Numerical modeling and simulation of marine tanker hydrodynamics: hull drag, dynamic drift, self propulsion

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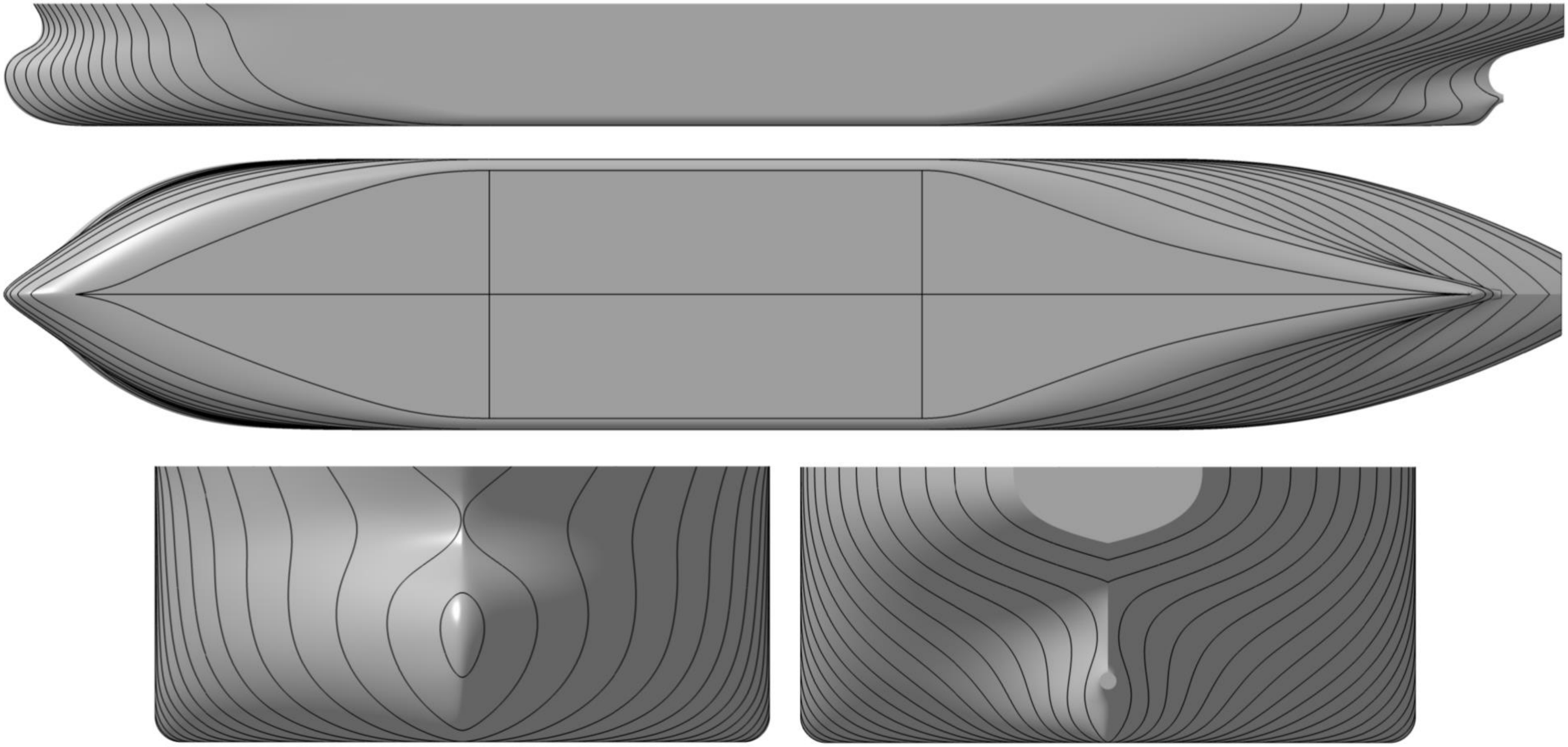
1st case: KVLCC2 Tanker – geometry (2)

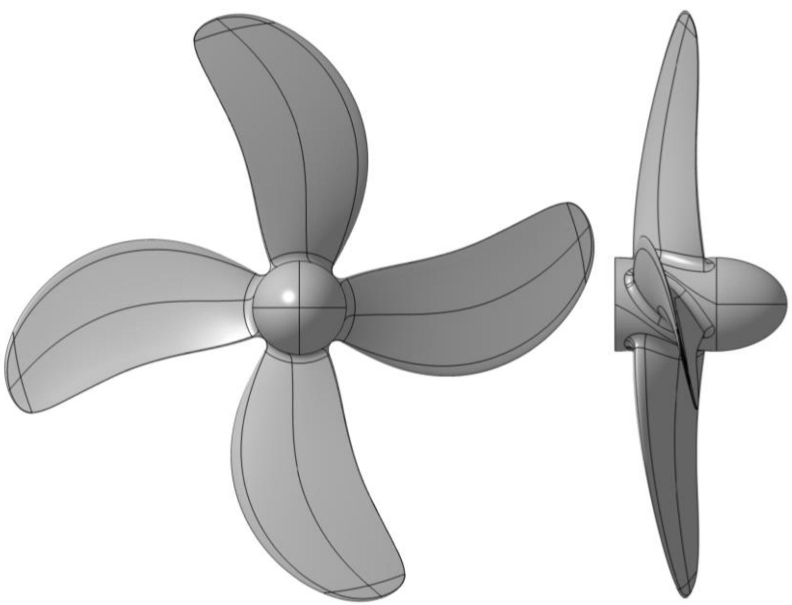
- **Our own CAD model of the hull:**

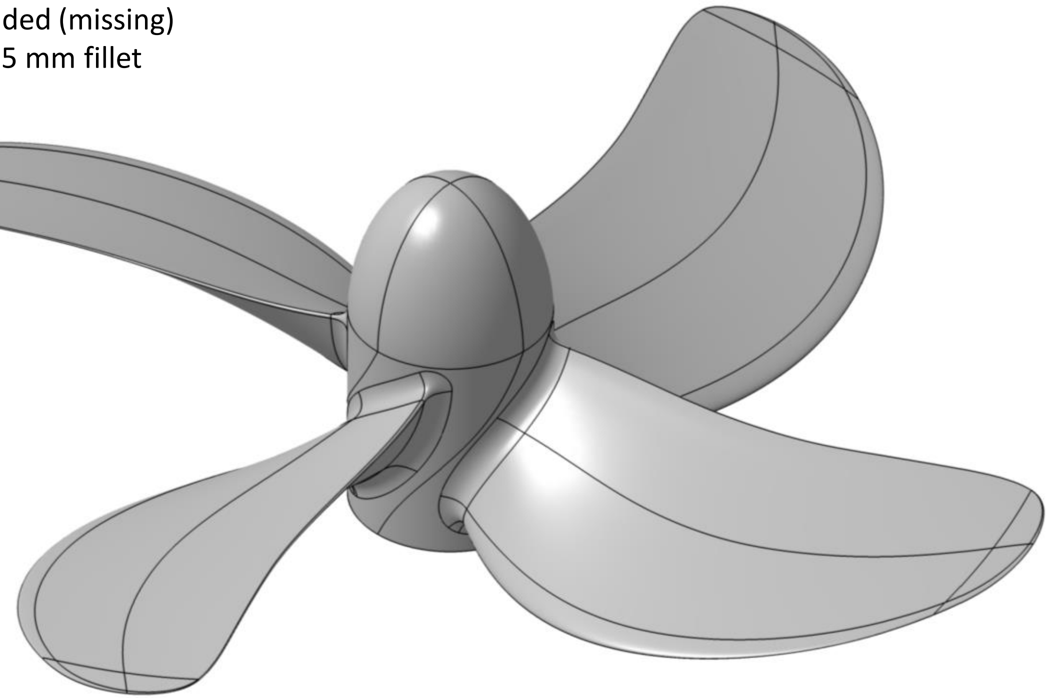


KVLCC2 Tanker – geometry (3)

