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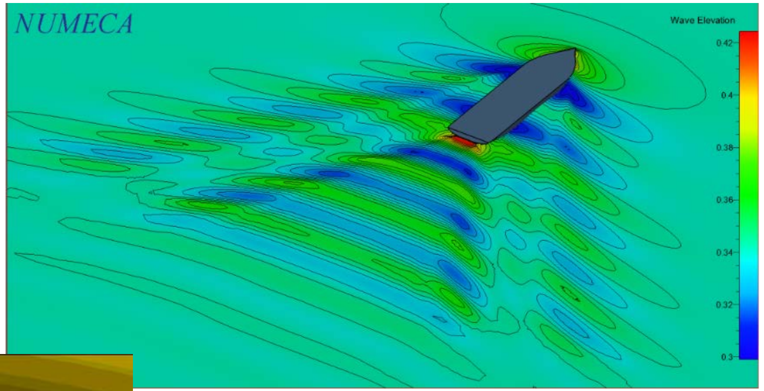
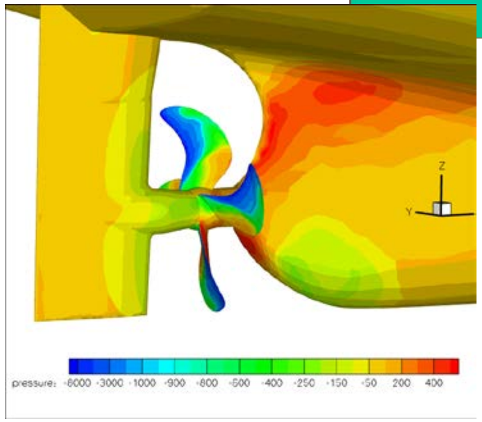
HOW TO USE CFD TO COST-EFFECTIVELY REDUCE FUEL CONSUMPTION

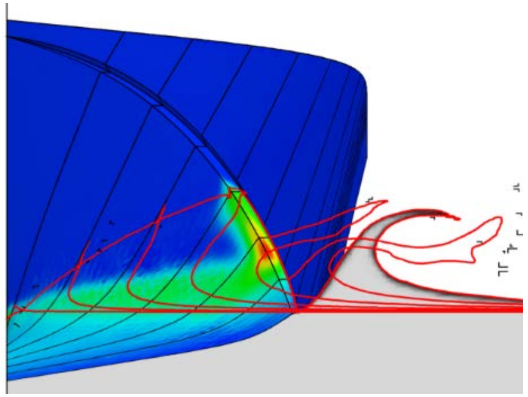
Anders Östman, SINTEF Ocean

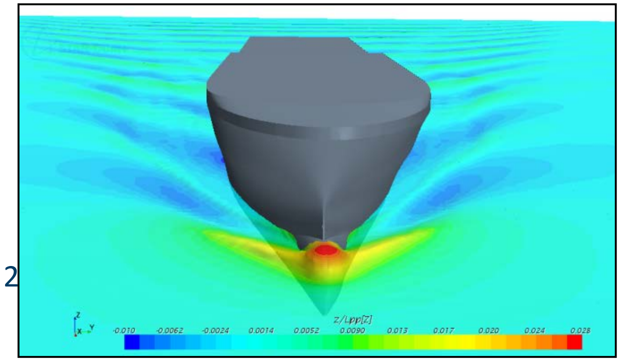
Increase the hydrodynamic performance of the vessel

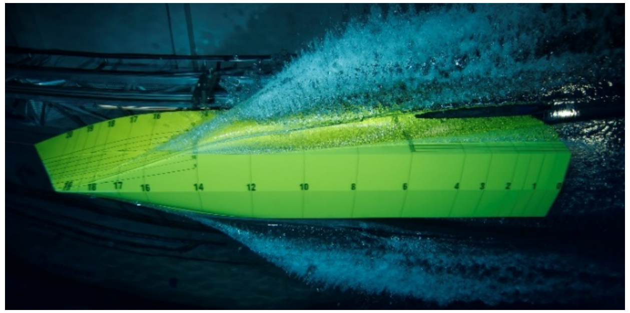
- Improving hull lines of new designs
- Energy Saving Devises (ESD)
- Wake adapted propeller
- Low roughness surface coating

