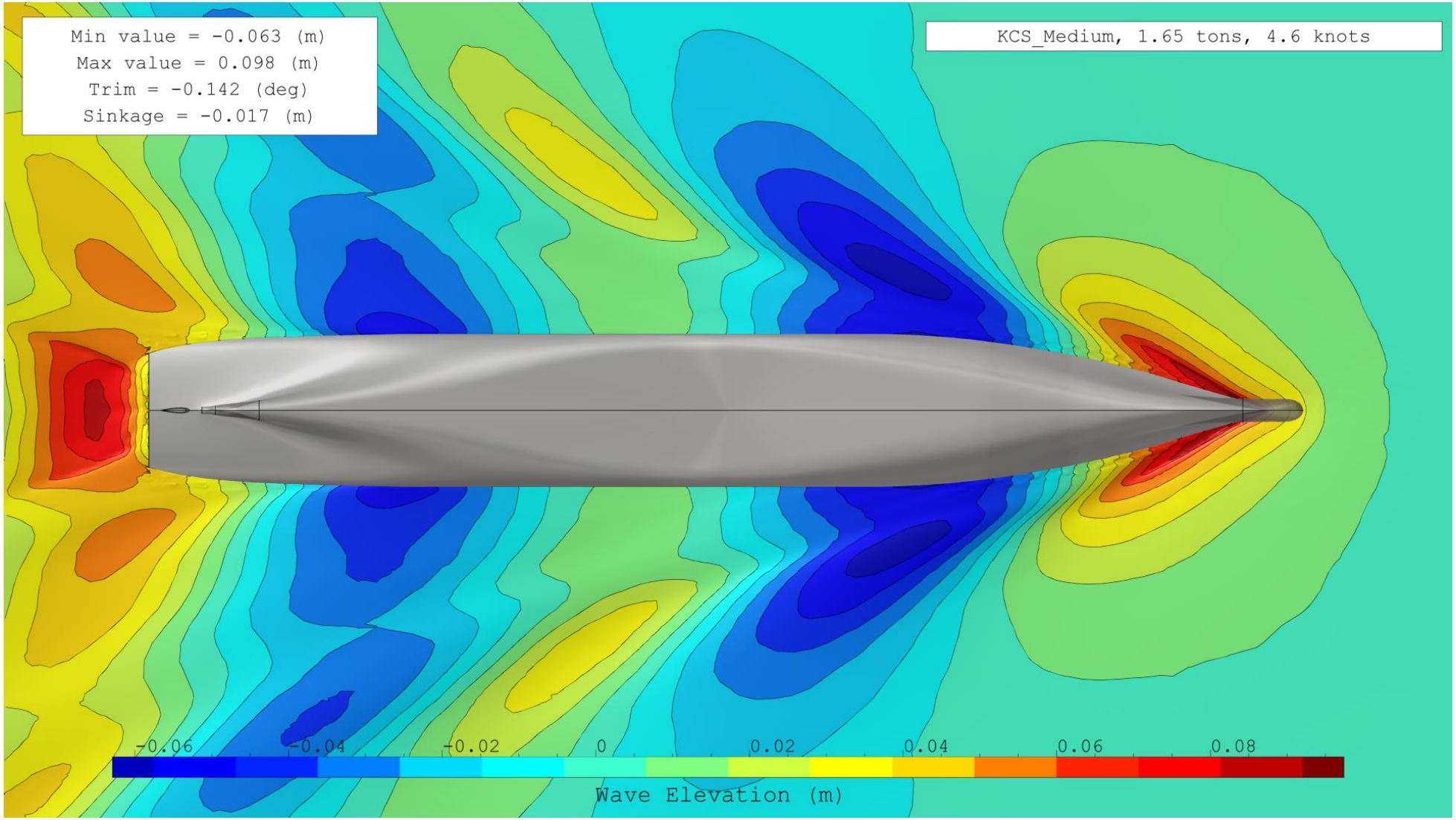
c. Free surface : near wall (independant scale)



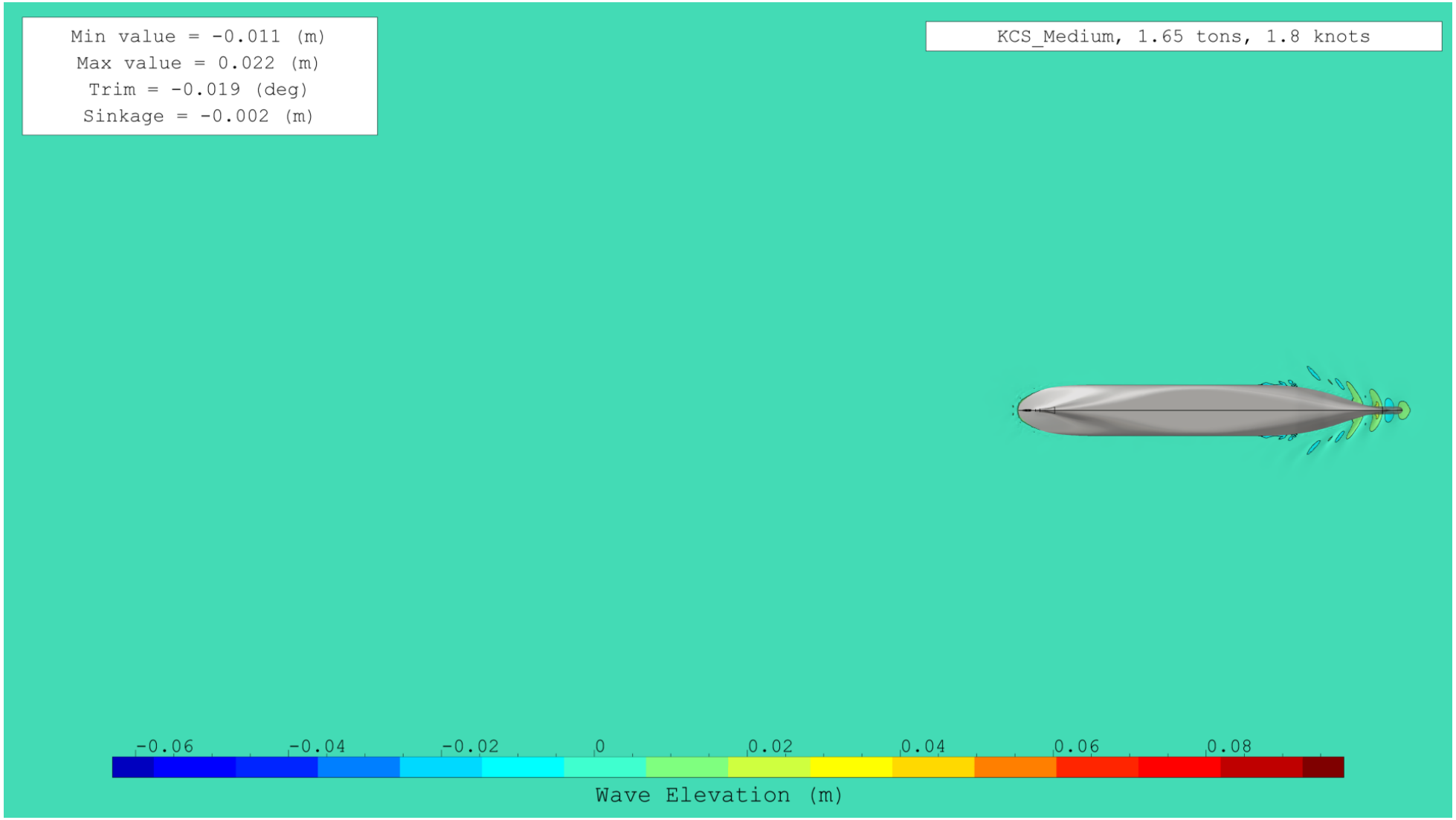
c. Free surface : near wall (independant scale)



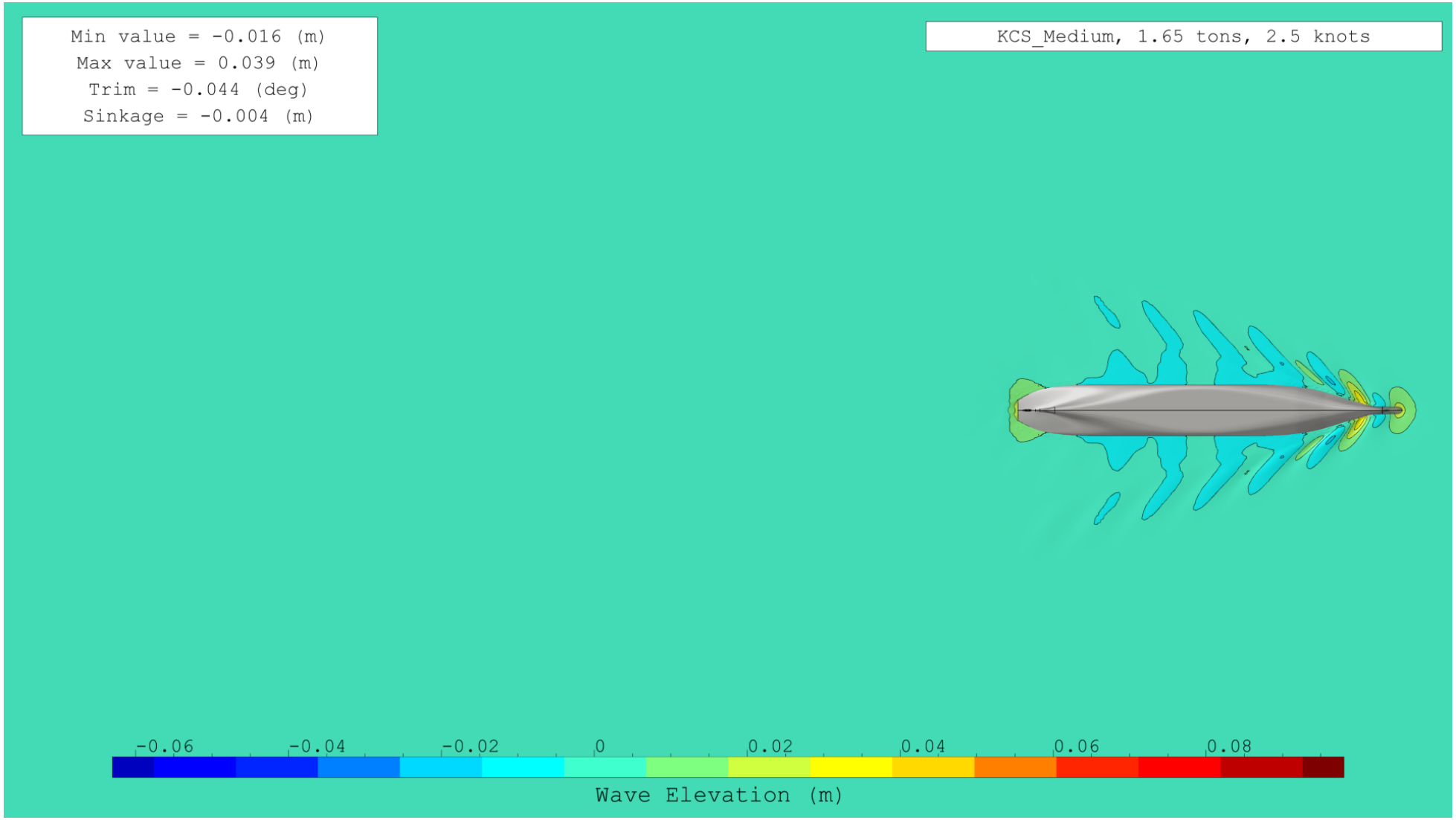
c. Free surface : near wall (independant scale)



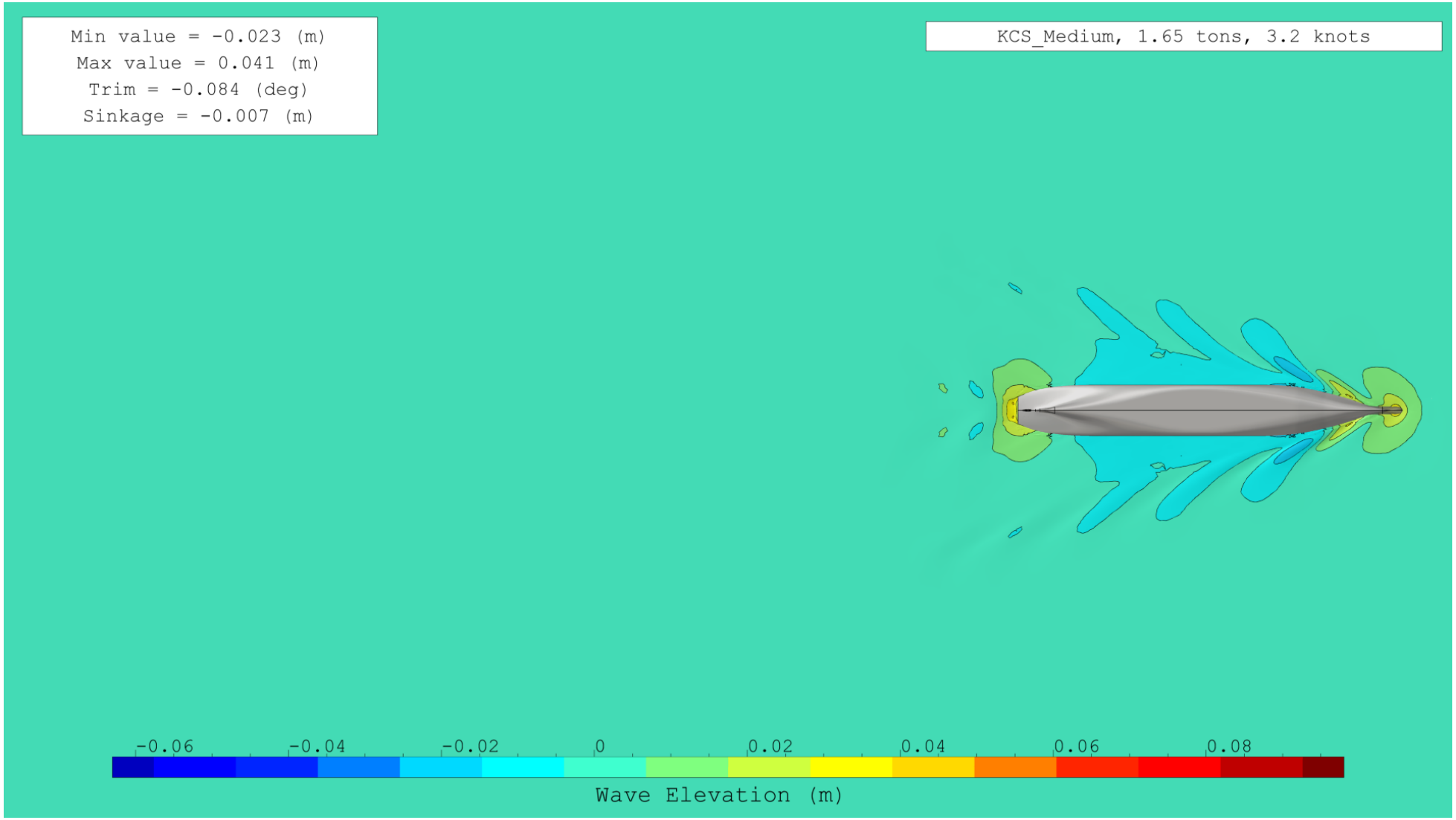
c. Free surface : far field (common scale)



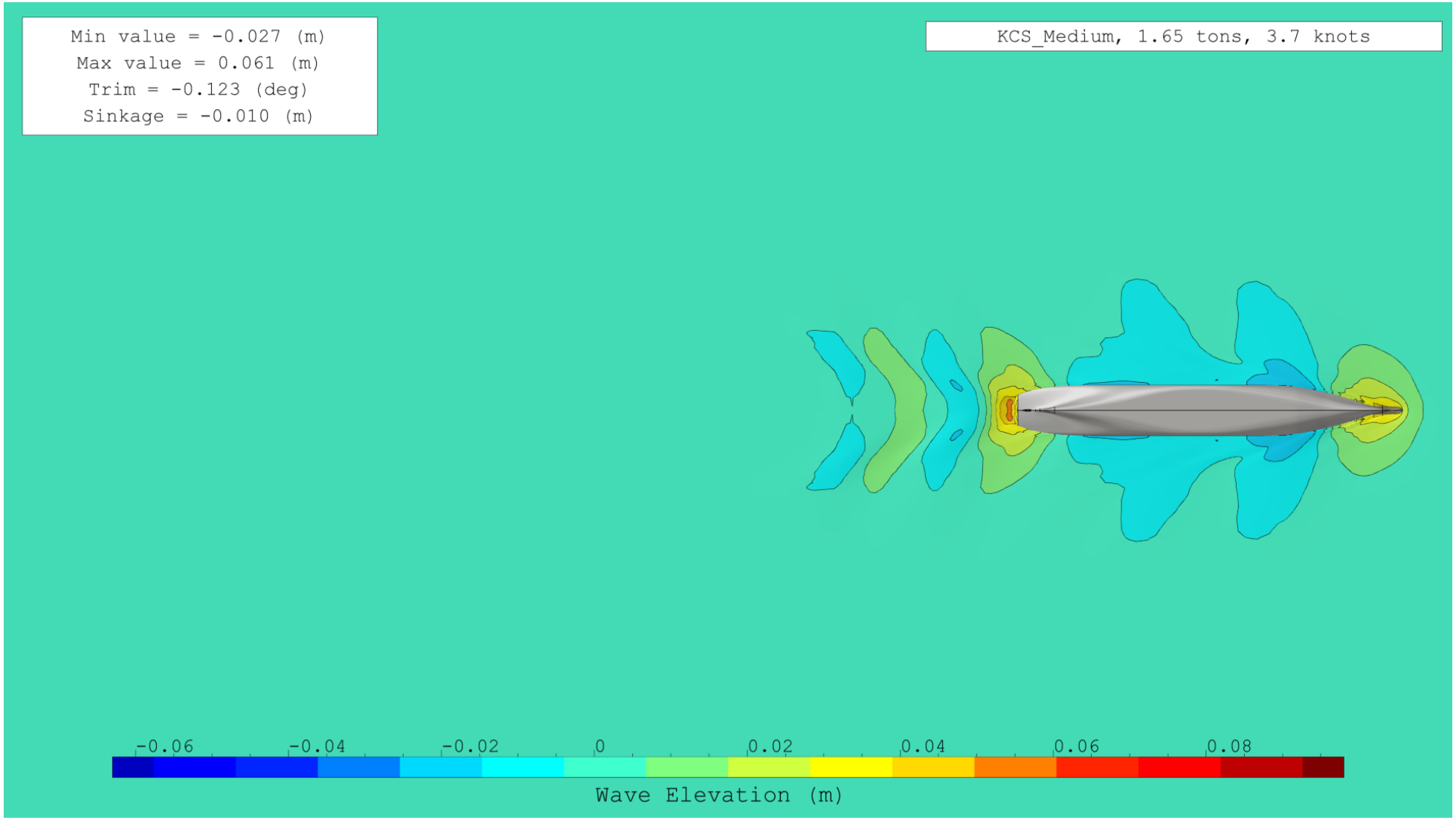
c. Free surface : far field (common scale)



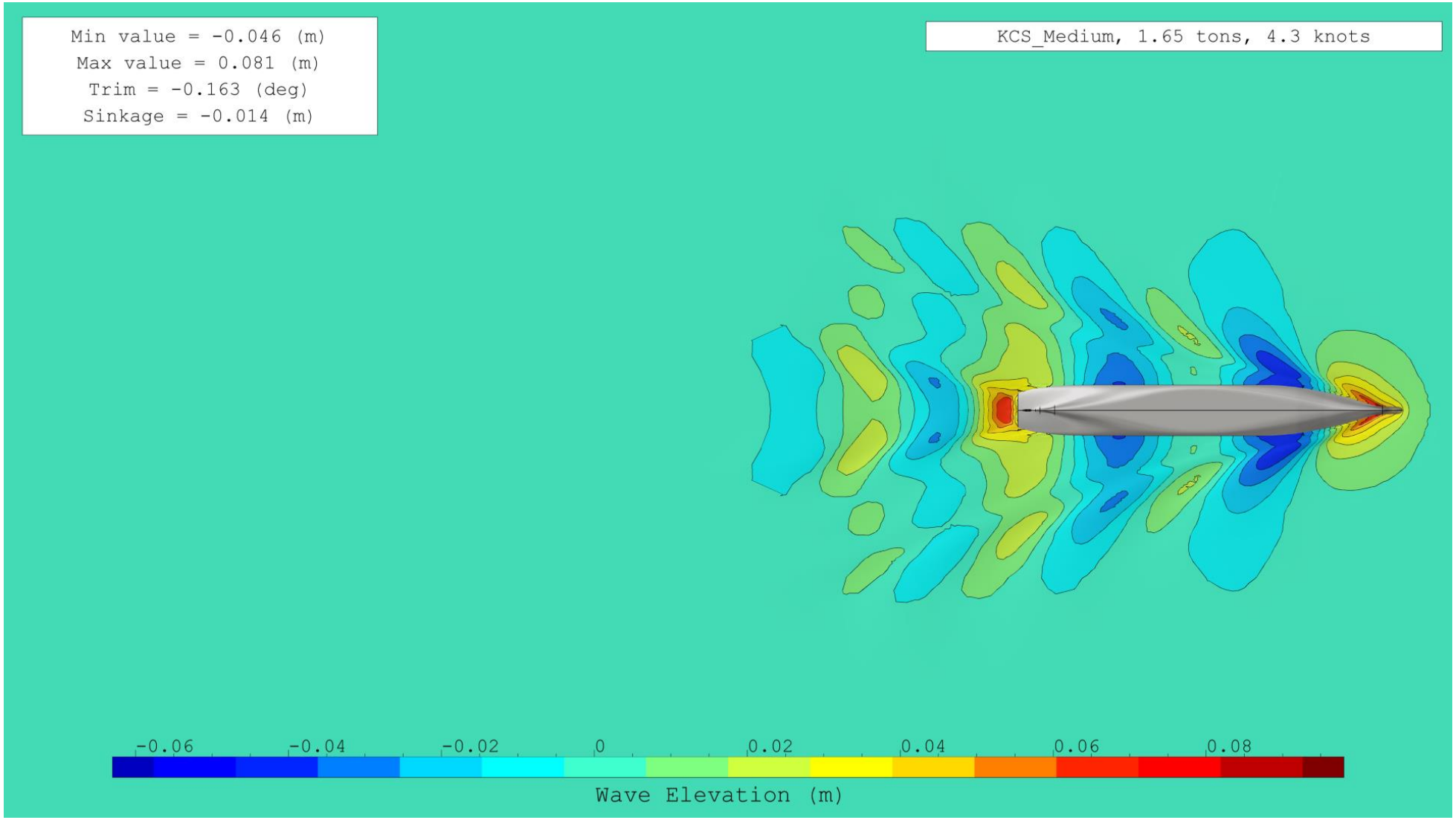
c. Free surface : far field (common scale)



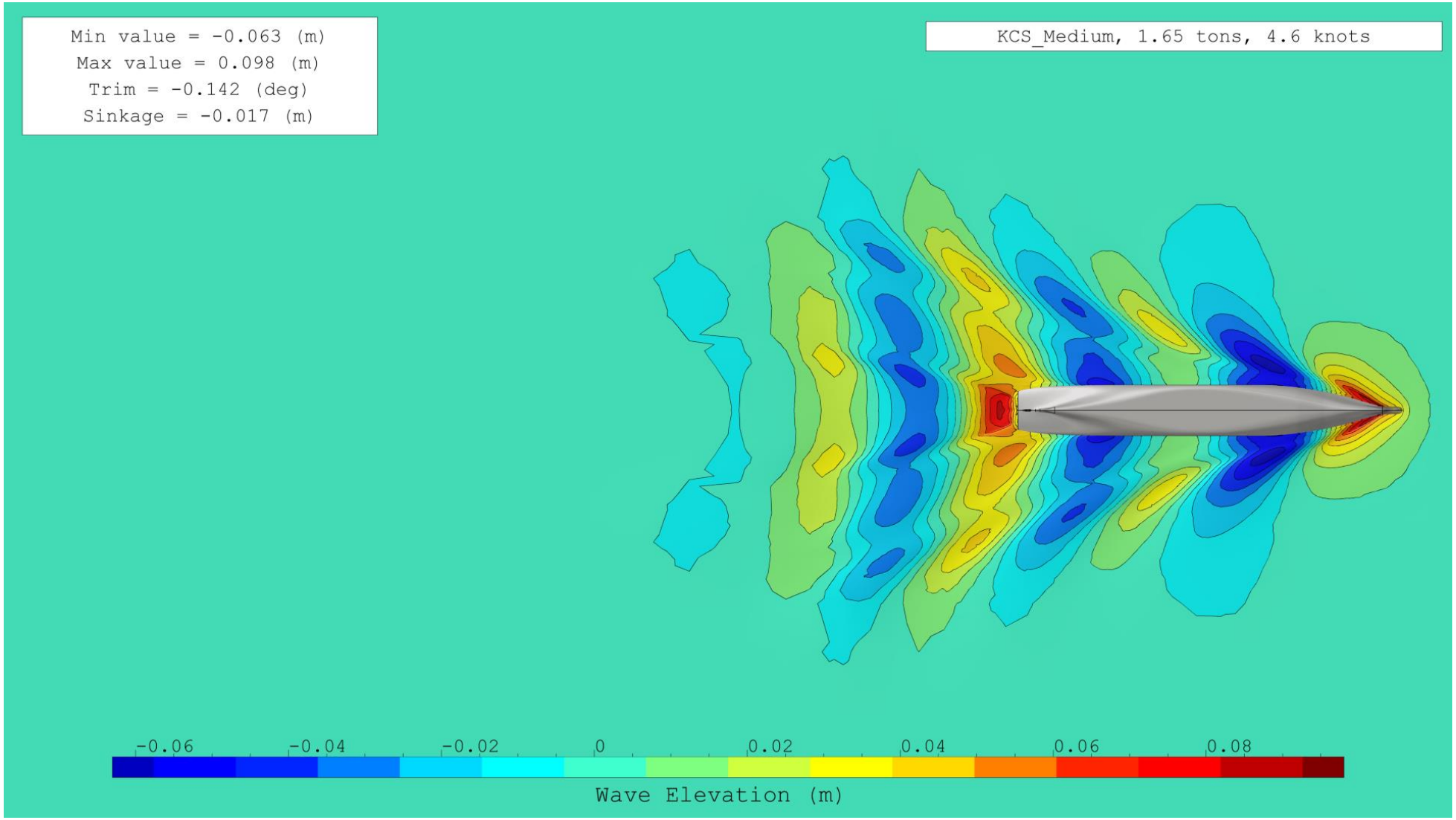
c. Free surface : far field (common scale)



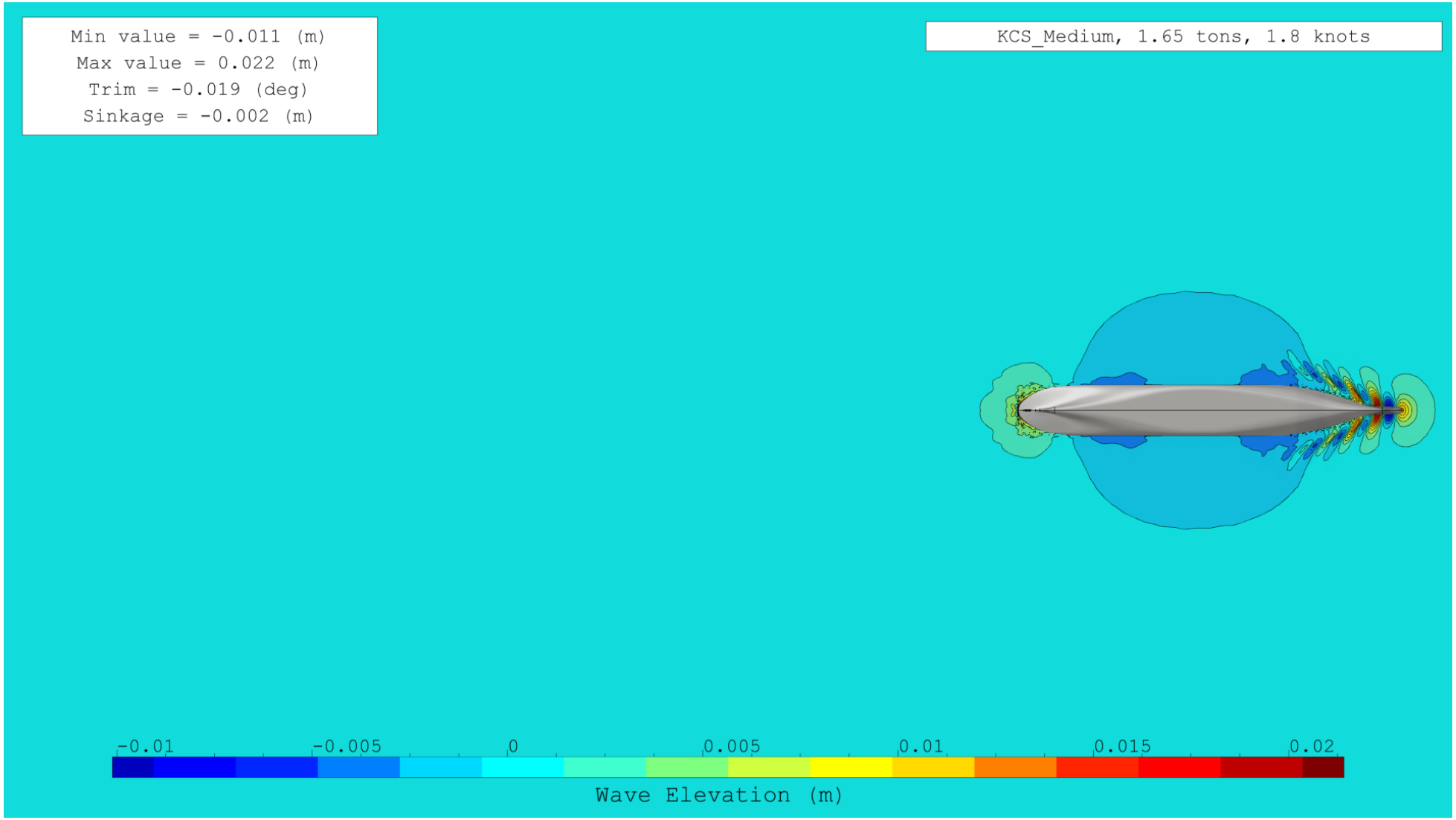
c. Free surface : far field (common scale)



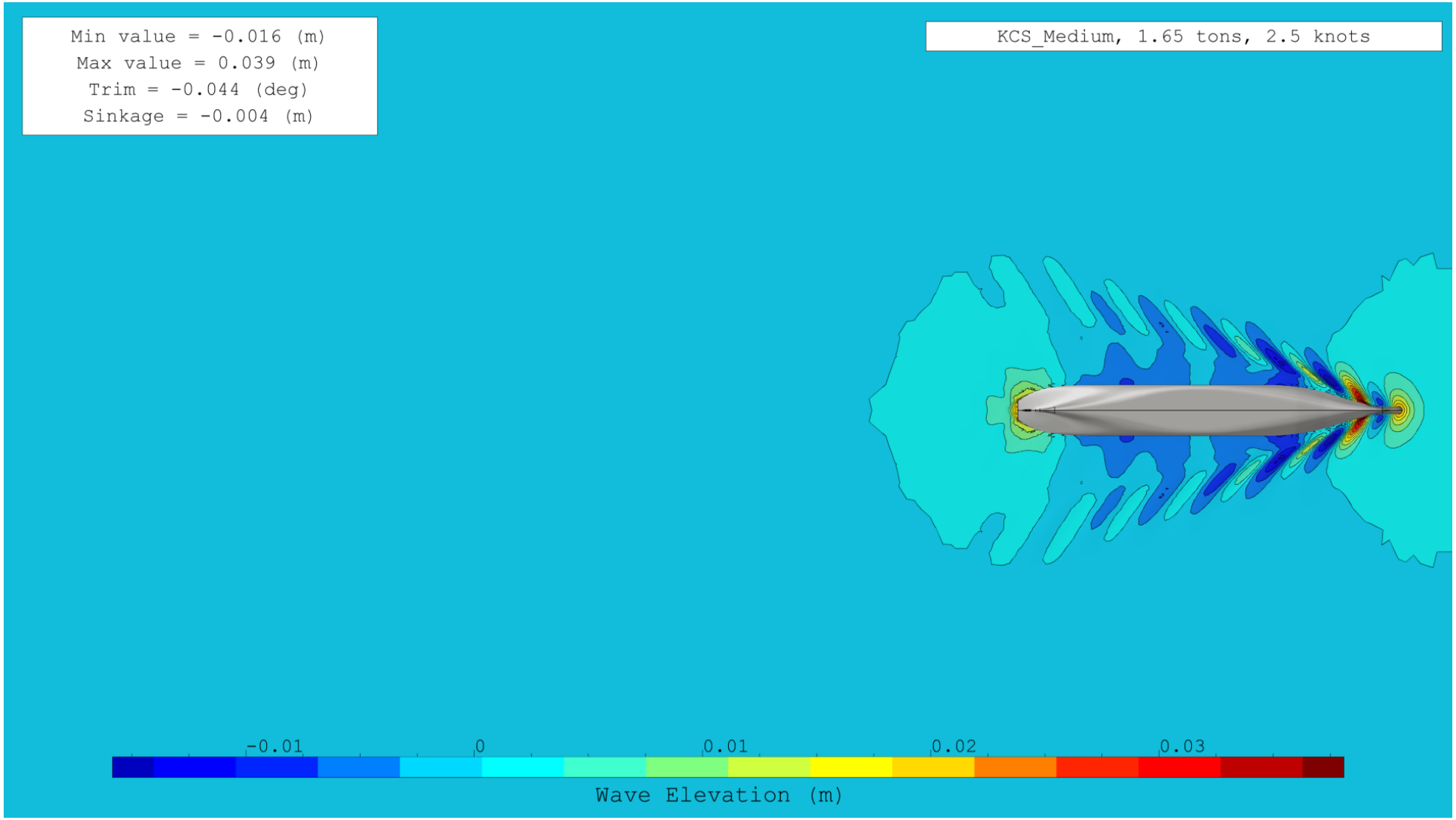
c. Free surface : far field (common scale)



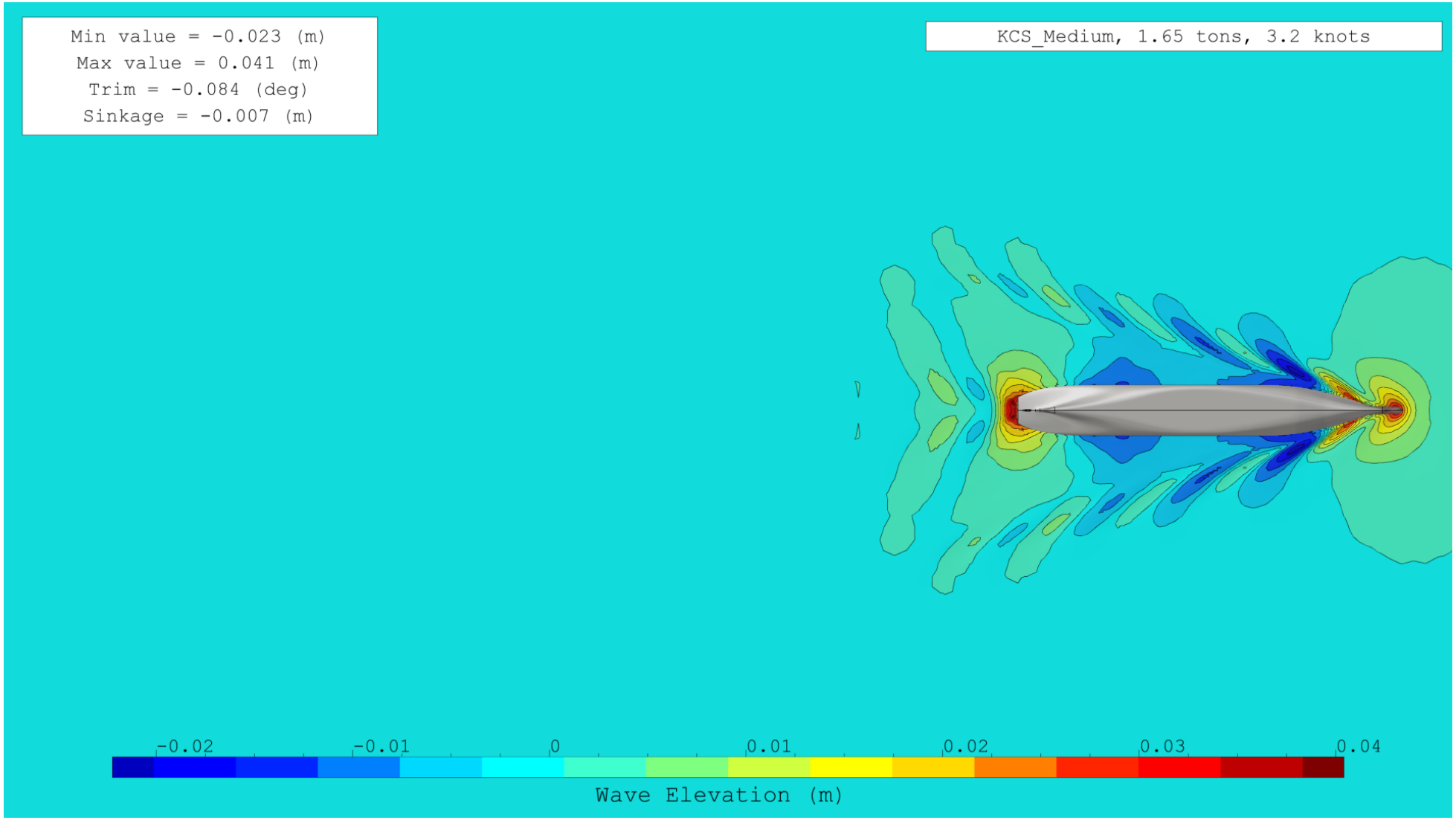
c. Free surface : far field (independant scale)