- **The repaired & completed propeller CAD model:**

- The leading edge and blade surfaces were completely repaired
- A rounded trailing edge and an ellipsoidal cap were added (missing)
- The propeller blade & hub were connected using a ≈2.5 mm fillet

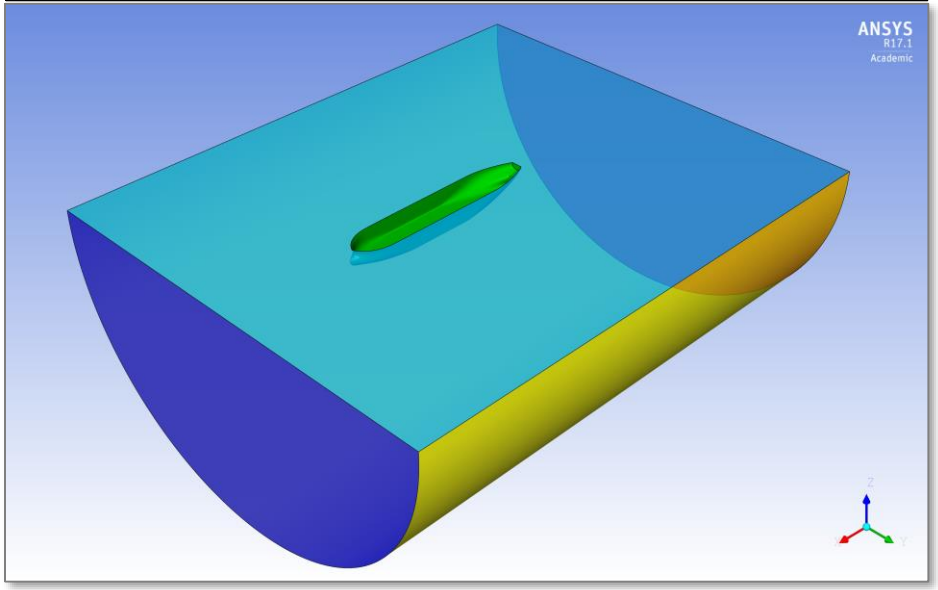


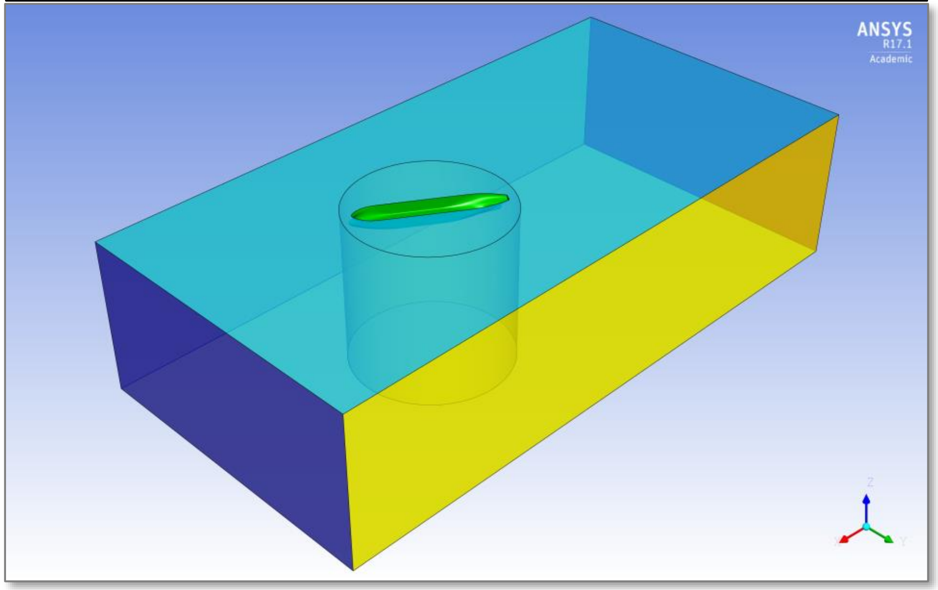


KVLCC2 Tanker – numerical model

- **<u>Computational domain</u>:**
  - Two main techniques were used:

A. Semi-cylindrical domain L = 2.5 x Lpp, D = 2 x Lpp Used for static hull simulations, i.e. drag estimation and appended hull w/ rotating propeller.	B. Rectangular domain L = 4 x Lpp, W = 2 x Lpp, D = 1 x Lpp Used for dynamic hull drift simulations (the cylindrical sub-domain position can be controlled).