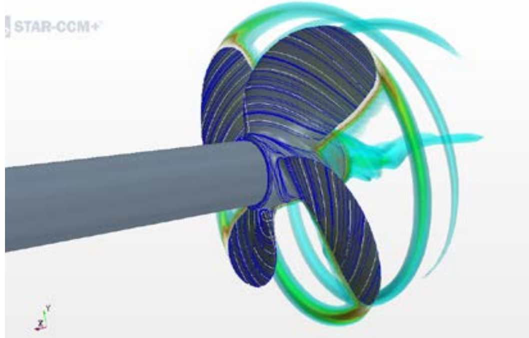


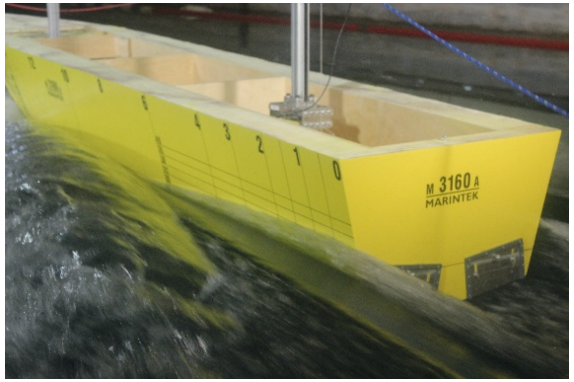






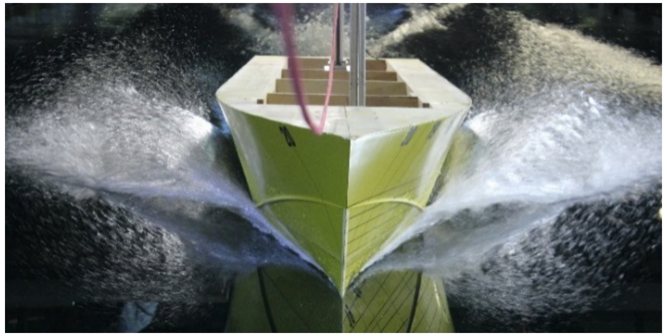


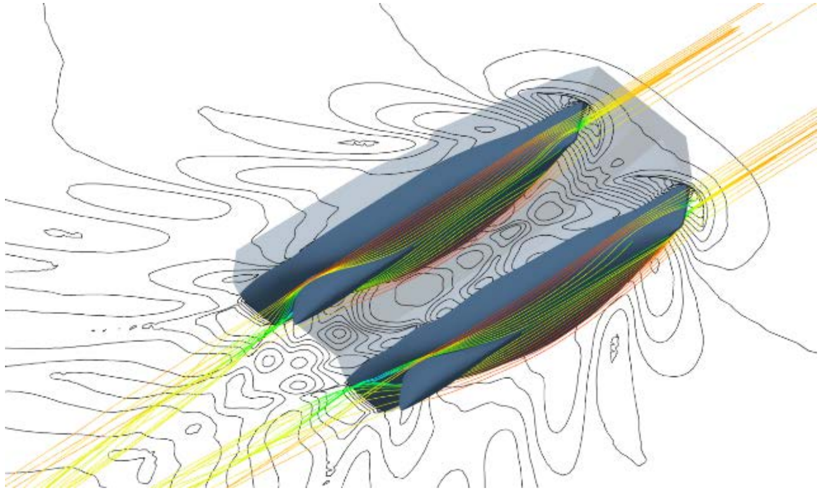


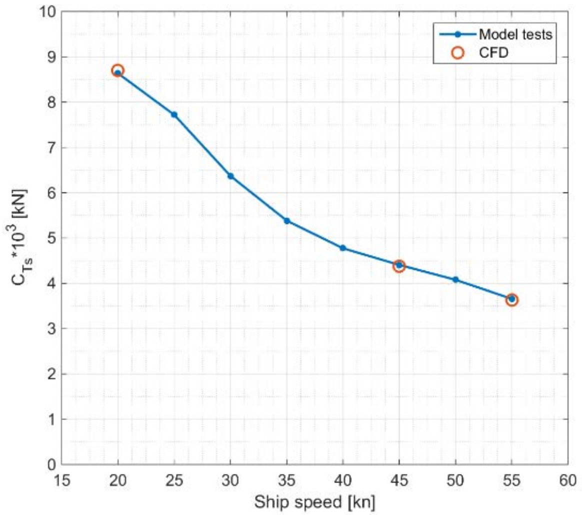


Improving hull lines of new designs

- At SINTEF Ocean we have access to a range of hydrodynamic expertise, tools and knowledge:
  - Use of our database to compare the vessel performances against a large range of other vessels
  - Simple numerical tools
  - CFD
  - Experimental model tests



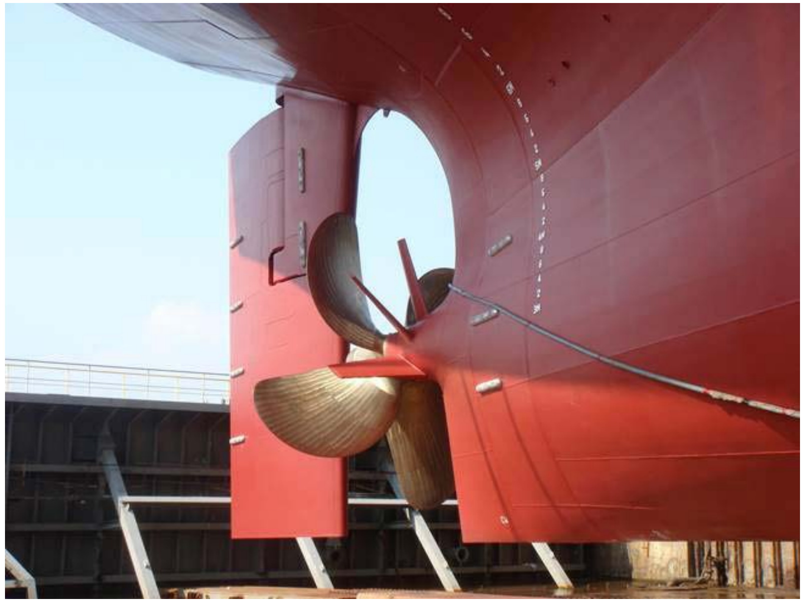


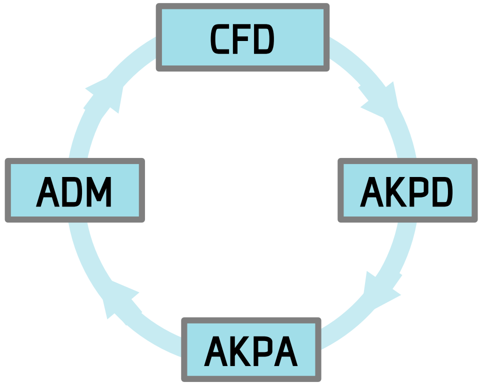


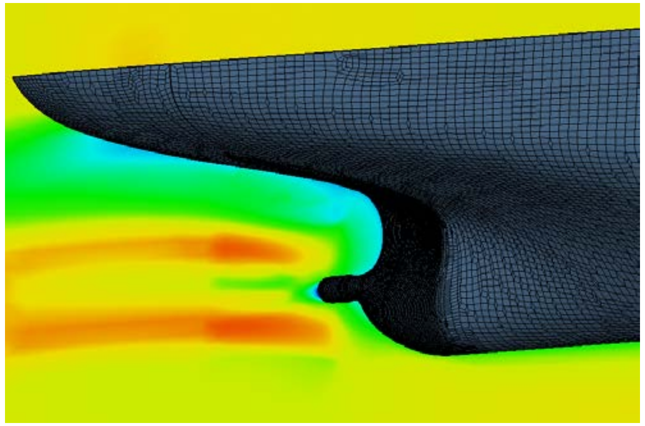
Improving performance of existing designs

- Use of Energy Saving Devises (ESD) to improve efficiency of the propulsion system

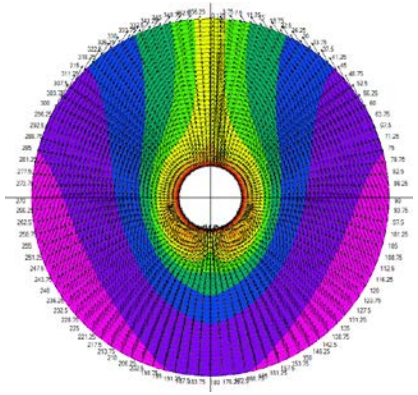
- Design of wake adapted propeller



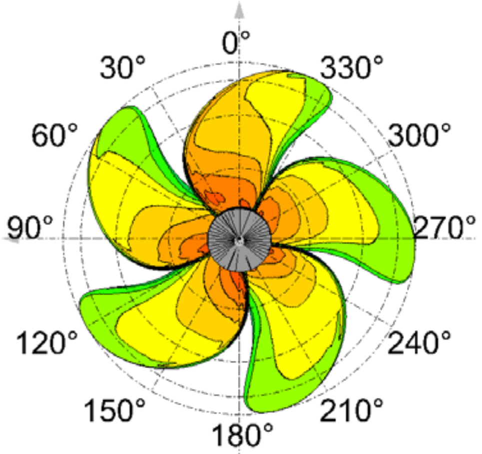




Velocity field behind hull



Effective wake on propeller operating behind hull



Propeller loading

CFD as a design optimization tool

- Computational Fluid Dynamics (CFD) in combination with multi-objective optimization algorithms offers a state-of-the art tool for the design of energy efficient propulsion systems.

- It can be employed in early design phases as a decision support tool, as well as for the final customization of ESD, propeller and rudder, including both the newbuilds and retrofit solutions.

- The benefits of the above approach become especially clear, when the initial ship and propeller designs have already been optimized, and the room for further improvements is fairly small. In such case, ESD and propeller need to be carefully wake-adapted and designed to operate as an entire system.

