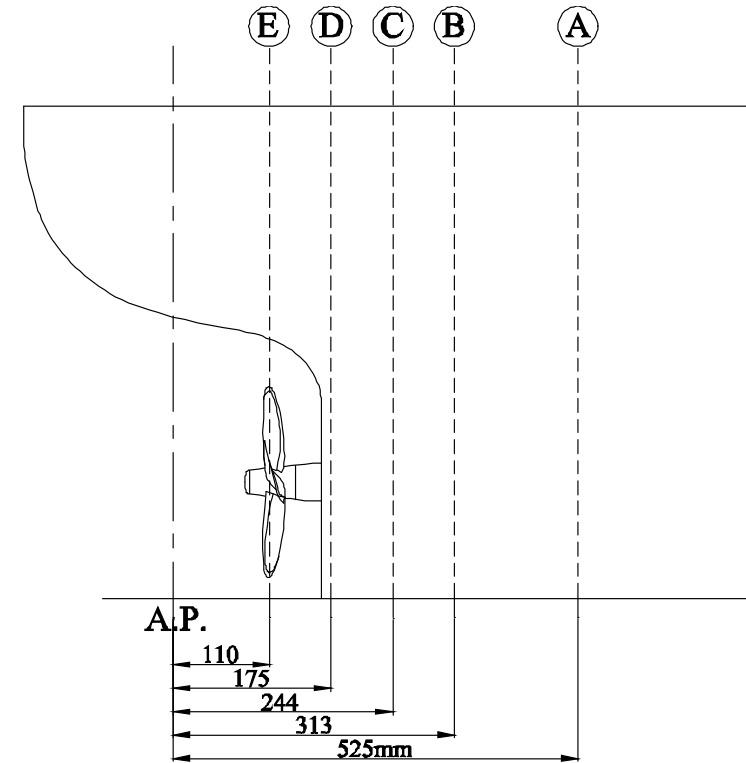
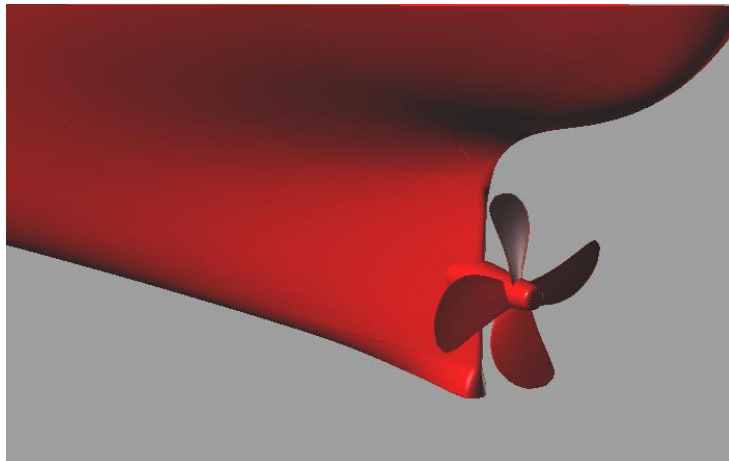
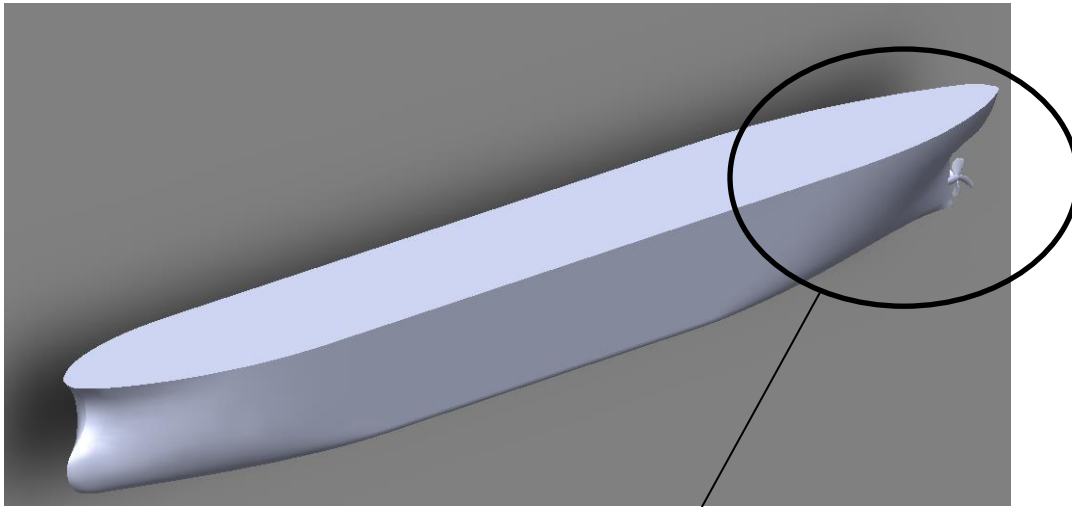