KVLCC2 Tanker – numerical model

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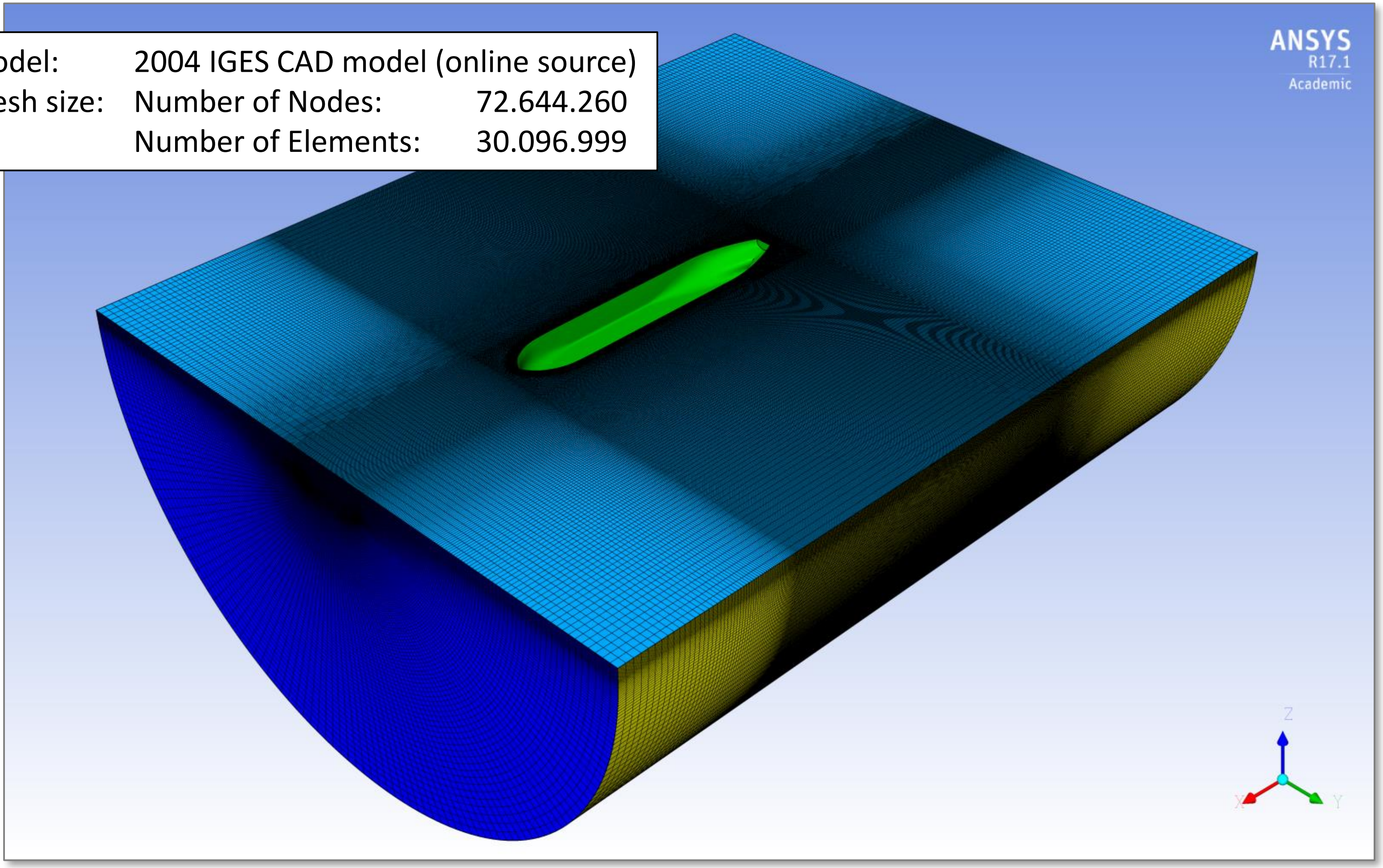
- **Numerical modeling (with ANSYS Fluent v16.2):**
  - Numerical solvers (double precision):
    - *Steady-state*: pressure-based coupled solver, with pseudo-transient under-relaxation
    - *Unsteady-state*: pressure-based segregated solver (for computational efficiency)
  - Discretization schemes:
    - *Pressure*: PRESTO
    - *Volume Fraction*: Compressive (most accurate implicit formulation scheme for VOF)
    - *Momentum & Turbulence*: Second-Order Upwind
    - *Time*: Bounded Second-Order Implicit
  - Gradient calculation:
    - Least-Squares Cell-Based (little to no improvement in solution accuracy was observed when using Green-Gauss Node-Based scheme on polyhedral meshes)
  - Boundary conditions:
    - All cases were simulated within the Open-Channel Model framework available in ANSYS Fluent, using Pressure-Inlet – Pressure-Outlet combinations, with phase velocity and free surface level specification

KVLCC2 Tanker – Hull Drag Assessment (1)

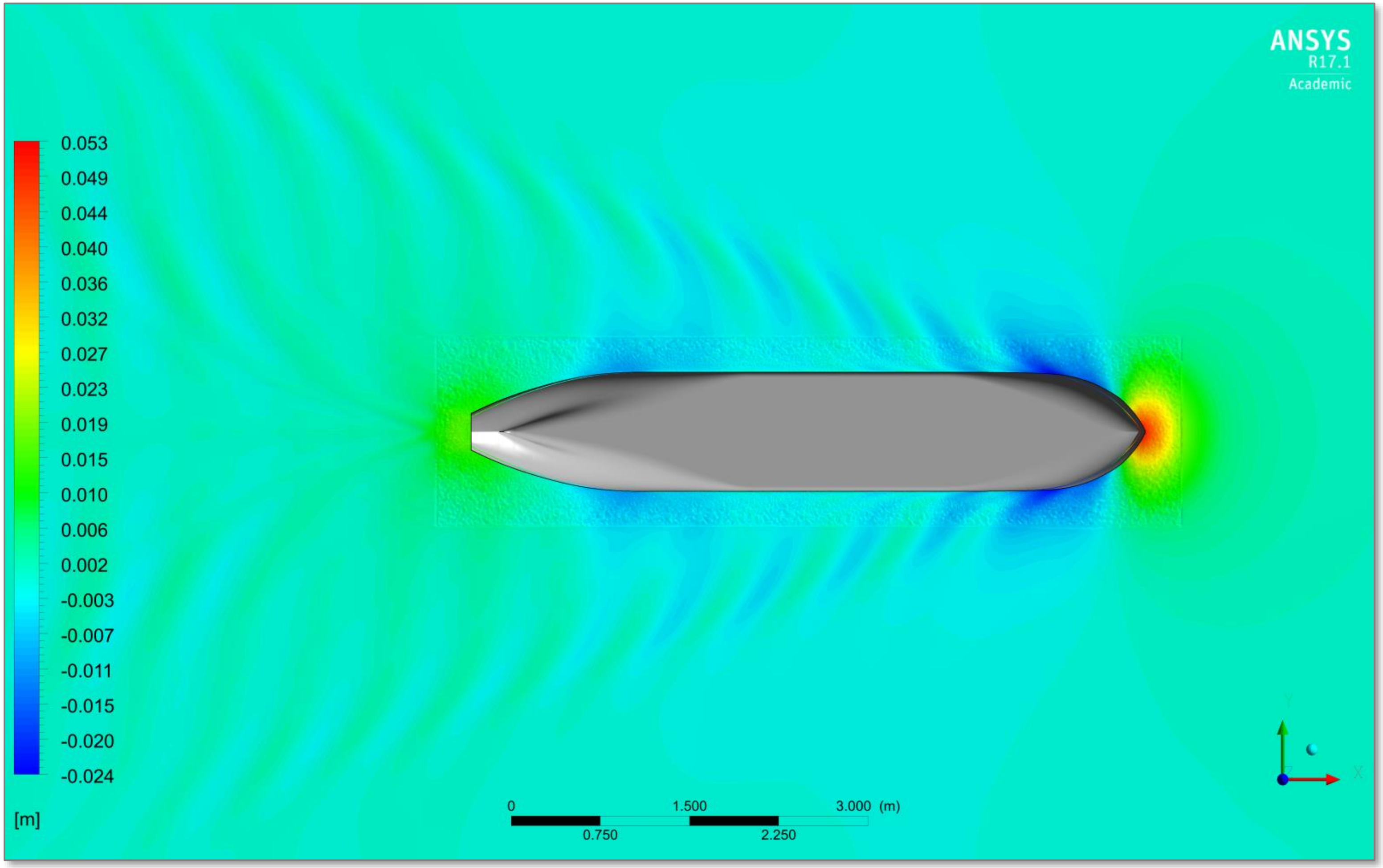
- **Computational mesh overview:**

Model:	2004 IGES CAD model (online source)	
Mesh size:	Number of Nodes:	72.644.260
	Number of Elements:	30.096.999