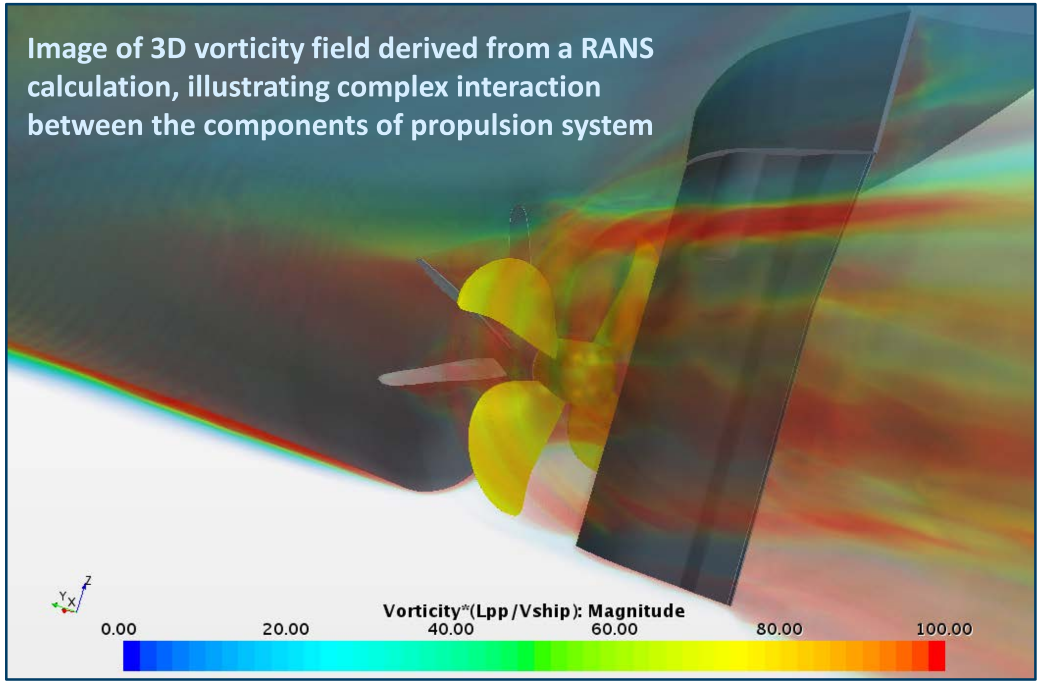
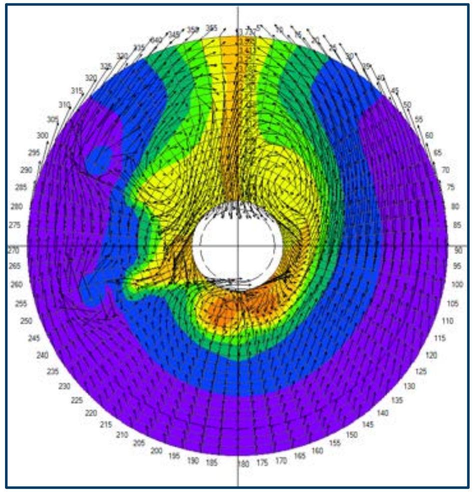
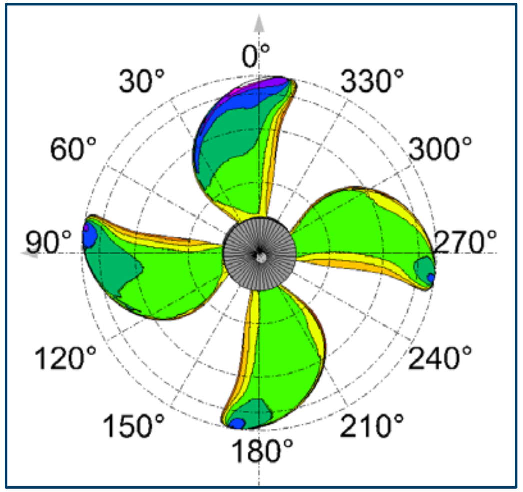


Image of 3D vorticity field derived from a RANS calculation, illustrating complex interaction between the components of propulsion system

Effective wake on propeller operating behind an ESD



Propeller analysis in effective wake



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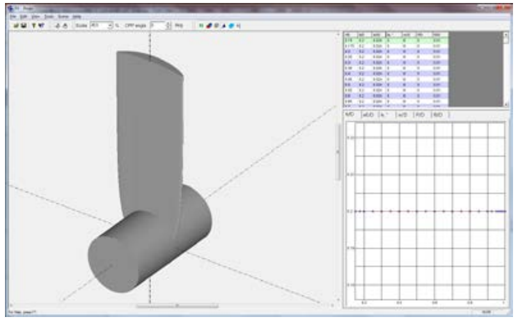
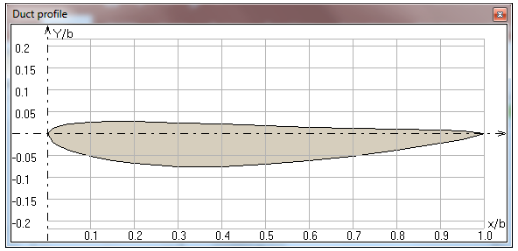
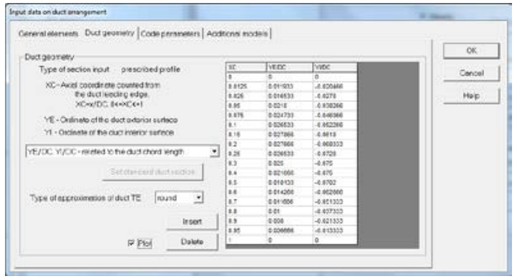
Optimization solution chain

- In the co-fund R&D project "NorSingProp", SINTEF Ocean explore energy saving solutions related to pre-swirl ESDs and propeller design.
- The optimization solution chain features in-house propeller design software AKPA, and geometry parametrization, CFD modelling and design exploration tools of STAR-CCM+ to ensure high degree of automation, user control and detailed customization of the components to realistic operation conditions in full scale.

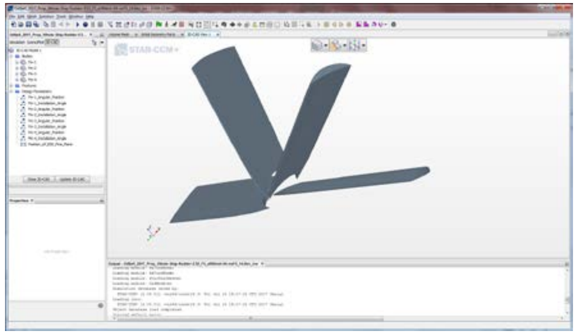
ESD Fins and Duct models in propeller design code AKPA