# Master Thesis

## Computation of the Stern Flow of a Full-Form Tanker at Both Model and Full Scale

Francesco Santo

# “Ryuko-Maru Tanker” & Measuring Program

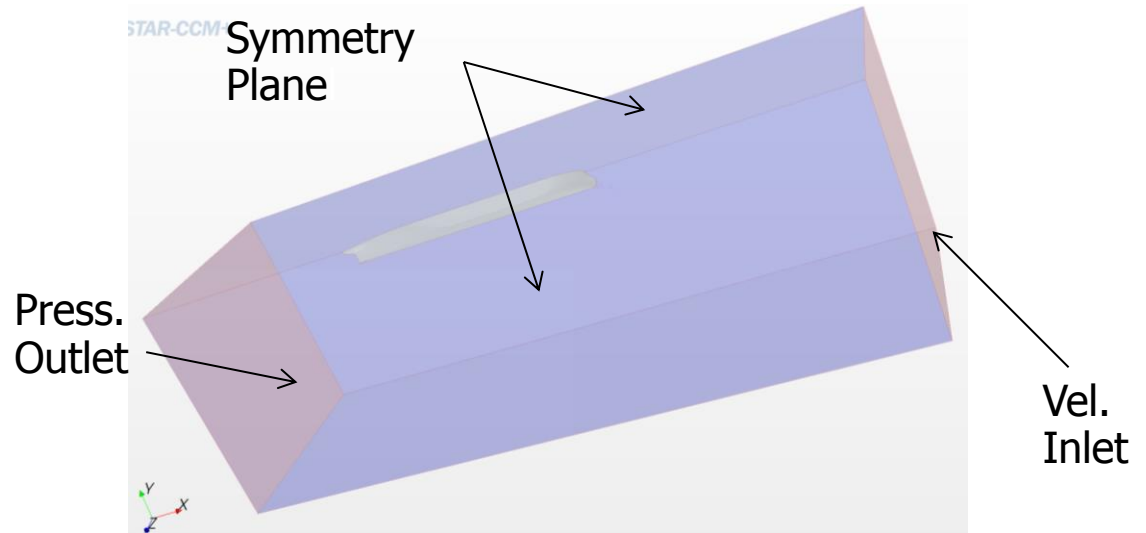


Surface preparation &  
Domain Definition

Boudary Conditions

Mesh Refinement

Physical Models settings



Coarse Mesh  $\approx 1M$

Medium Mesh  $\approx 2-3M$

Fine Mesh  $\approx 7M$

Turbulent Flow

Segregated flow

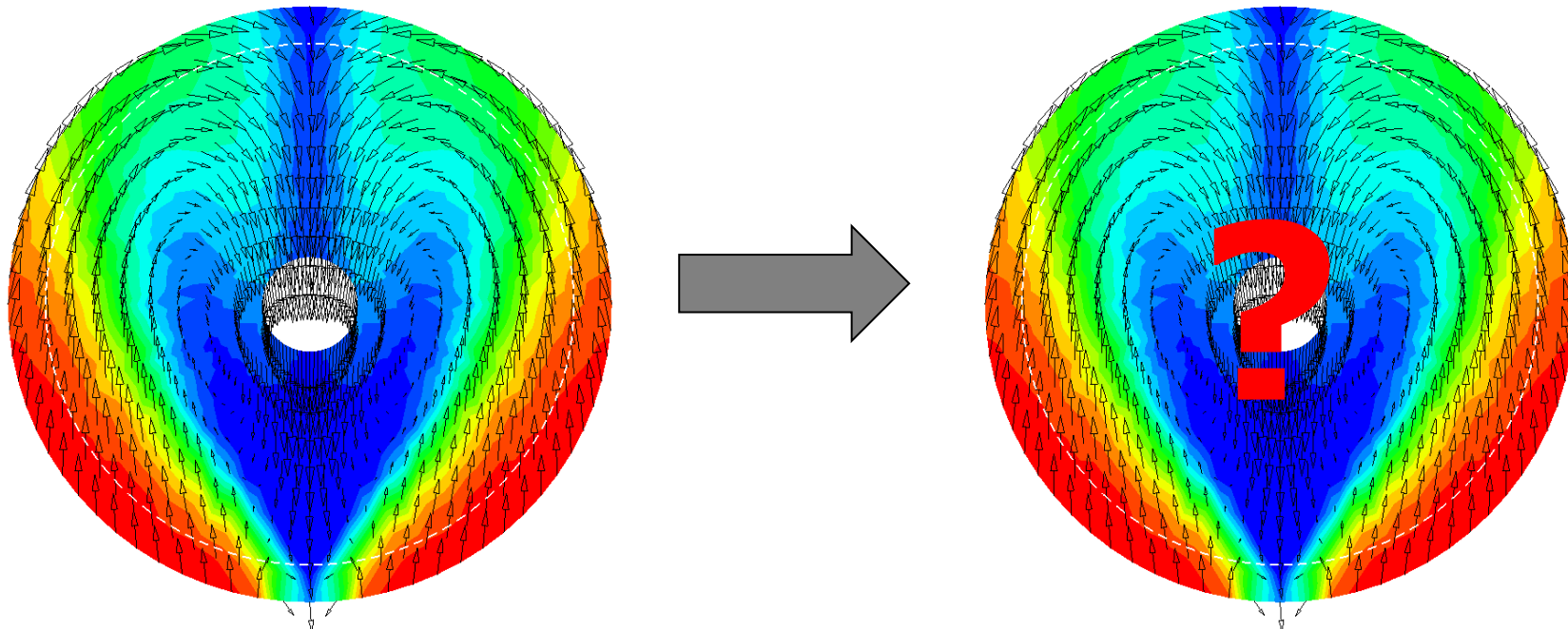
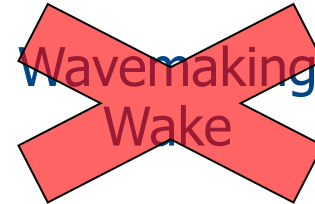
SST K- $\omega$