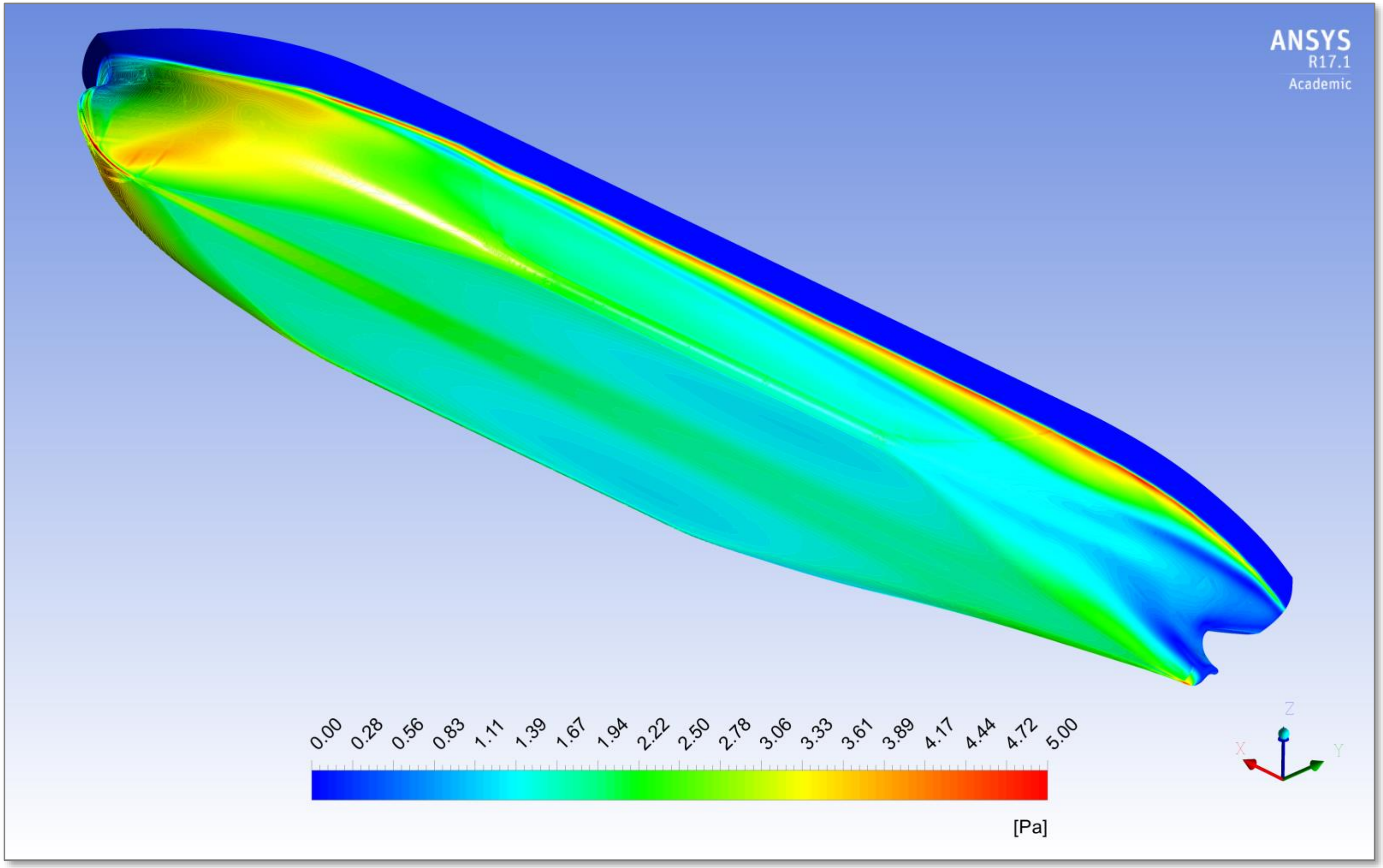
KVLCC2 Tanker – Hull Drag Assessment (2)

- **Results: Free surface elevation**



KVLCC2 Tanker – Hull Drag Assessment (3)

- **Results: Hull wall shear stress**



KVLCC2 Tanker – Hull Drag Assessment (4)