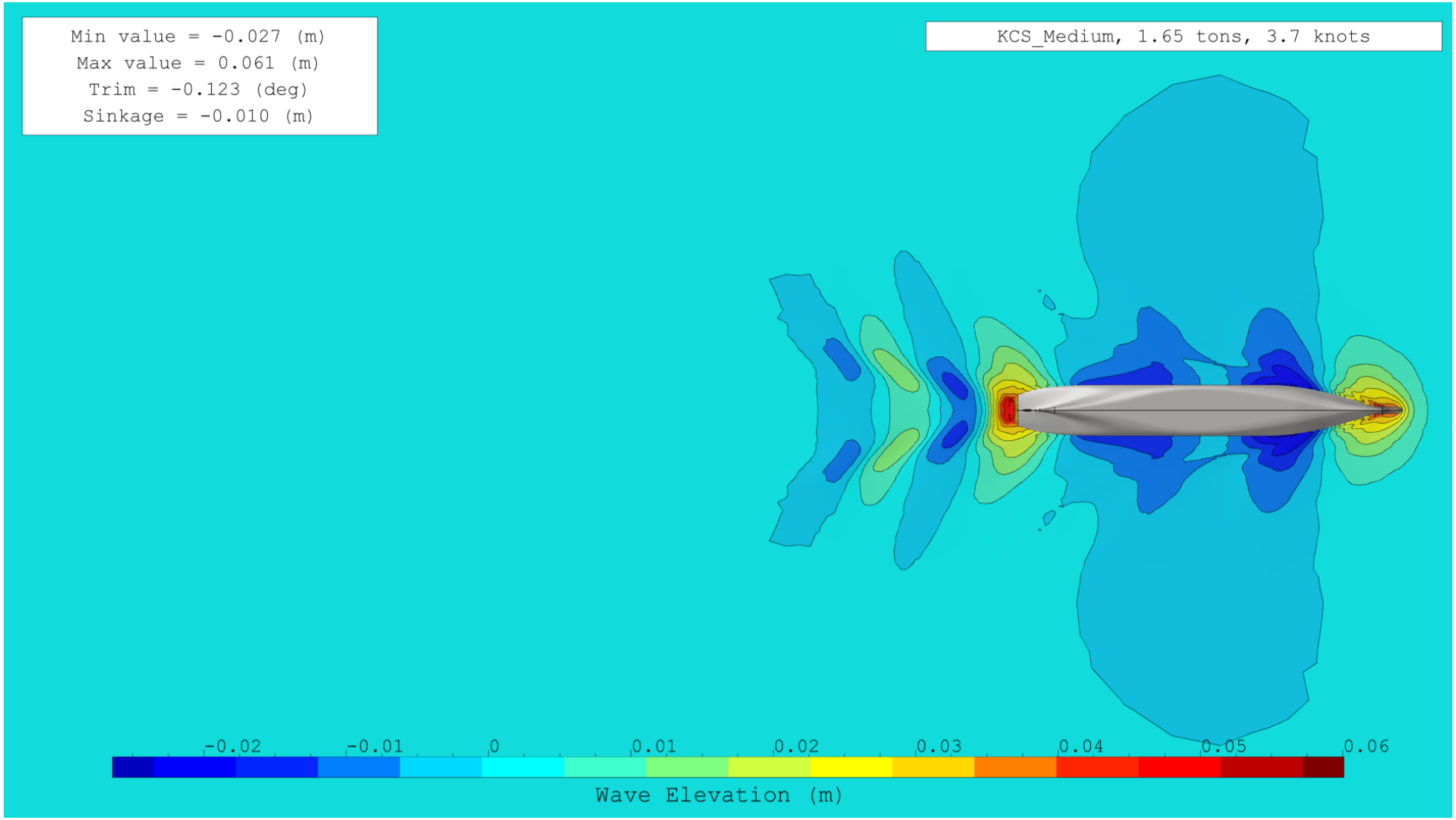
c. Free surface : far field (independant scale)



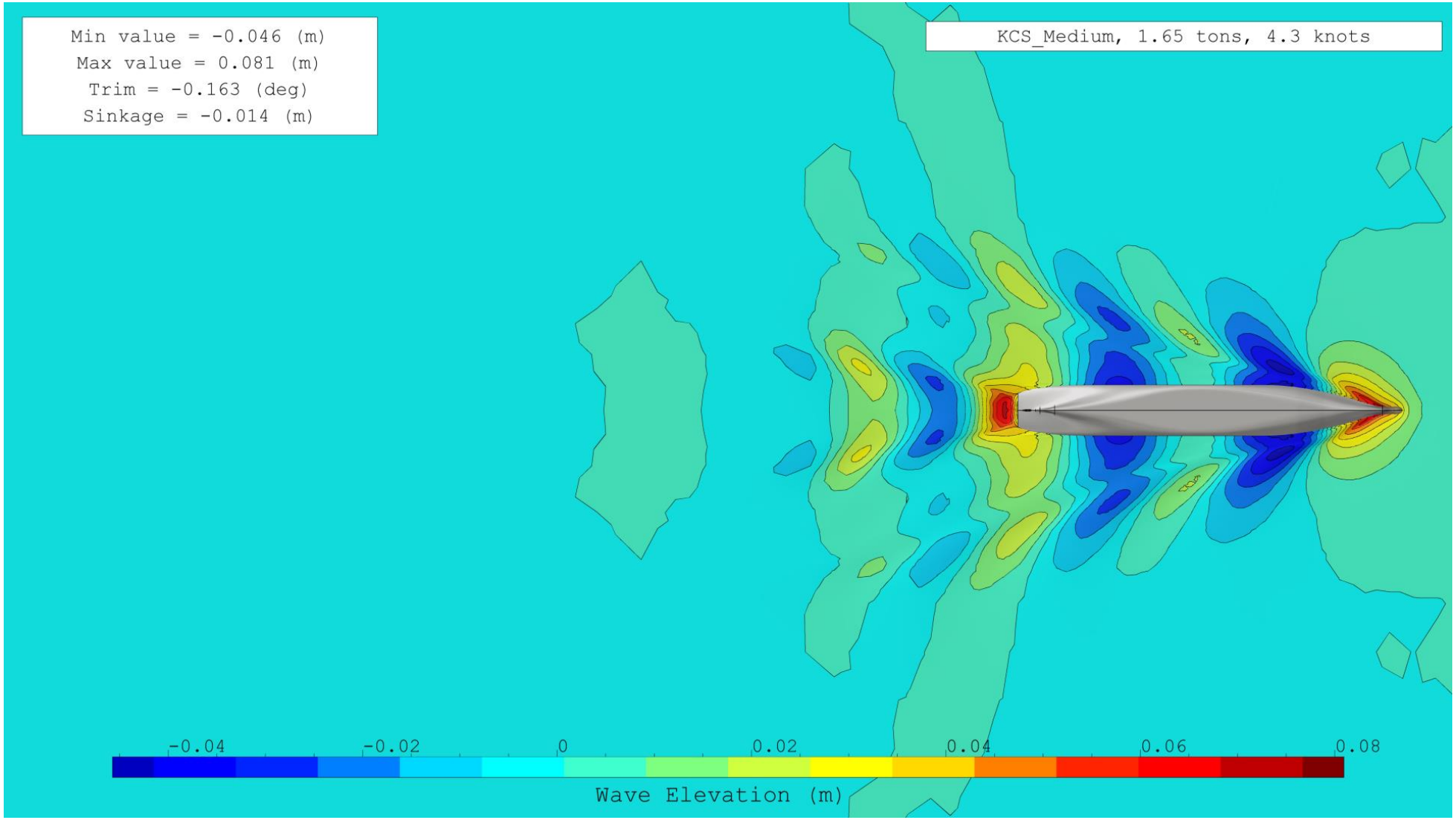
c. Free surface : far field (independant scale)



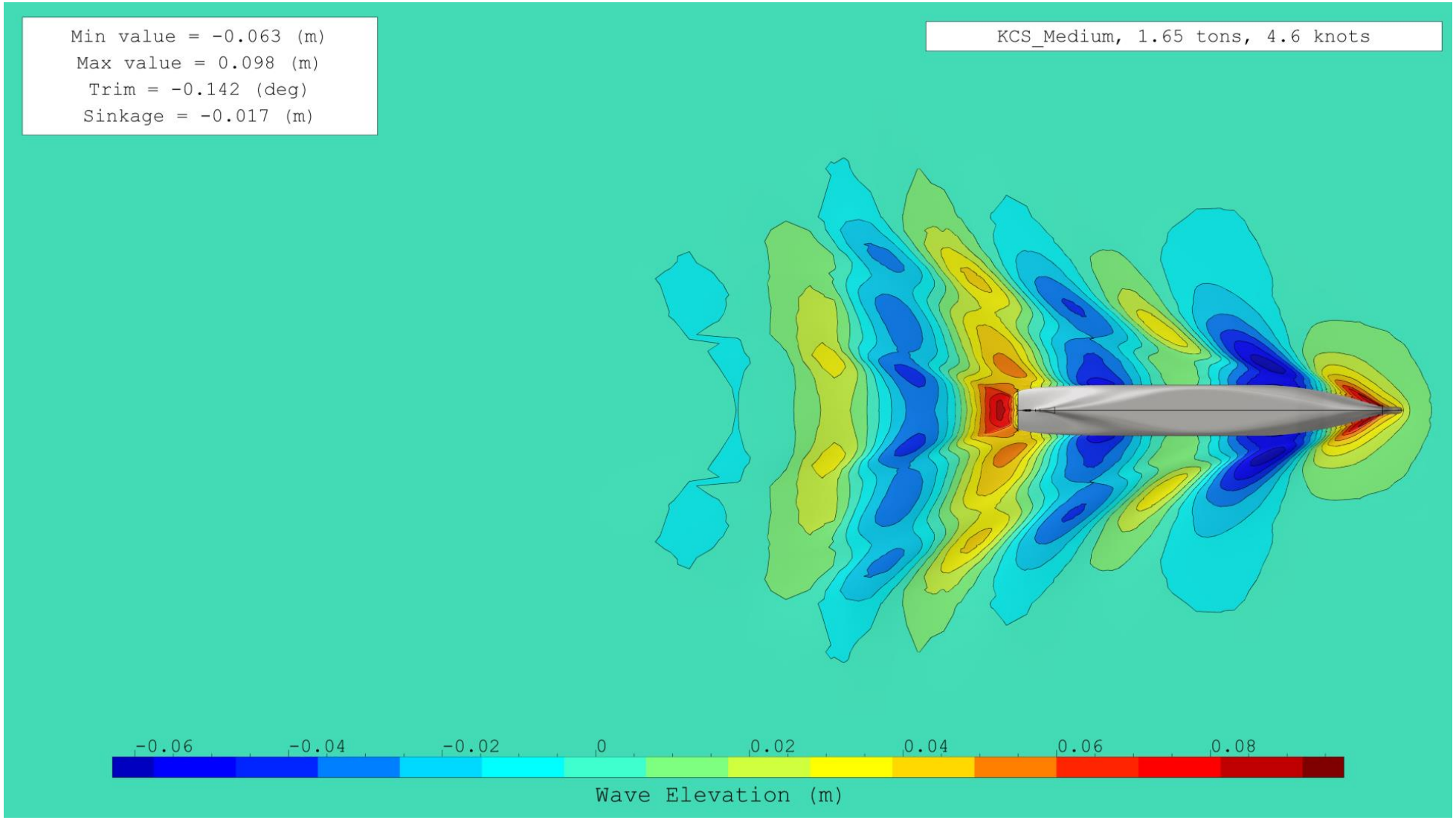
c. Free surface : far field (independant scale)



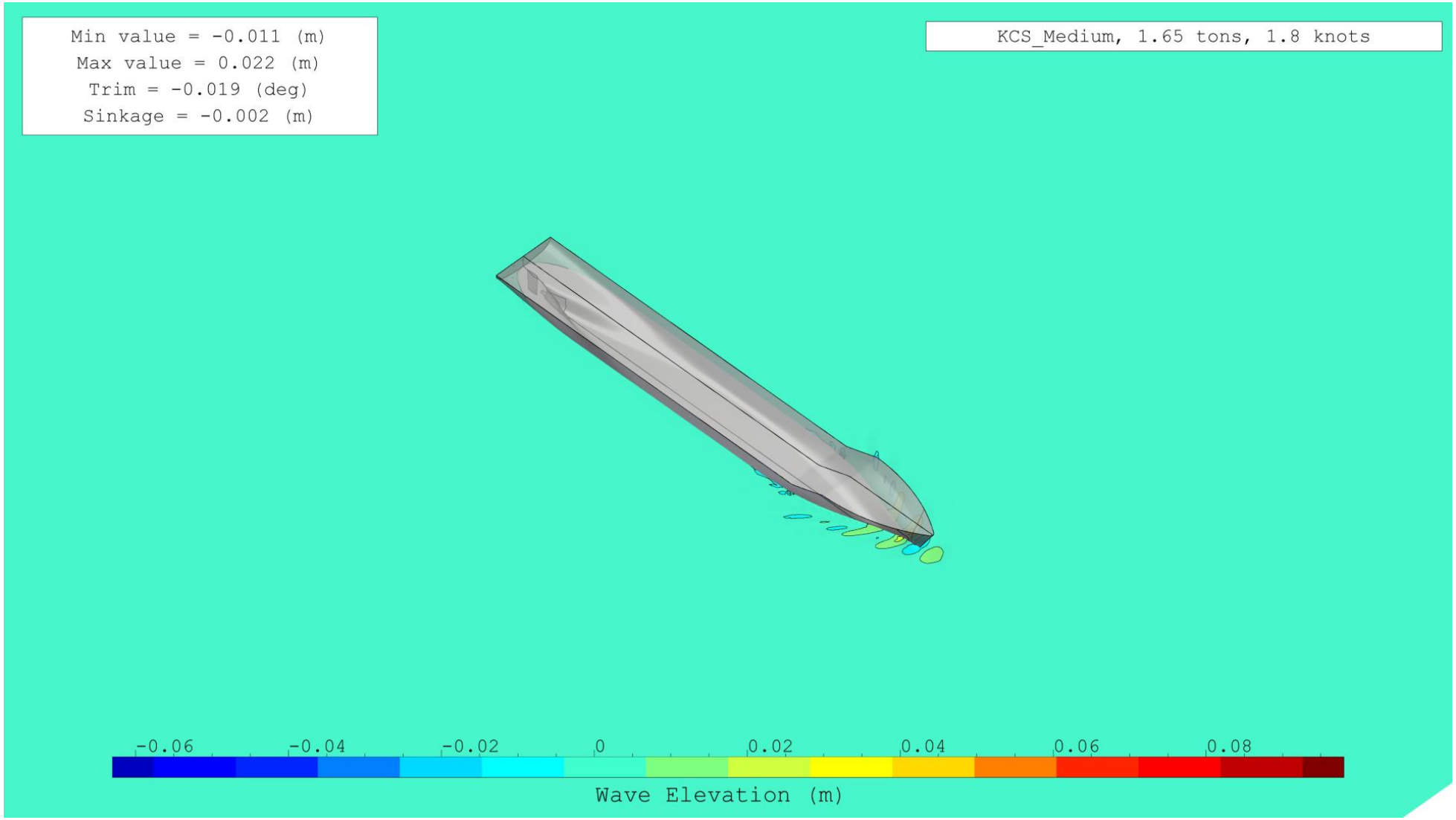
c. Free surface : far field (independant scale)



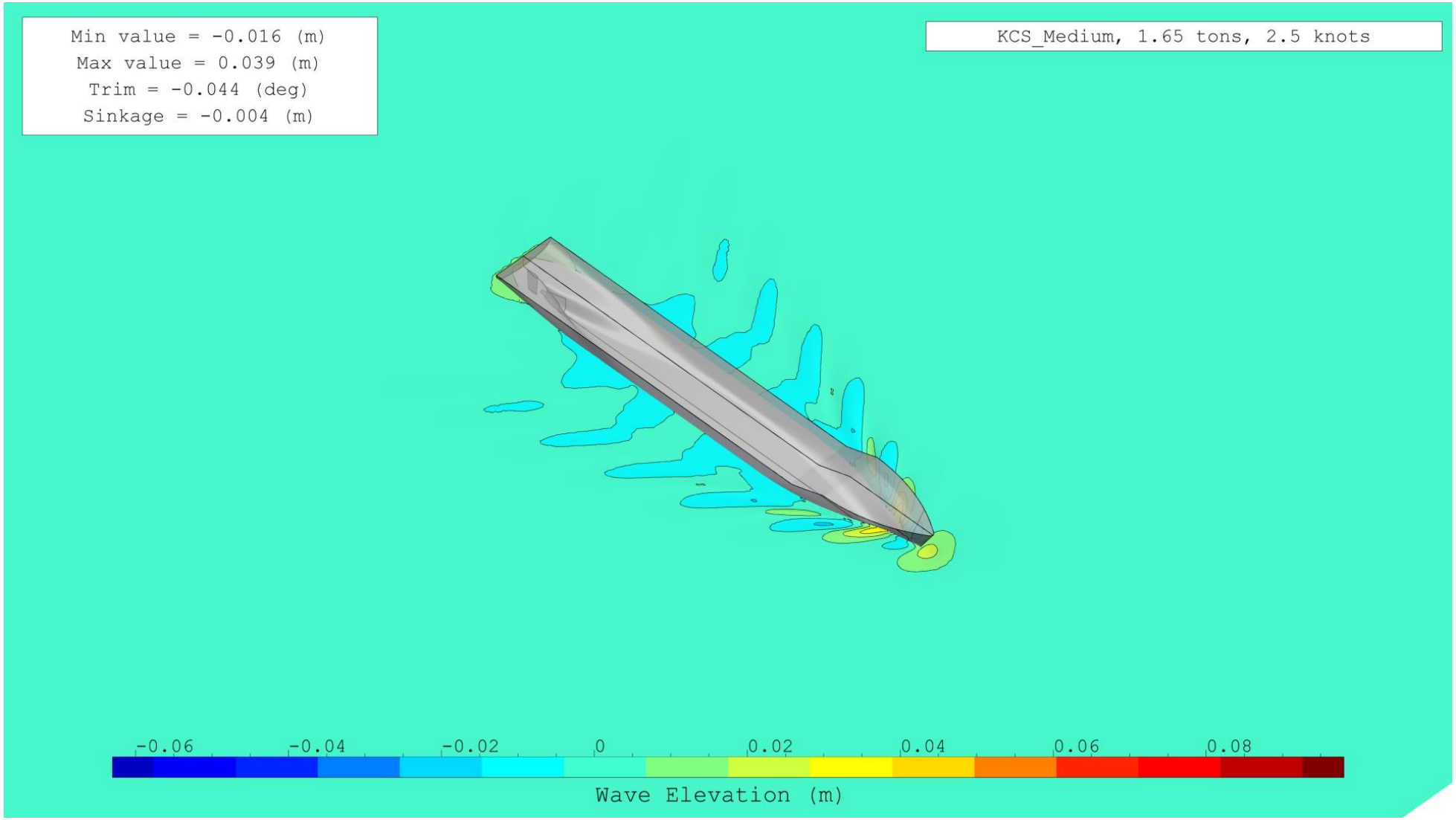
c. Free surface : far field (independant scale)



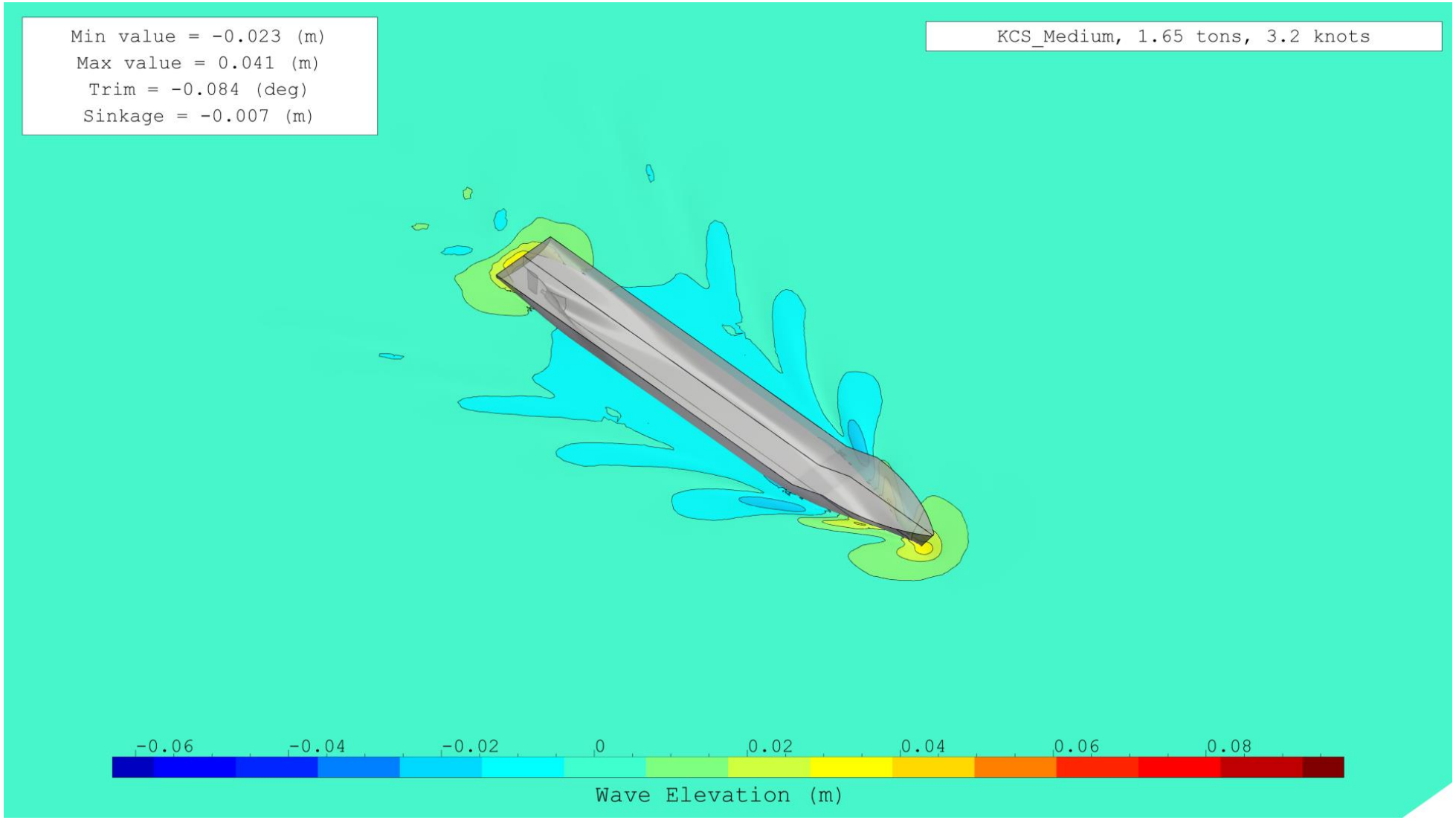
c. Free surface : ¾ front view (common scale)



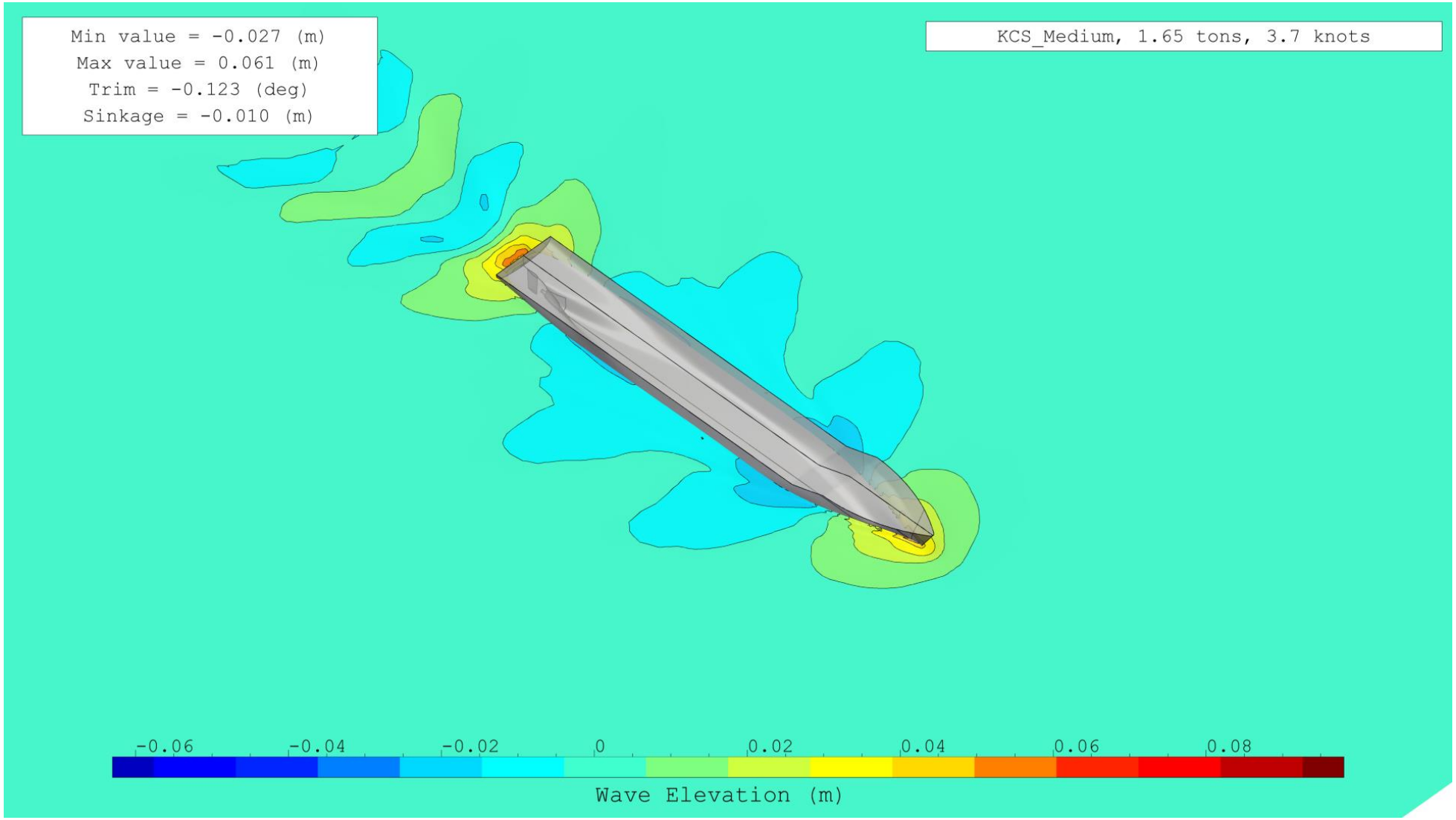
c. Free surface : ¾ front view (common scale)



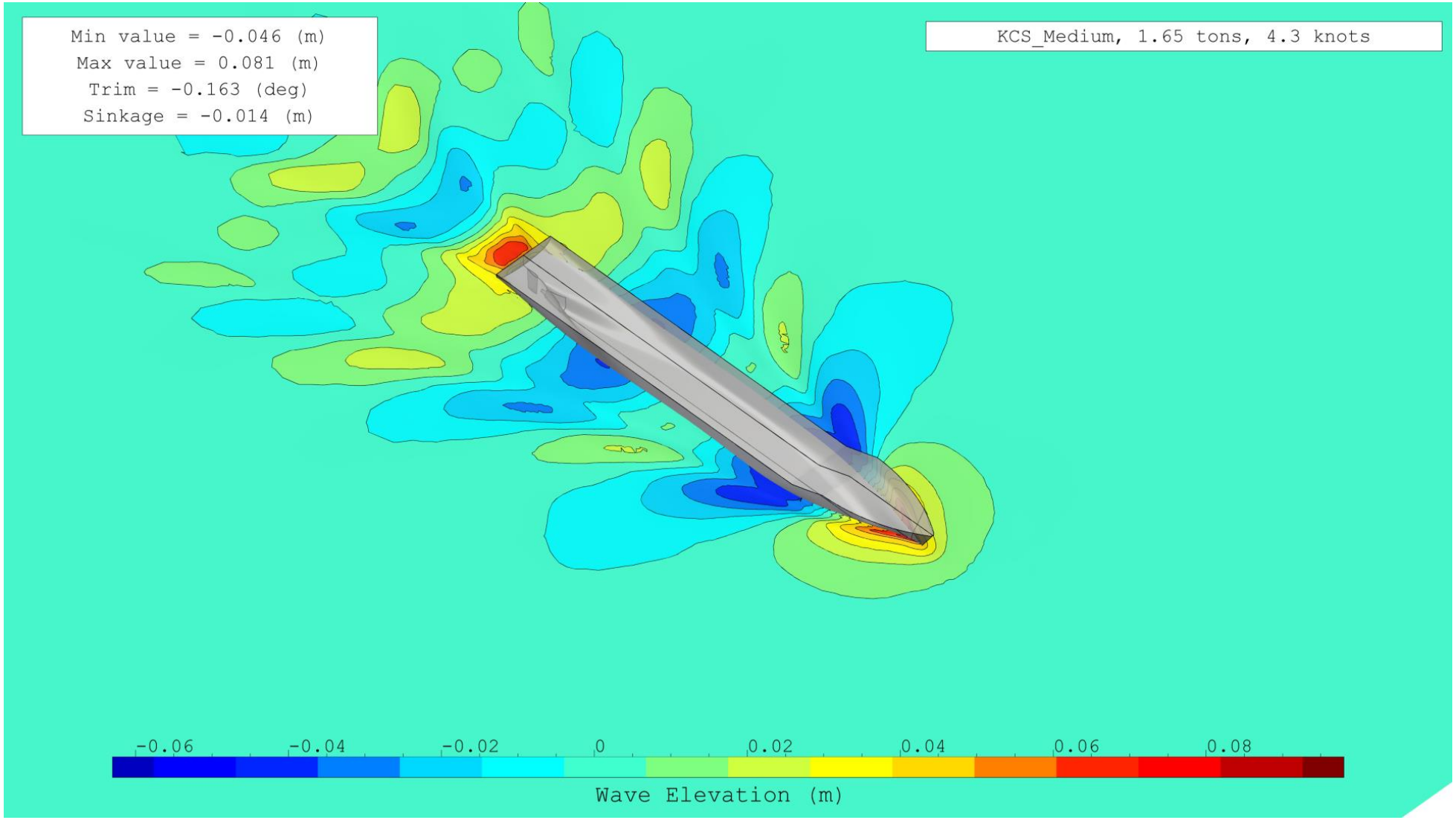
c. Free surface : ¾ front view (common scale)



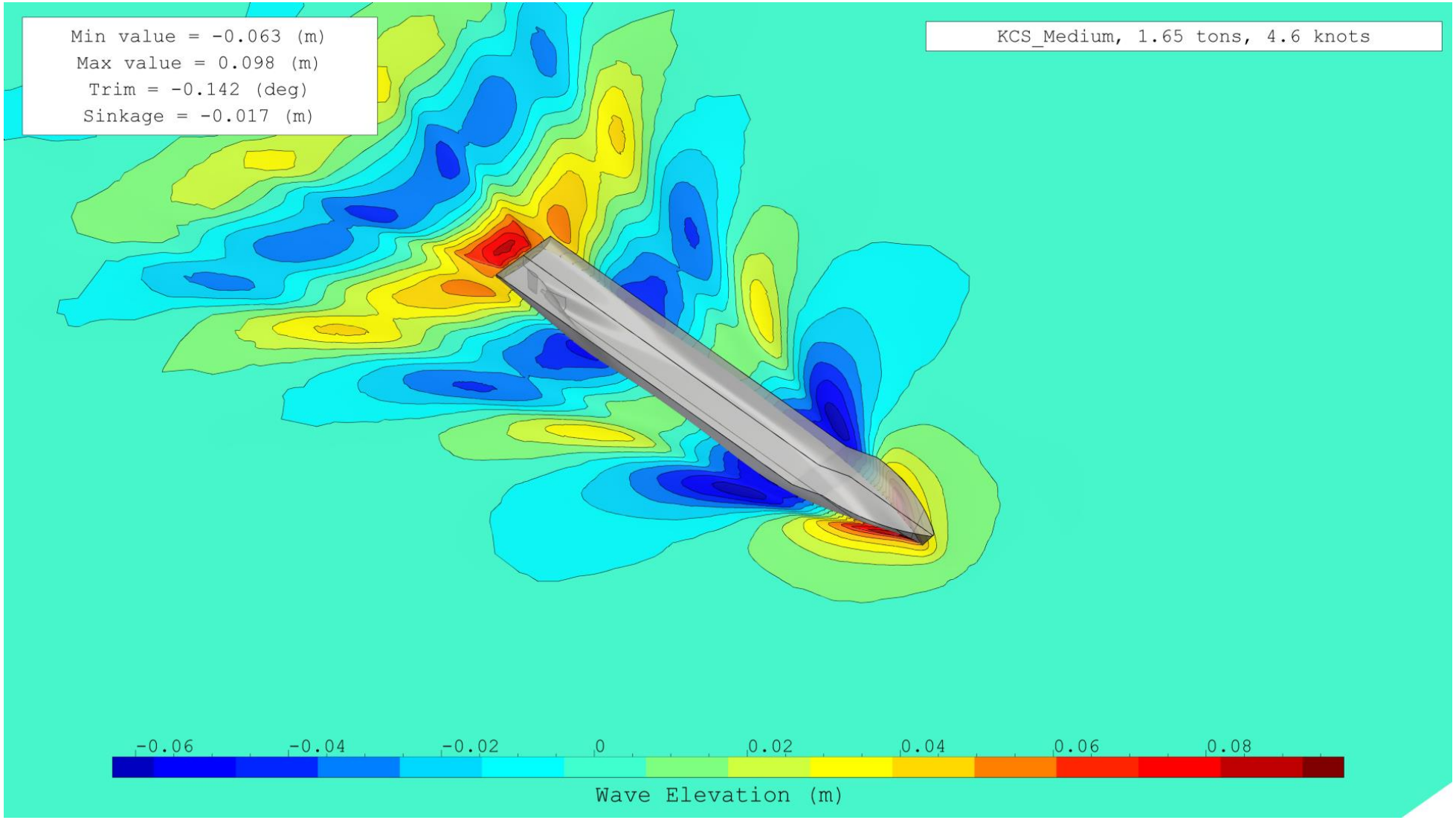
c. Free surface : ¾ front view (common scale)



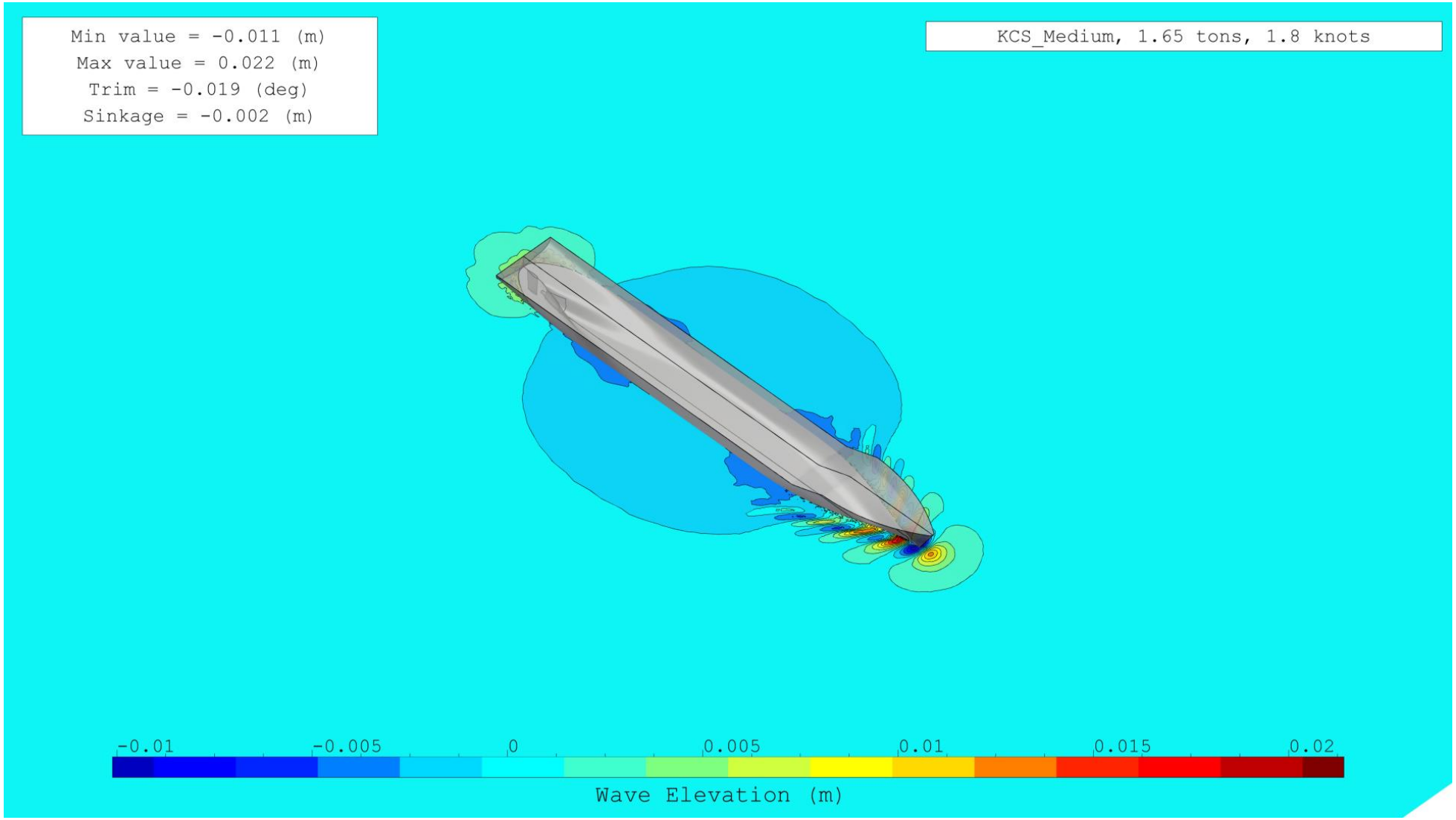
c. Free surface : ¾ front view (common scale)