Realizable K- $\epsilon$

RST

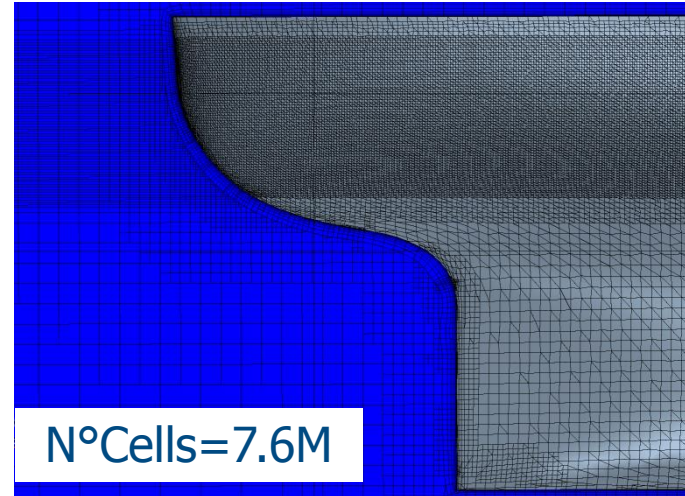
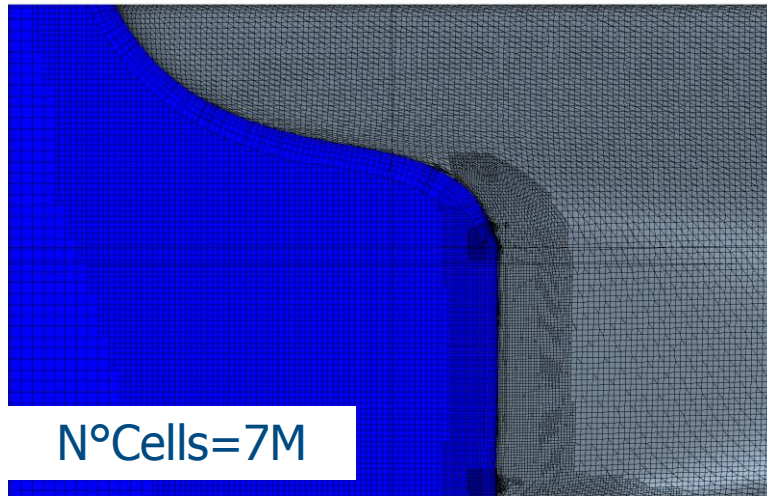
# Free Surface Effect

$$\text{Total Wake} = \text{Displacement Wake} + \text{Friction Wake} + \text{Wavemaking Wake}$$