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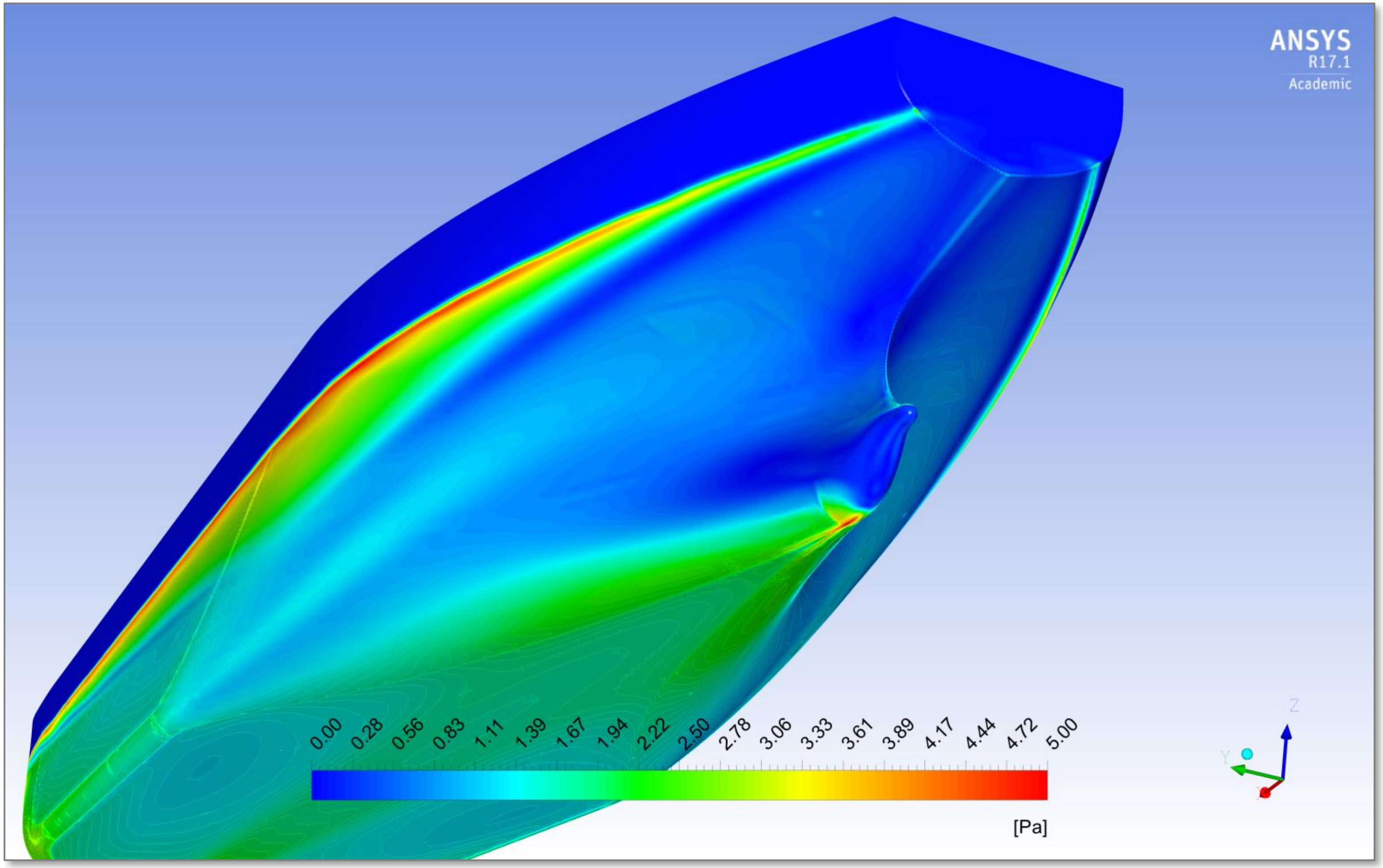
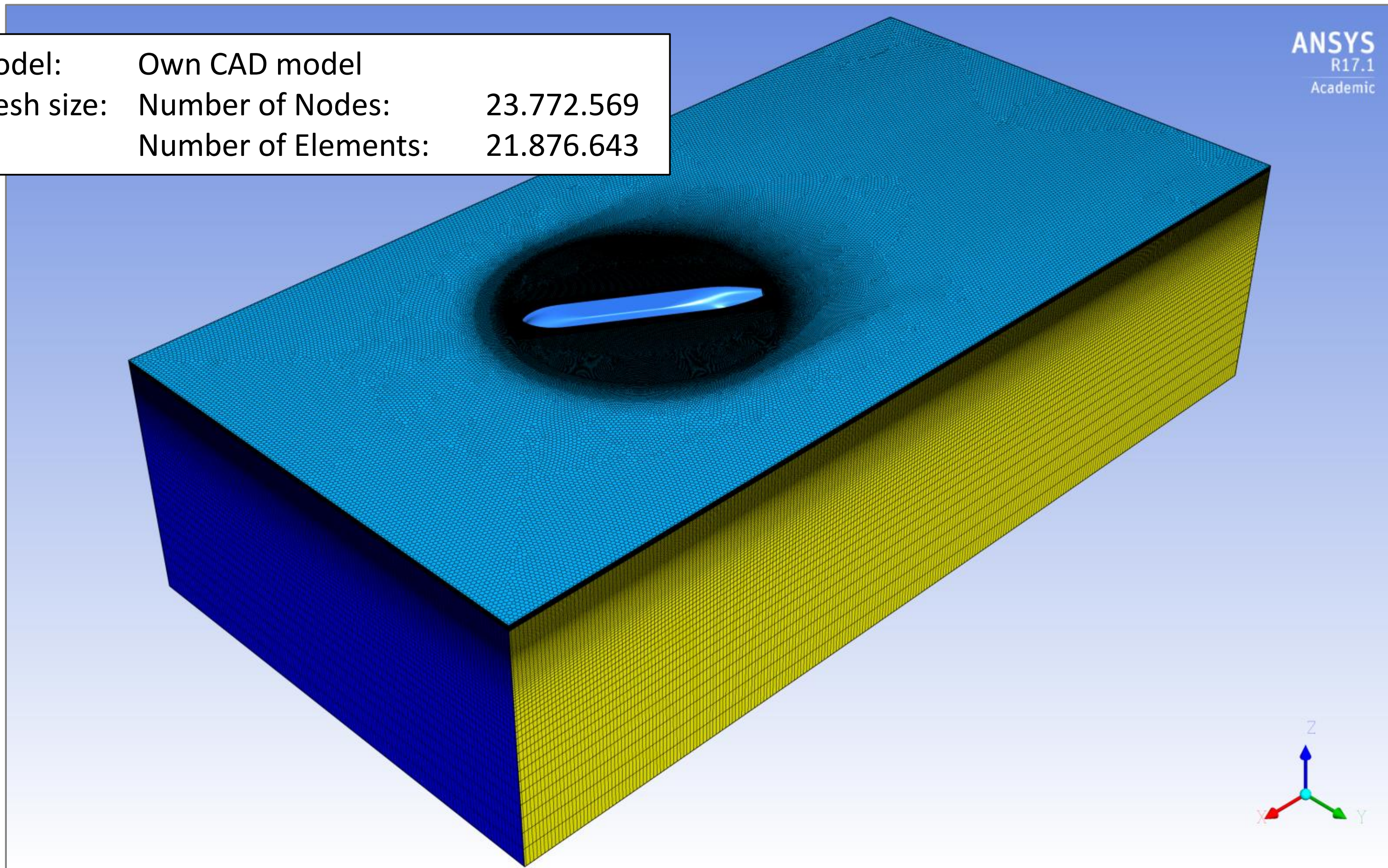
- **Results: Hull wall shear stress**



KVLCC2 Tanker – Dynamic Drift Simulation (1)

- **Computational mesh overview:**

Model:	Own CAD model	
Mesh size:	Number of Nodes:	23.772.569
	Number of Elements:	21.876.643



KVLCC2 Tanker – Dynamic Drift Simulation (2)