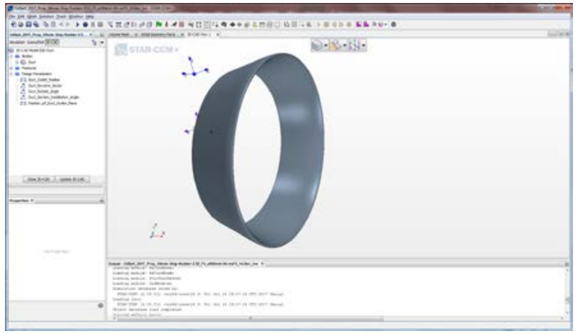




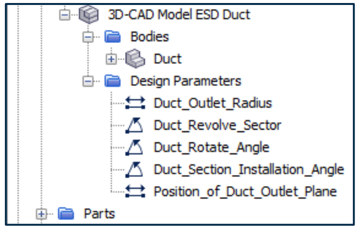


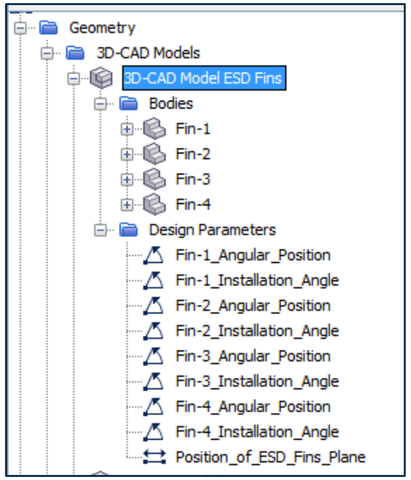
Parametrized geometry in 3D-CAD

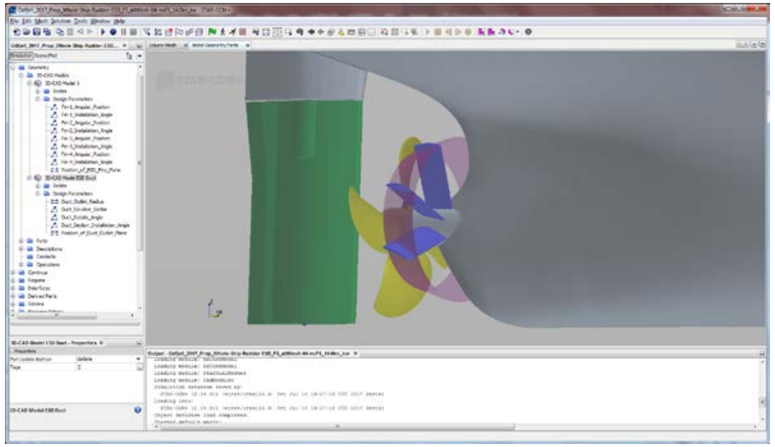




CFD model in STAR-CCM+ with exposed design parameters







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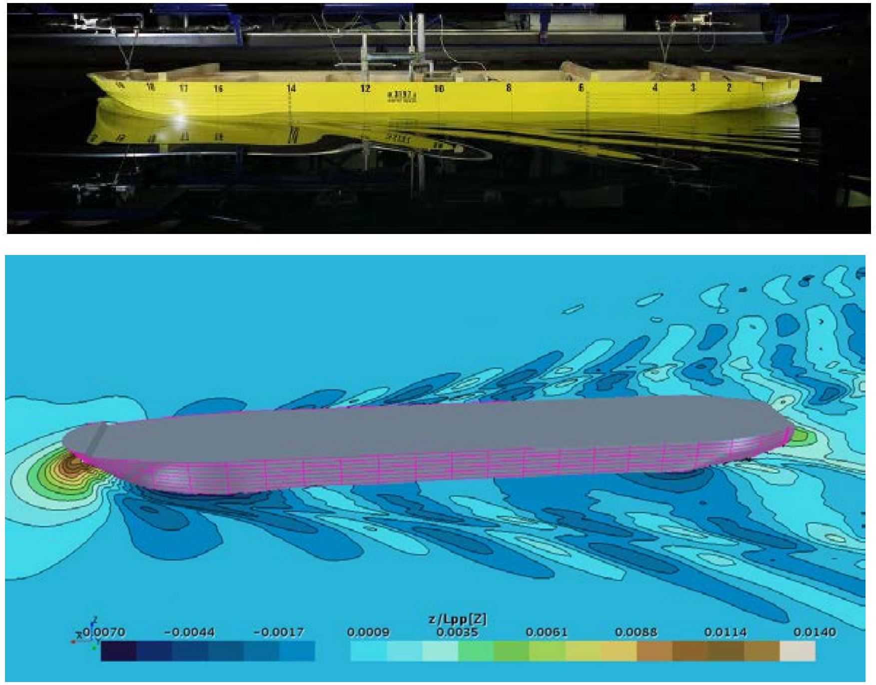
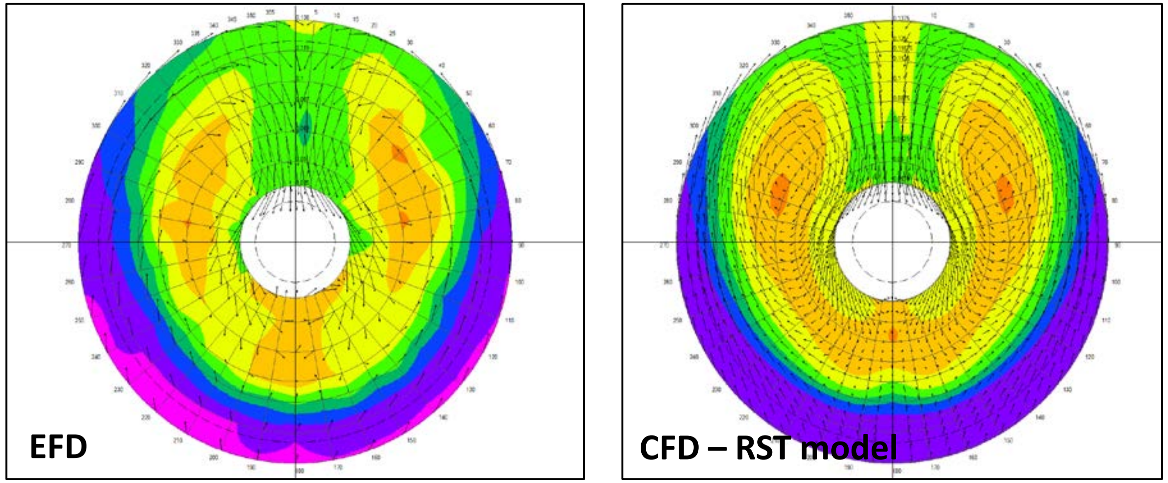
CFD validation in model and full scale

Free surface waves pattern



Nominal wake field on propeller plane



- For confidence in design performance prediction, validation of CFD methods is crucial. This is achieved through continuous validation exercises with the existing and new benchmark cases, including those in full scale.
- On this slide, CFD vs EFD comparisons are presented for one of the vessels studied in the "NorSingProp" project, regarding free surface waves pattern, nominal wake on propeller plane and full-scale propulsion characteristics.
- More advanced turbulence models, such as for example anisotropic Reynolds Stress Turbulence (RST) model, are shown to offer higher accuracy for single-screw ships featuring relatively heavy wake fields.

Vessel propulsion characteristics in full scale (at design speed, w/o ESD)

	EFD, Prediction (w/o sea margin)	CFD, SSTkw	(CFD-EFD)/EFD	CFD, RST	(CFD-EFD)/EFD
			%		%
n (rps)	1.44	1.472	2.22	1.453	0.90
TB (kN)	690.72	695.57	0.70	689.72	-0.15
PD (kW)	5596.68	5820.38	4.00	5671.31	1.33
ETAD	0.715	0.708	-1.04	0.724	1.14

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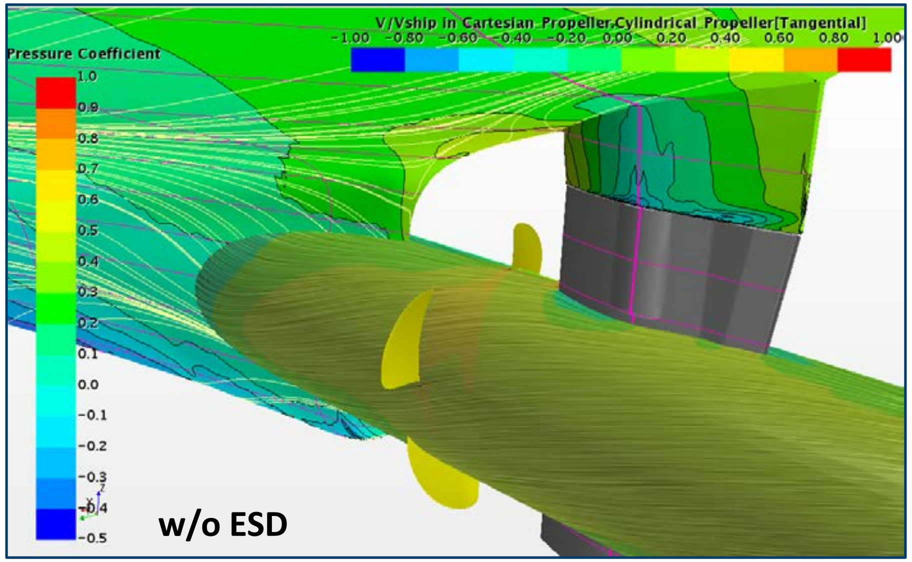
Propulsion characteristics of the vessel with optimized ESD and propeller