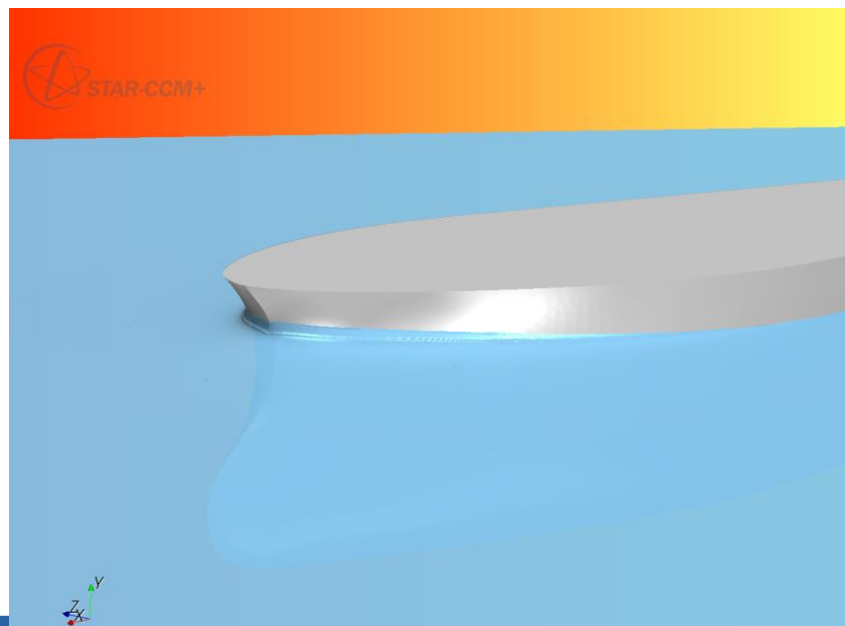


## Free Surface Effect (Drawback)

- ▶ Different Mesh refinement

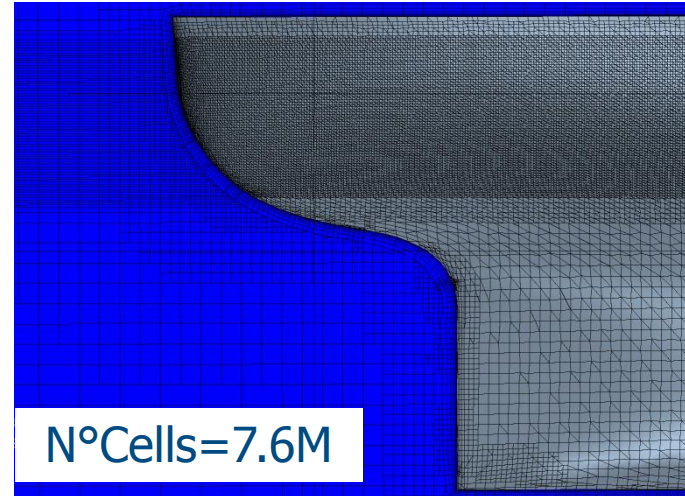
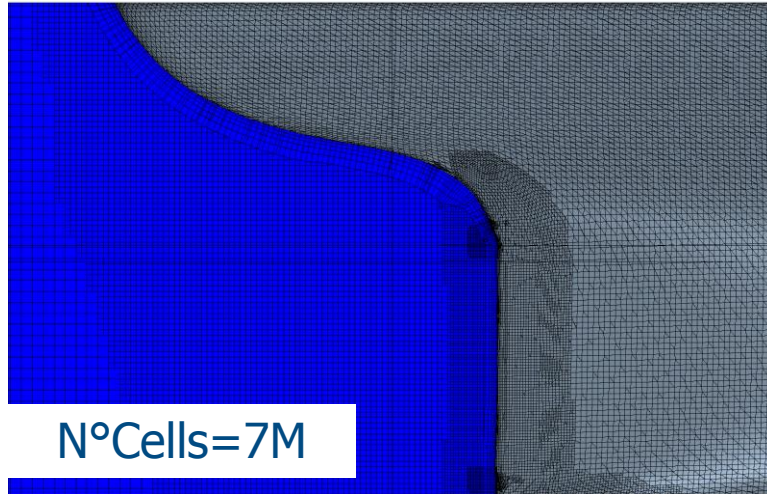