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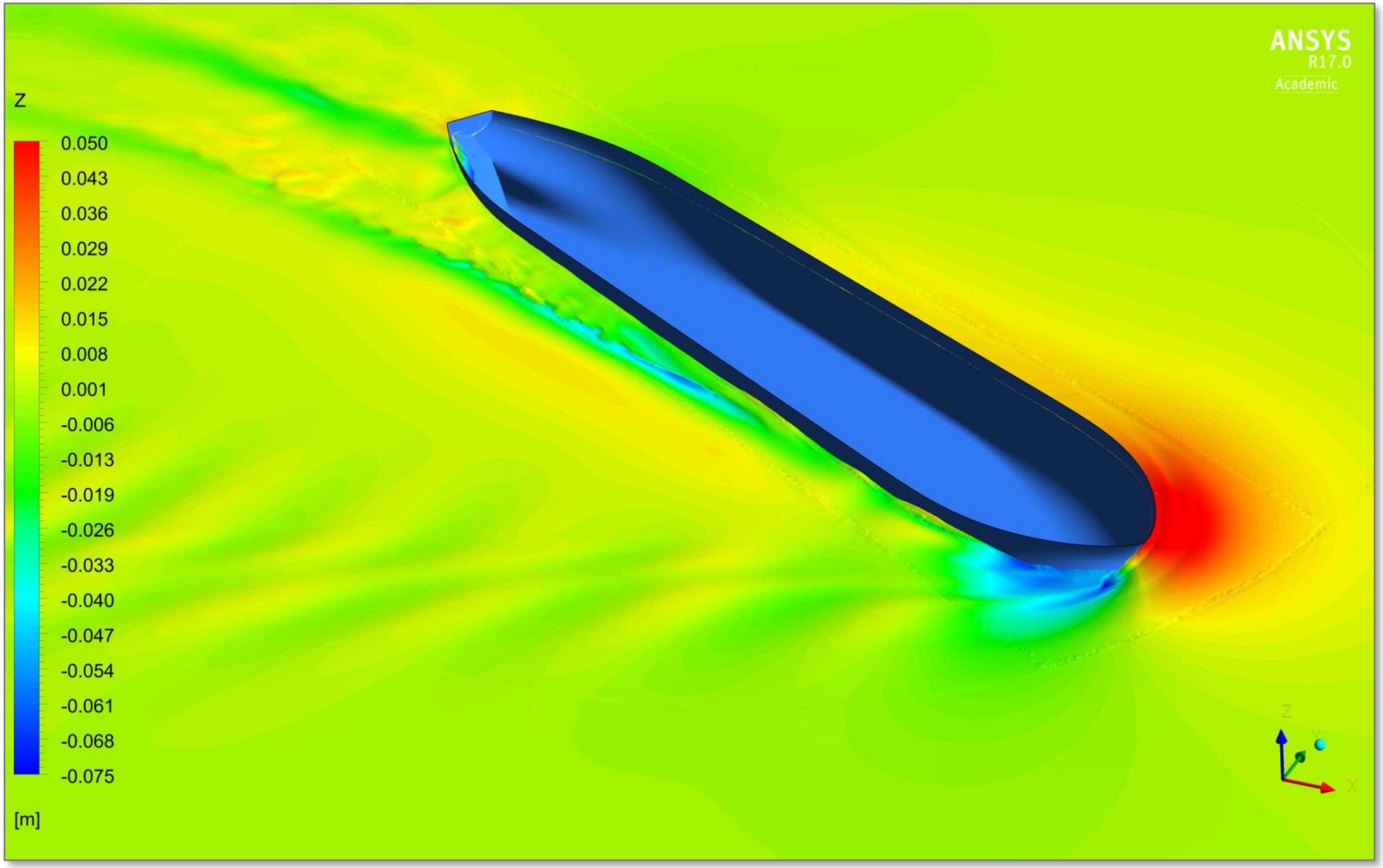
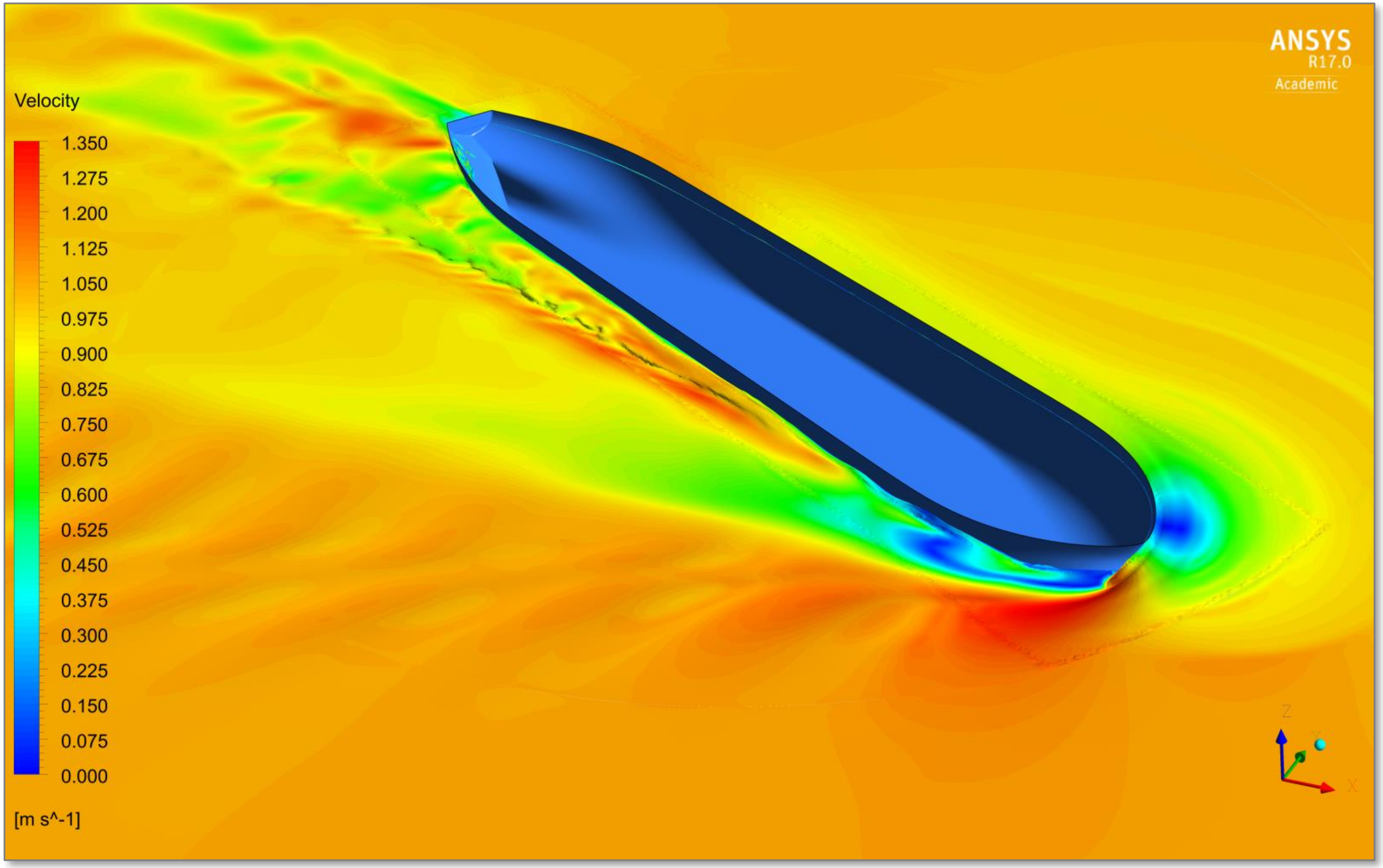
- **Results @ 32 deg: Free surface elevation**



KVLCC2 Tanker – Dynamic Drift Simulation (3)