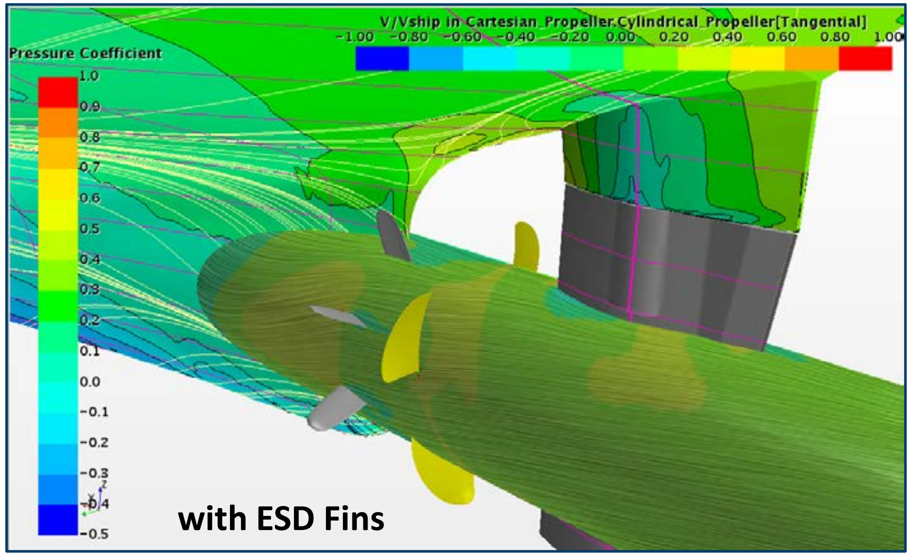
Vessel propulsion characteristics in full scale (at design speed)

	w/o ESD	ESD + new propeller	Δ, %
n (rps)	1.472	1.42	-3.53
PD (kW)	5820.38	5537.73	-4.86
Ct, ship	0.00269	0.002739	
Ct, ESD-Fins	0	-0.000008	
Vt/V (Sect1)	-0.000237	-0.03269	
Vt/V (Sect2)	0.089347	0.05865	

- Power savings of 4.86% are predicted for the vessel equipped with the designed Pre-Swirl Stator Fins and new wake-adapted propeller design, at the vessel design speed in full scale.
- Each ESD fin is individually twisted and cambered to maximize the pre-swirl effect on propeller and minimize fin appendage resistance.
- Apart from additional energy saving, a wake-adapted propeller design allows for the reduction of blade load amplitudes.

Effect of pre-swirl and recovery of rotational energy in propeller slipstream





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Surface Roughness

- What is the effect of paint application on the ship resistance?
  - Sandblast surface vs Over coating
  - Quality of the application

- How can we measure effect of roughness experimantaly?
- Can we model the effect of this type of roughness in CFD?
- The presented work has been performed within the Byefouling EU-project

Byefouling SINTEF

Experimental tests

Laser scan of the surface of the plates

Smooth plate
Sq=1.22 µm

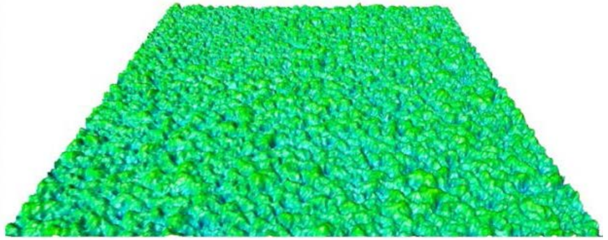


Plate A
Sq=8.51 µm

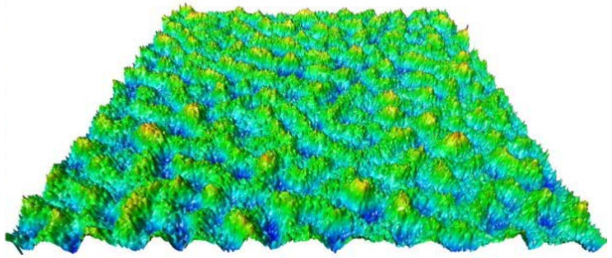


Plate B
Sq=41.15 µm

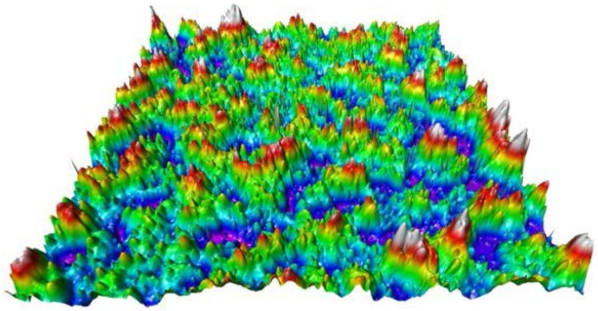
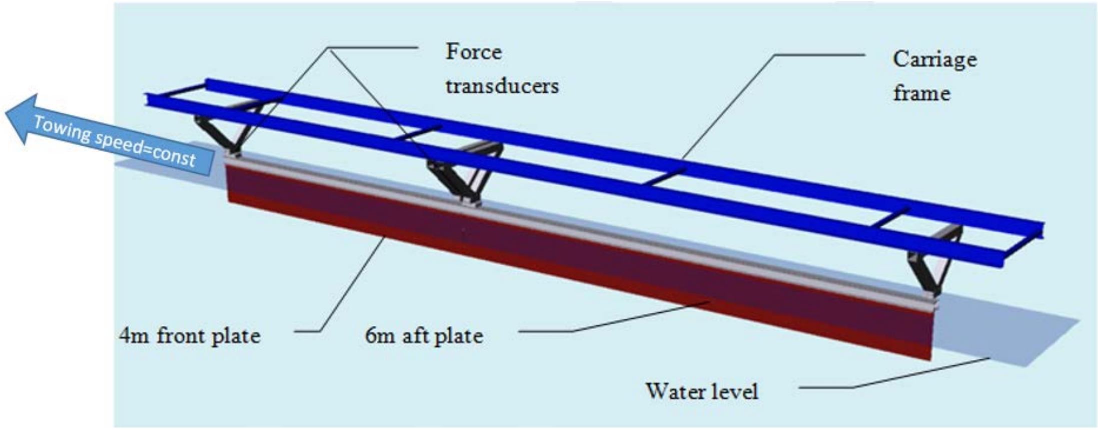
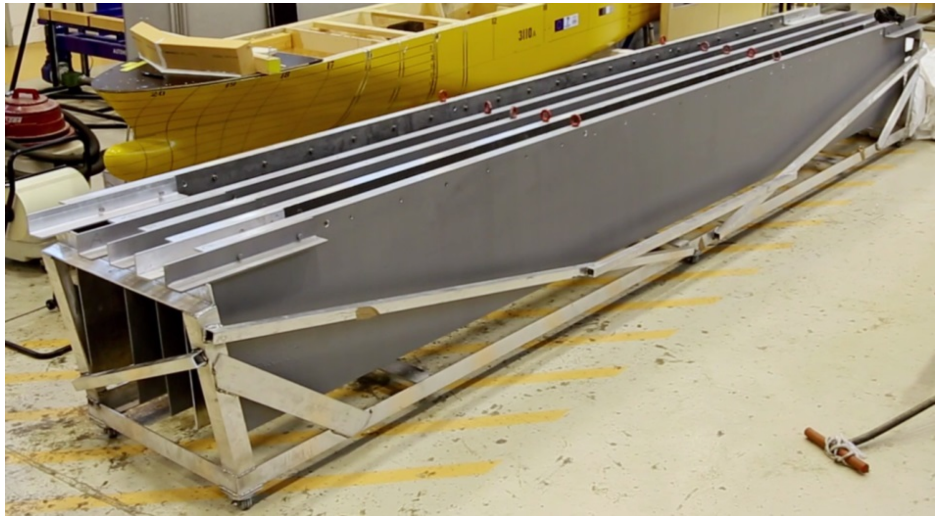