- ▶ Elevated time to achieve steady state

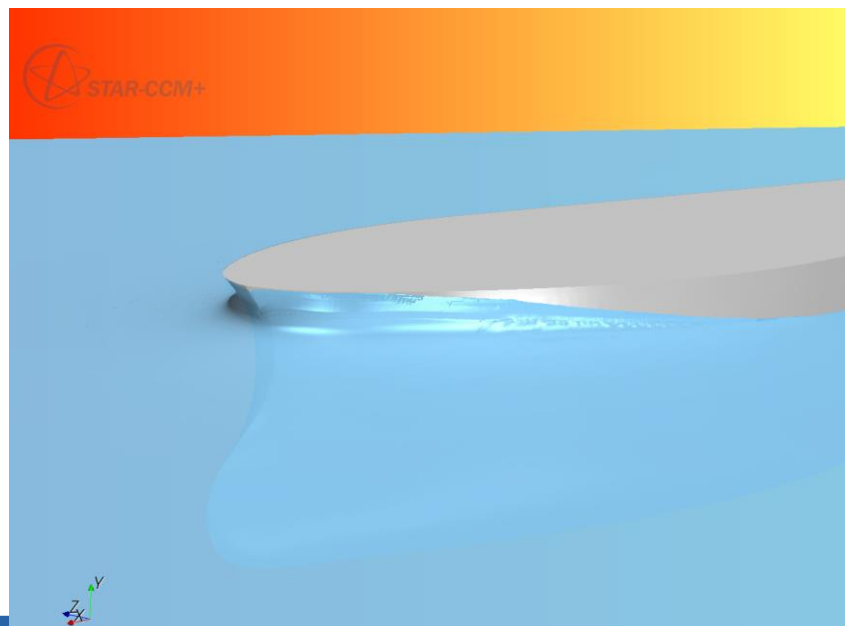


## Free Surface Effect (Drawback)

- ▶ Different Mesh refinement

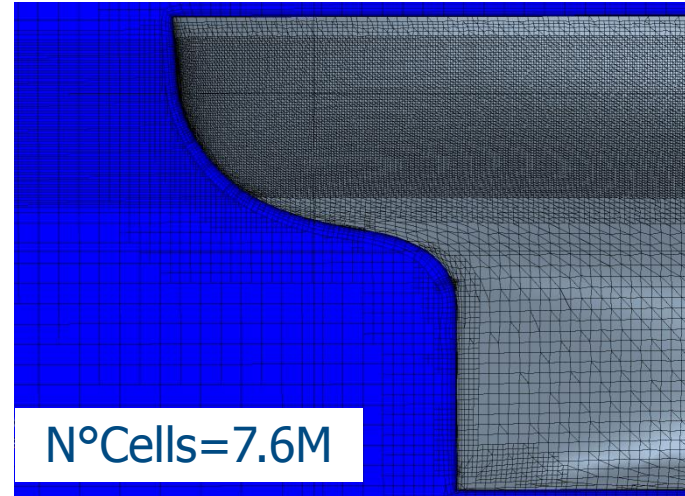
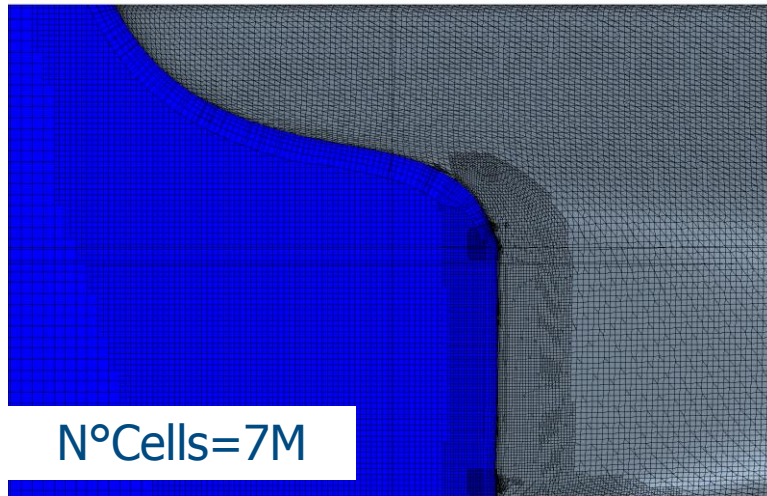