- **Results @ 32 deg: Velocity on the Free surface**

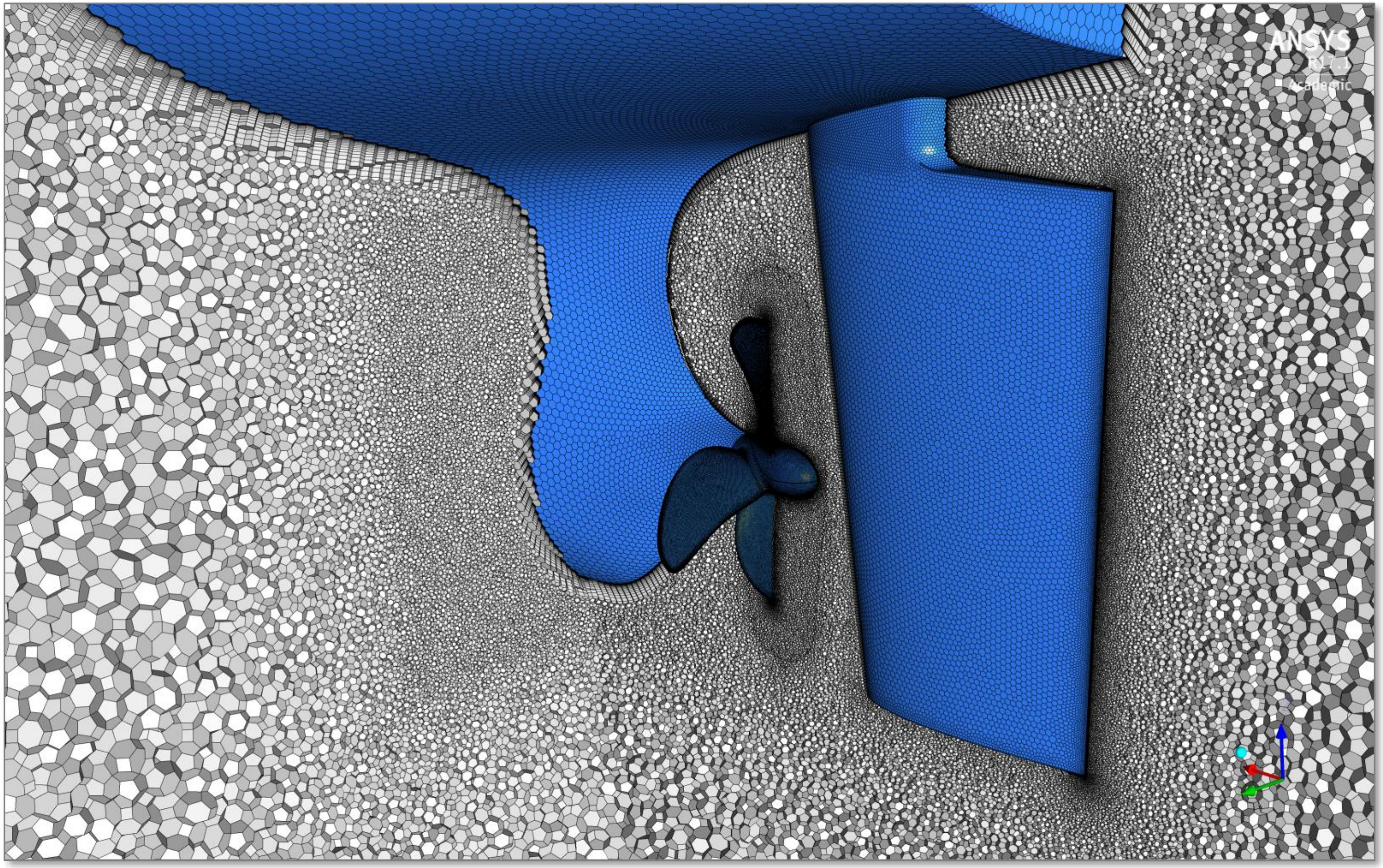


KVLCC2 Tanker – Self-propulsion Point Simulation (1)

- **Conditions:**
  - Fully appended, fixed hull
  - Constant forward velocity, U_0= 1.047 m/s
  - No drift angle, zero rudder angle
  - Constant propeller turn rate, n = 732 rpm
- **Numerical model:**
  - The same flow domain size & shape as for hull drag assessment
  - Our own CAD model was used for hull modeling
  - Mesh metrics:
    - Number of Nodes: 65.882.769
    - Number of Elements: 26.138.110
- **Simulation:**
  - Time-step size: Δt = 2.277e-04 s ≡ 1 deg prop. turn / time-step
  - 5 iterations / time-step

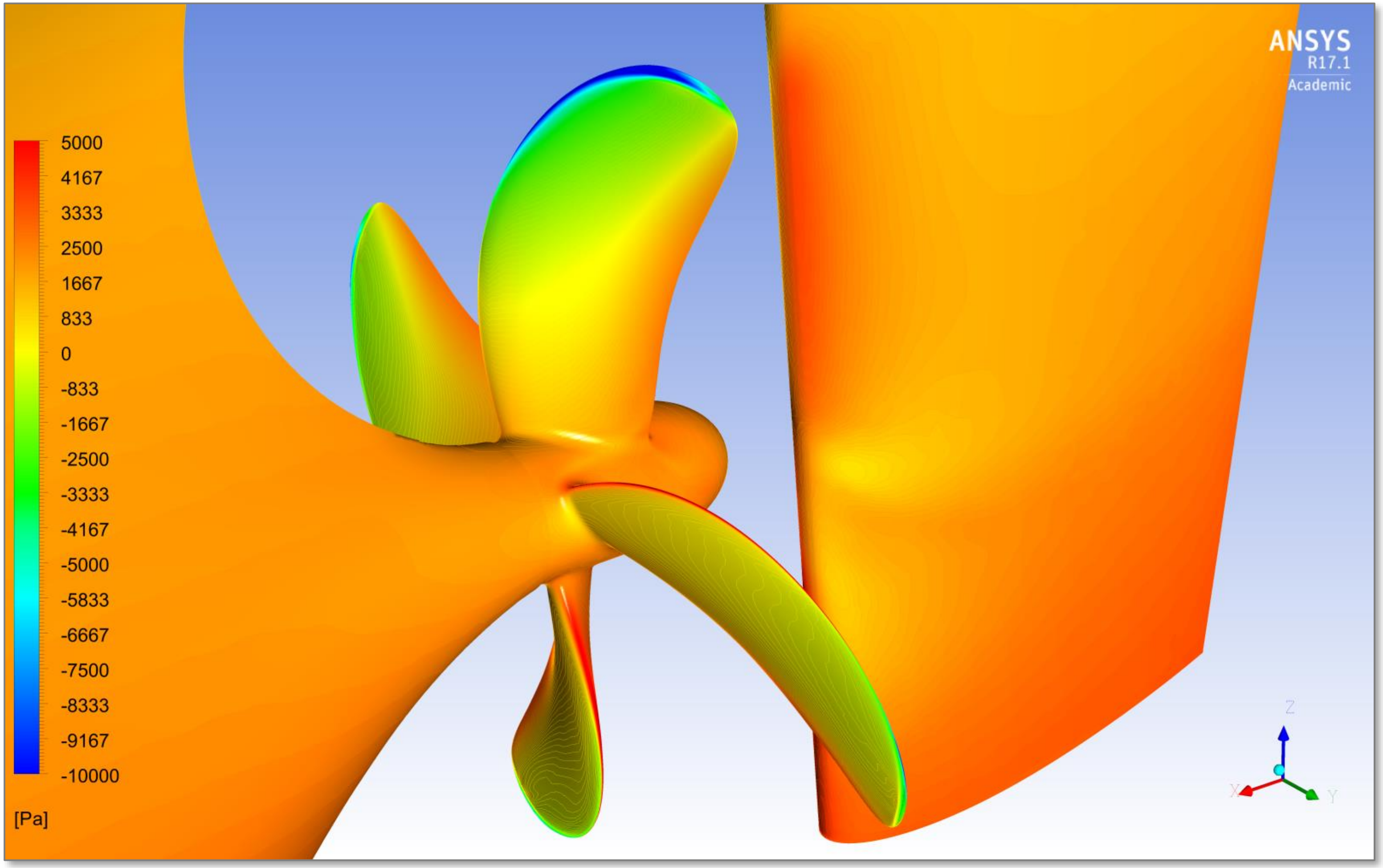
KVLCC2 Tanker – Self-propulsion Point Simulation (2)