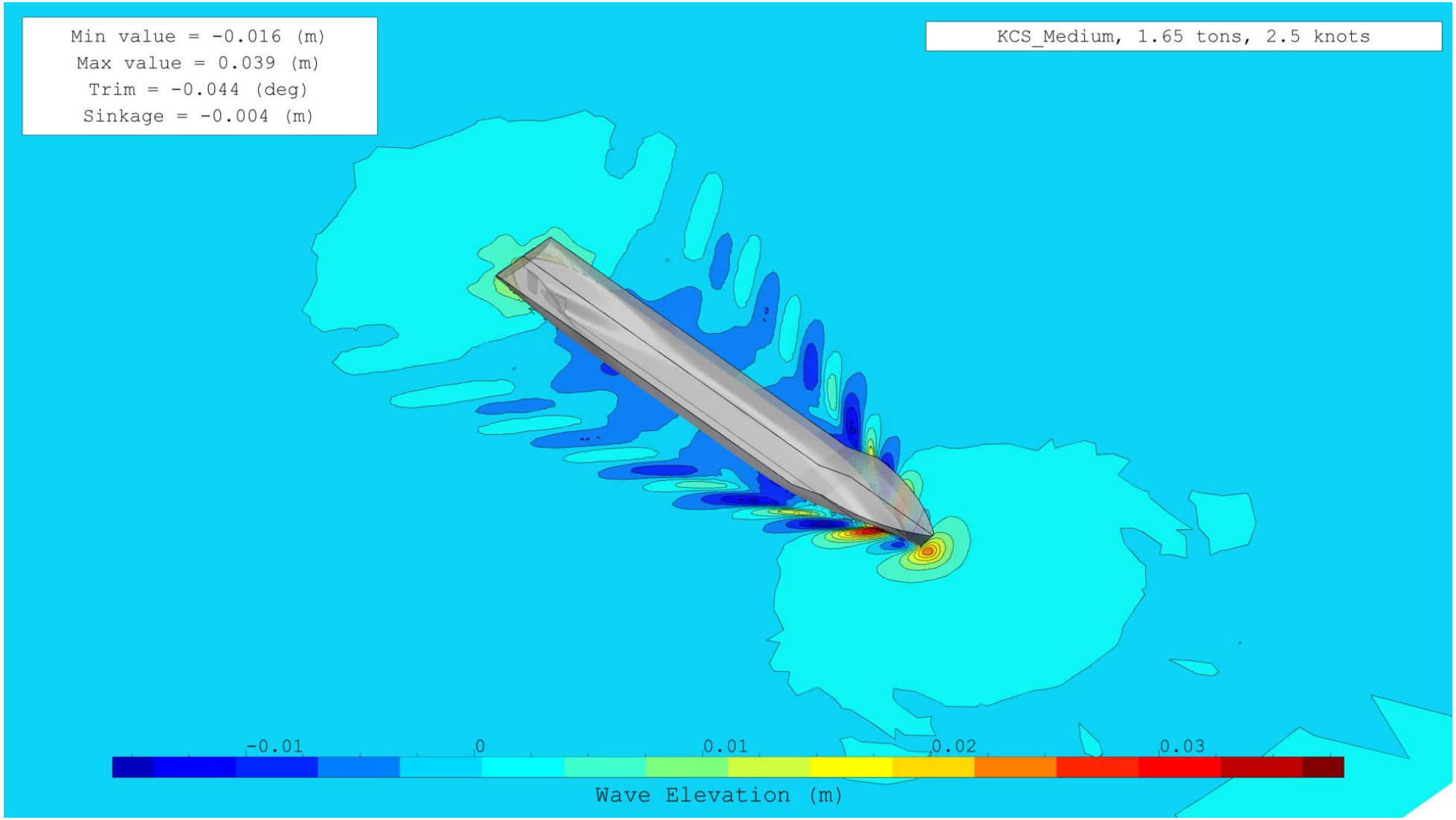
c. Free surface : ¾ front view (common scale)



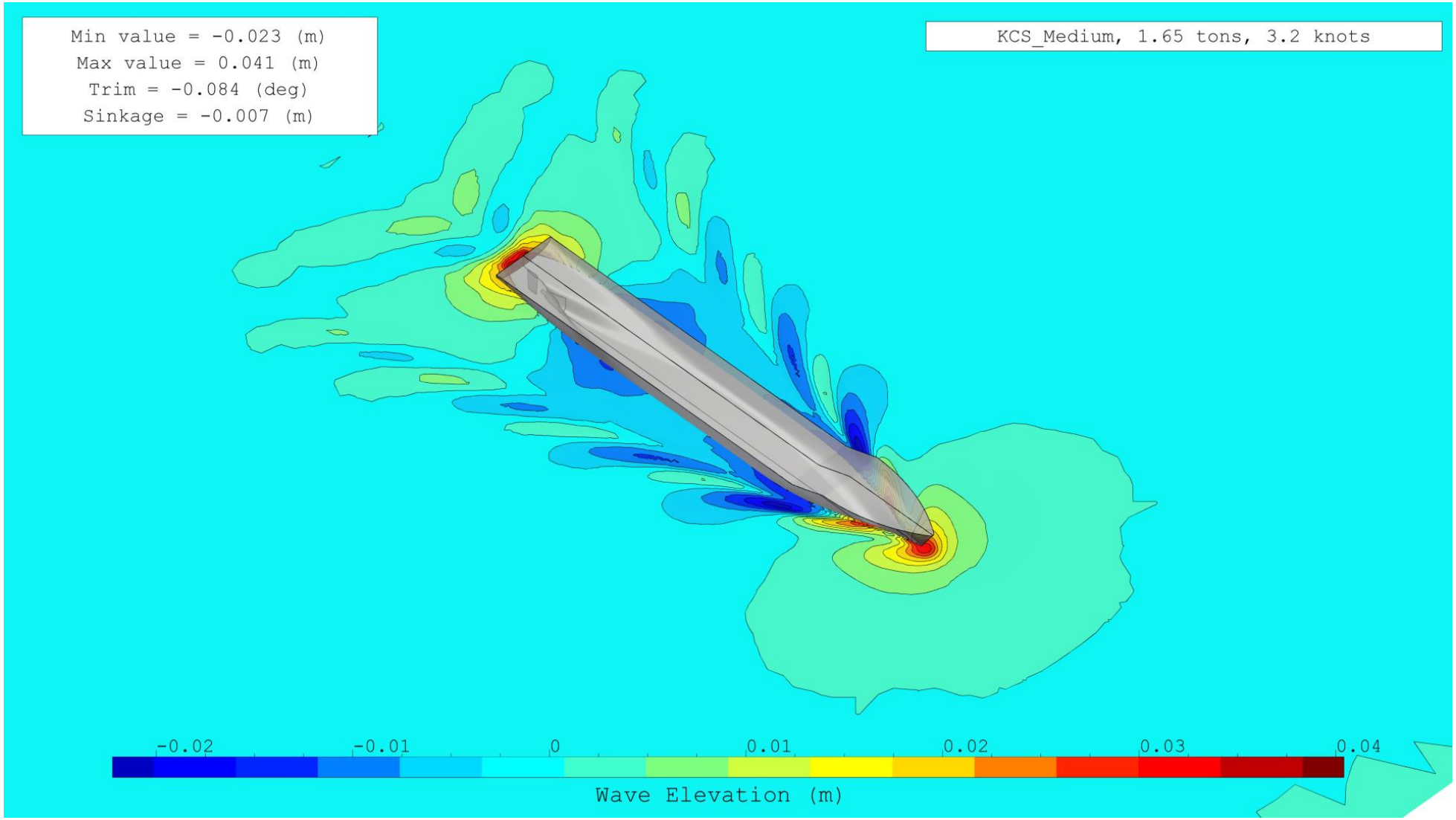
c. Free surface : ¾ front view (independant scale)



c. Free surface : ¾ front view (independant scale)



c. Free surface : ¾ front view (independant scale)



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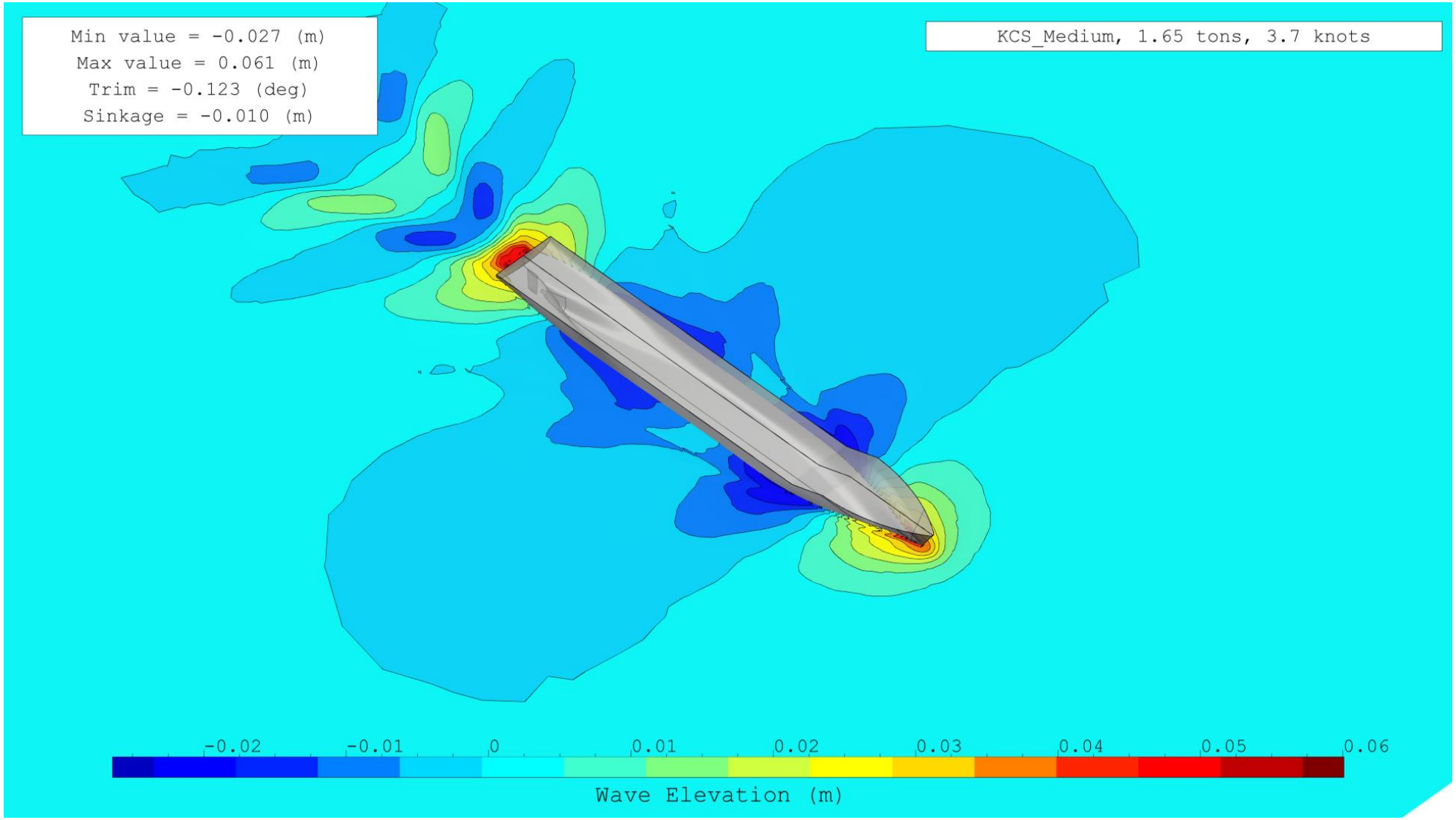
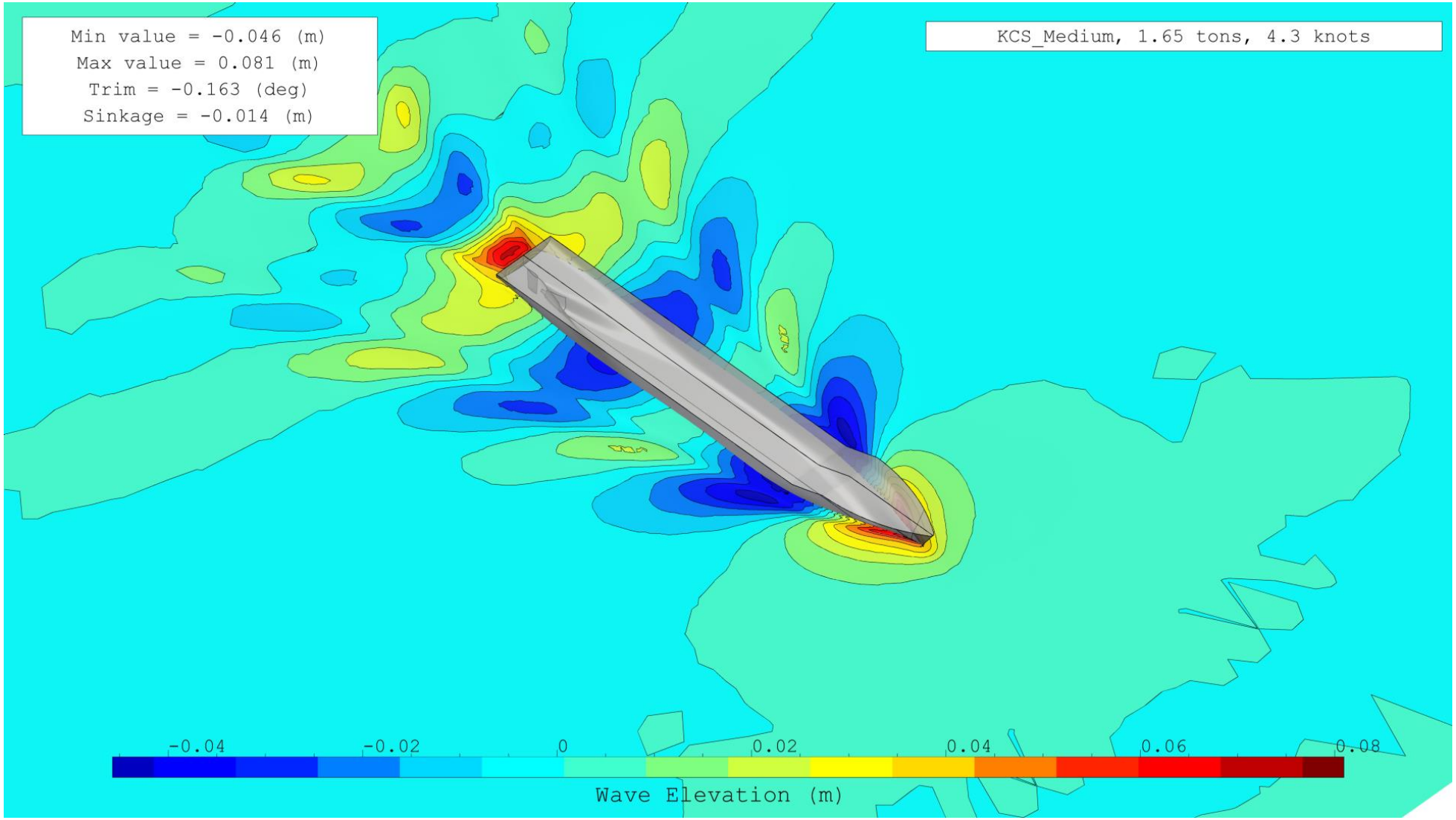
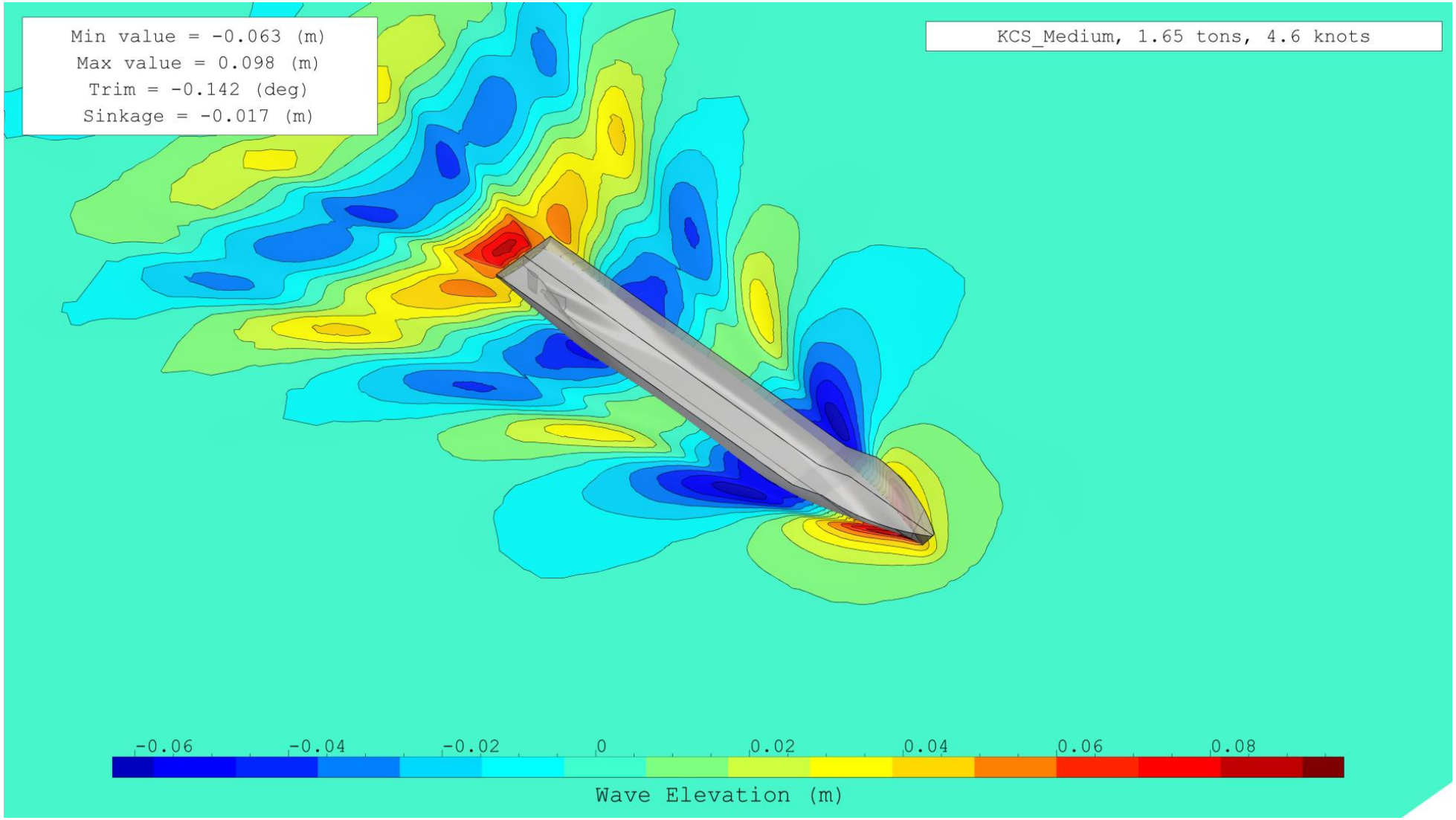


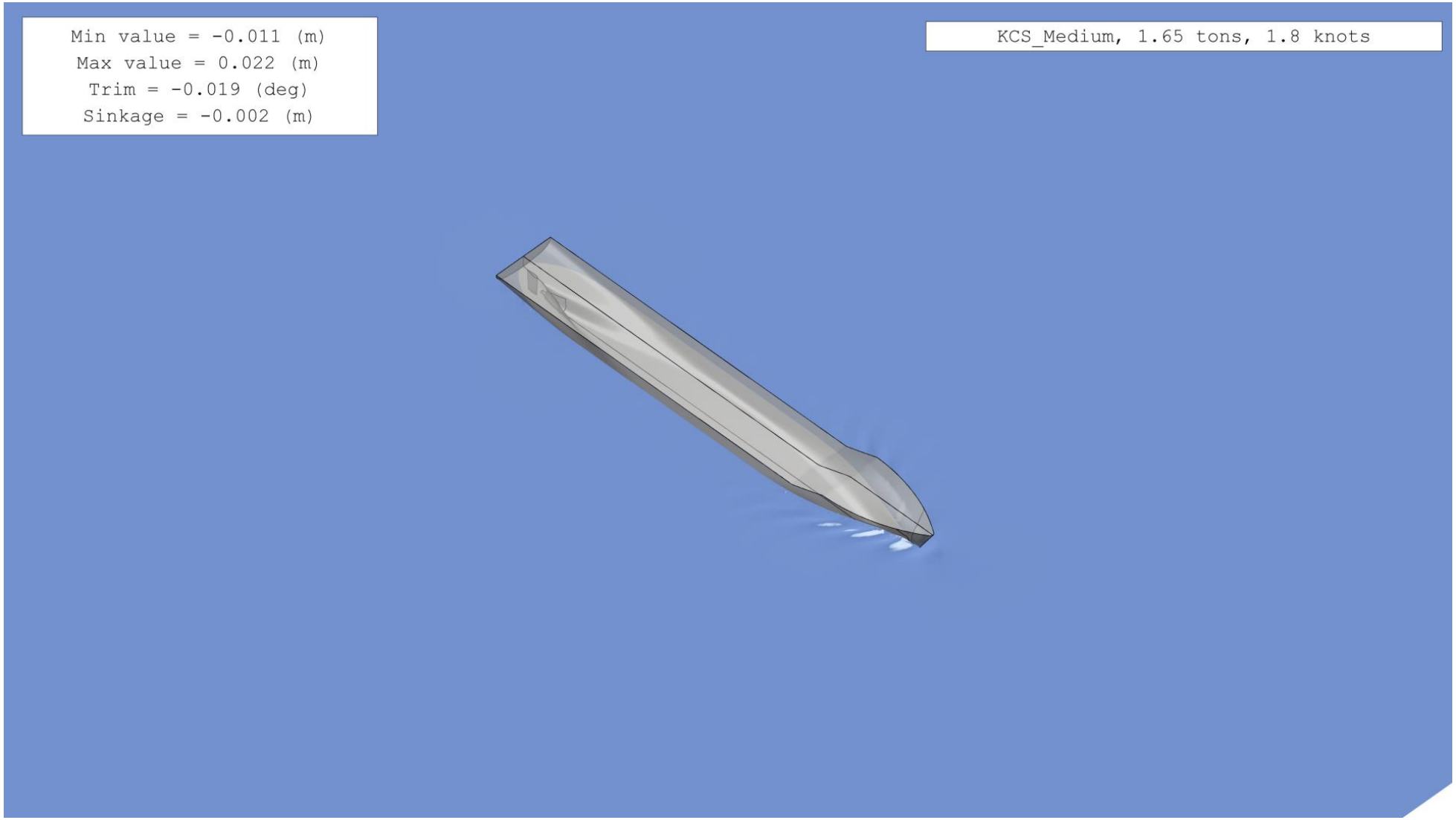
c. Free surface : ¾ front view (independant scale)



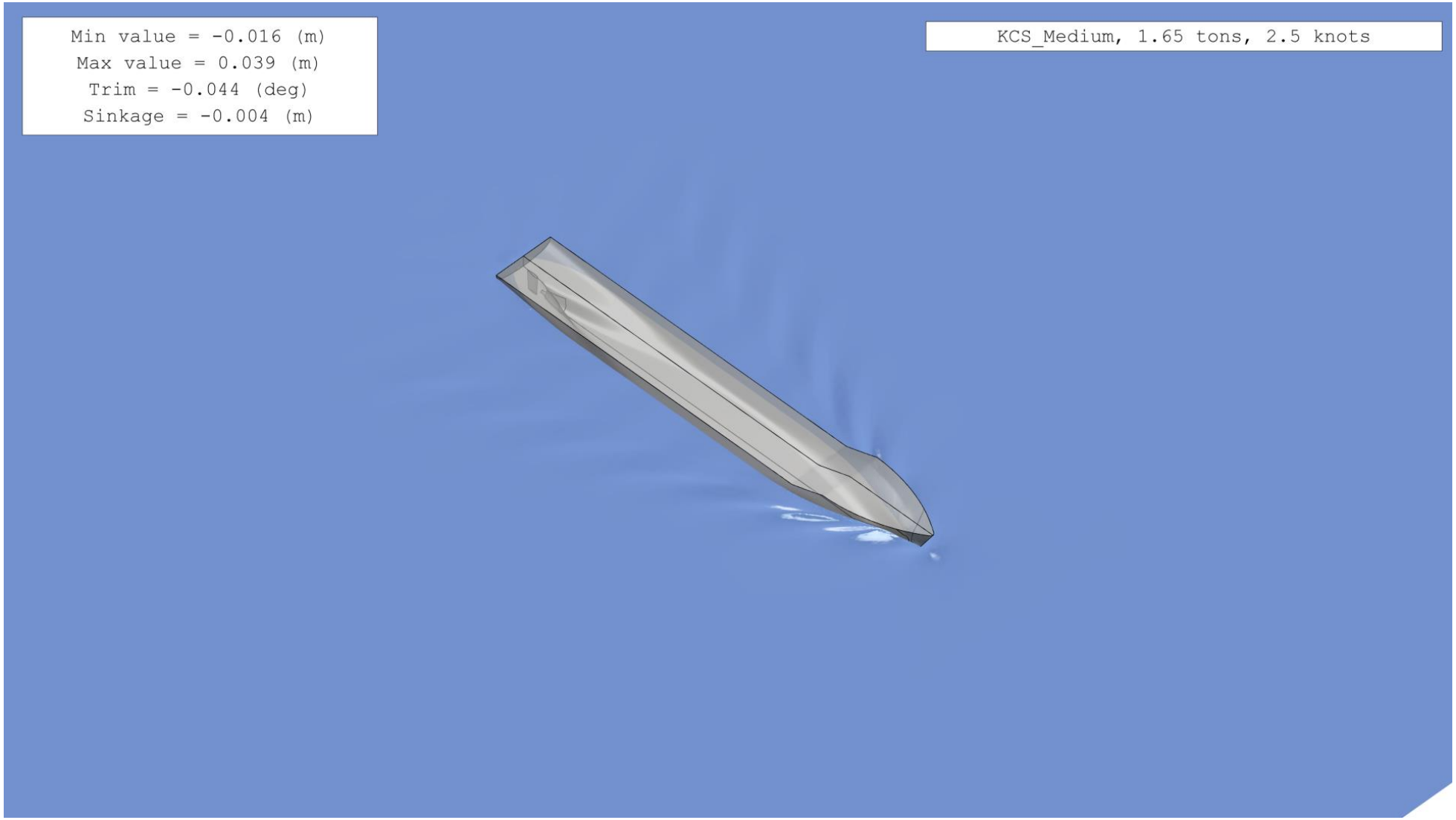
c. Free surface : ¾ front view (independant scale)



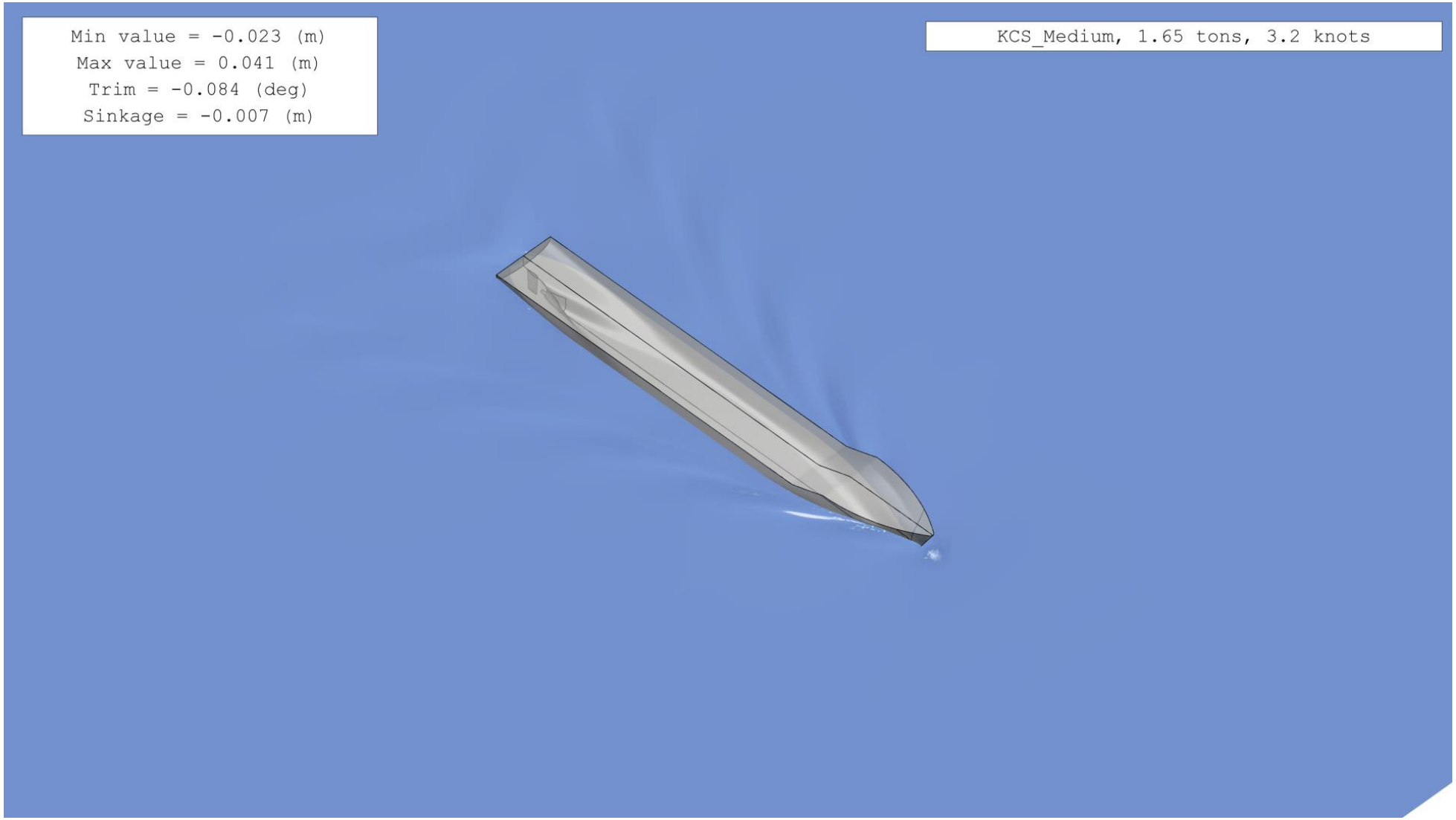
c. Free surface : ¾ front view, realistic rendering



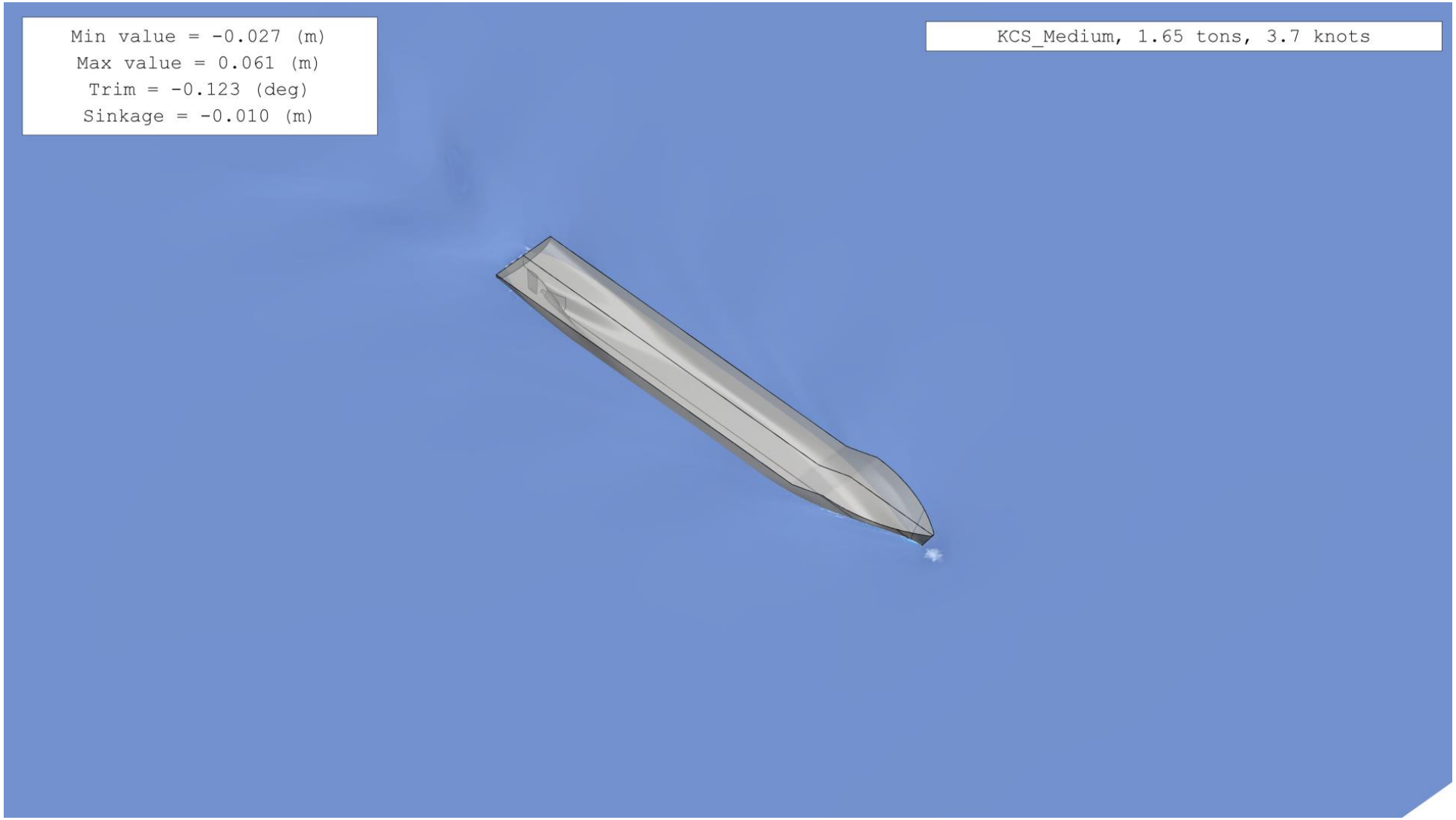
c. Free surface : ¾ front view, realistic rendering



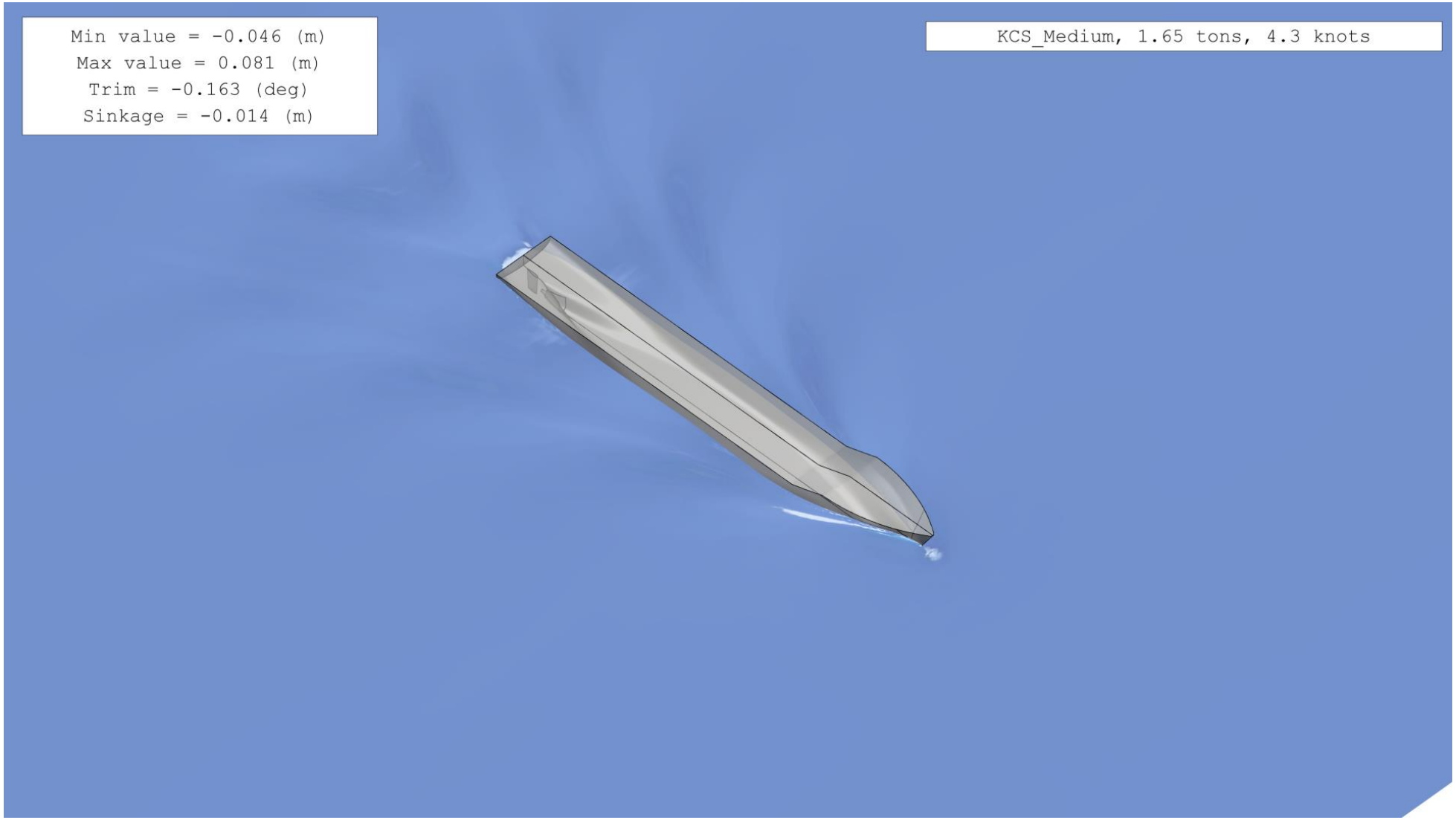
c. Free surface : ¾ front view, realistic rendering