- ▶ Elevated time to achieve steady state

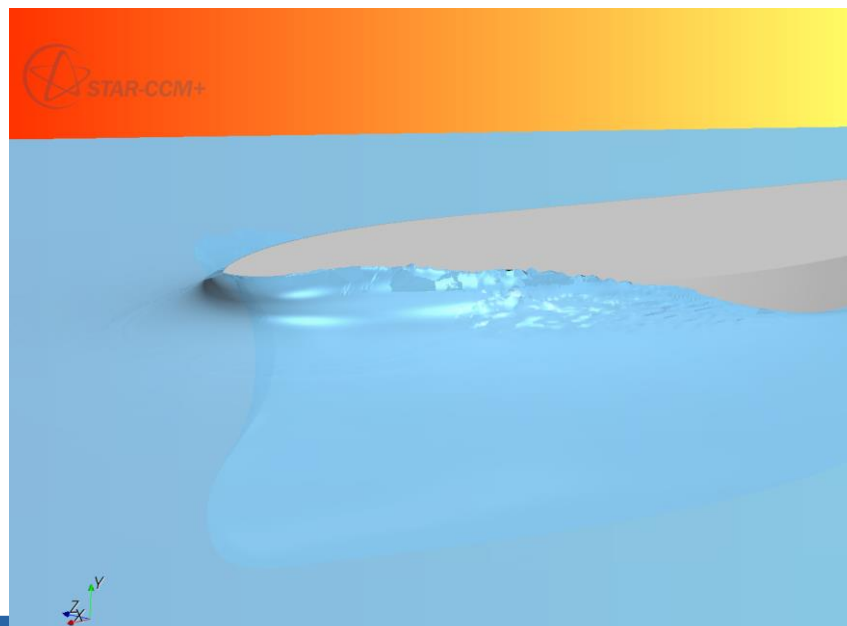


## Free Surface Effect (Drawback)

- ▶ Different Mesh refinement

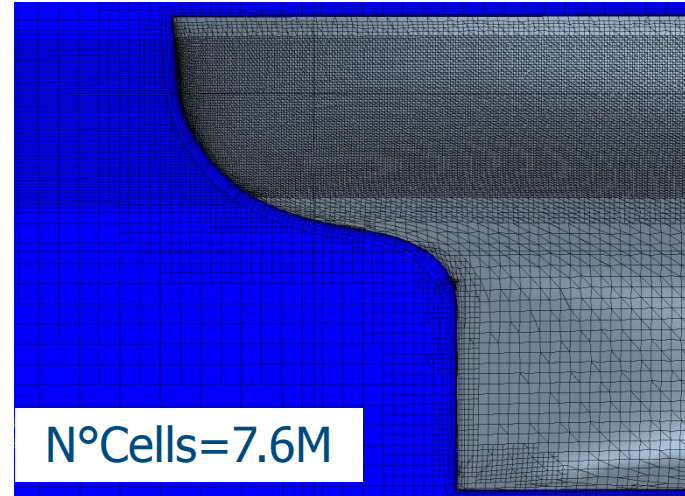
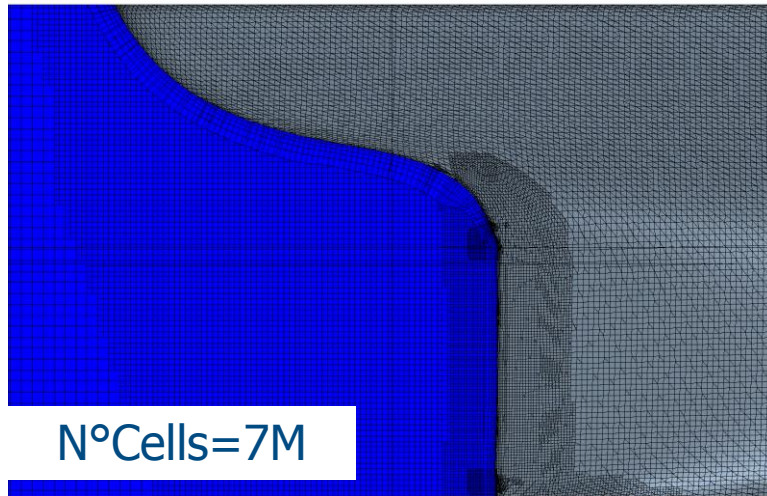