- **Computational mesh details (cont.):**



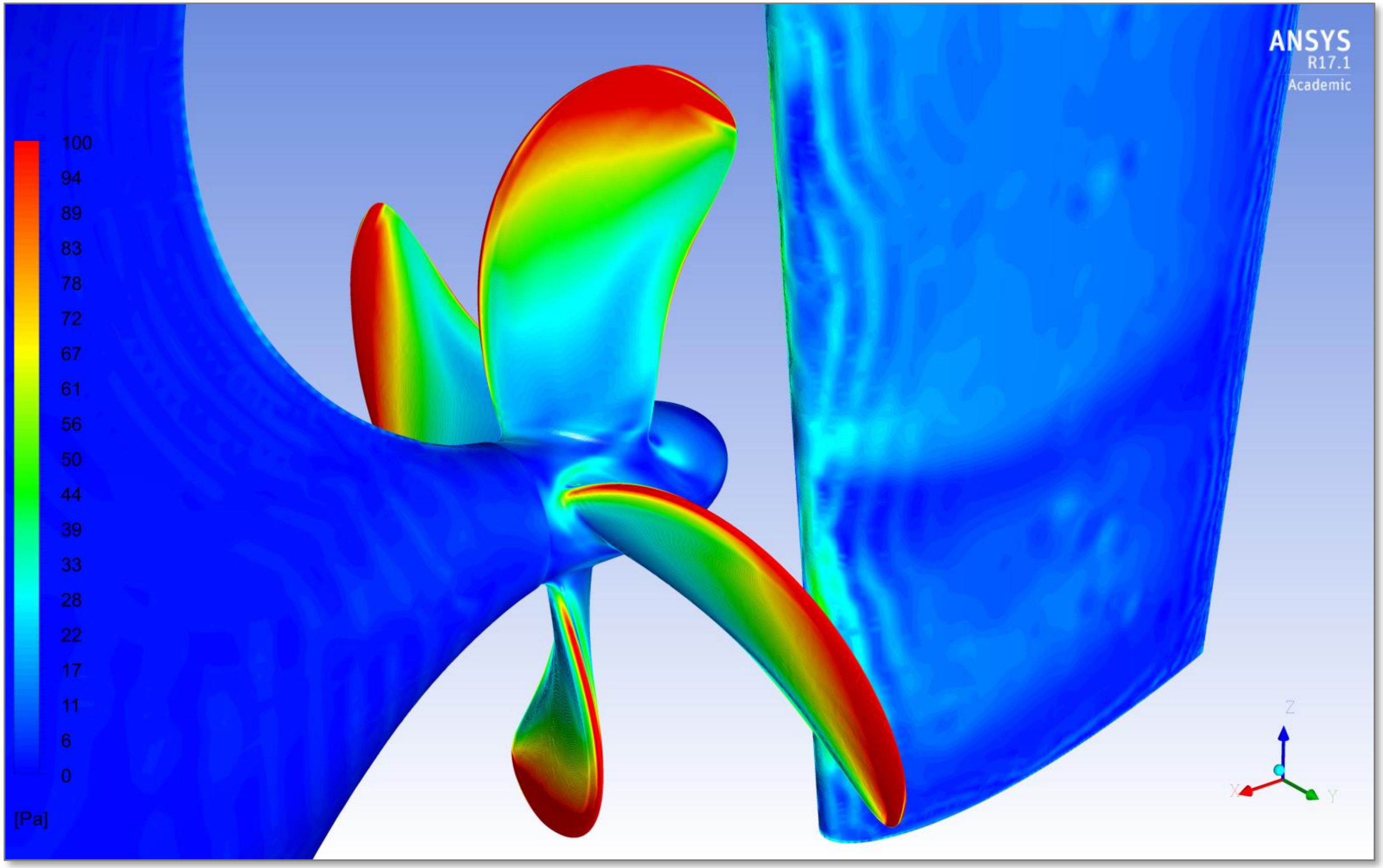
KVLCC2 Tanker – Self-propulsion Point Simulation (3)

- **Results: Static pressure**



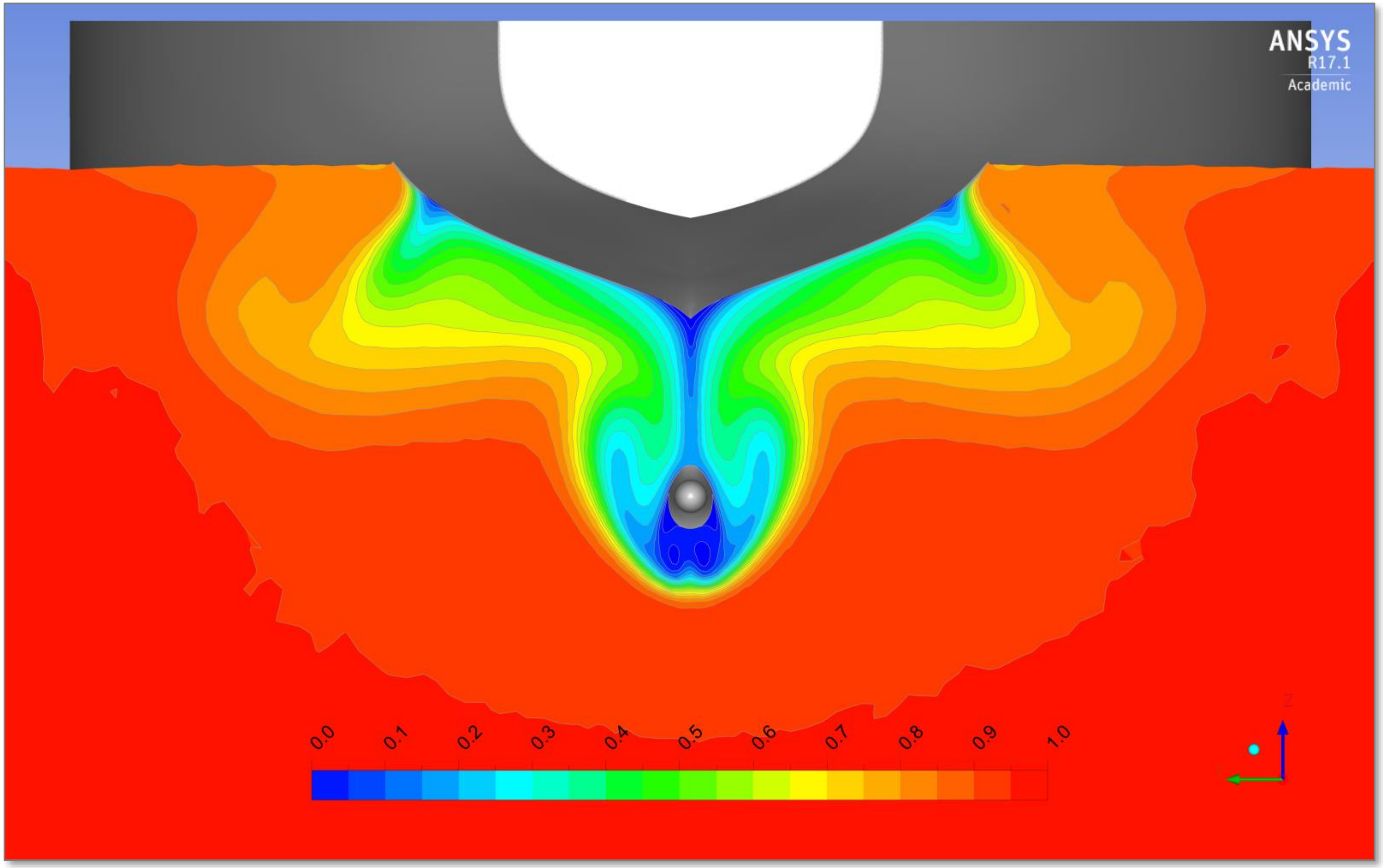
KVLCC2 Tanker – Self-propulsion Point Simulation (4)

- **Results: Wall shear stress**



KVLCC2 Tanker – Self-propulsion Point Simulation (5)

- **Results: Velocity in front of the propeller plane – w/o propeller**



KVLCC2 Tanker – Self-propulsion Point Simulation (6)

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- **Results: Velocity in front of the propeller plane – w/ propeller**