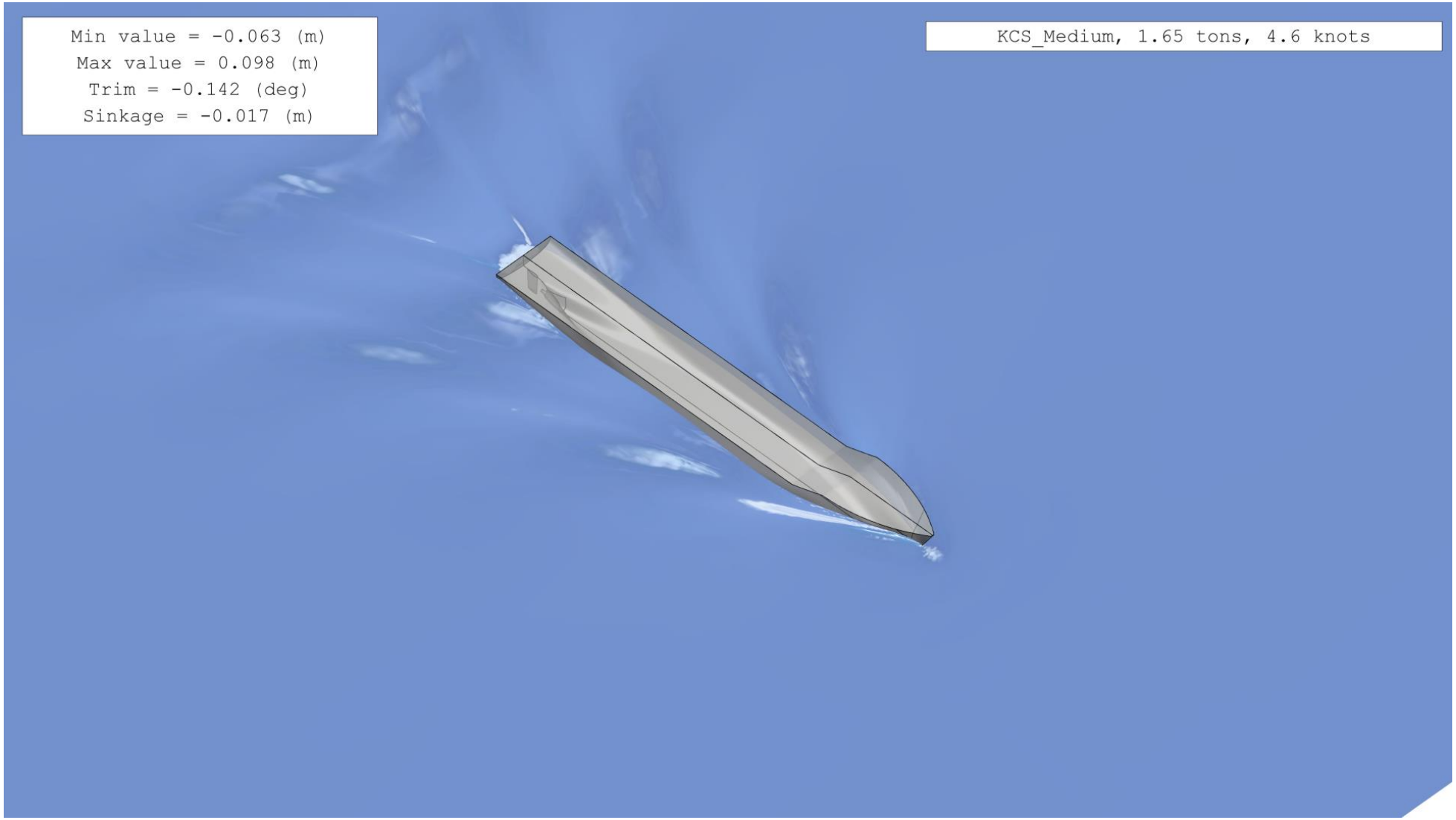
c. Free surface : ¾ front view, realistic rendering



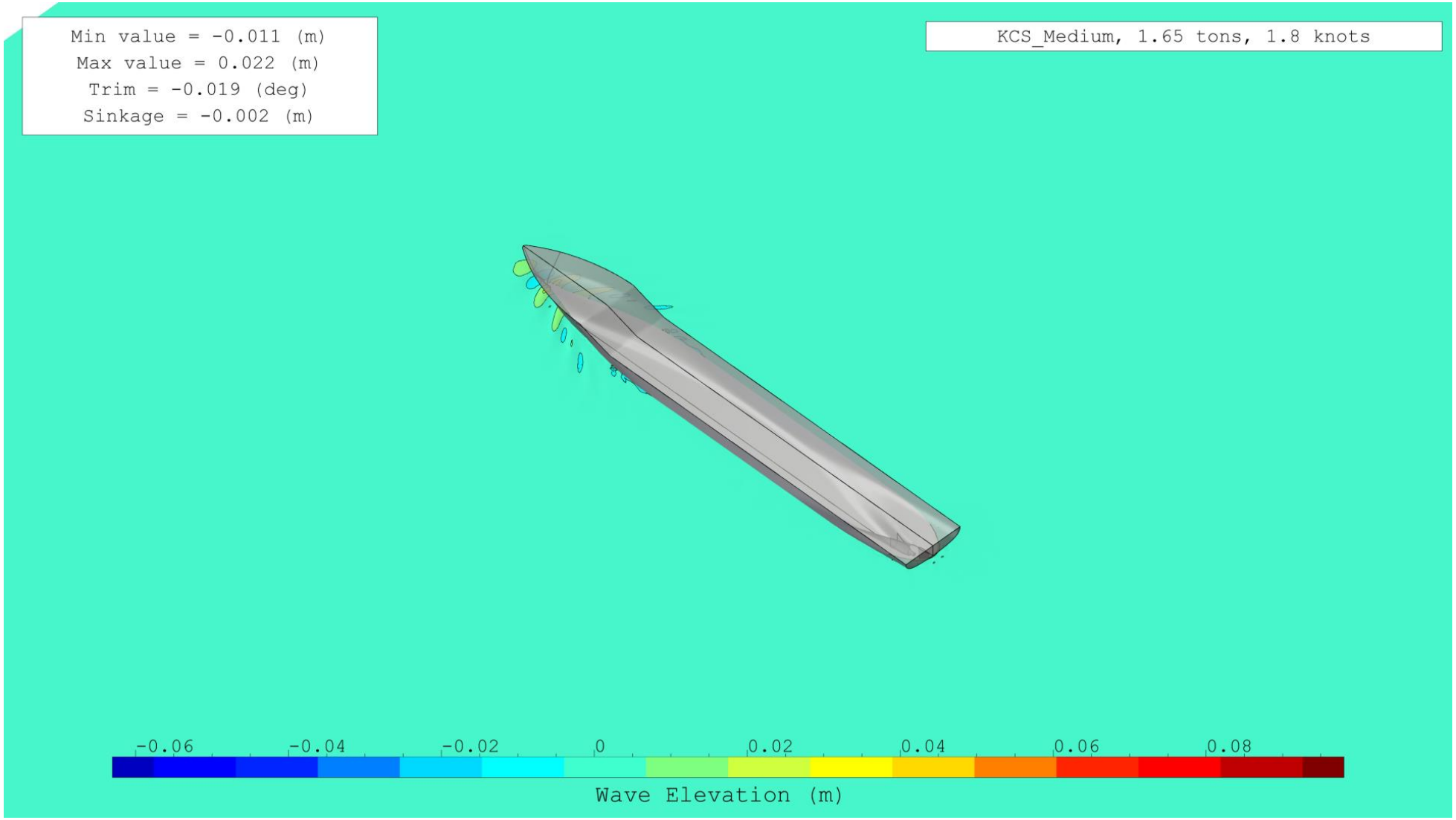
c. Free surface : ¾ front view, realistic rendering



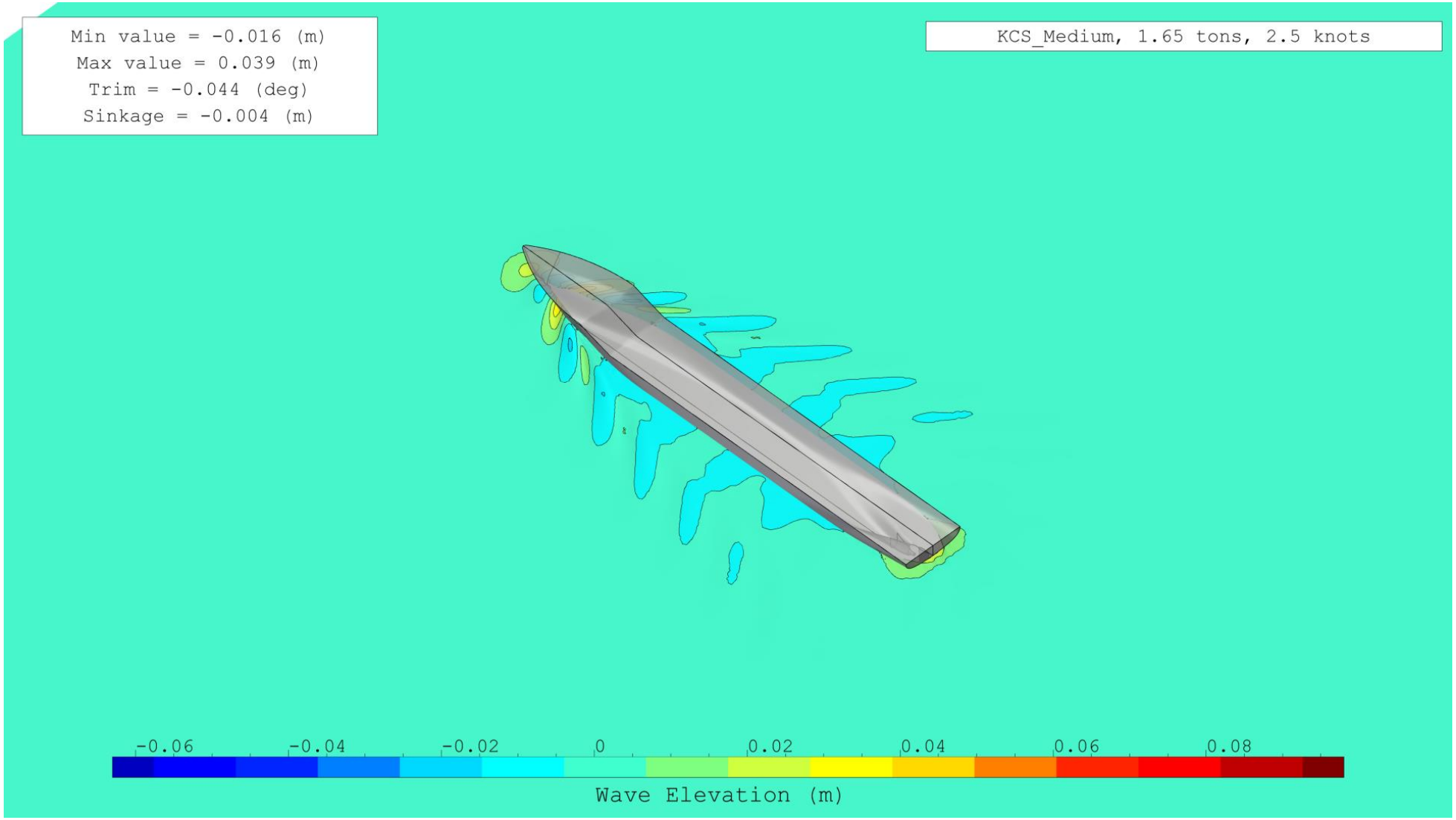
c. Free surface : ¾ front view, realistic rendering



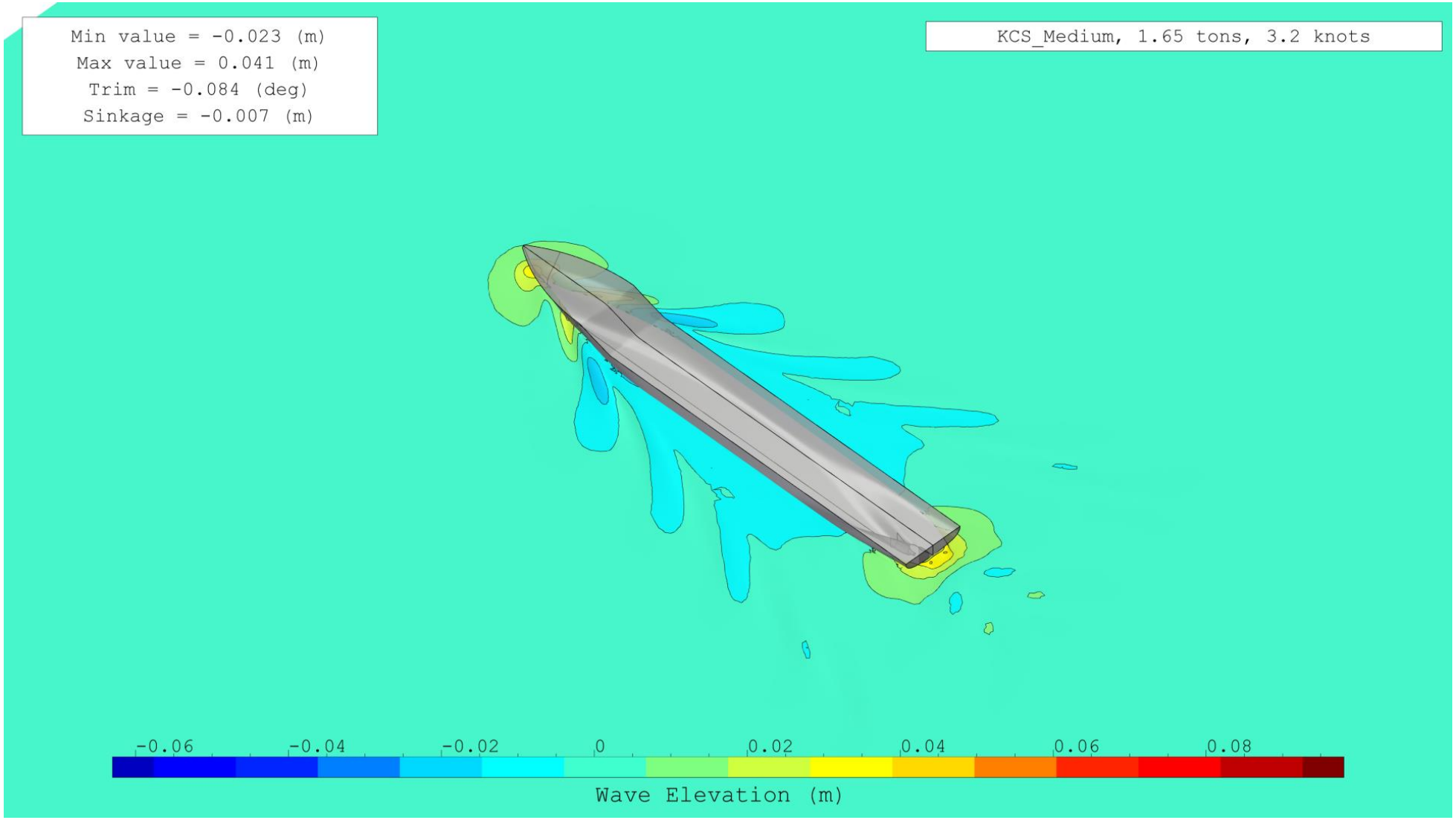
c. Free surface : ¾ rear view (common scale)



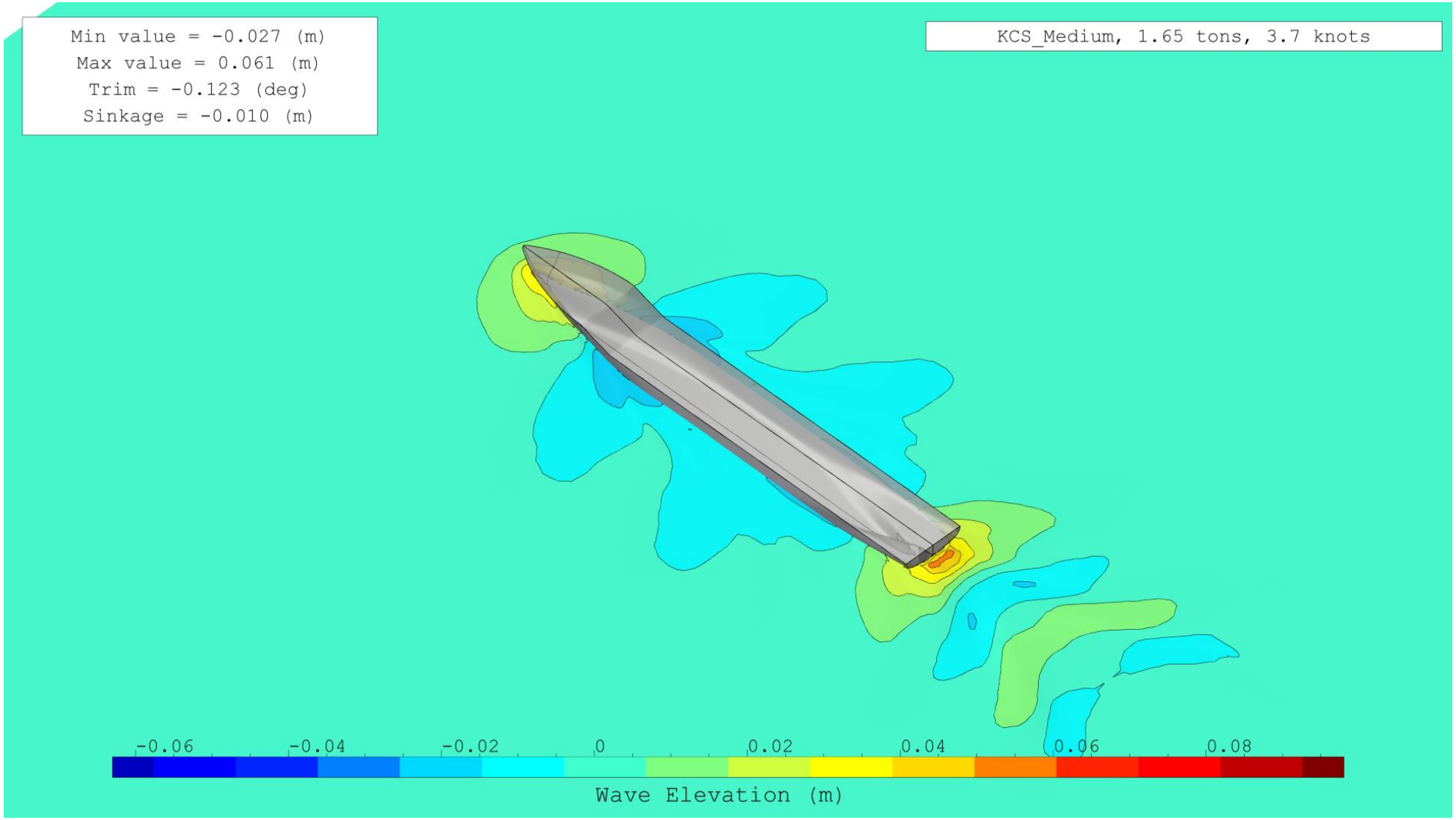
c. Free surface : ¾ rear view (common scale)



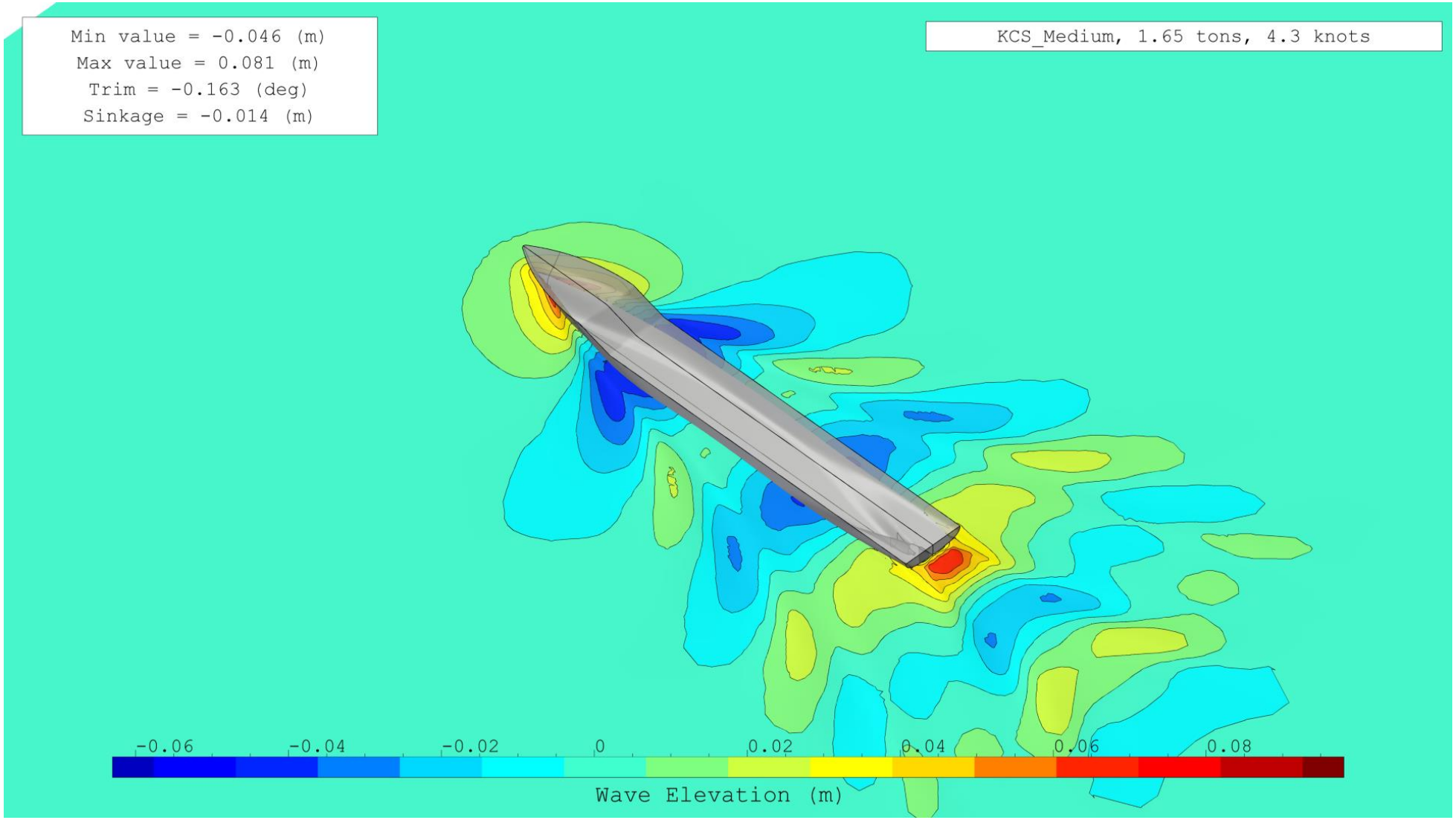
c. Free surface : ¾ rear view (common scale)



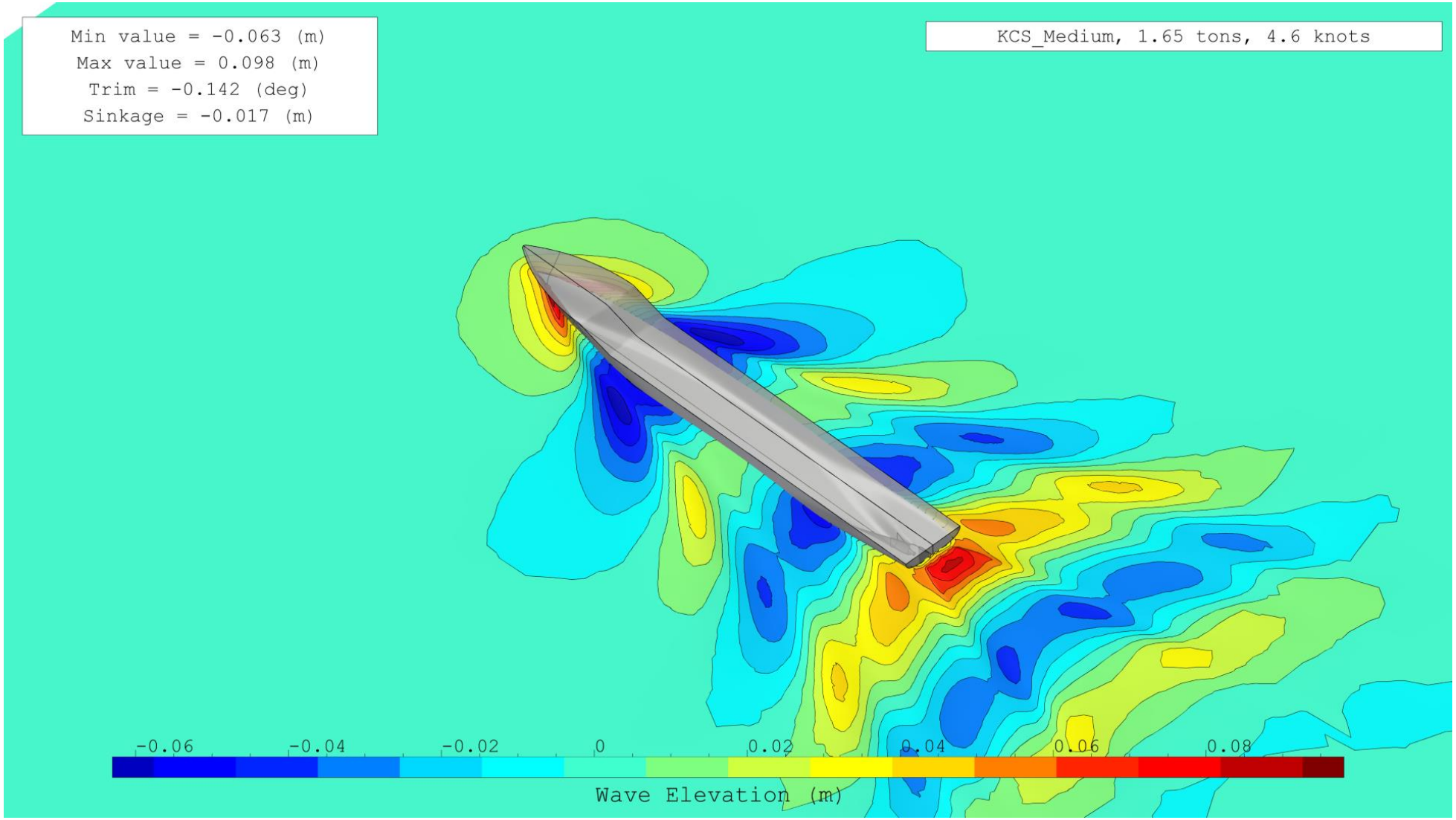
c. Free surface : ¾ rear view (common scale)



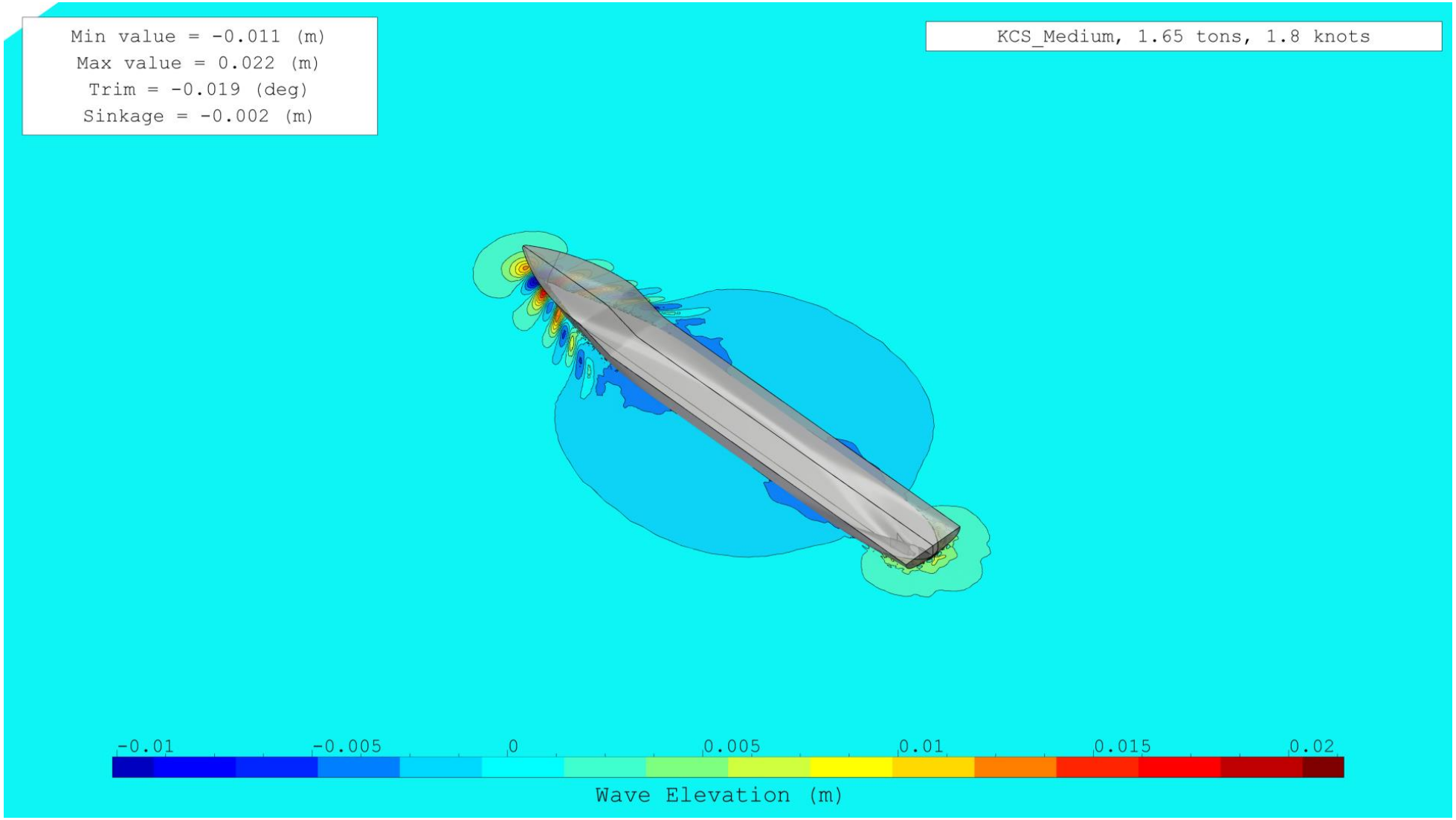
c. Free surface : ¾ rear view (common scale)



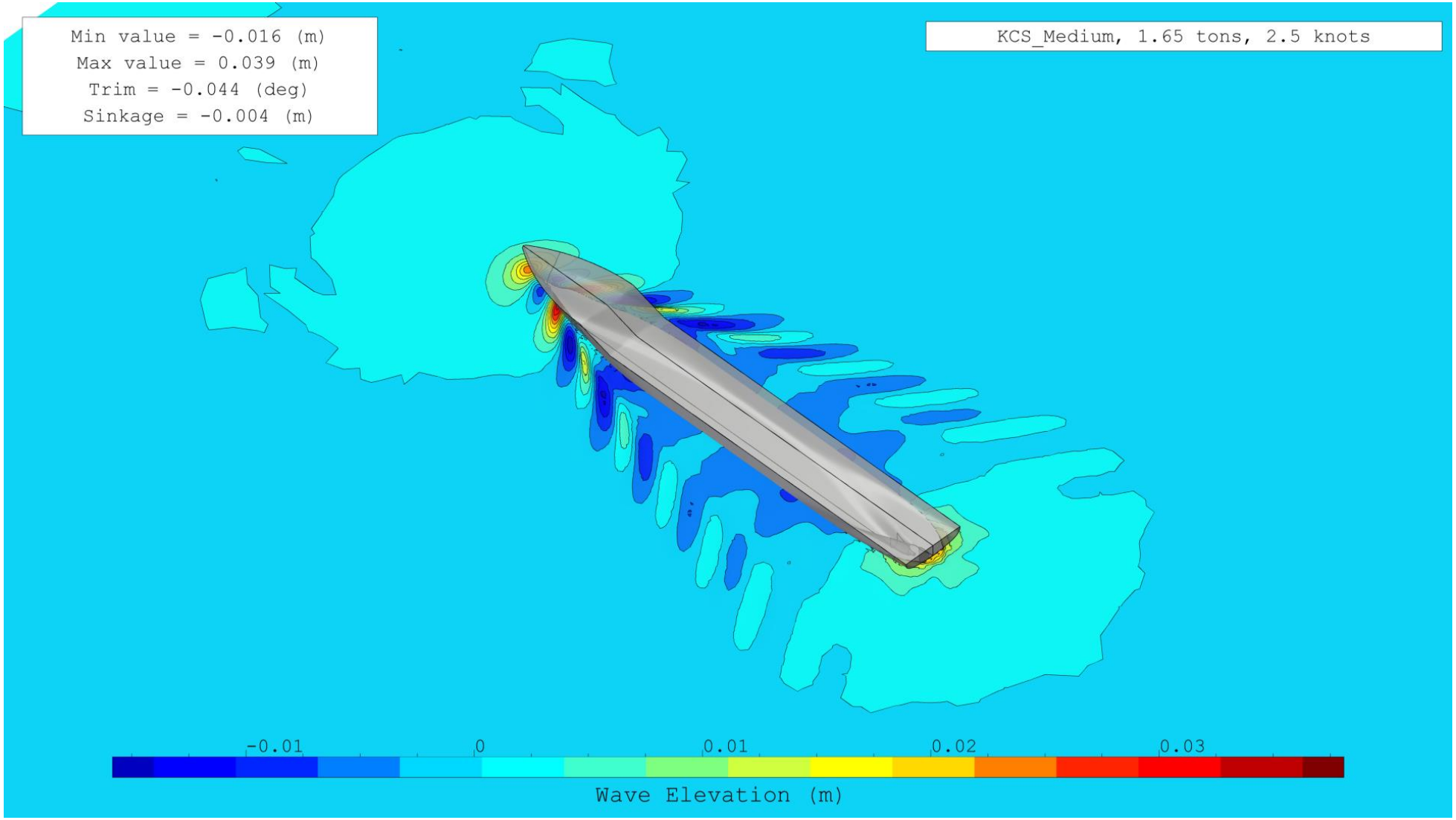
c. Free surface : ¾ rear view (common scale)