- ▶ Elevated time to achieve steady state

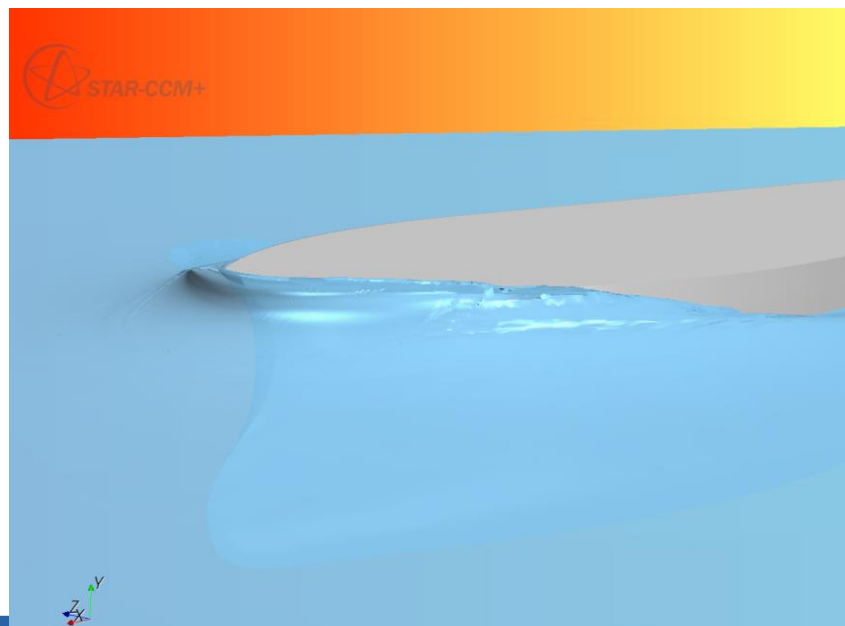


## Free Surface Effect (Drawback)

- ▶ Different Mesh refinement



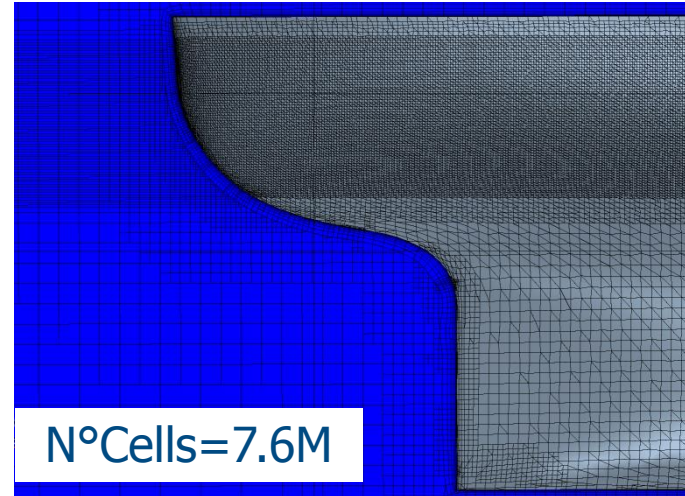
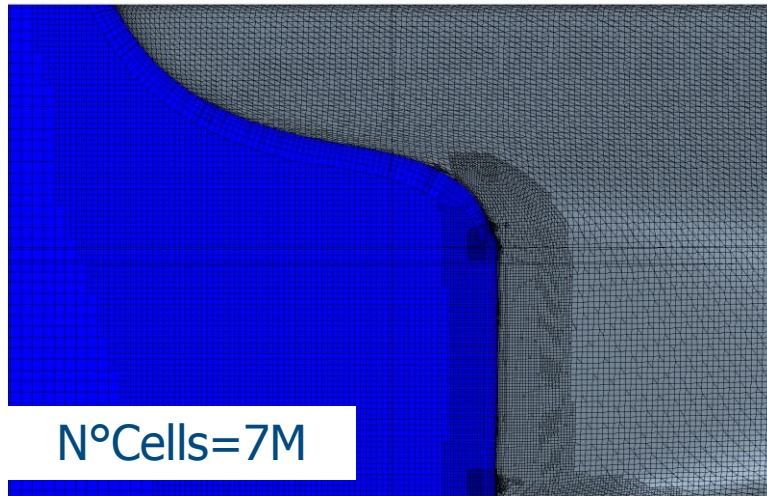
- ▶ Elevated time to achieve steady state