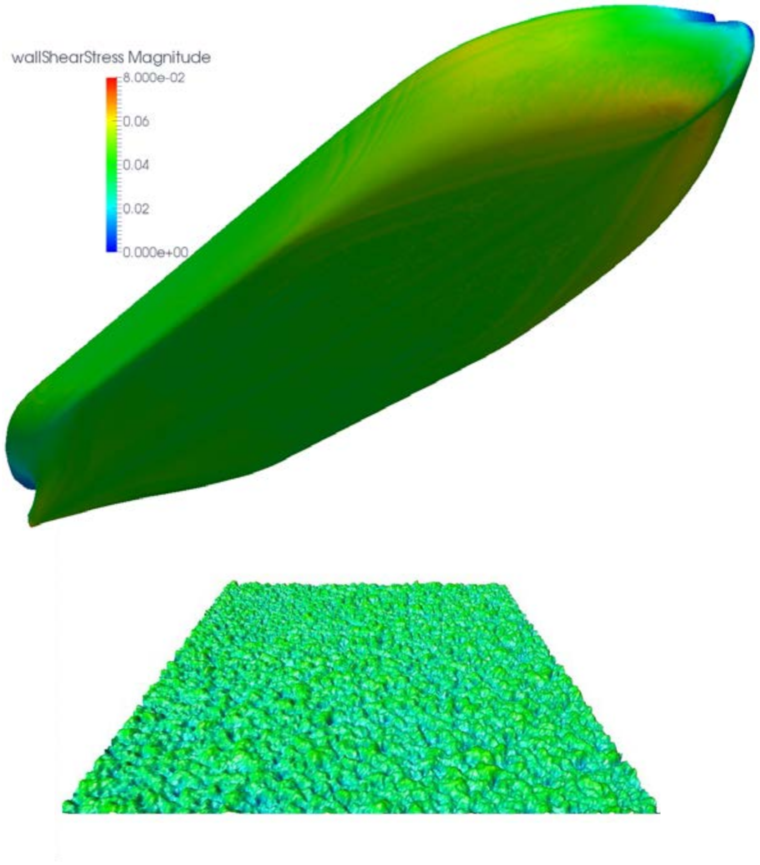
Plate C
Sq=64.44 µm



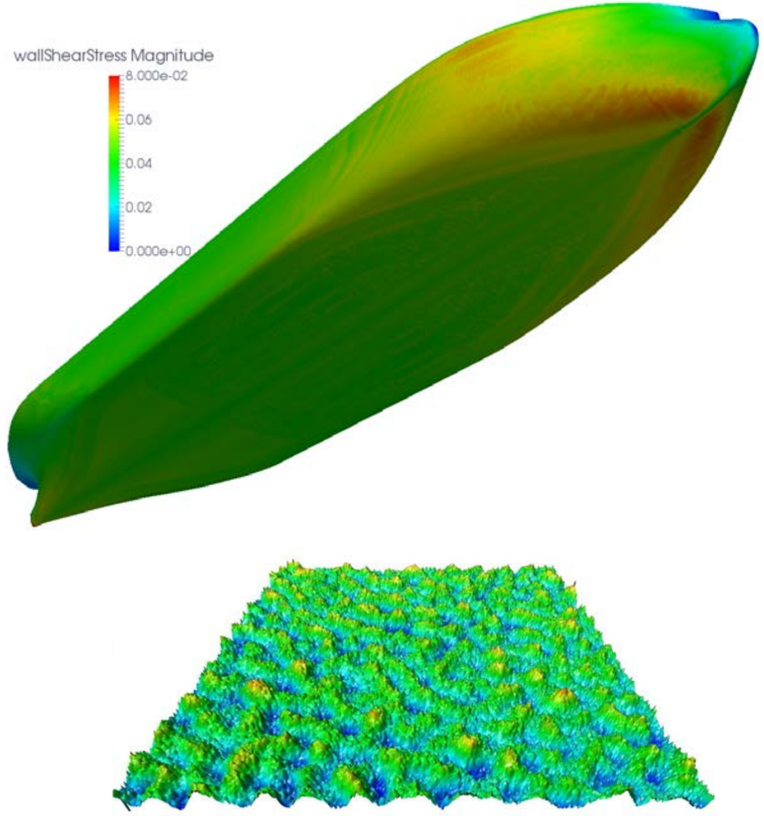
Plates with various quality of the surface coating



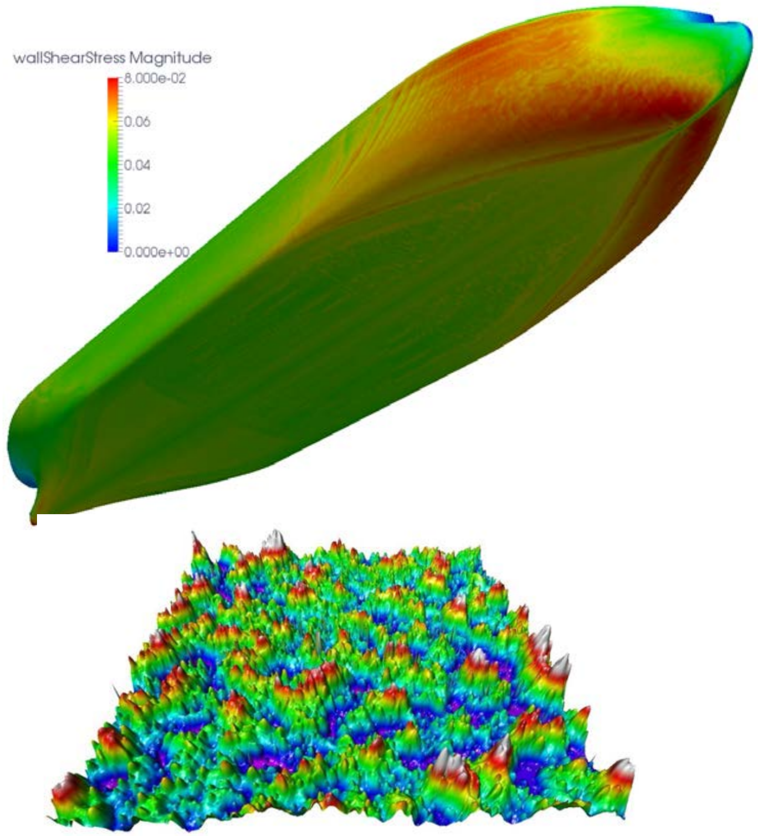
Skin friction on hulls with different surface roughness