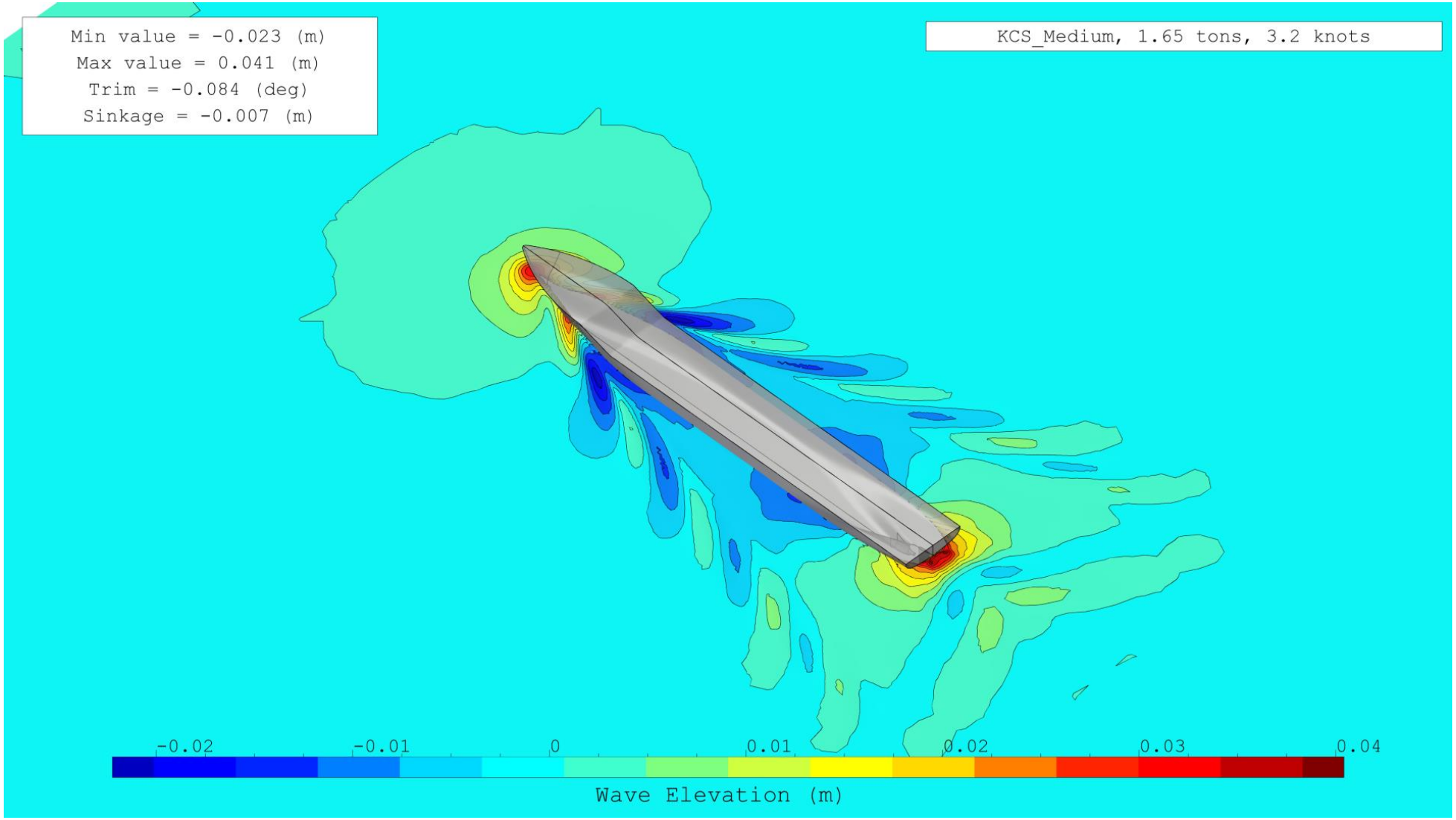
c. Free surface : ¾ rear view (independant scale)



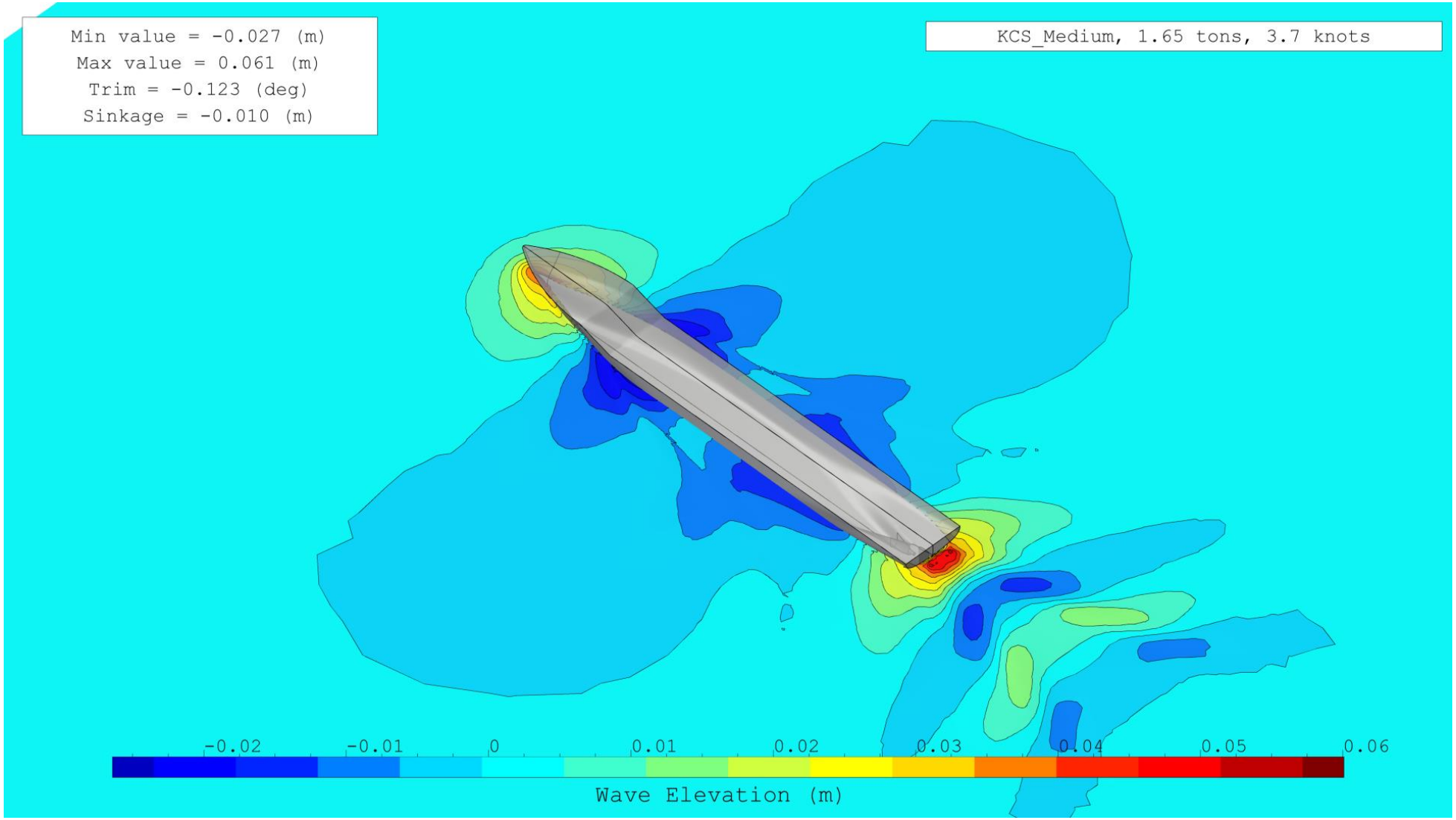
c. Free surface : ¾ rear view (independant scale)



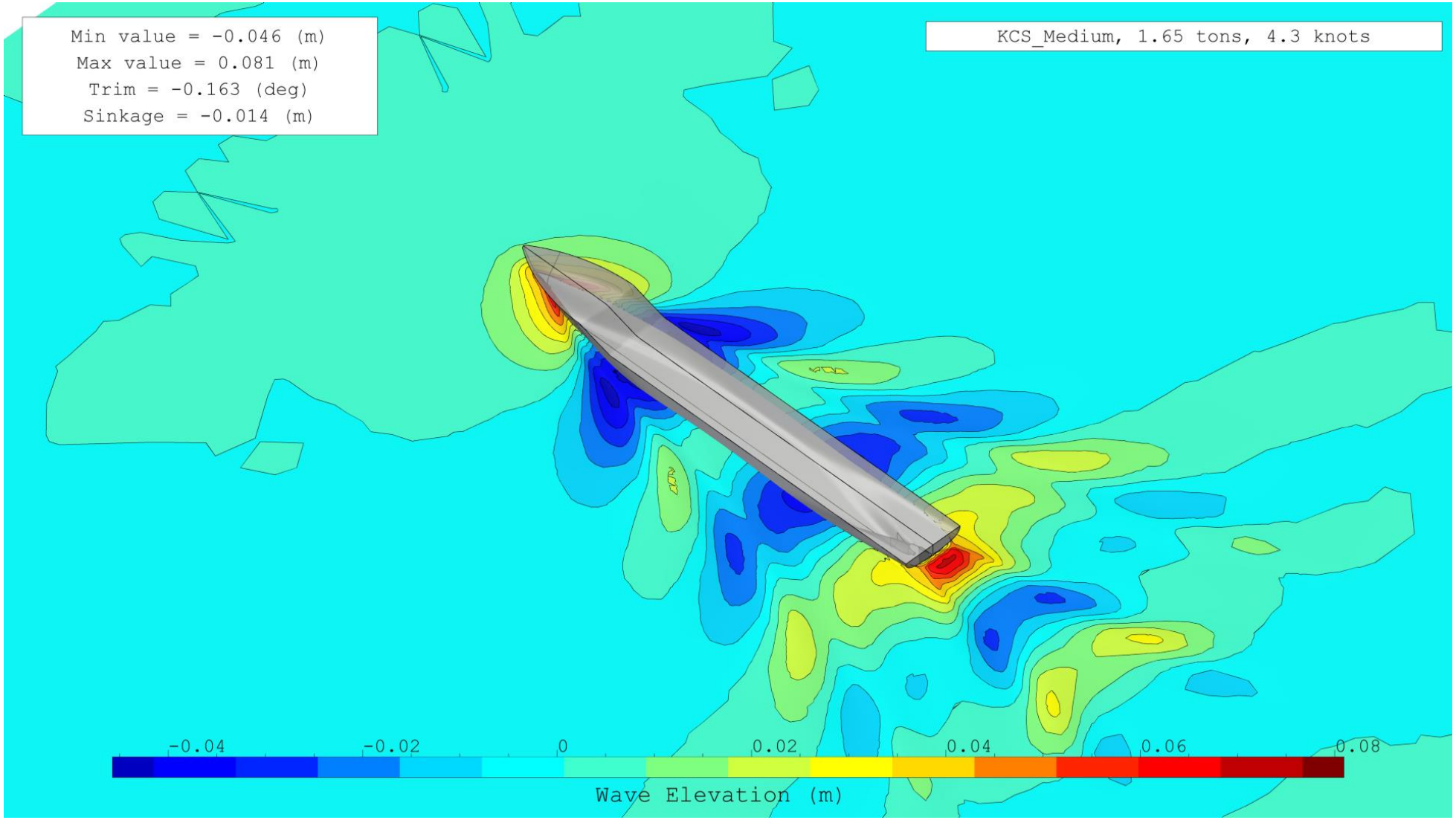
c. Free surface : ¾ rear view (independant scale)



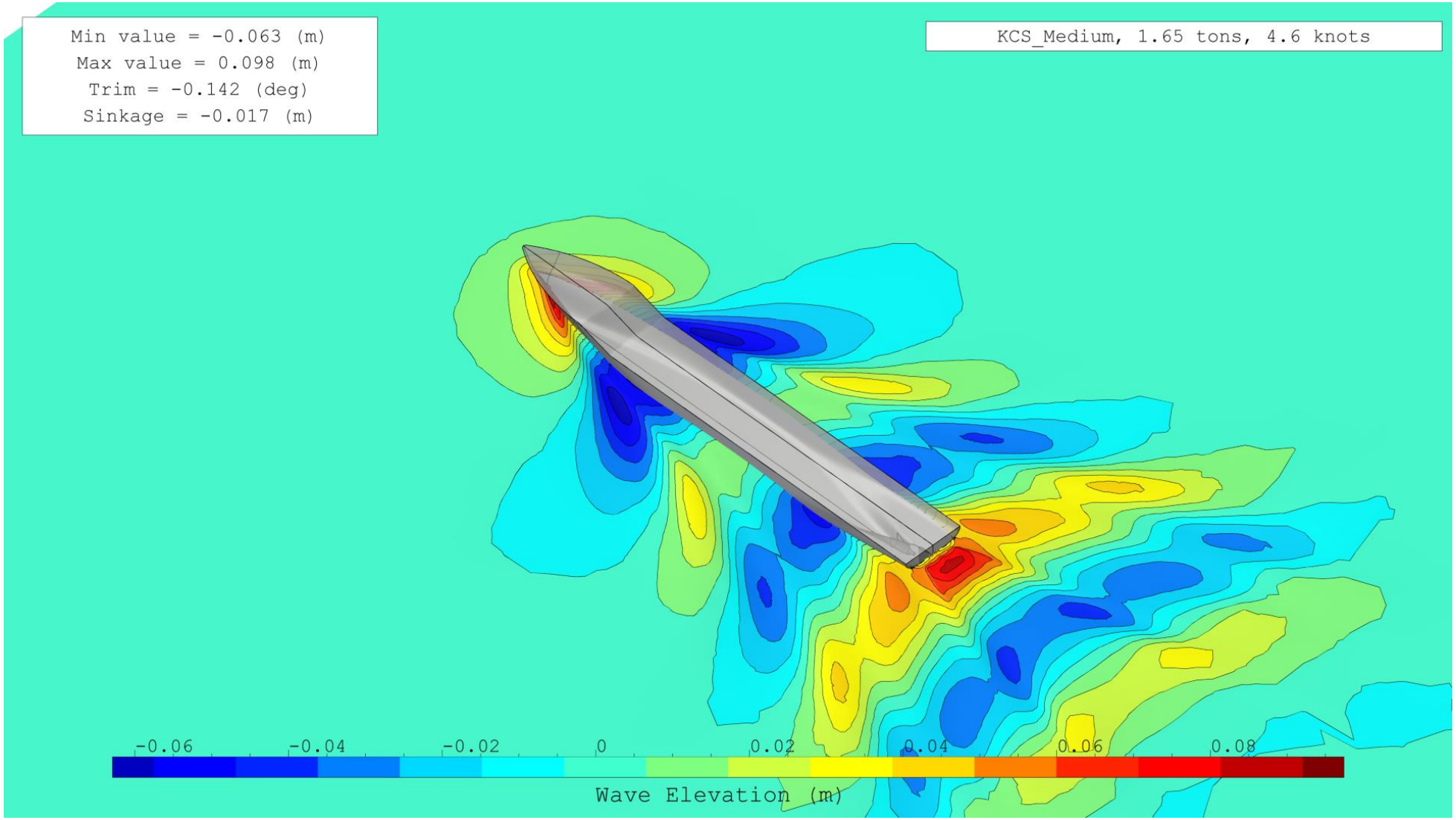
c. Free surface : ¾ rear view (independant scale)



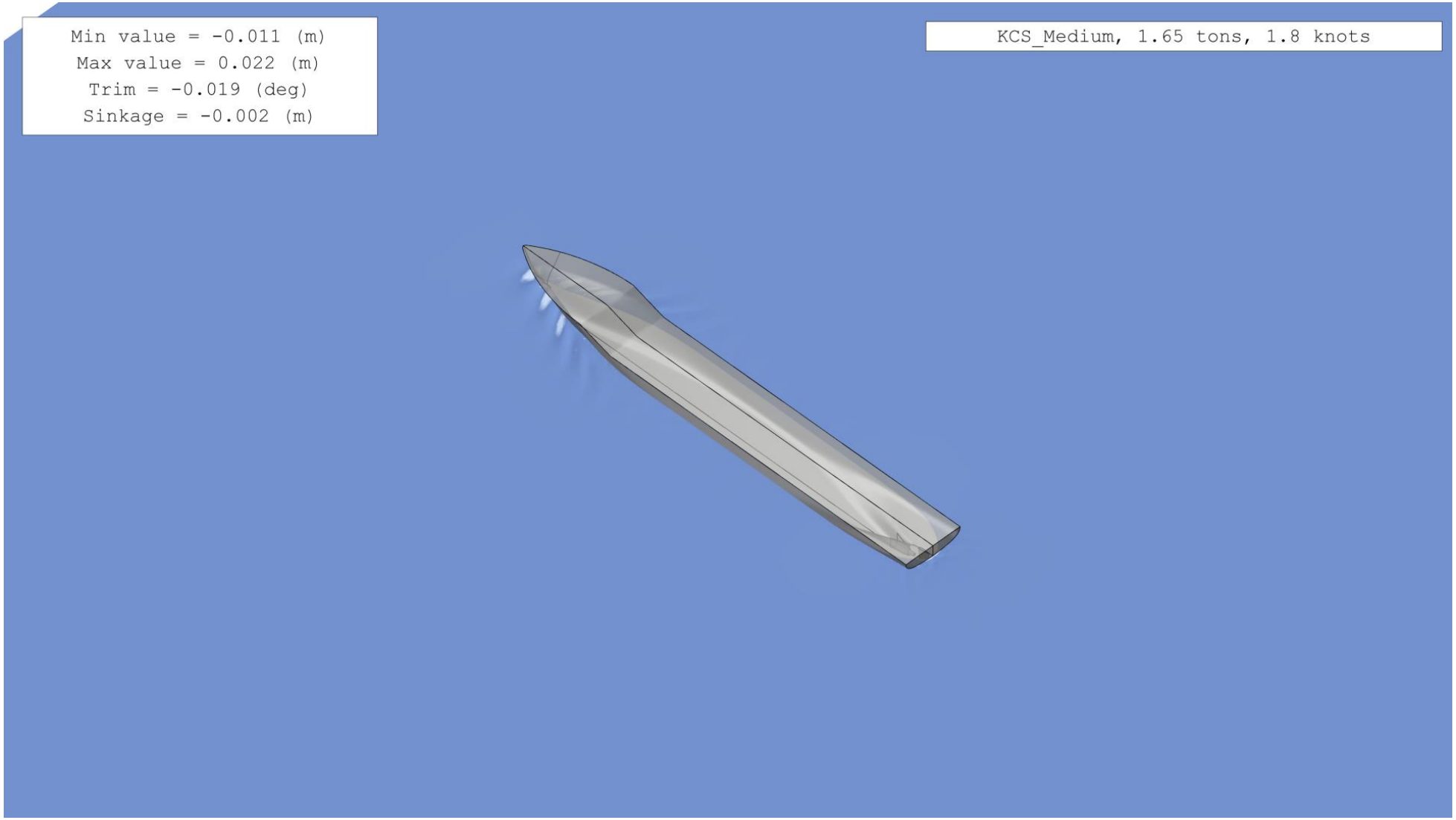
c. Free surface : ¾ rear view (independant scale)



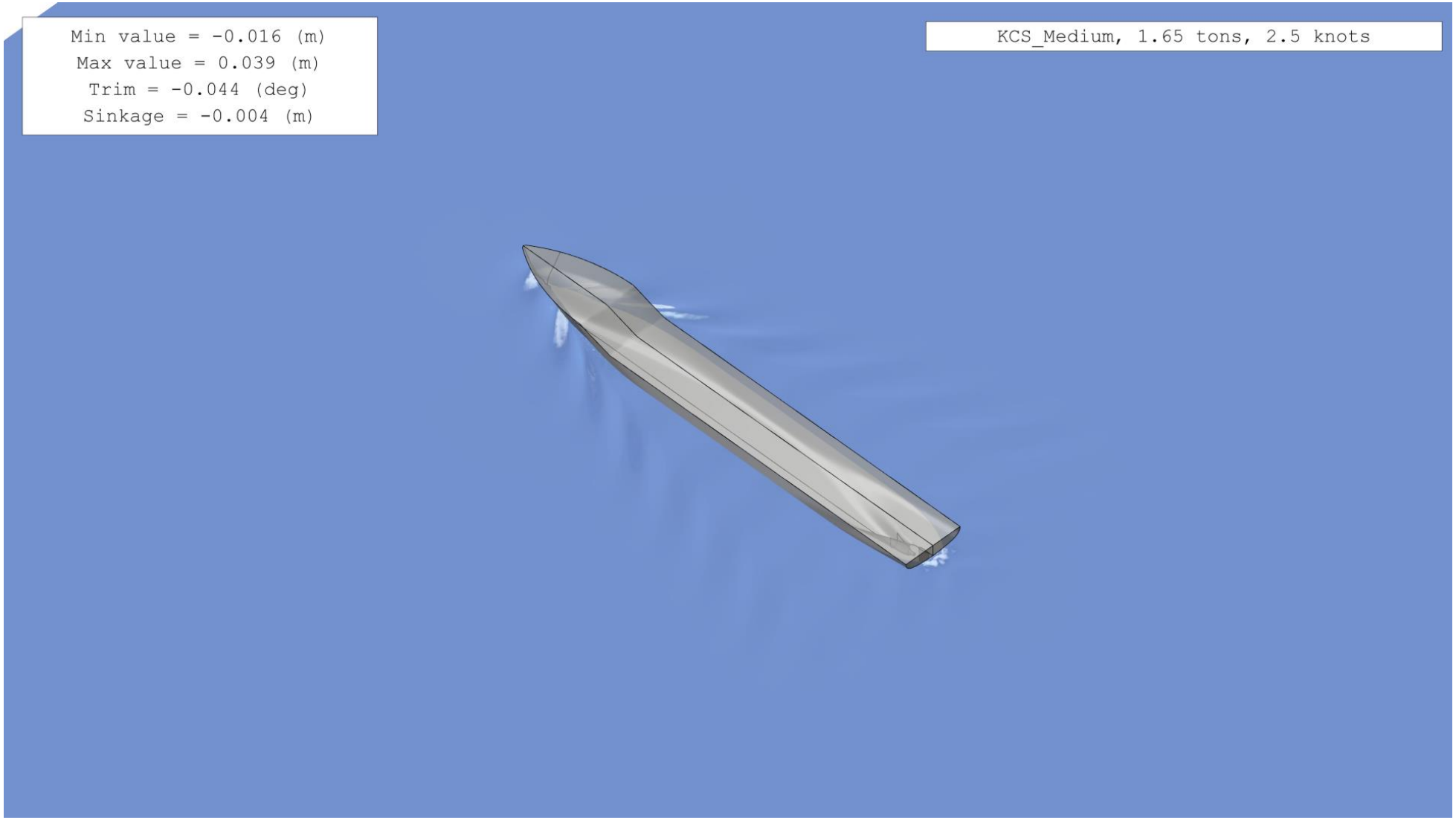
c. Free surface : ¾ rear view (independant scale)



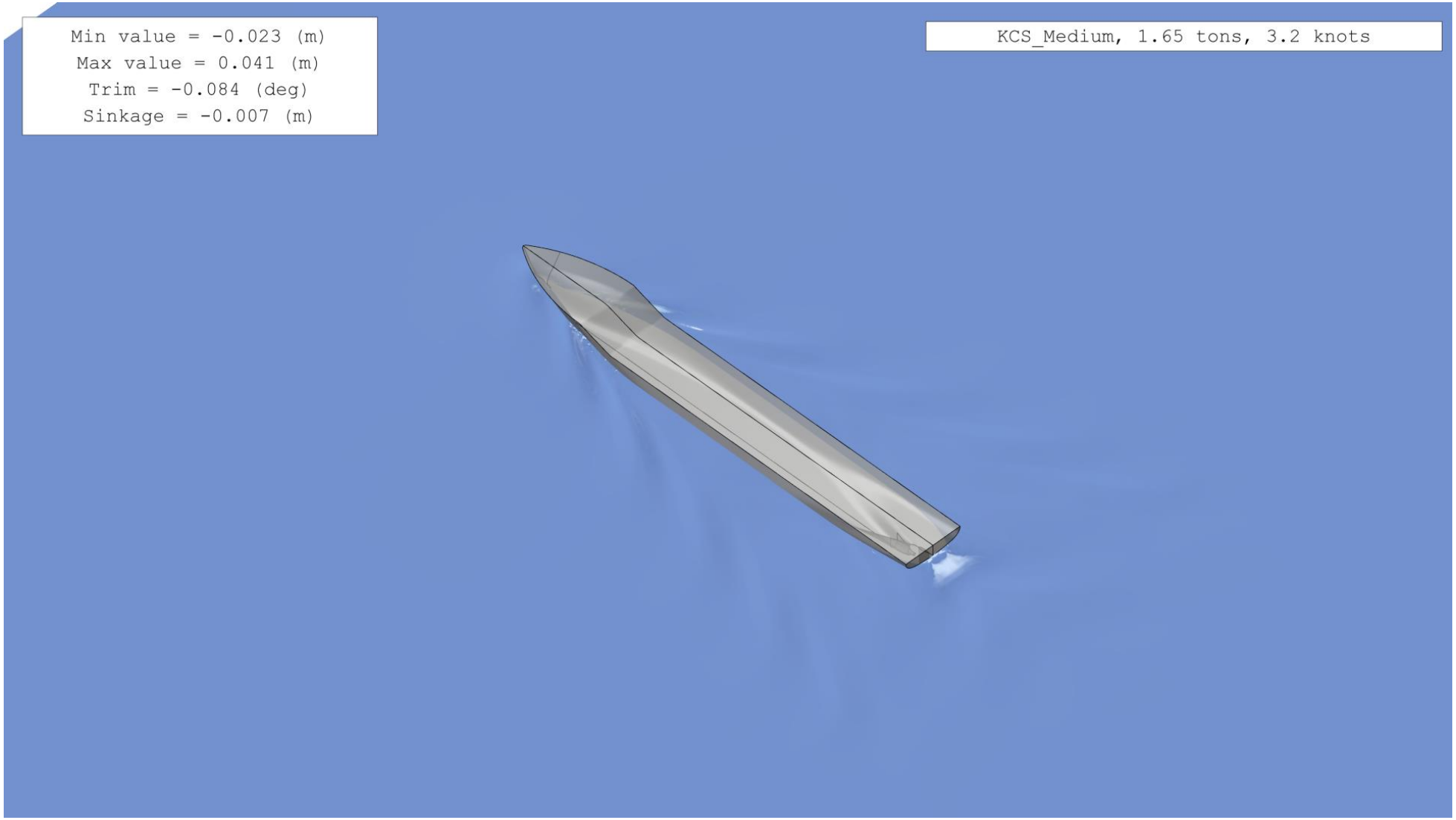
c. Free surface : ¾ rear view, realistic rendering



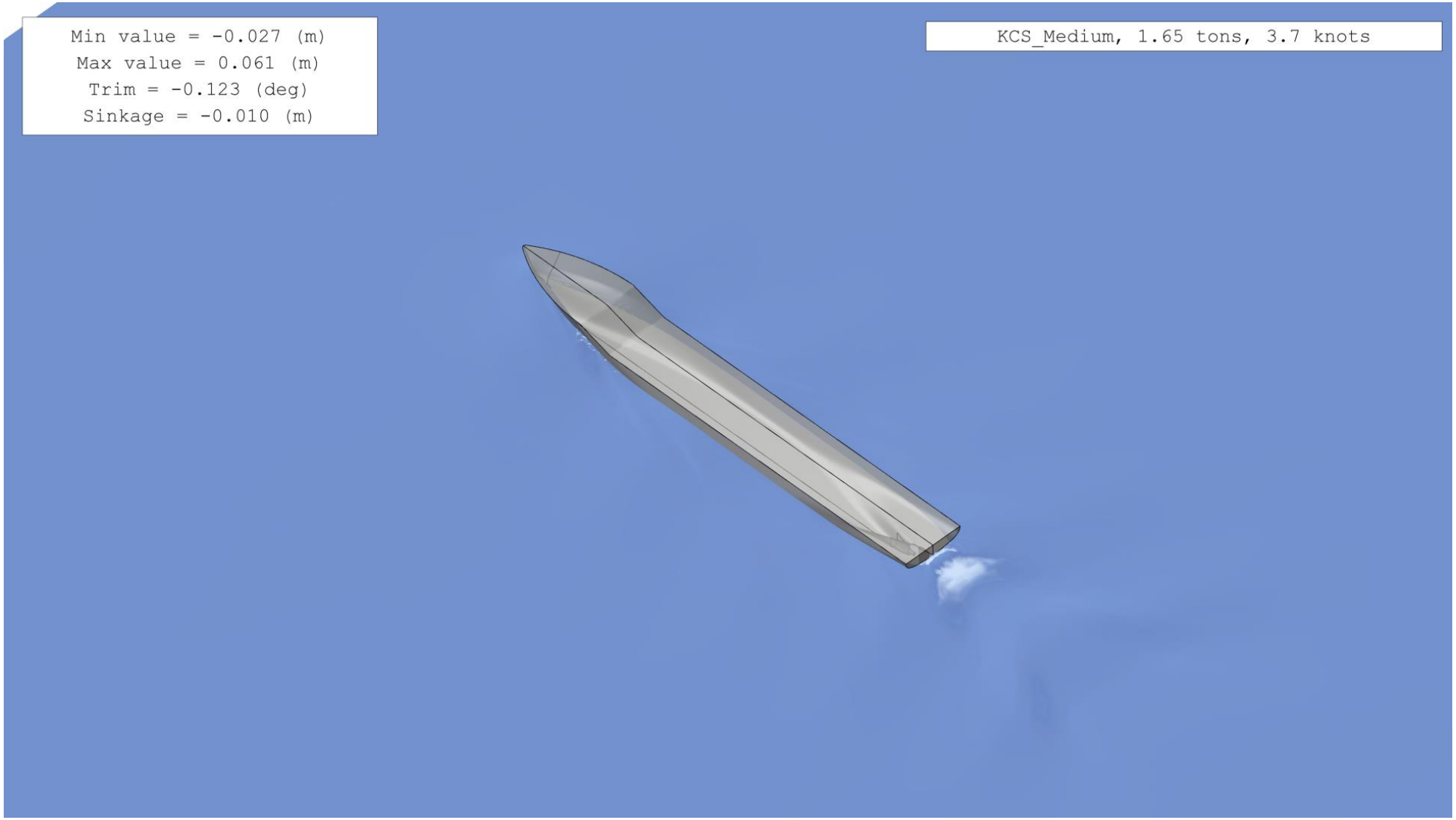
c. Free surface : ¾ rear view, realistic rendering



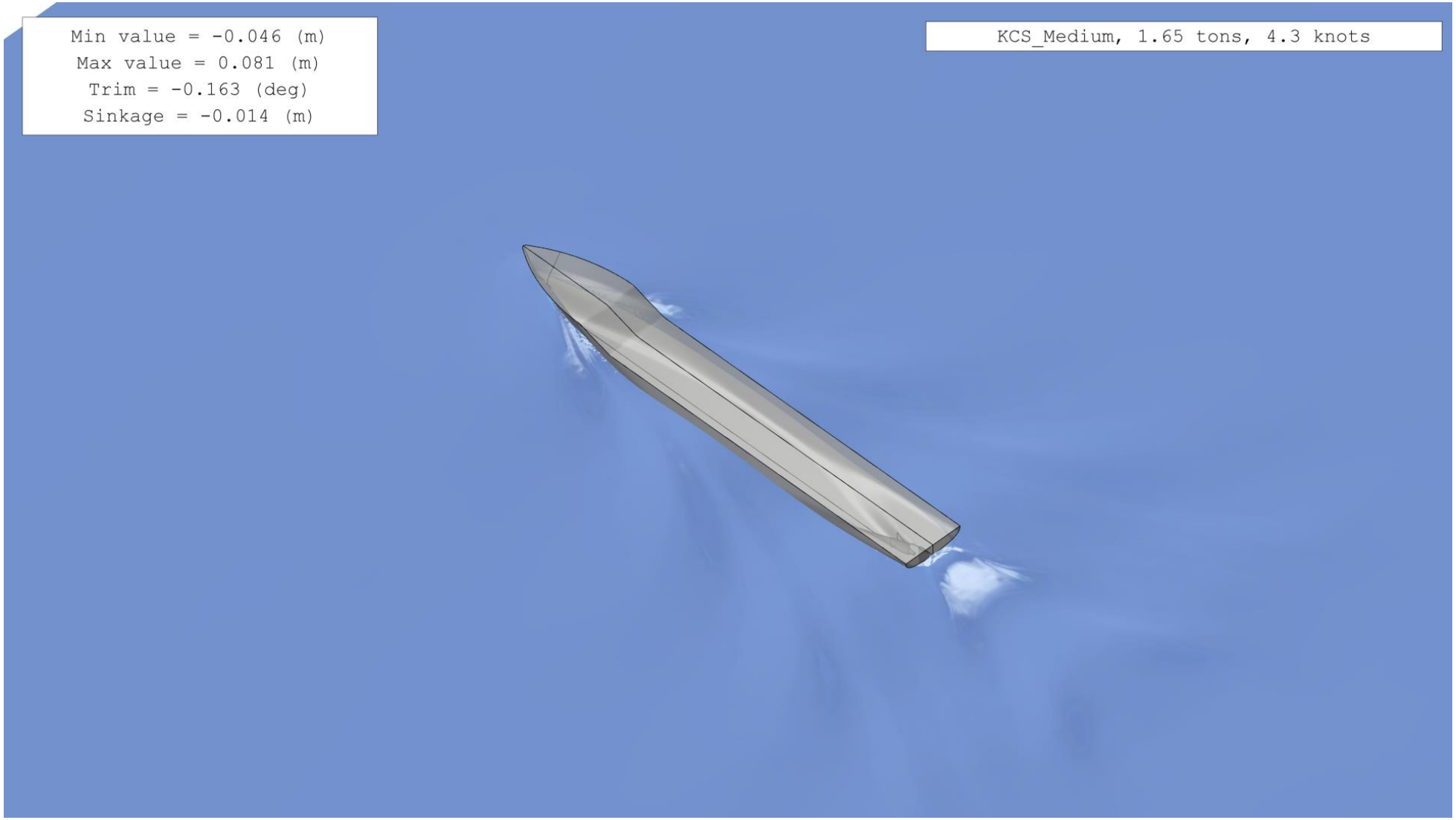
c. Free surface : ¾ rear view, realistic rendering



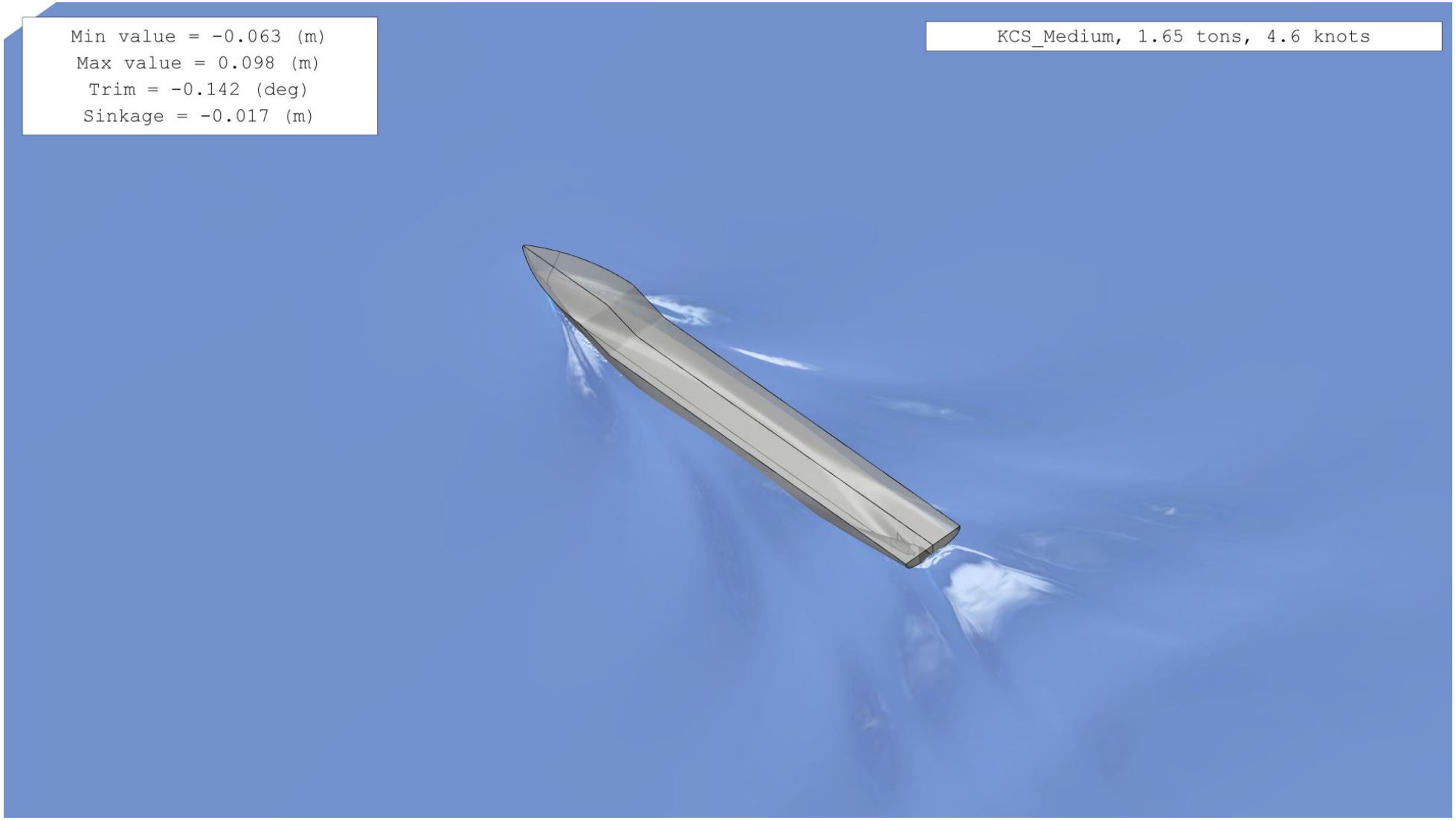
c. Free surface : ¾ rear view, realistic rendering



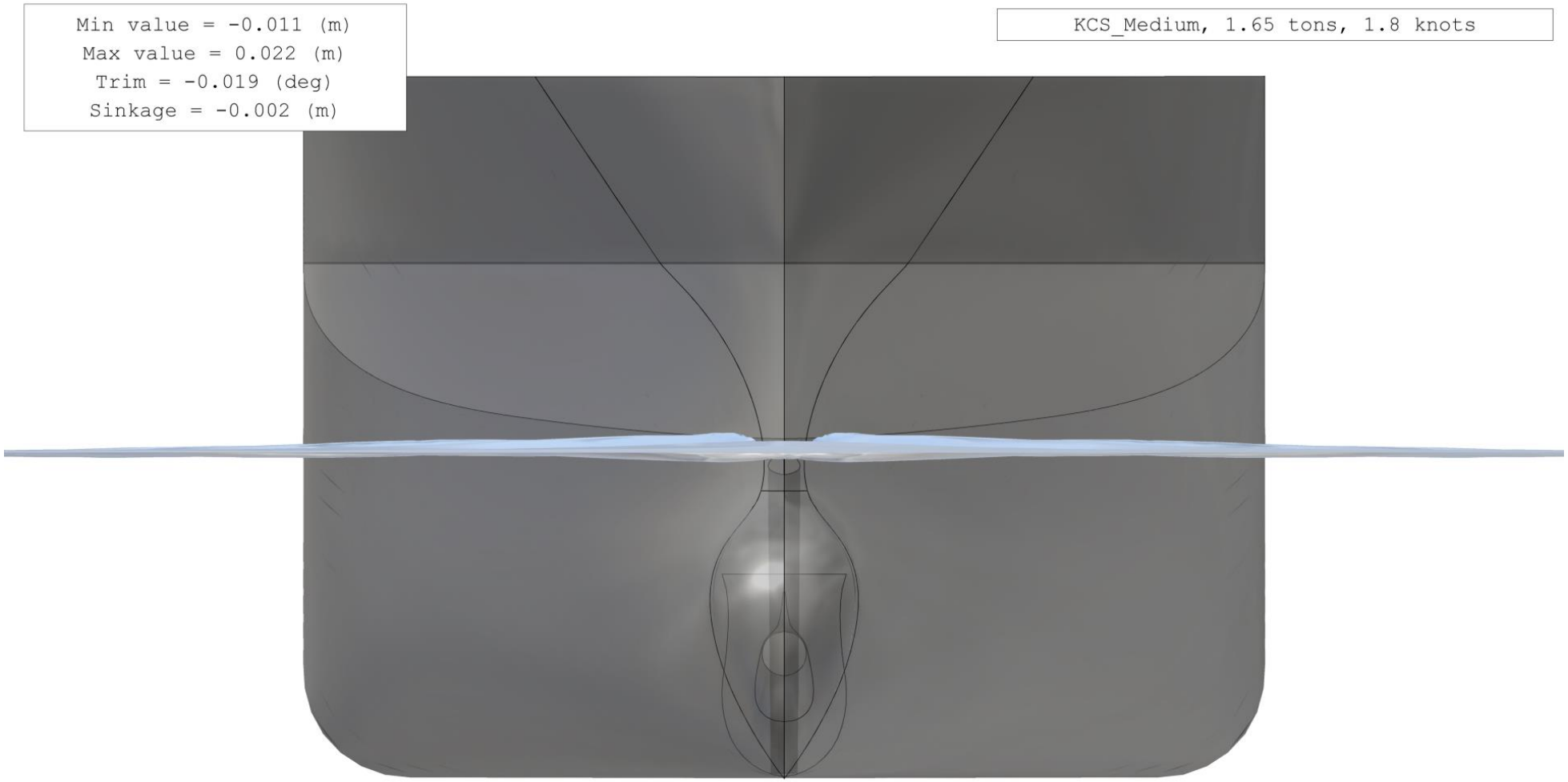
c. Free surface : ¾ rear view, realistic rendering



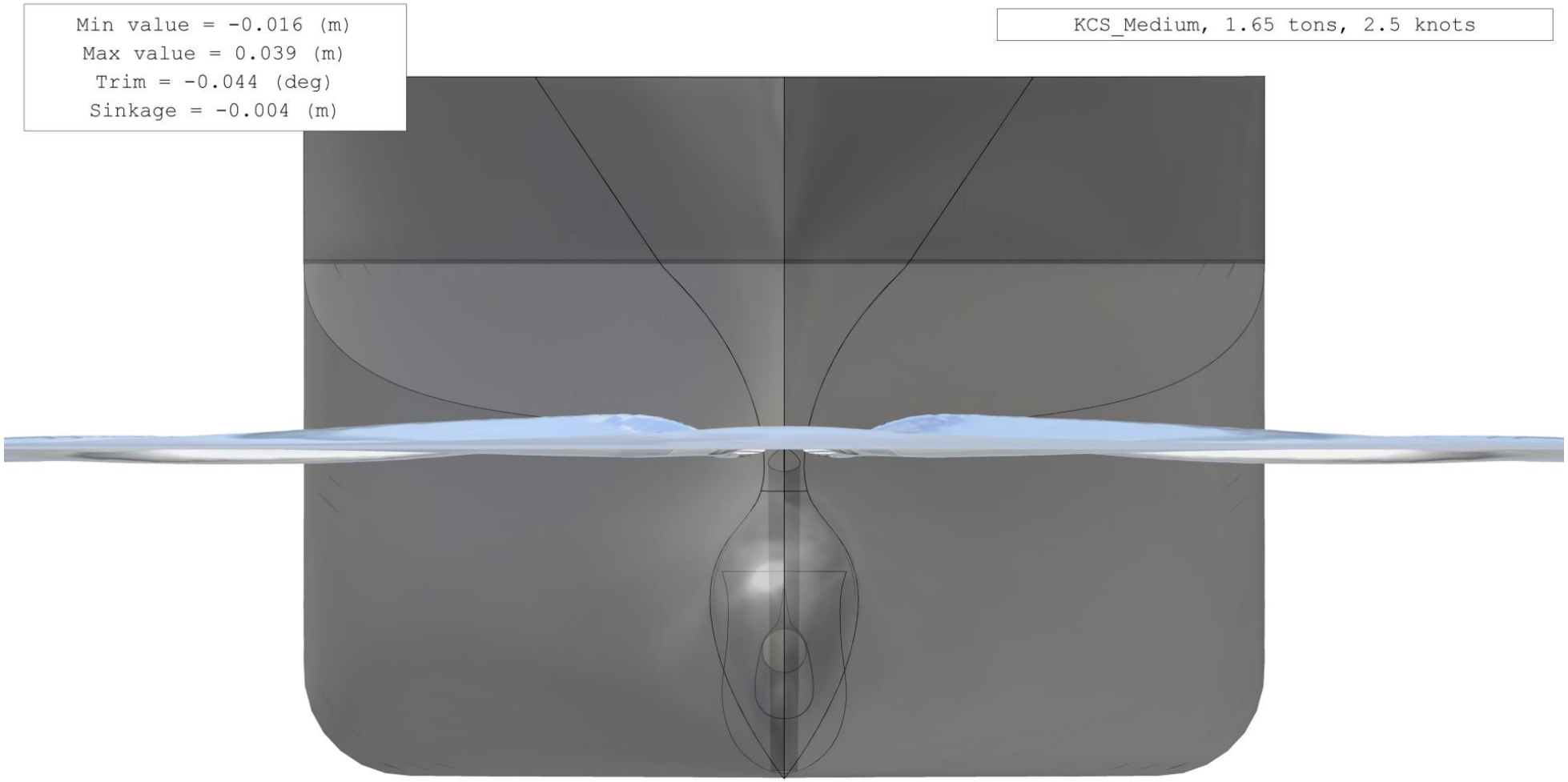
c. Free surface : ¾ rear view, realistic rendering



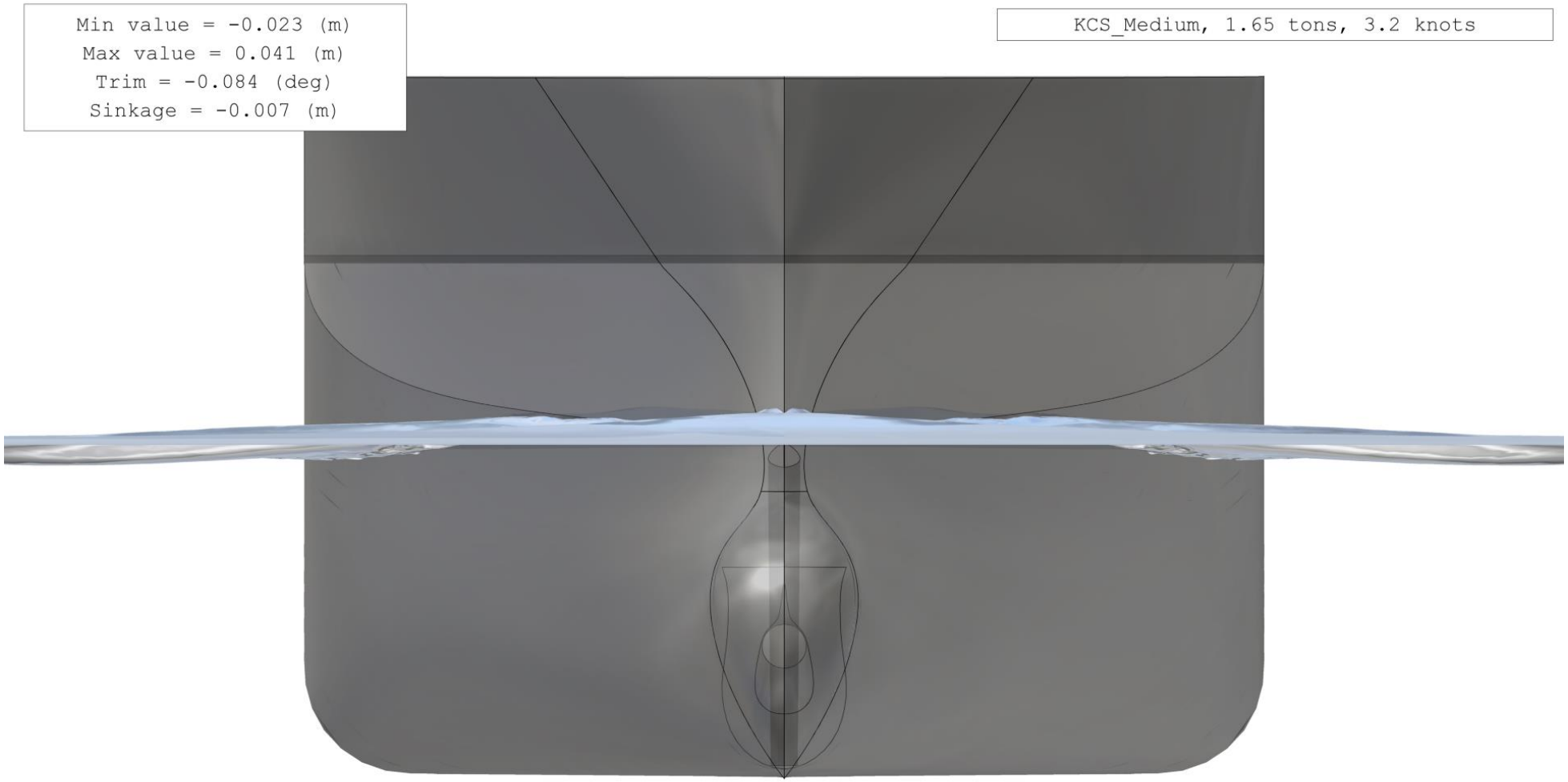
c. Free surface : front view, realistic rendering



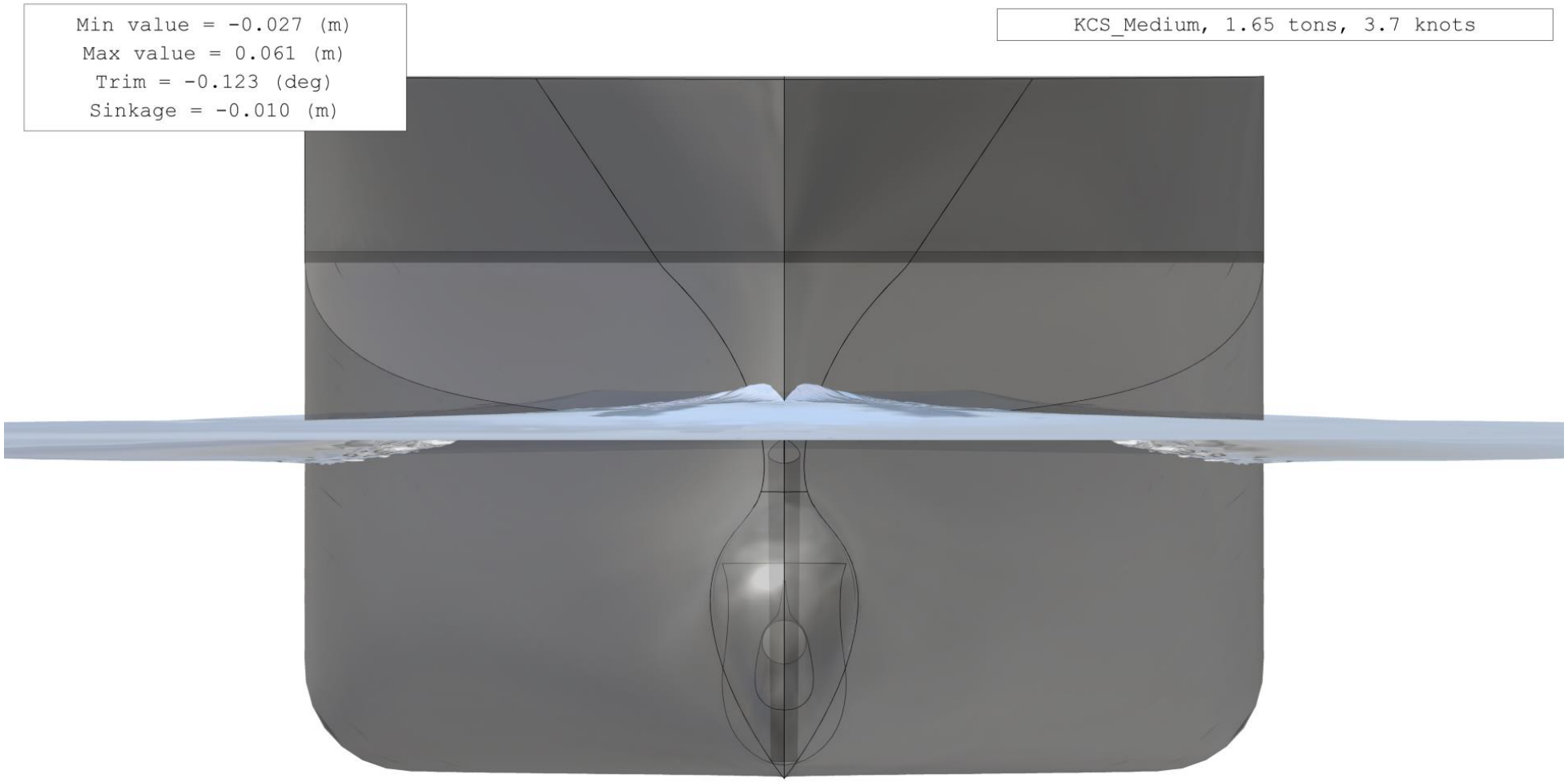
c. Free surface : front view, realistic rendering



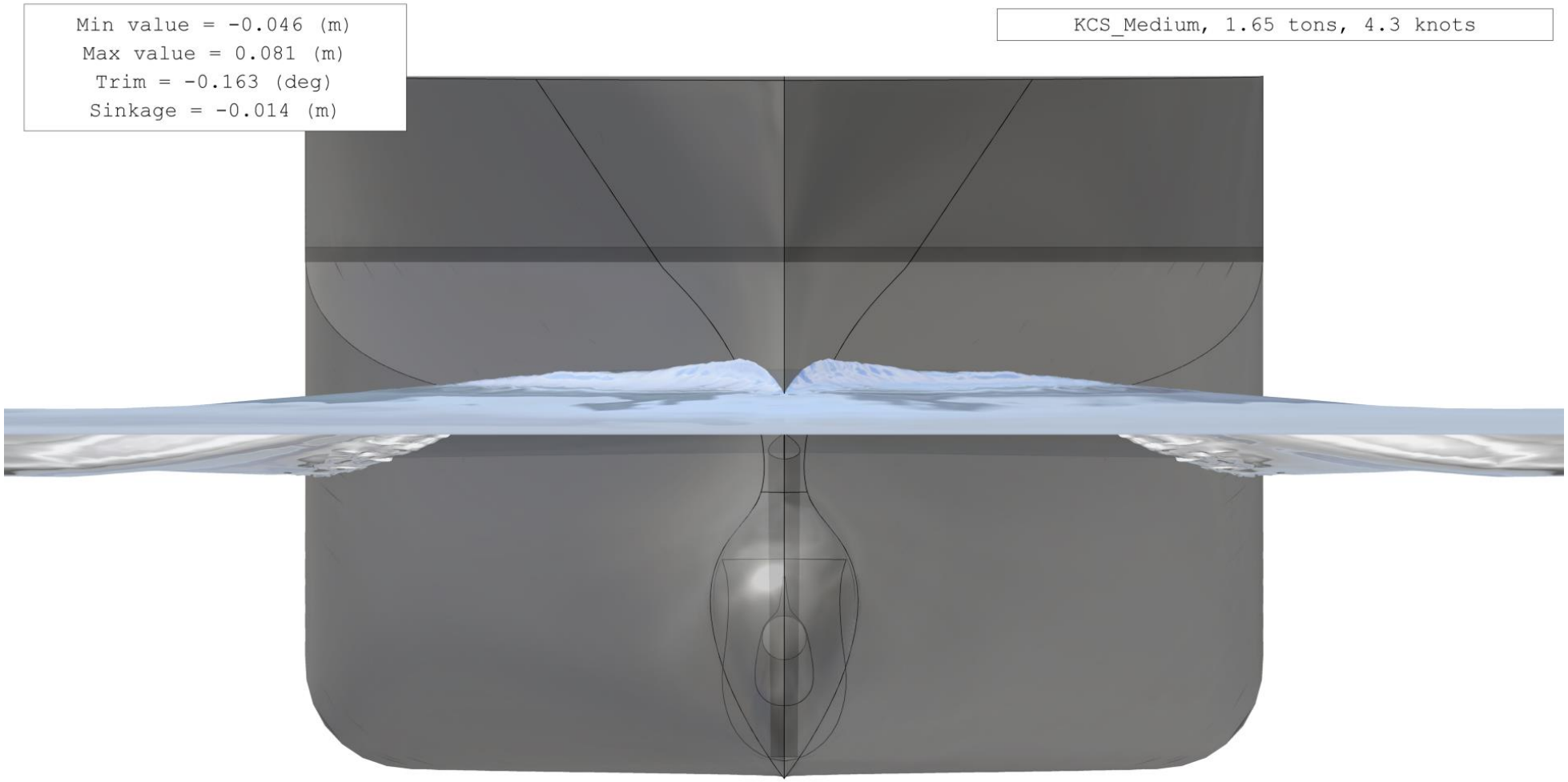
c. Free surface : front view, realistic rendering



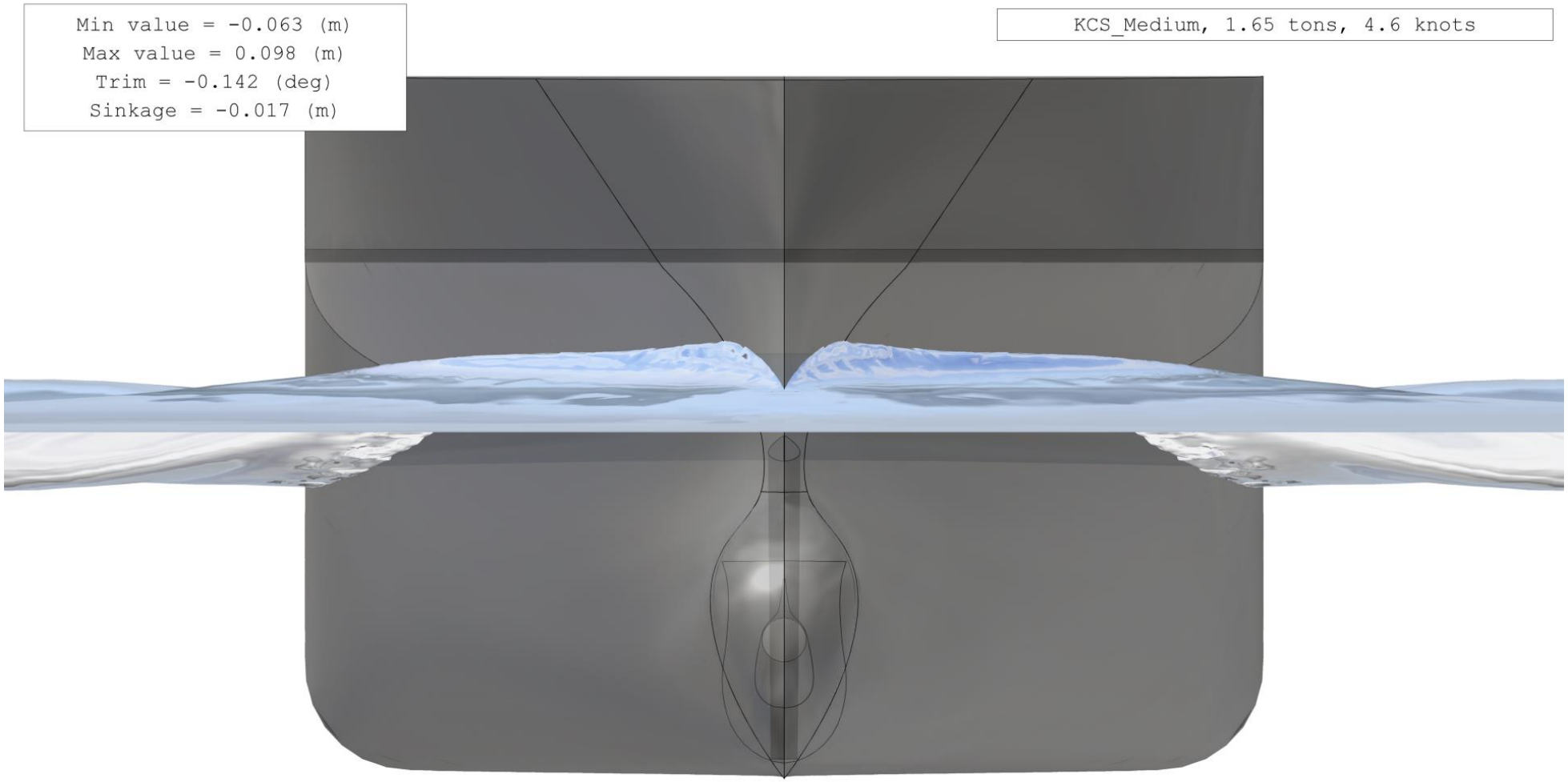
c. Free surface : front view, realistic rendering



c. Free surface : front view, realistic rendering



c. Free surface : front view, realistic rendering



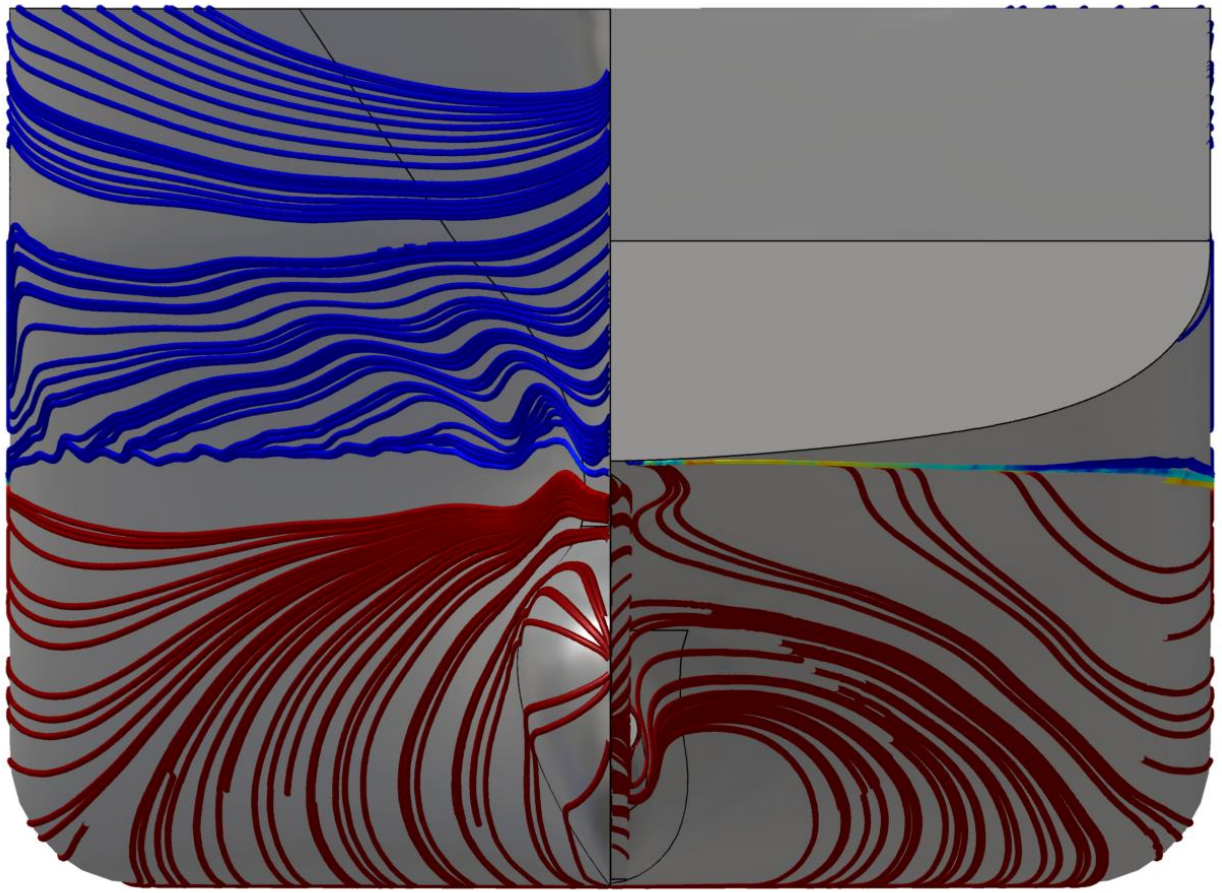
6. Visuals

a. Mass fraction
b. Pressure coefficient
c. Free surface
d. Streamlines
    1. Surfacic
    2. Volumic

d. Streamlines (surfacic) : front and rear view

Surfacic streamlines (-)

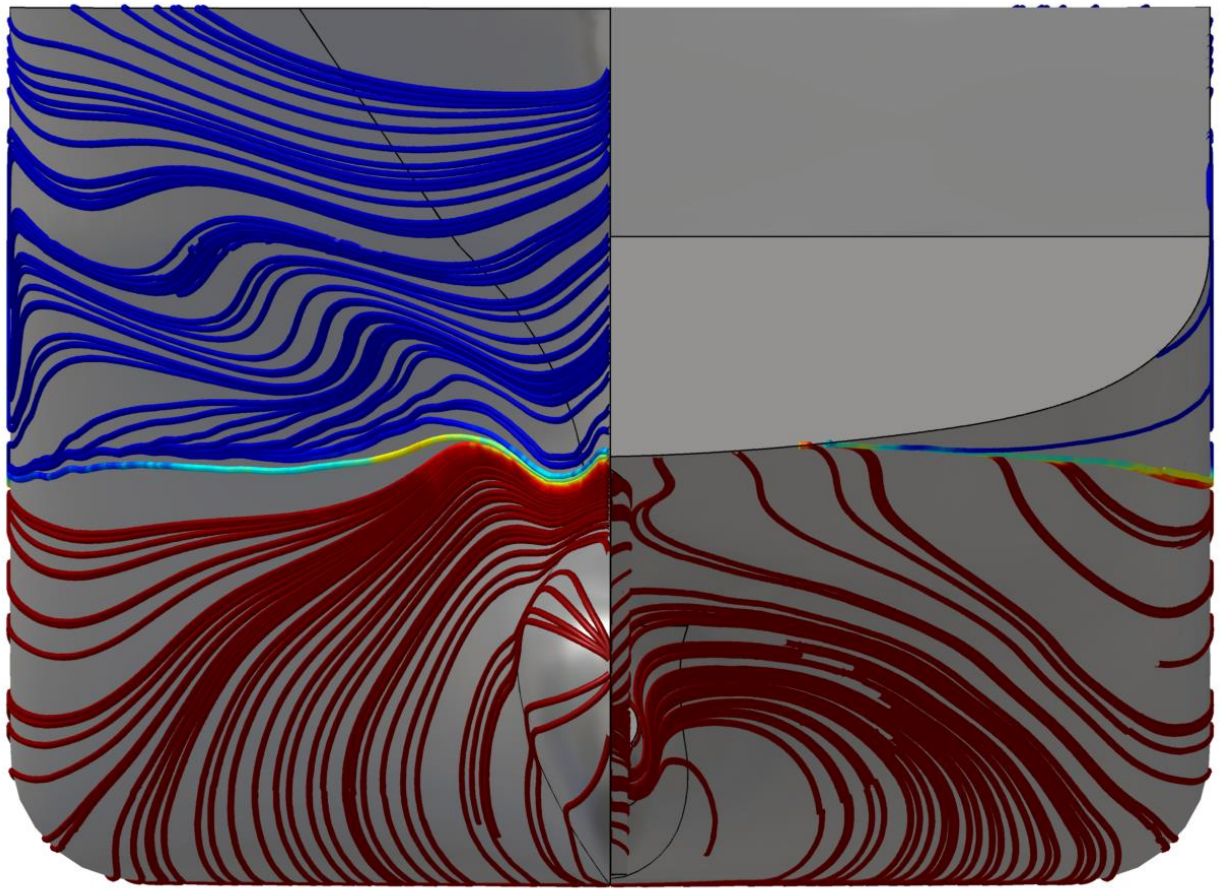
KCS_Medium, 1.65 tons, 1.8 knots



d. Streamlines (surfacic) : front and rear view

Surfacic streamlines (-)

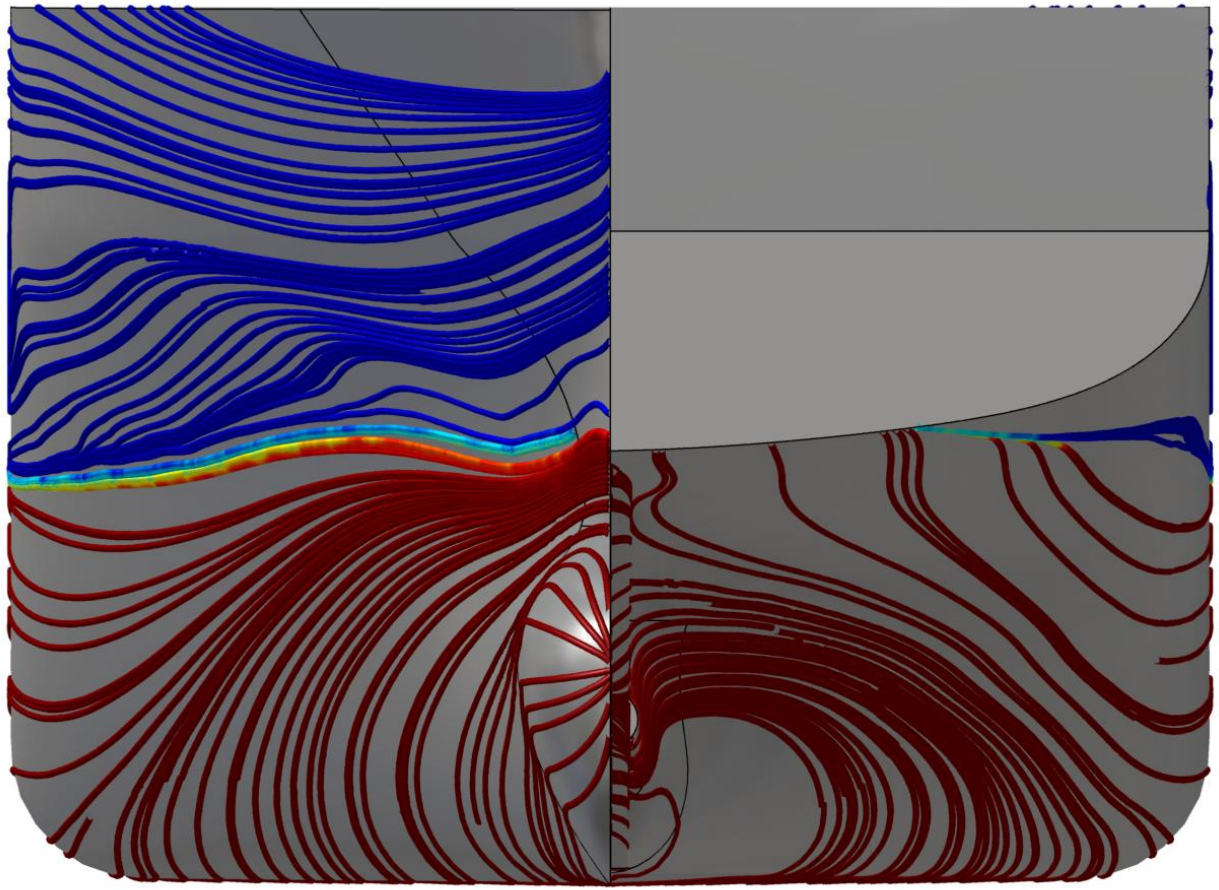
KCS_Medium, 1.65 tons, 2.5 knots



d. Streamlines (surfacic) : front and rear view

Surfacic streamlines (-)

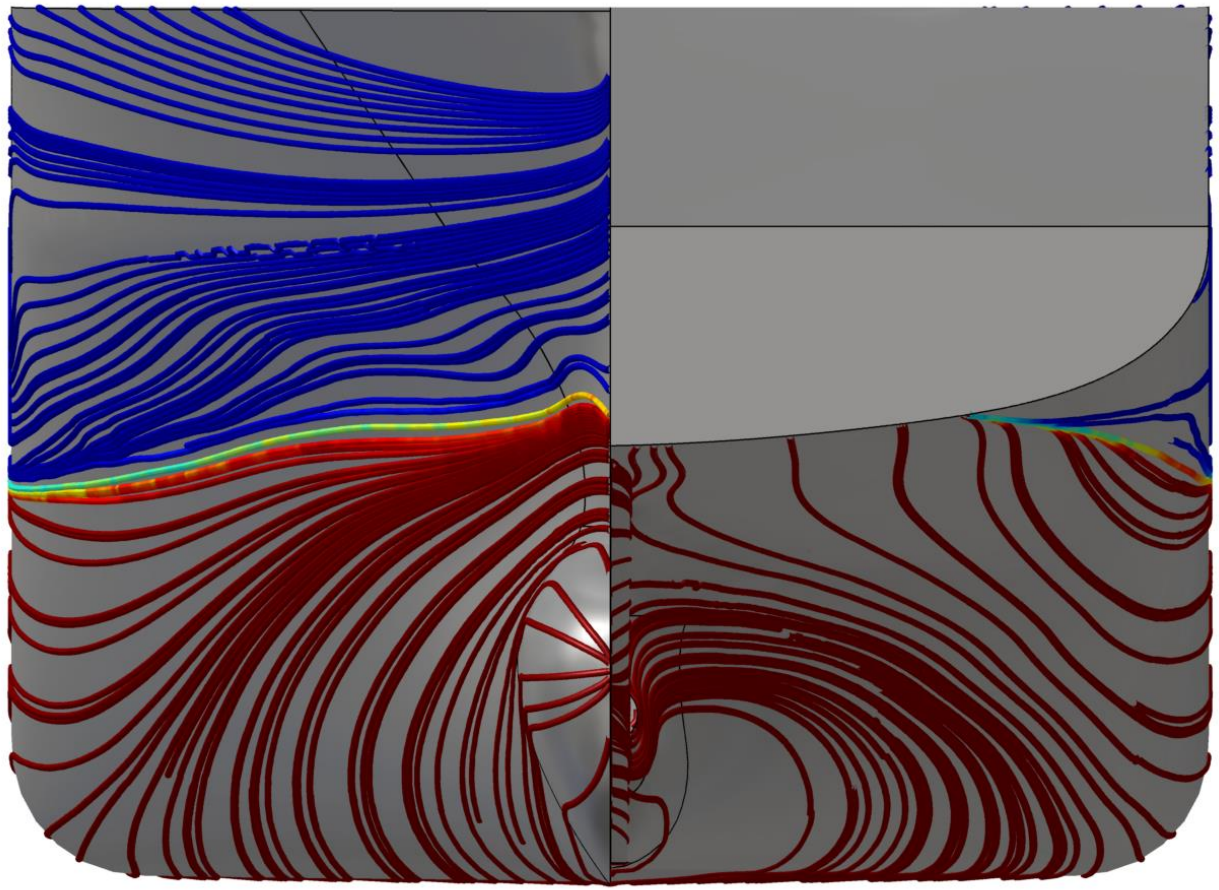
KCS_Medium, 1.65 tons, 3.2 knots



d. Streamlines (surfacic) : front and rear view

Surfacic streamlines (-)