Coating A
Sq=8.51 µm

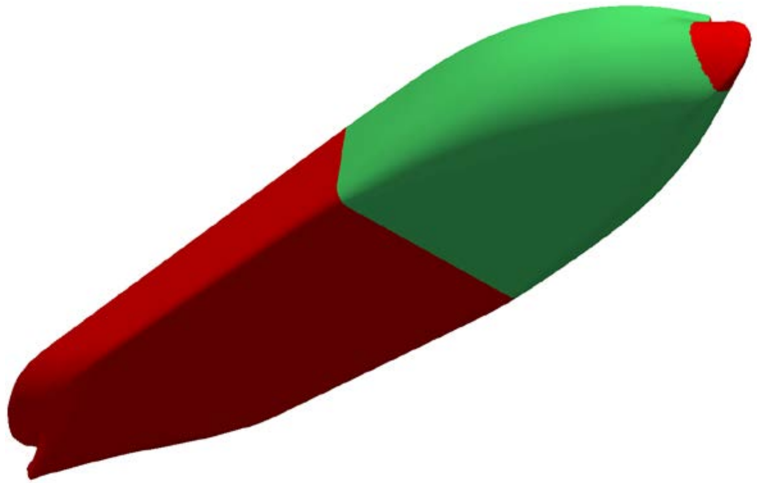


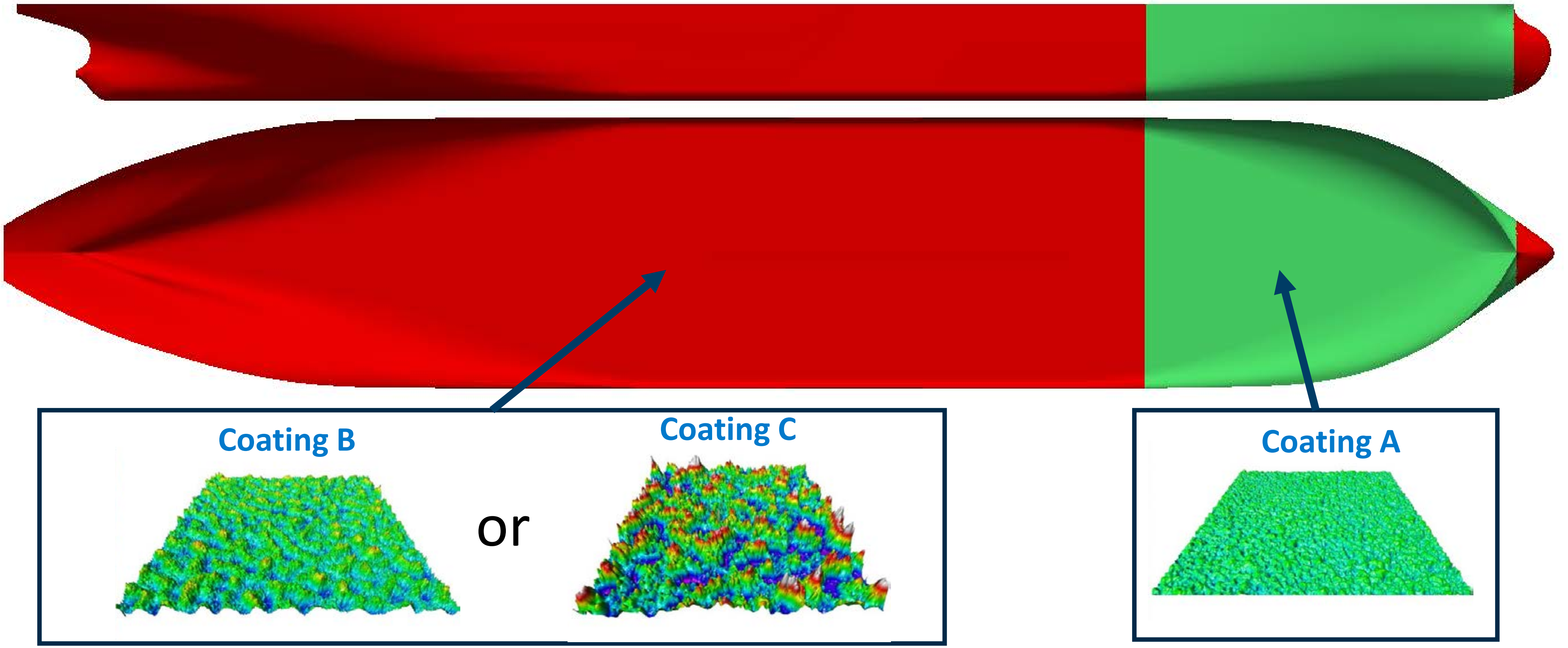
Coating B
Sq=41.15 µm



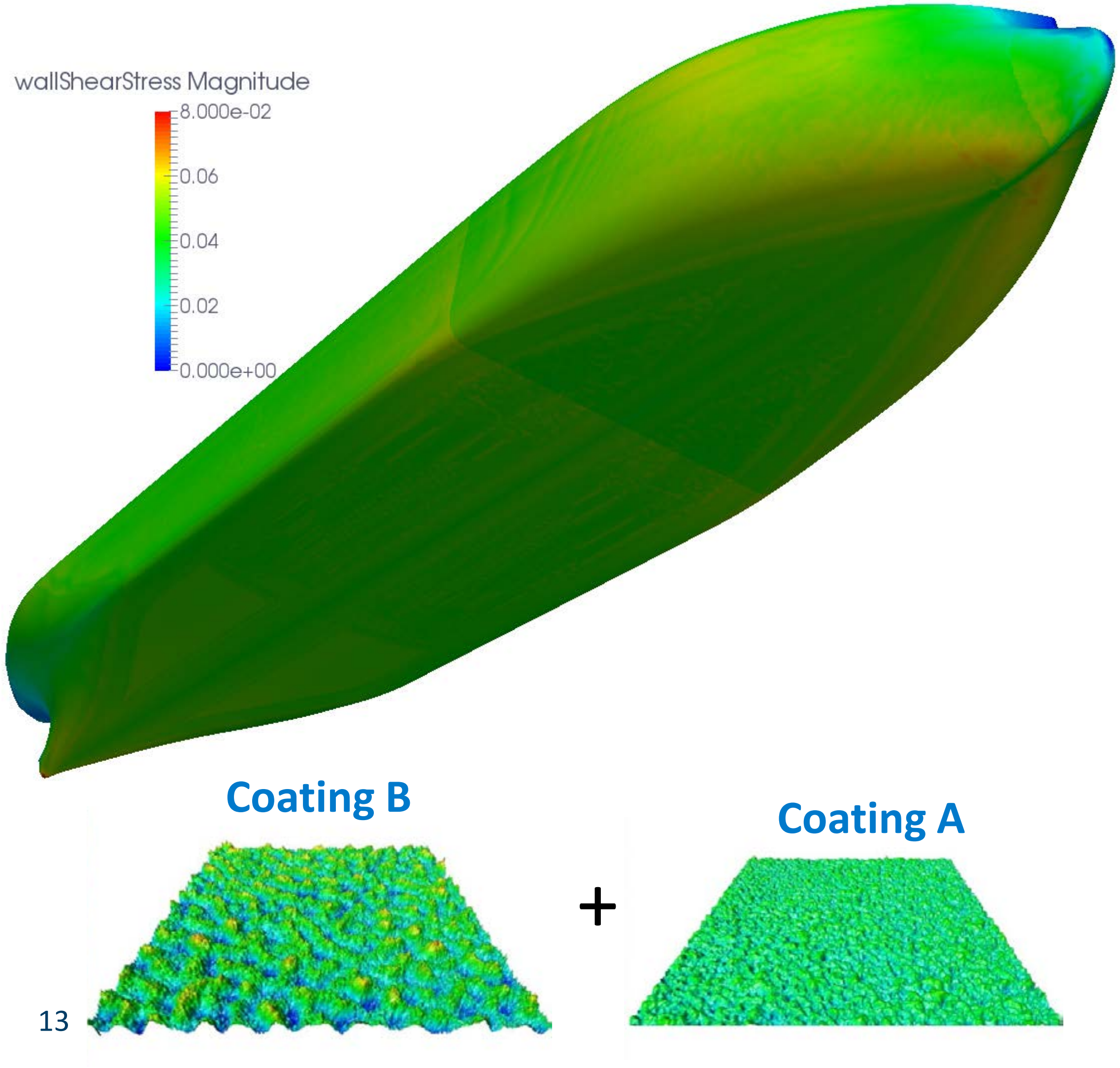
Coating C
Sq=64.44 µm

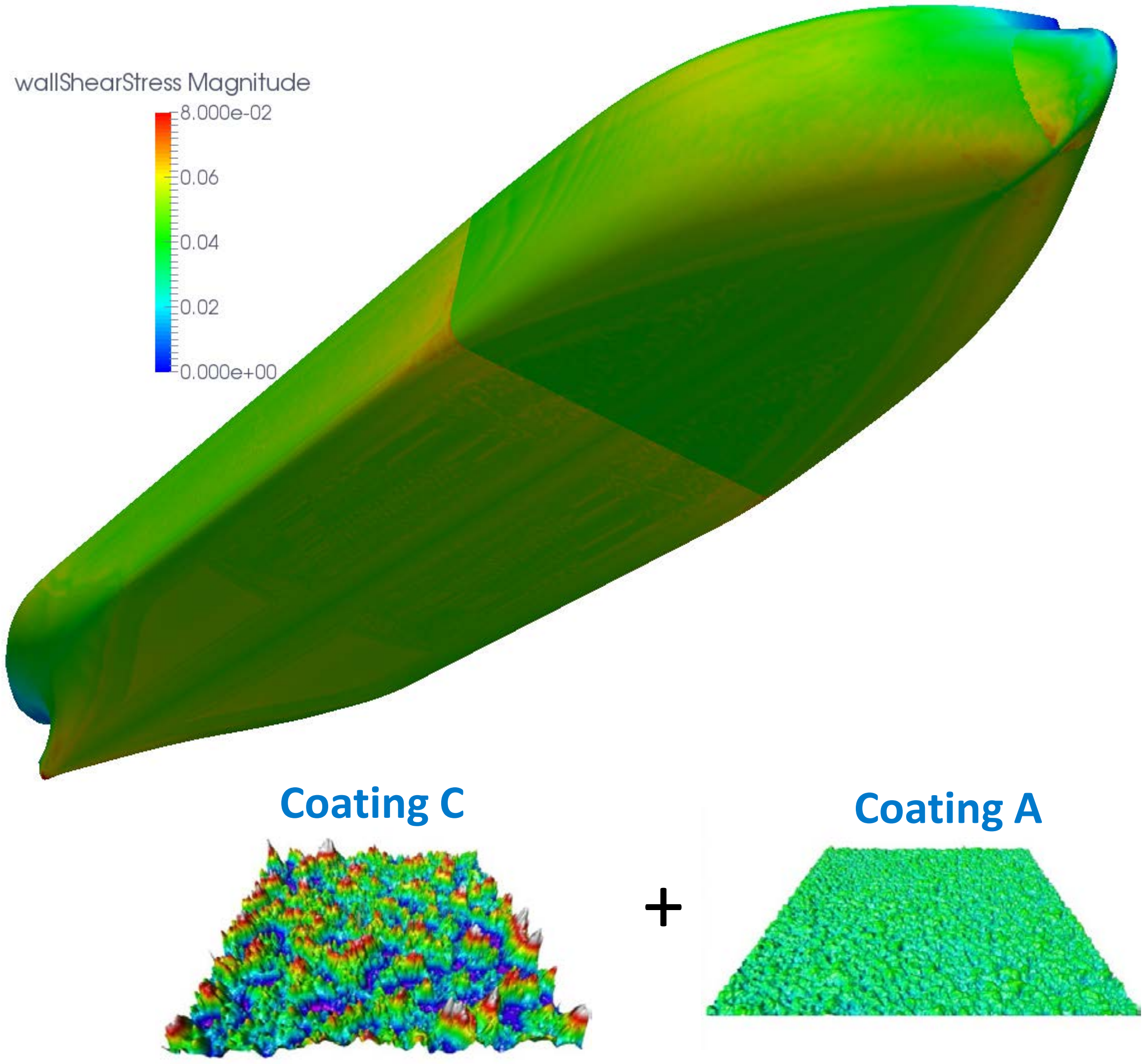
Idea: Apply low roughness coating at areas with high skin friction



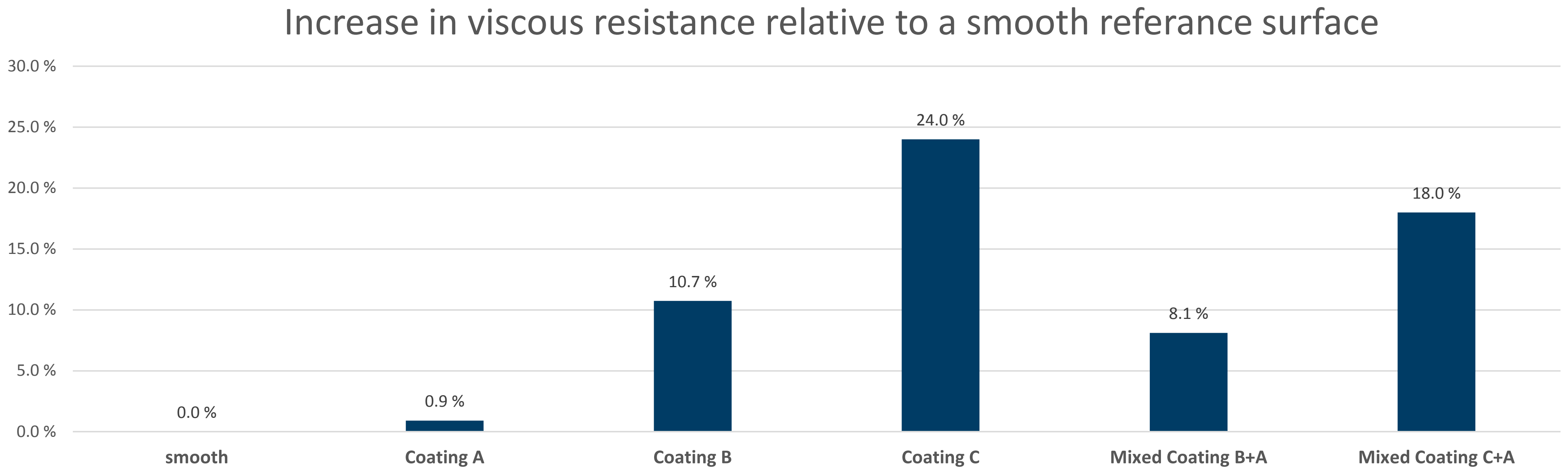


Resulting skin friction





Comparison of results



- **Coating A** is very smooth, adding less than 1% increase in viscous resistance compared to a perfect smooth surface.
- **Coating C** results in an increased viscous resistance of 24%
- Using **Coating C** together with **Coating A** at areas with high skin friction, the increase in viscous resistance is reduced to 18%.

Summary

- The use of CFD has been demonstrated for four different areas
- The resistance/efficiency of the vessel can be significant improved by use of CFD to guidance the optimization of the design
- The examples show usage which span from the **initial hull design phase** to the **vessel operating phase**, including improvements gained by retrofitting energy saving devises and propellers of **existing ships**

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