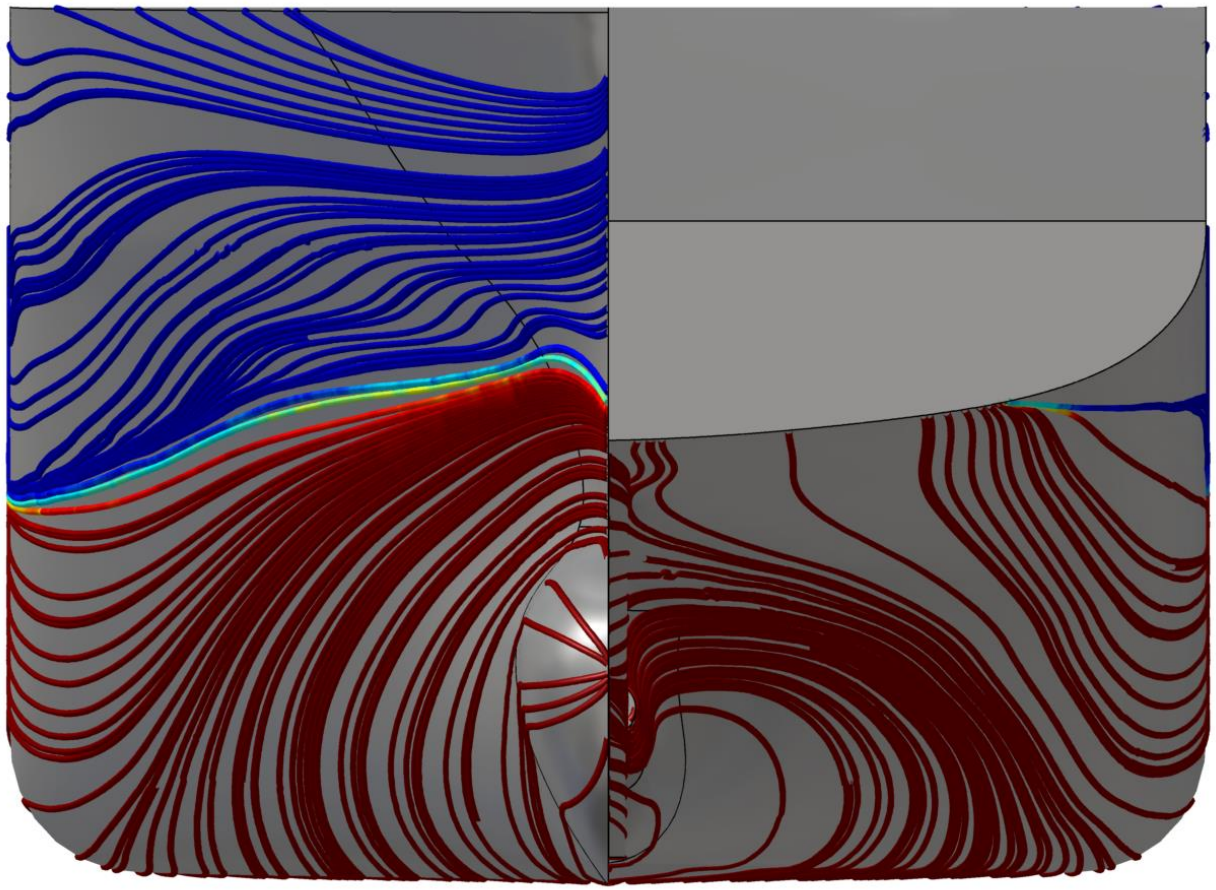
KCS_Medium, 1.65 tons, 3.7 knots



d. Streamlines (surfacic) : front and rear view

Surfacic streamlines (-)

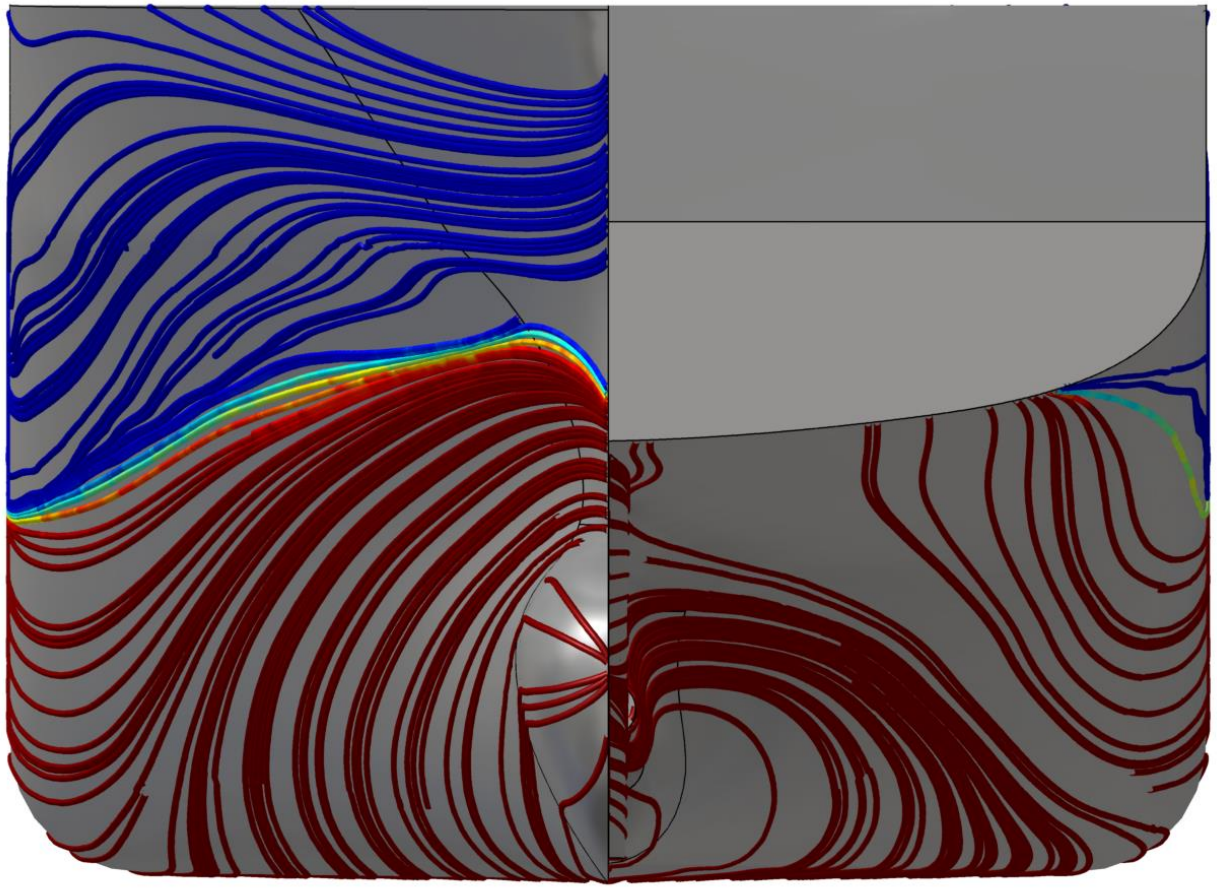
KCS_Medium, 1.65 tons, 4.3 knots



d. Streamlines (surfacic) : front and rear view

Surfacic streamlines (-)

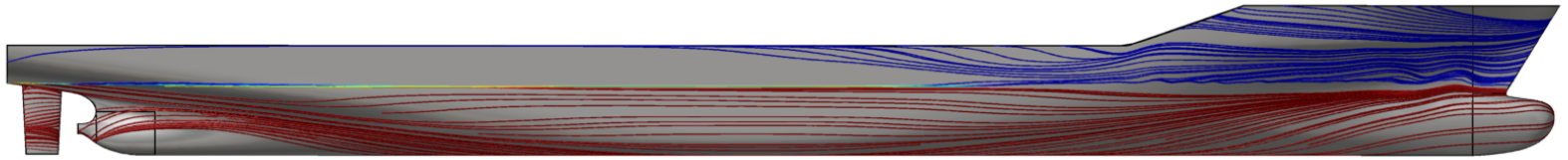
KCS_Medium, 1.65 tons, 4.6 knots



d. Streamlines (surfacic) : side view(s)

Surfacic streamlines (-)

KCS_Medium, 1.65 tons, 1.8 knots

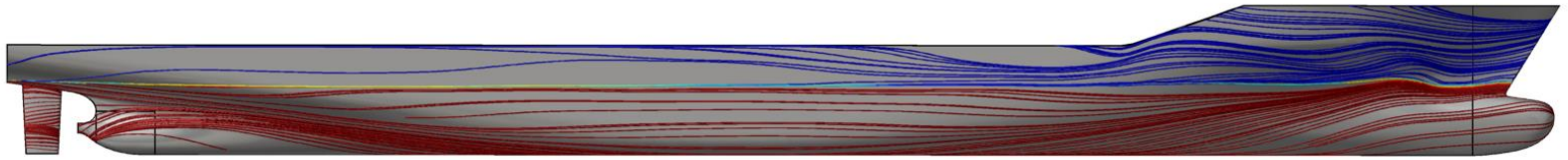


Exterior Side View

d. Streamlines (surfacic) : side view(s)

Surfacic streamlines (-)

KCS_Medium, 1.65 tons, 2.5 knots

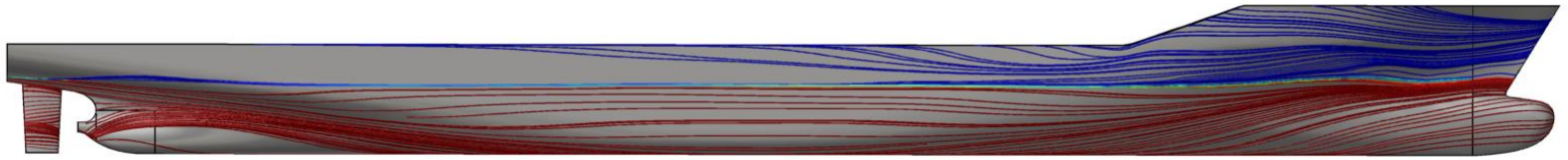


Exterior Side View

d. Streamlines (surfacic) : side view(s)

Surfacic streamlines (-)

KCS_Medium, 1.65 tons, 3.2 knots

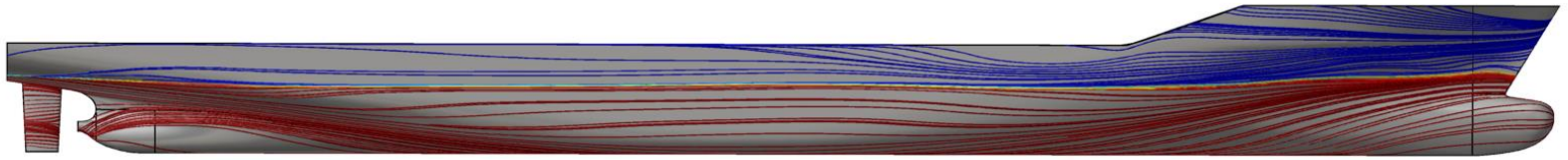


Exterior Side View

d. Streamlines (surfacic) : side view(s)

Surfacic streamlines (-)

KCS_Medium, 1.65 tons, 3.7 knots

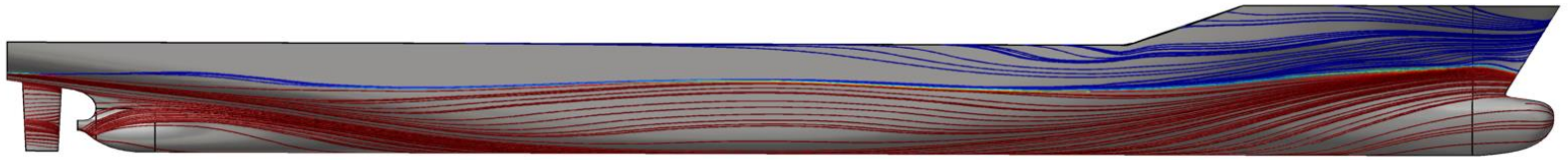


Exterior Side View

d. Streamlines (surfacic) : side view(s)

Surfacic streamlines (-)

KCS_Medium, 1.65 tons, 4.3 knots

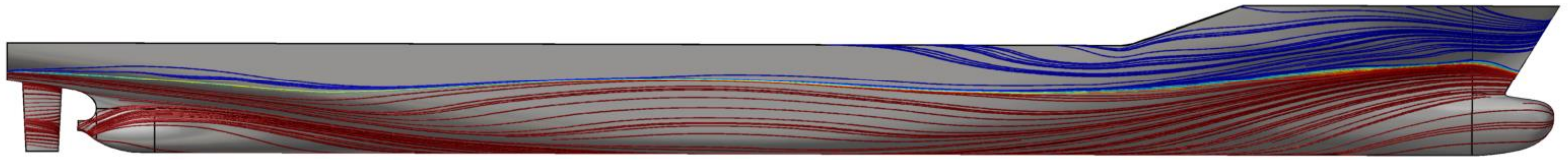


Exterior Side View

d. Streamlines (surfacic) : side view(s)

Surfacic streamlines (-)

KCS_Medium, 1.65 tons, 4.6 knots

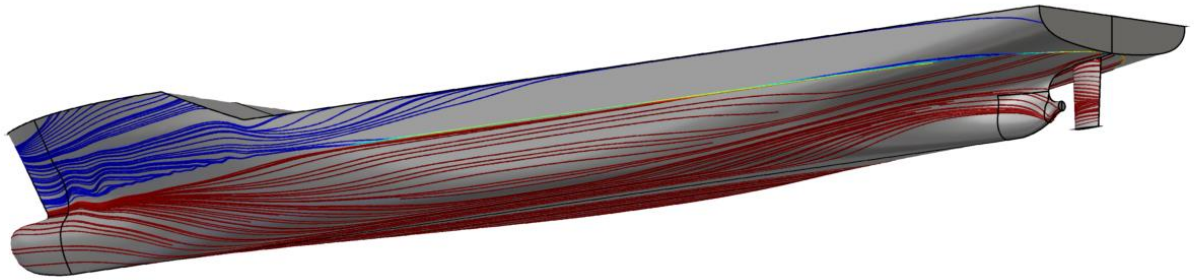


Exterior Side View

d. Streamlines (surfacic) : ¾ rear view

Surfacic streamlines (-)

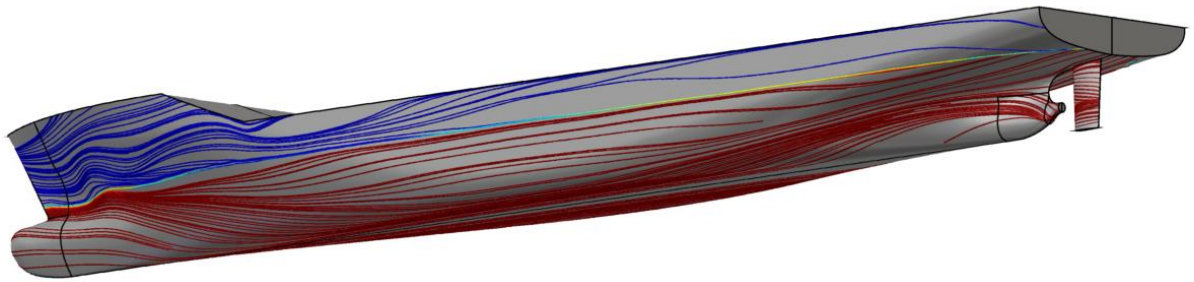
KCS_Medium, 1.65 tons, 1.8 knots



d. Streamlines (surfacic) : ¾ rear view

Surfacic streamlines (-)

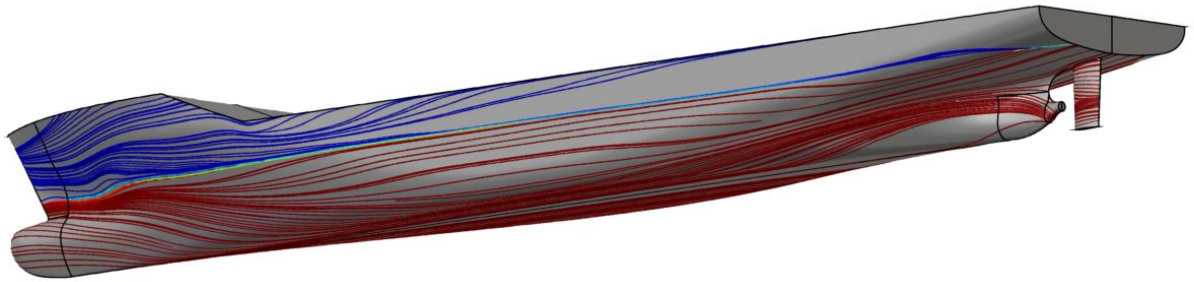
KCS_Medium, 1.65 tons, 2.5 knots



d. Streamlines (surfacic) : ¾ rear view

Surfacic streamlines (-)

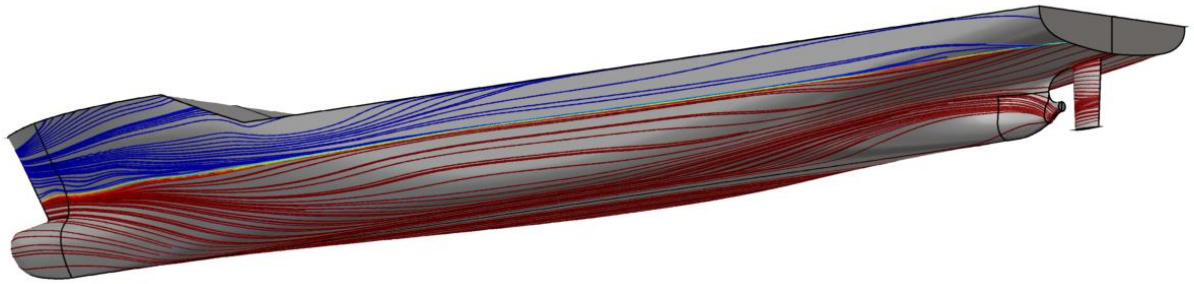
KCS_Medium, 1.65 tons, 3.2 knots



d. Streamlines (surfacic) : ¾ rear view

Surfacic streamlines (-)

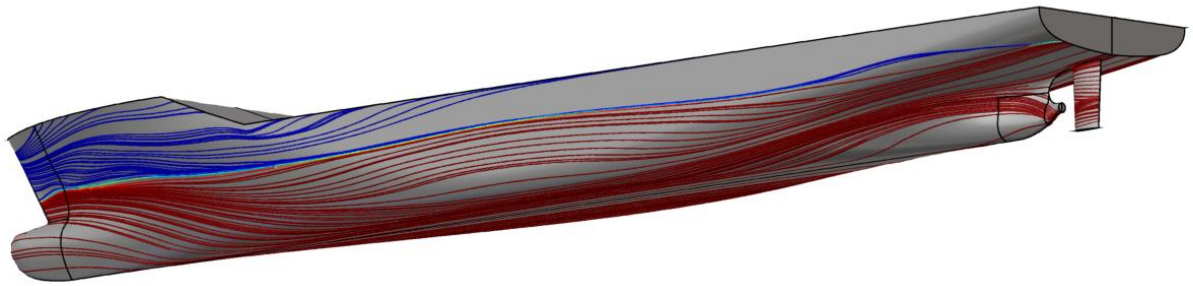
KCS_Medium, 1.65 tons, 3.7 knots



d. Streamlines (surfacic) : ¾ rear view

Surfacic streamlines (-)

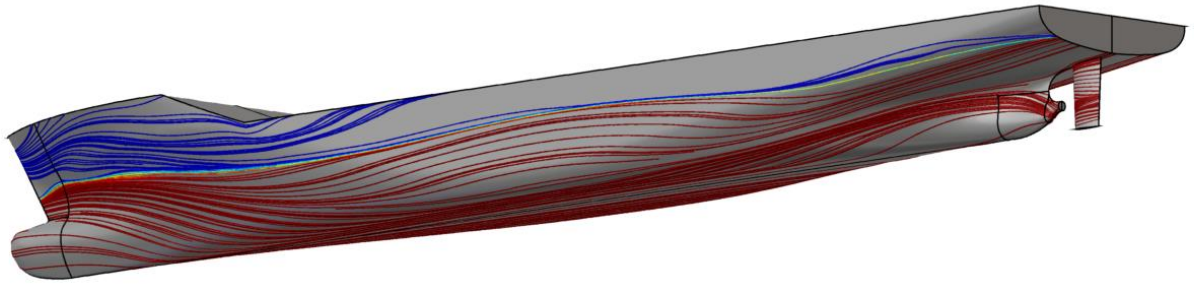
KCS_Medium, 1.65 tons, 4.3 knots



d. Streamlines (surfacic) : ¾ rear view

Surfacic streamlines (-)

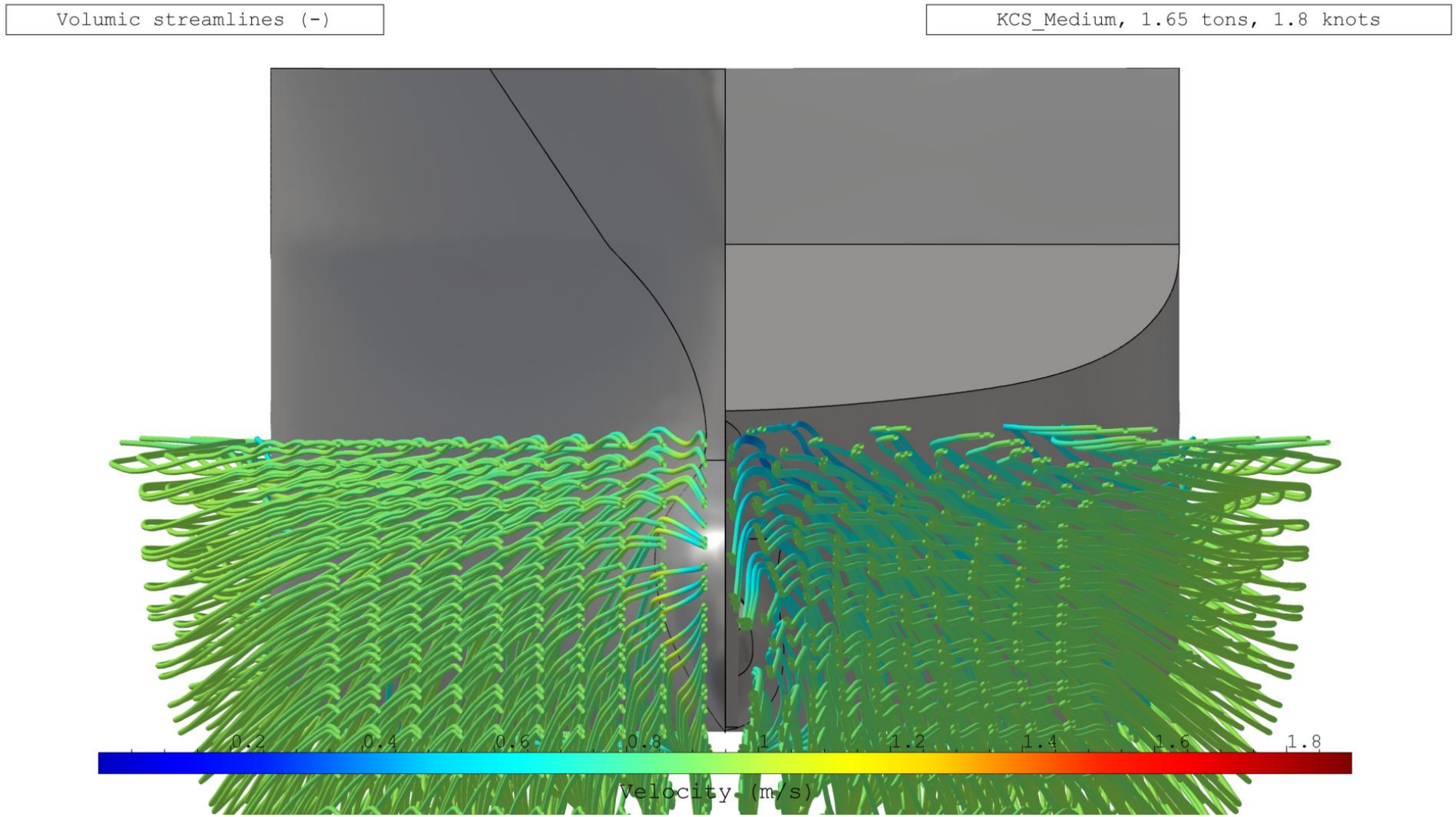
KCS_Medium, 1.65 tons, 4.6 knots



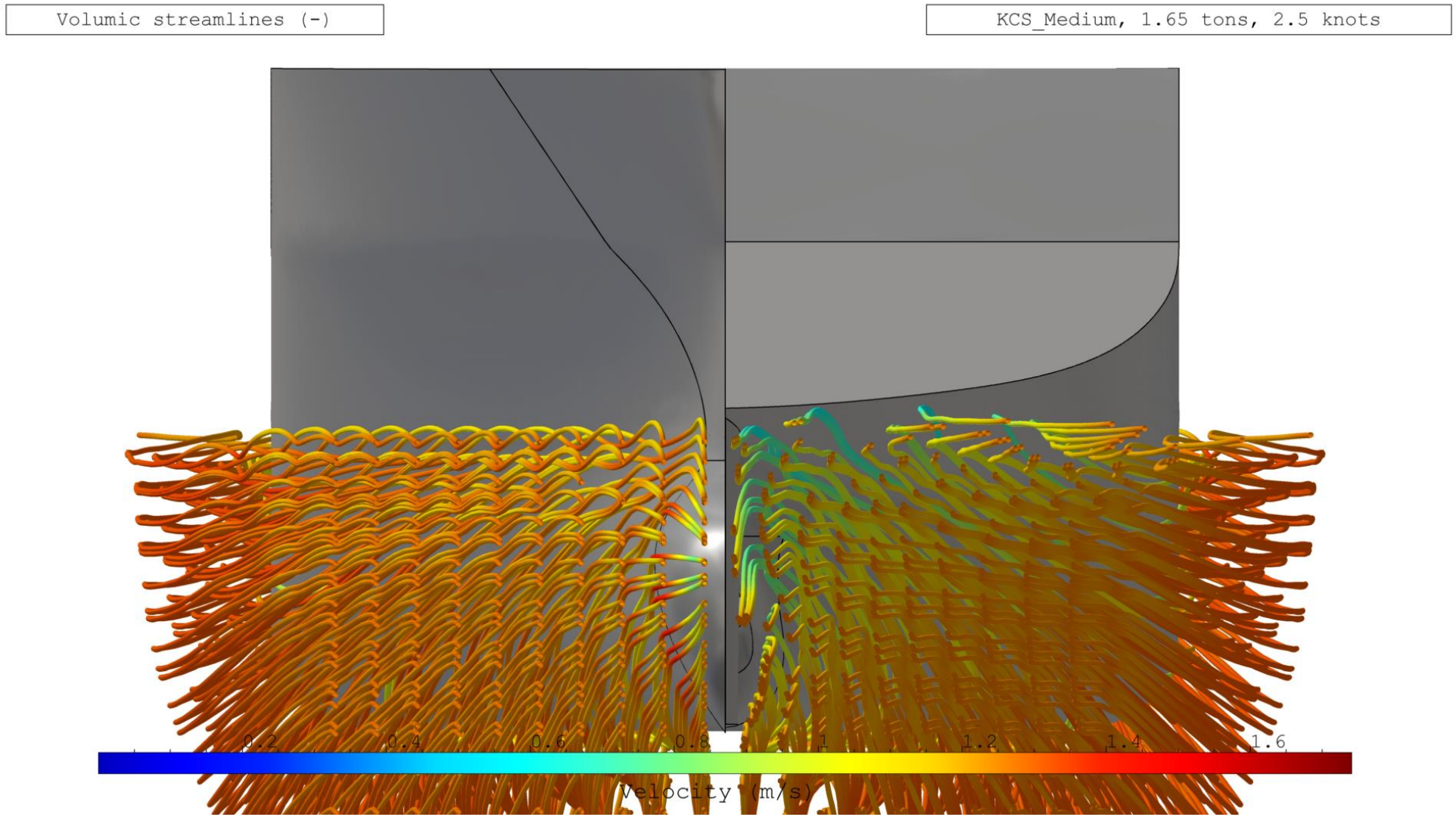
6. Visuals

a. Mass fraction
b. Pressure coefficient
c. Free surface
d. Streamlines
    1. Surfacic
    2. Volumic

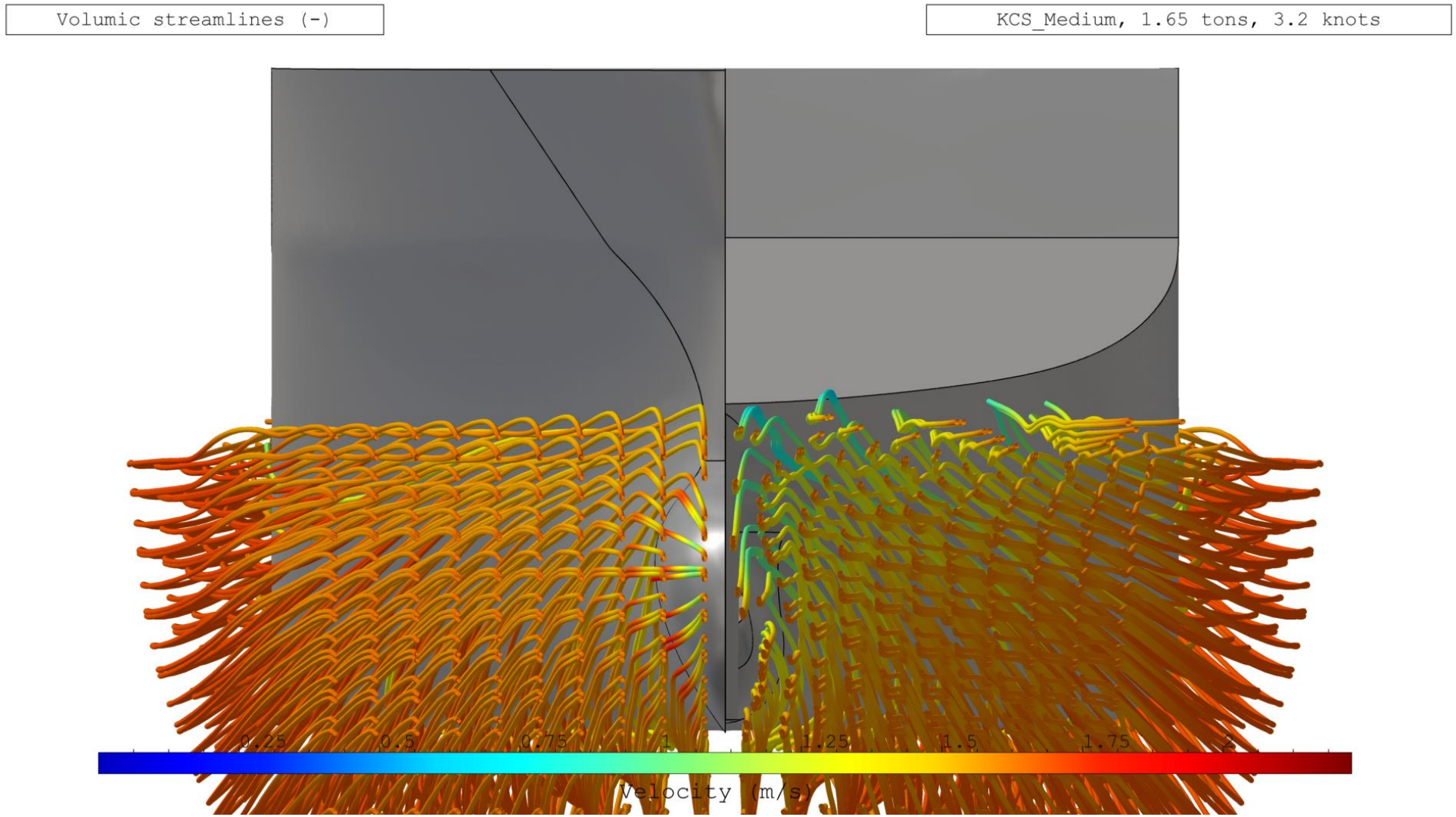
d. Streamlines (volumic) : front and rear view



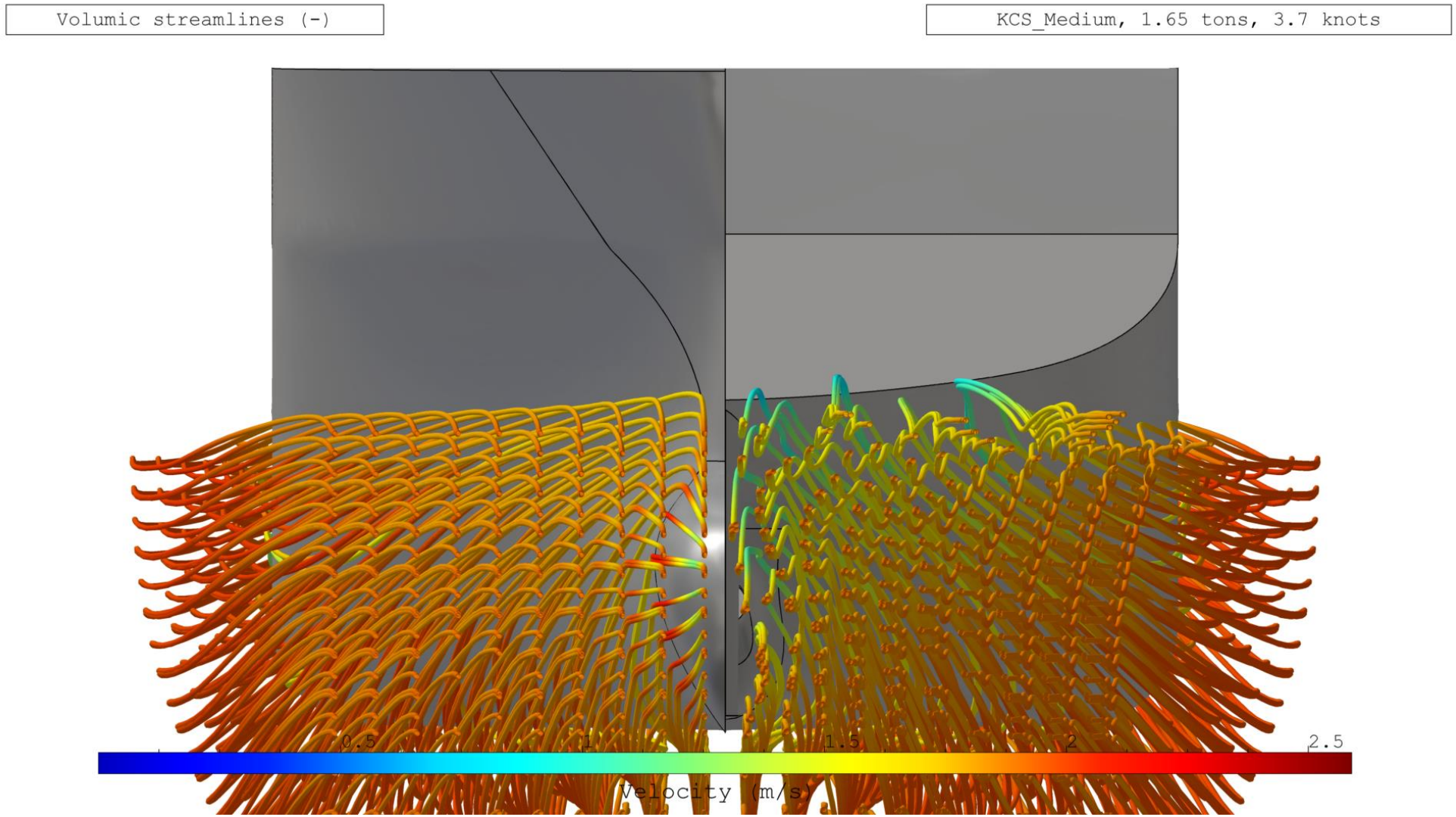
d. Streamlines (volumic) : front and rear view



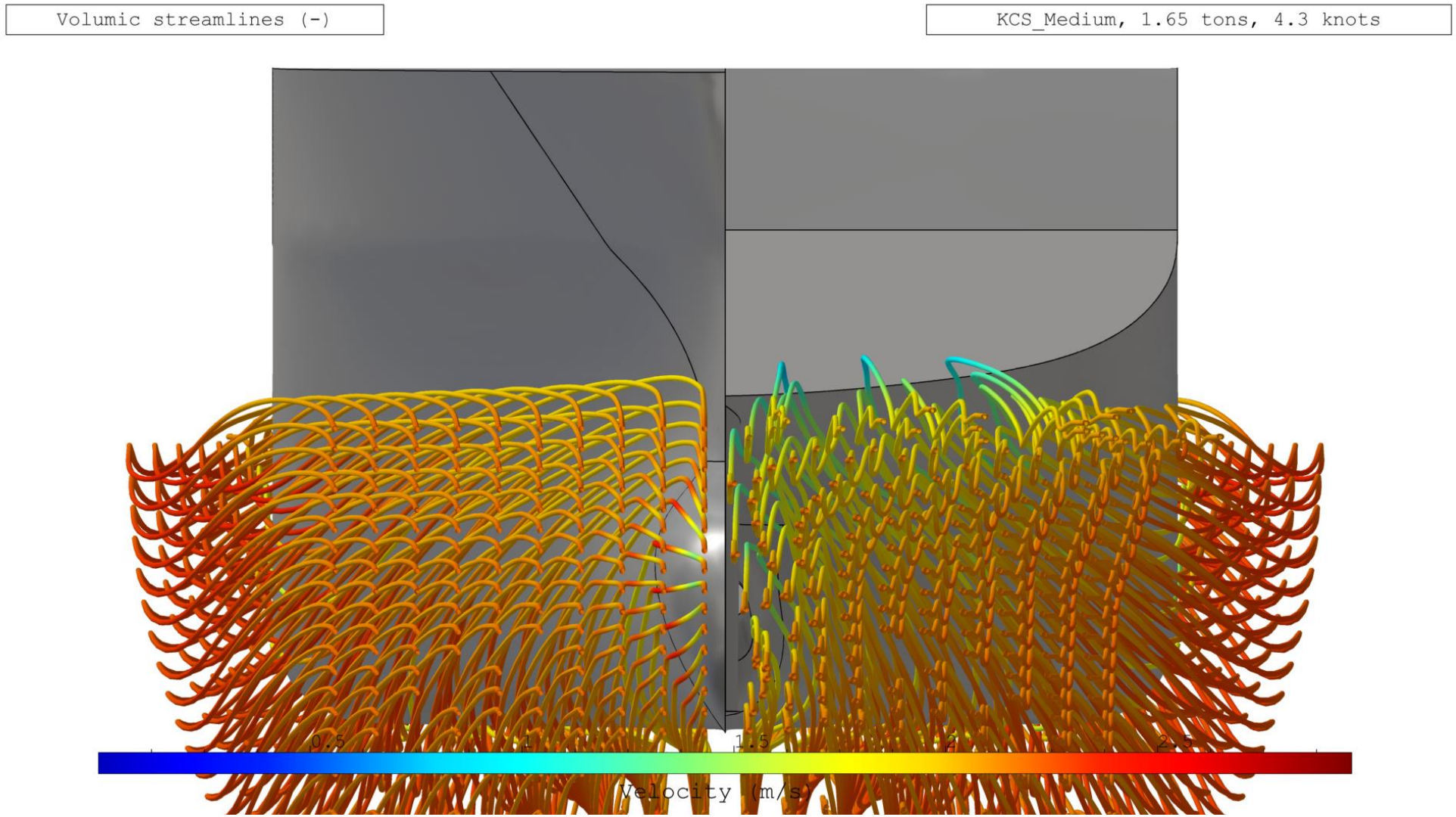
d. Streamlines (volumic) : front and rear view



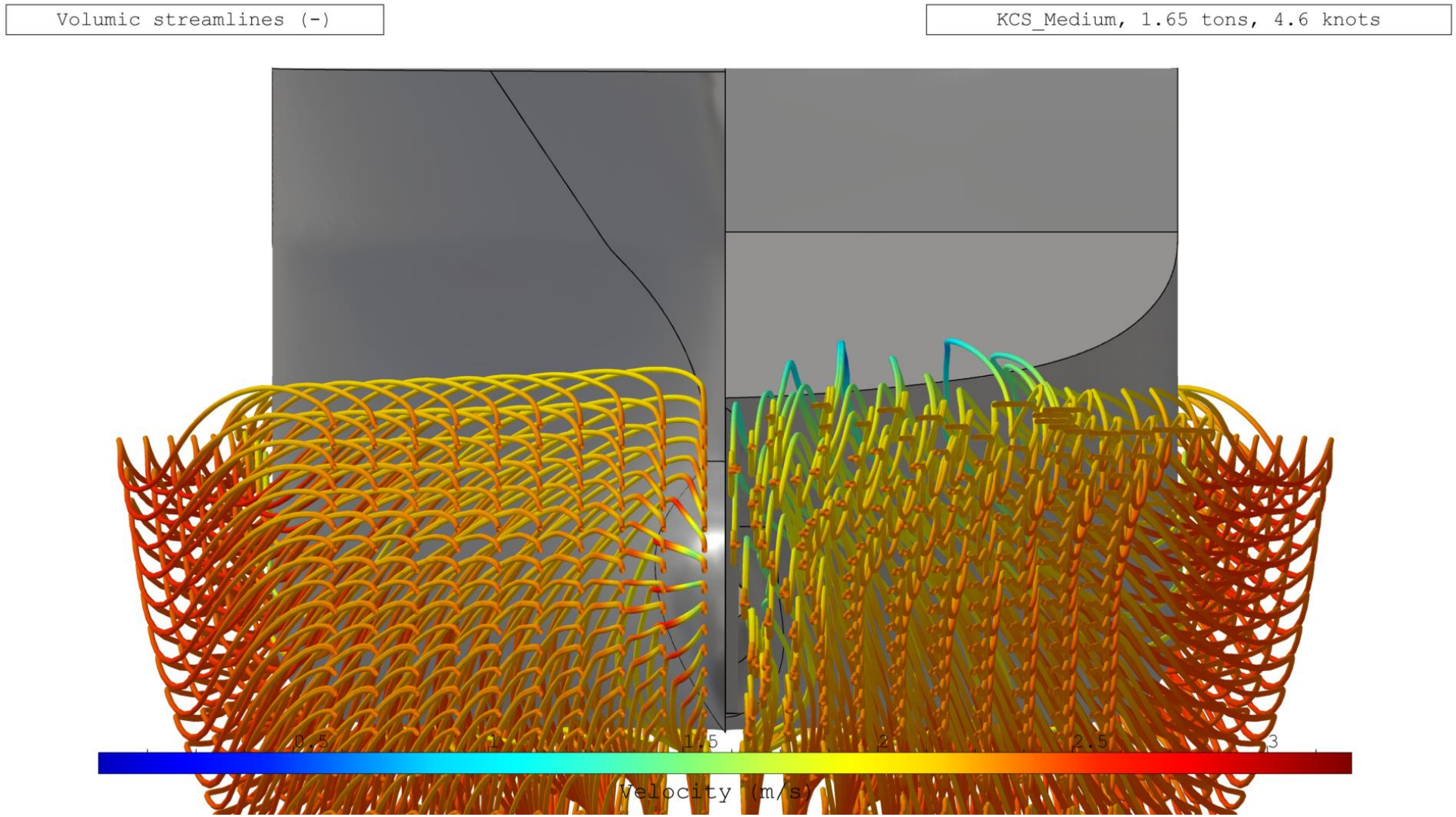
d. Streamlines (volumic) : front and rear view



d. Streamlines (volumic) : front and rear view



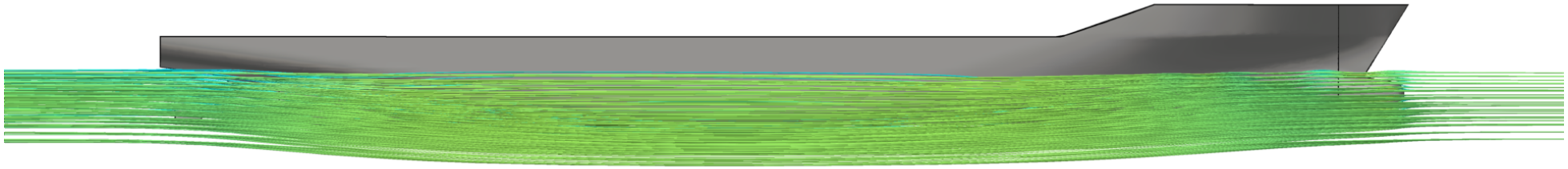
d. Streamlines (volumic) : front and rear view



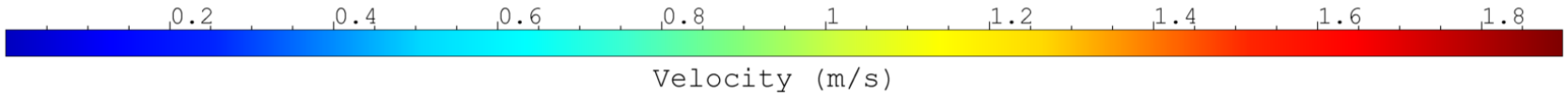
d. Streamlines (volumic) : side view(s)

Volumic streamlines (-)

KCS_Medium, 1.65 tons, 1.8 knots



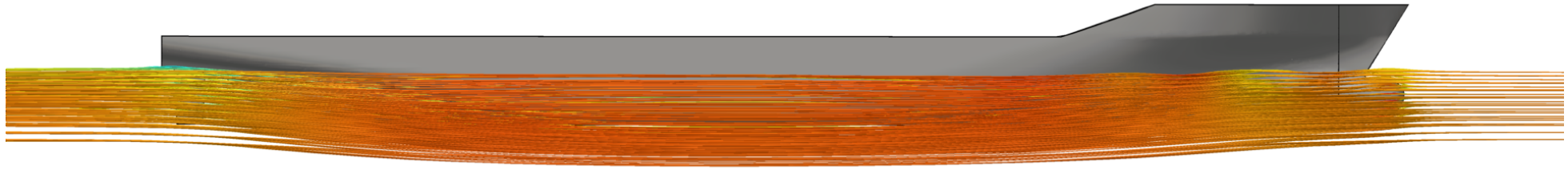
Exterior Side View



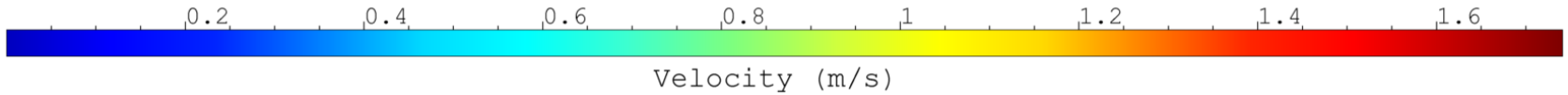
d. Streamlines (volumic) : side view(s)

Volumic streamlines (-)

KCS_Medium, 1.65 tons, 2.5 knots



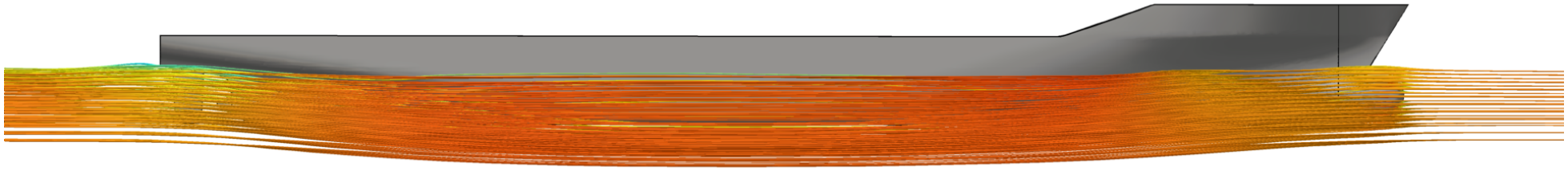
Exterior Side View



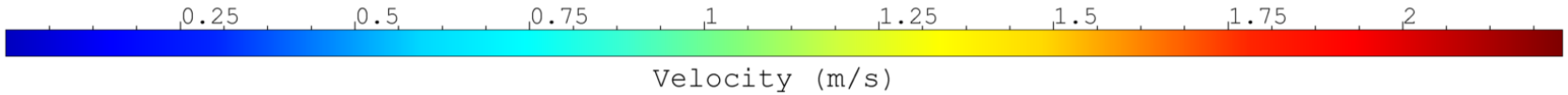
d. Streamlines (volumic) : side view(s)

Volumic streamlines (-)

KCS_Medium, 1.65 tons, 3.2 knots



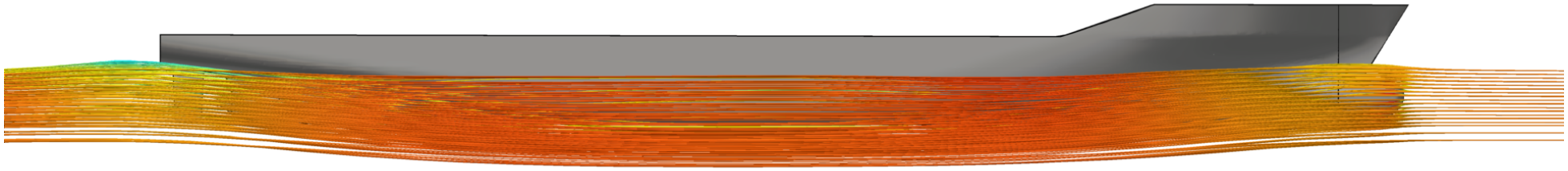
Exterior Side View



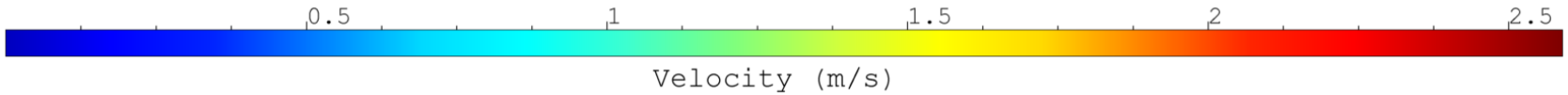
d. Streamlines (volumic) : side view(s)

Volumic streamlines (-)

KCS_Medium, 1.65 tons, 3.7 knots



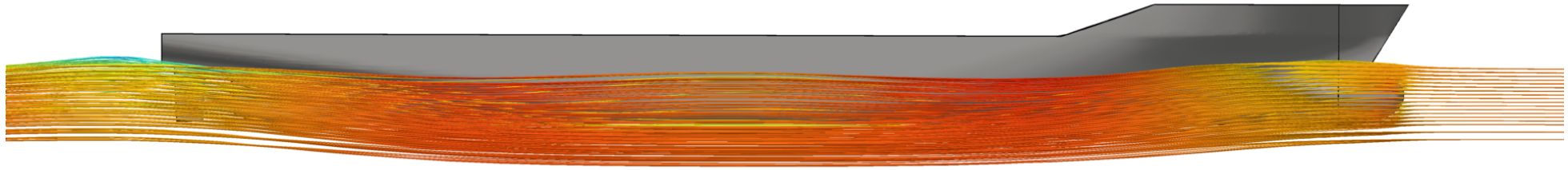
Exterior Side View



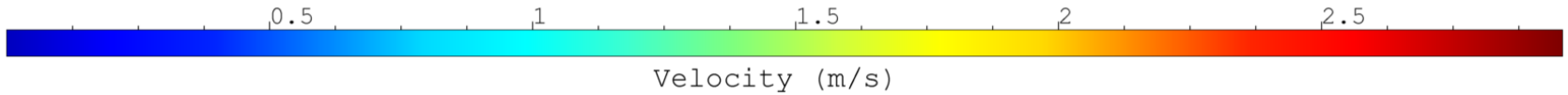
d. Streamlines (volumic) : side view(s)

Volumic streamlines (-)

KCS_Medium, 1.65 tons, 4.3 knots



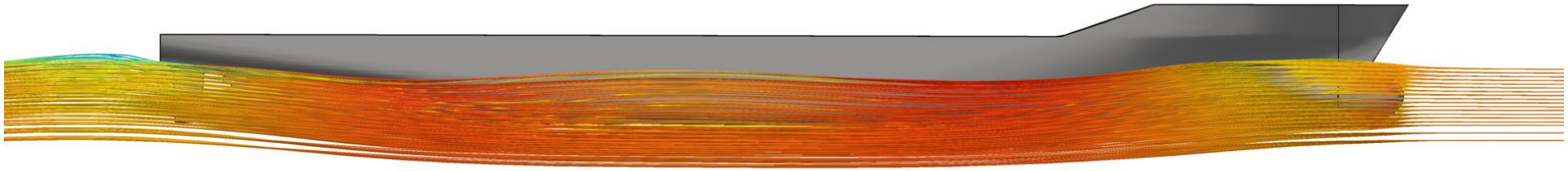
Exterior Side View



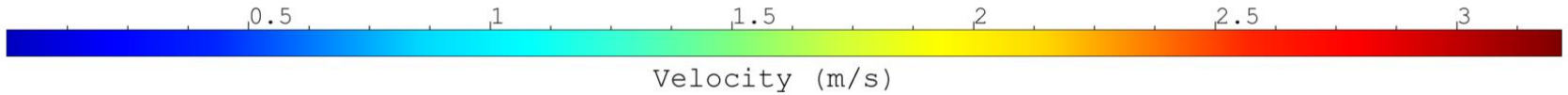
d. Streamlines (volumic) : side view(s)

Volumic streamlines (-)

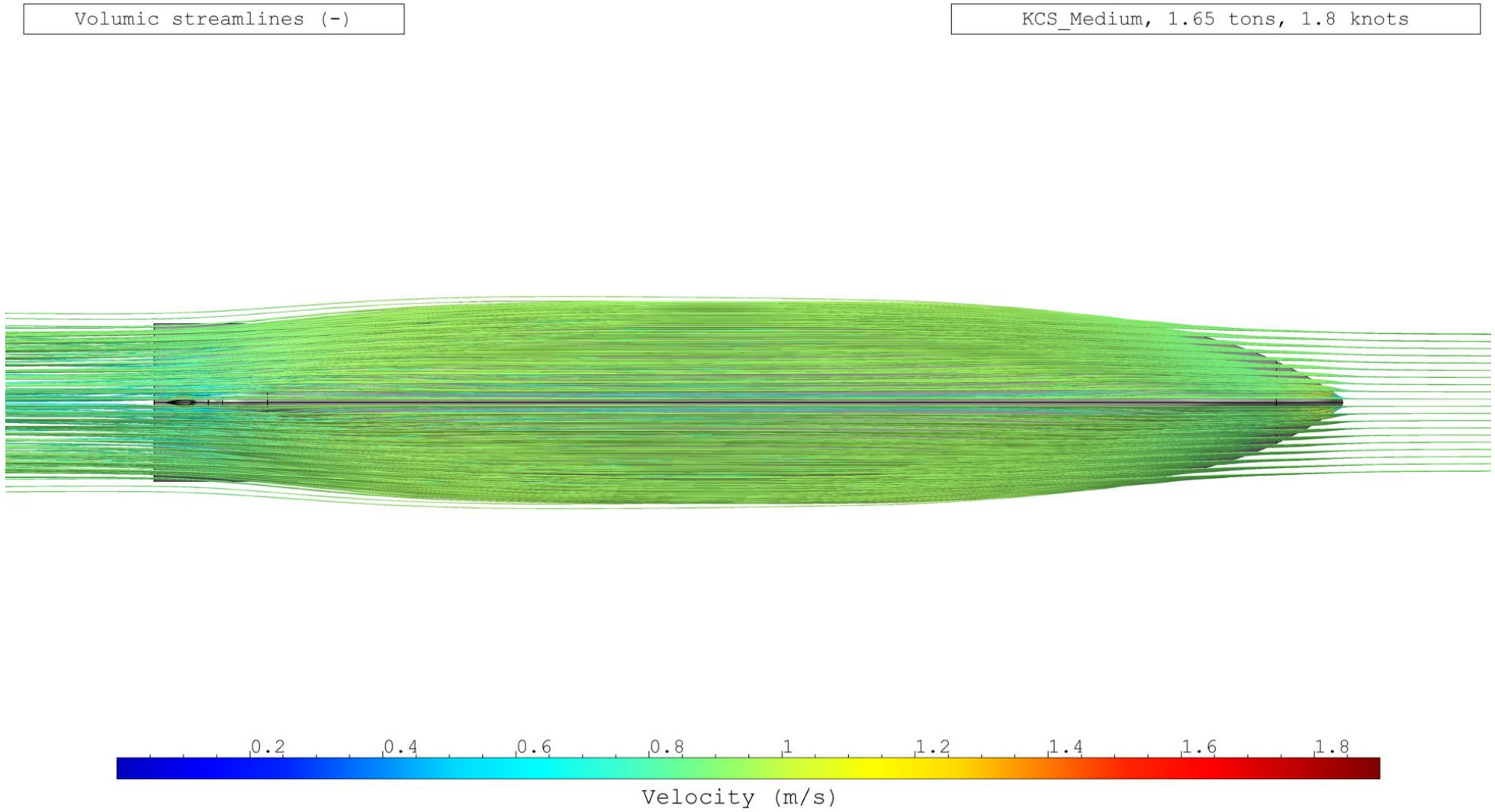
KCS_Medium, 1.65 tons, 4.6 knots



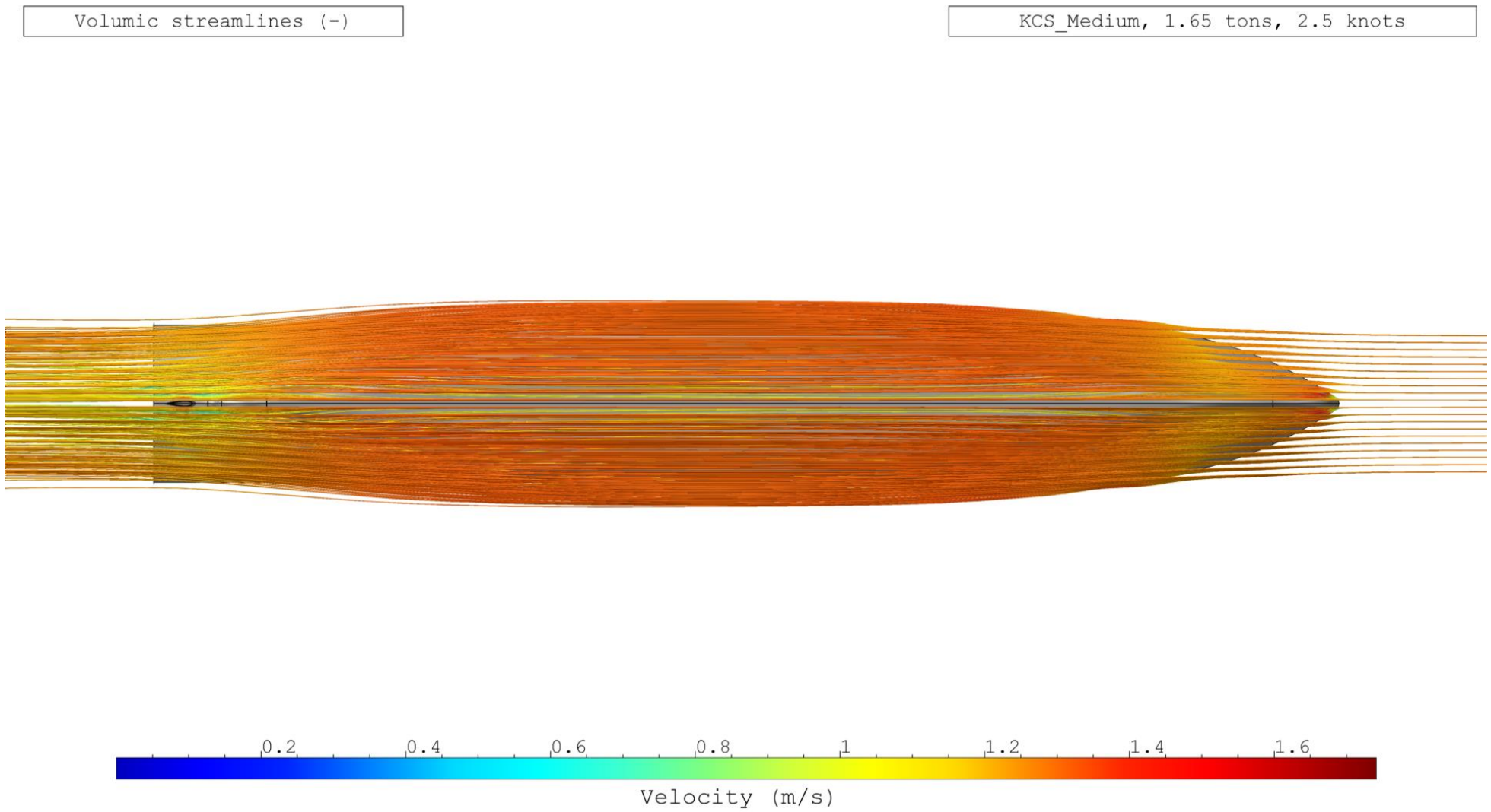
Exterior Side View



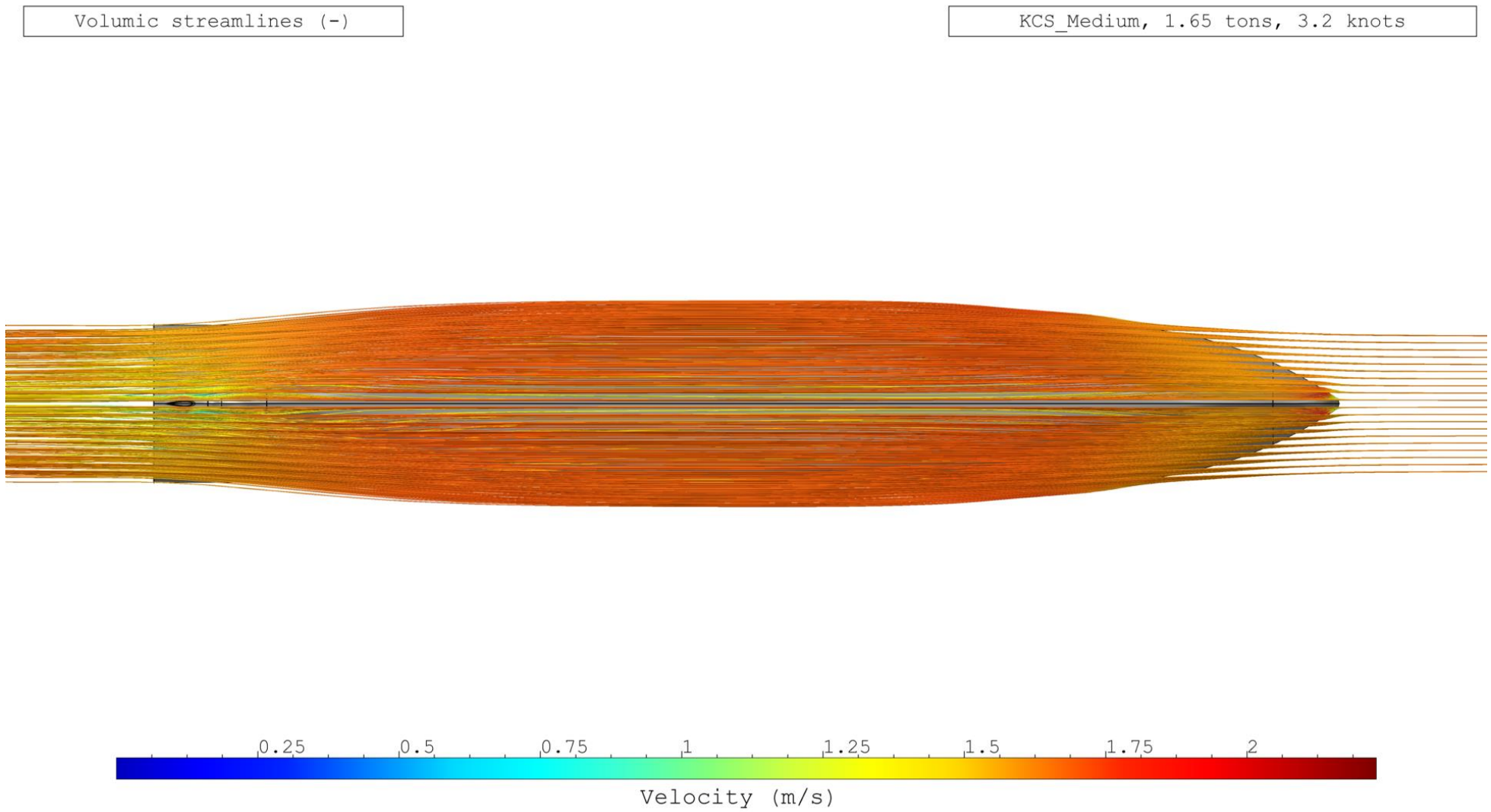
d. Streamlines (volumic) : bottom view



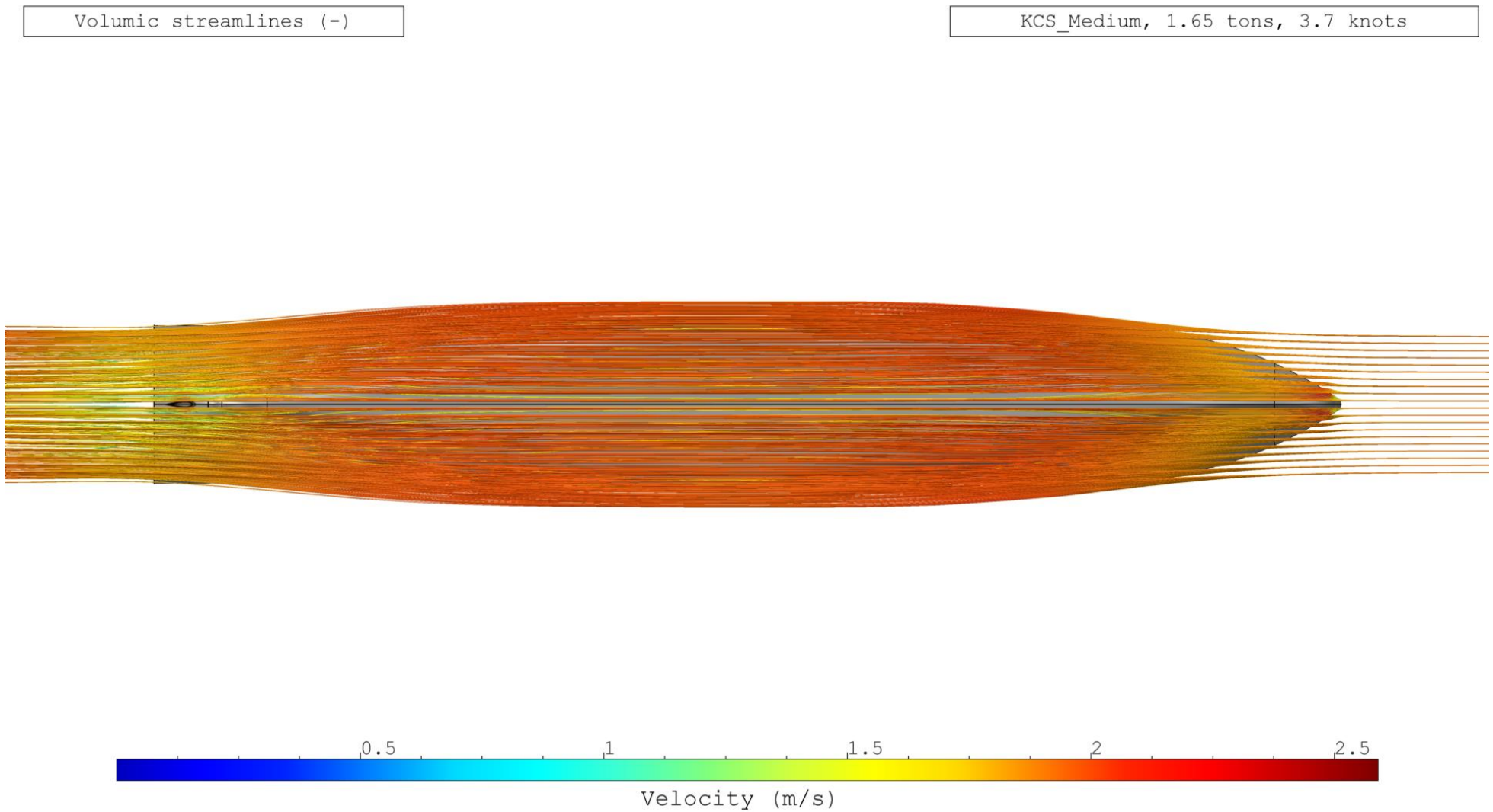
d. Streamlines (volumic) : bottom view



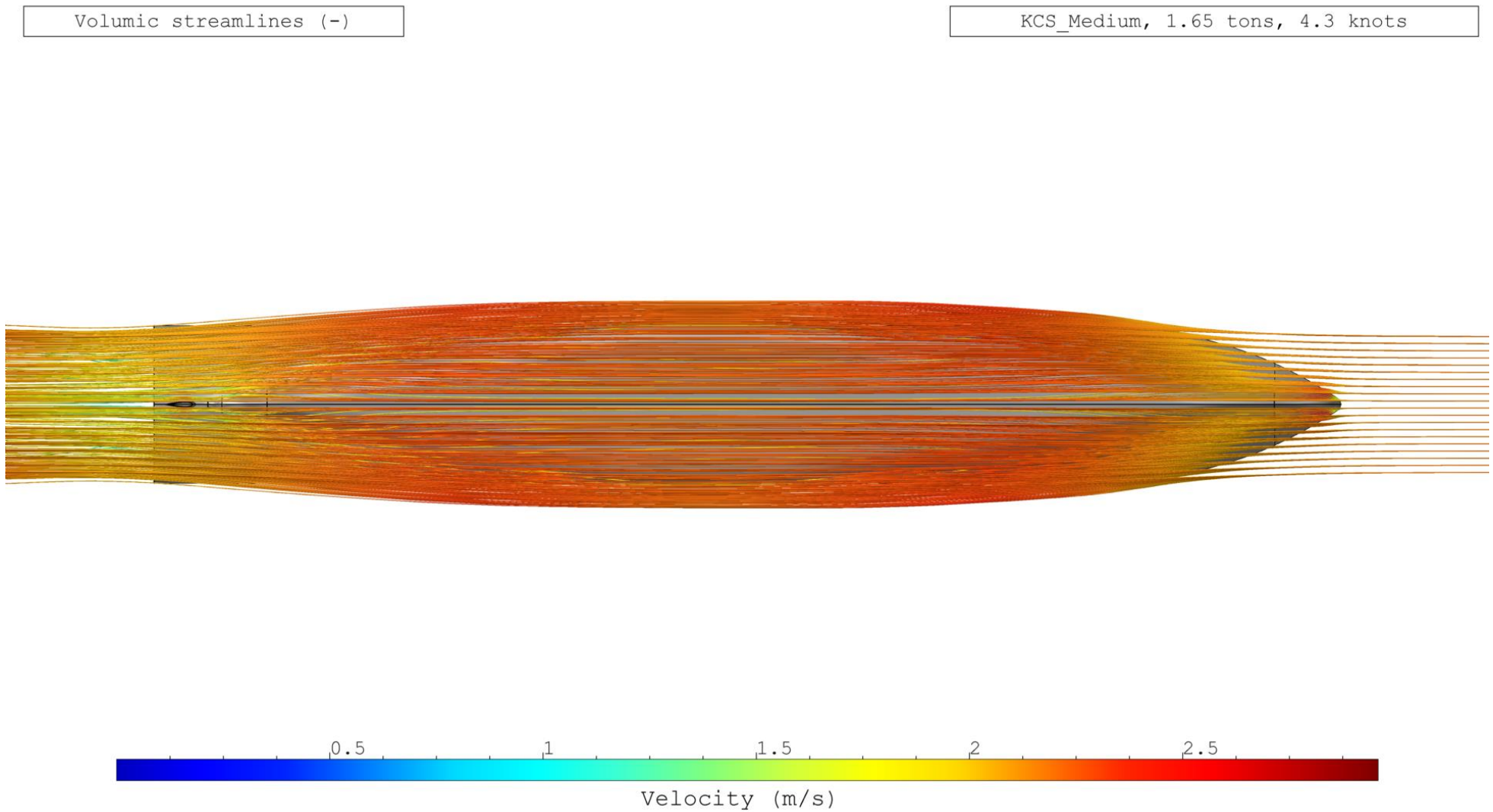
d. Streamlines (volumic) : bottom view



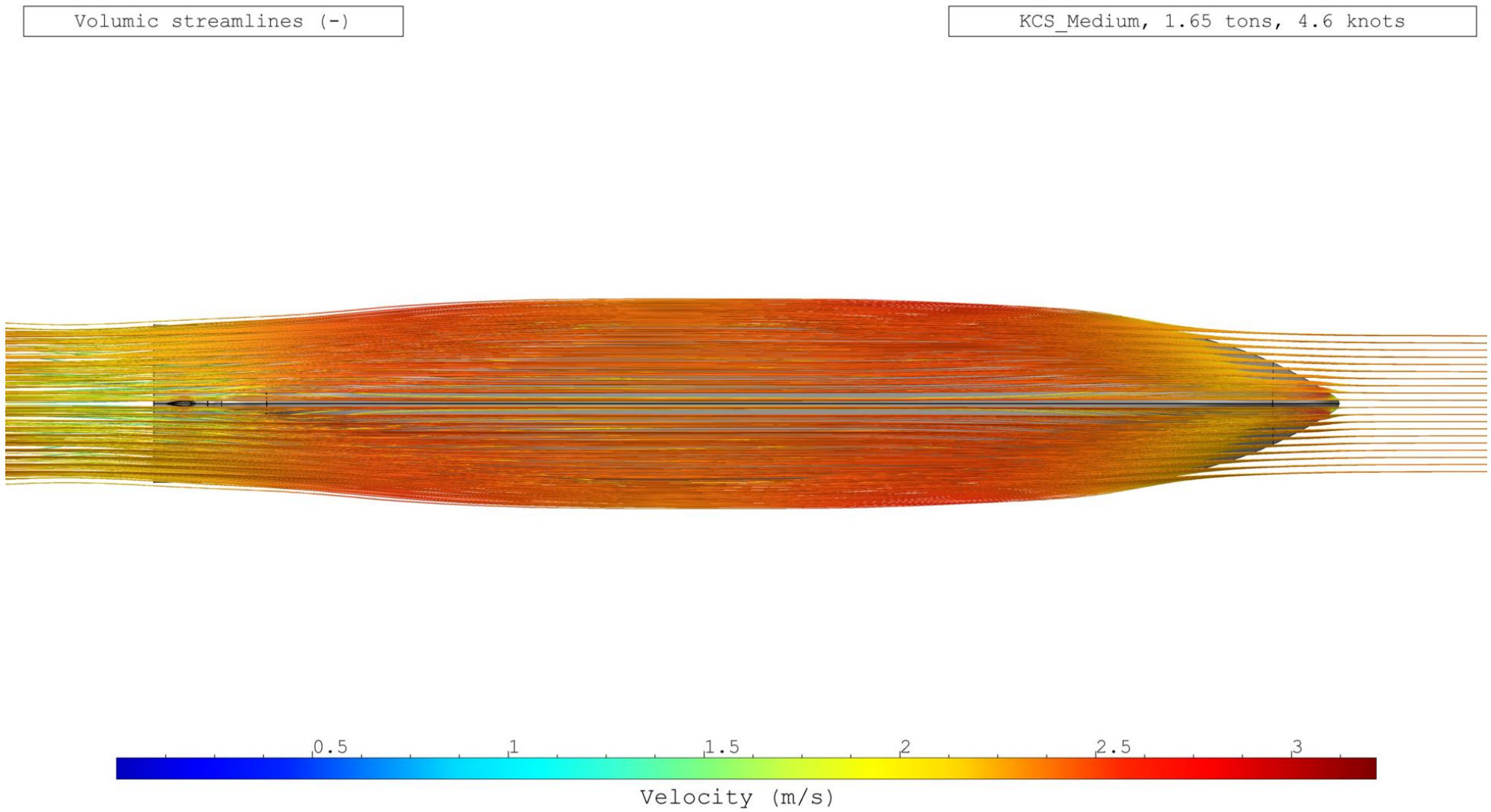
d. Streamlines (volumic) : bottom view



d. Streamlines (volumic) : bottom view



d. Streamlines (volumic) : bottom view



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Intelligent sea mobility