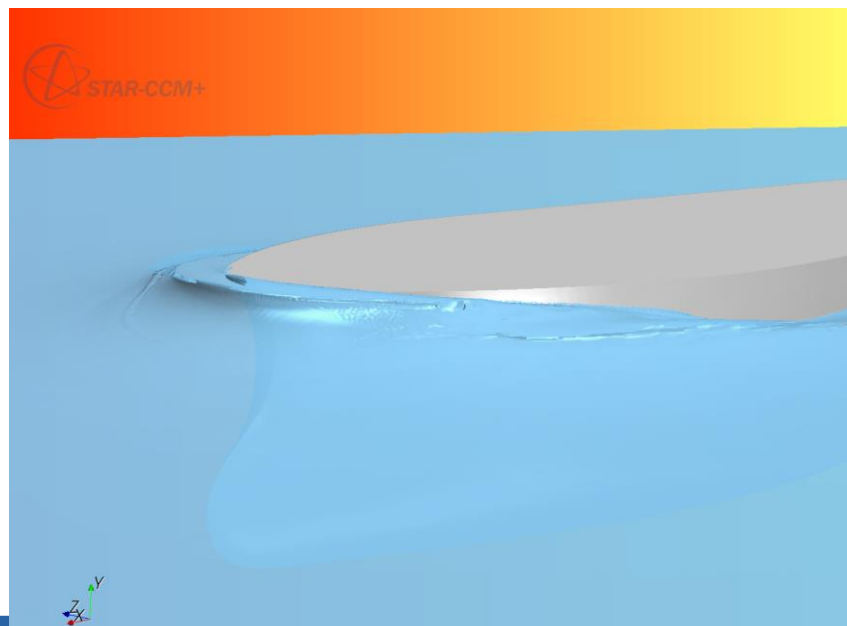


## Free Surface Effect (Drawback)

- ▶ Different Mesh refinement

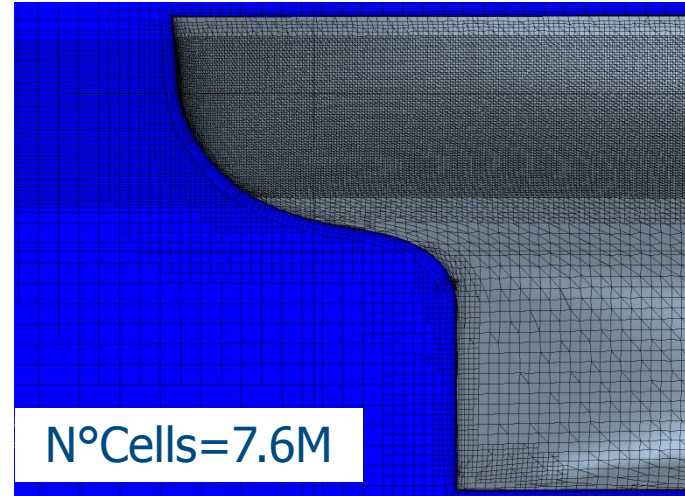
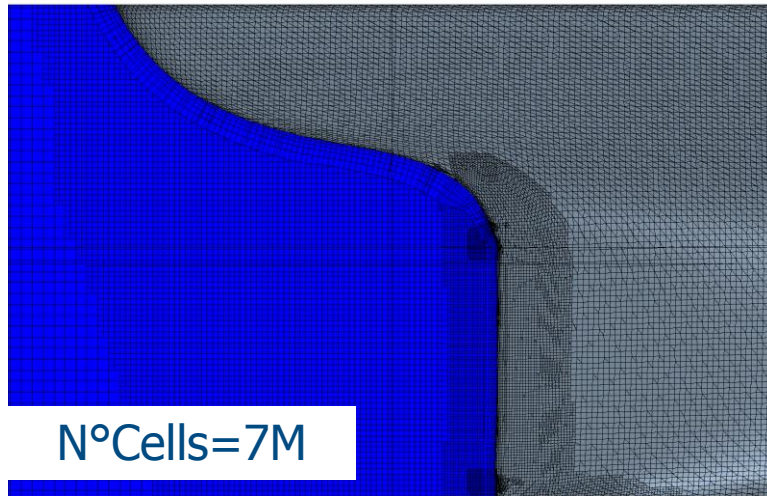


- ▶ Elevated time to achieve steady state

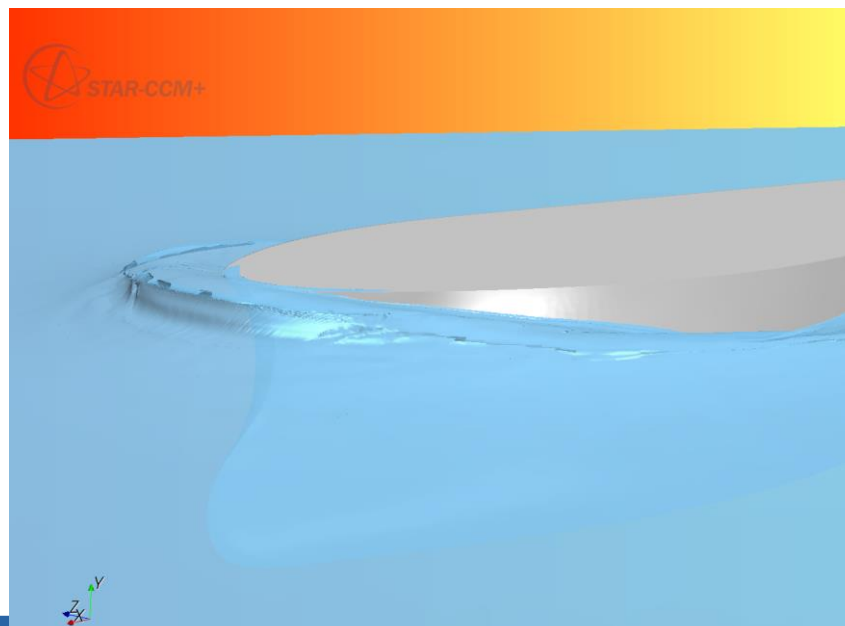


## Free Surface Effect (Drawback)

- ▶ Different Mesh refinement

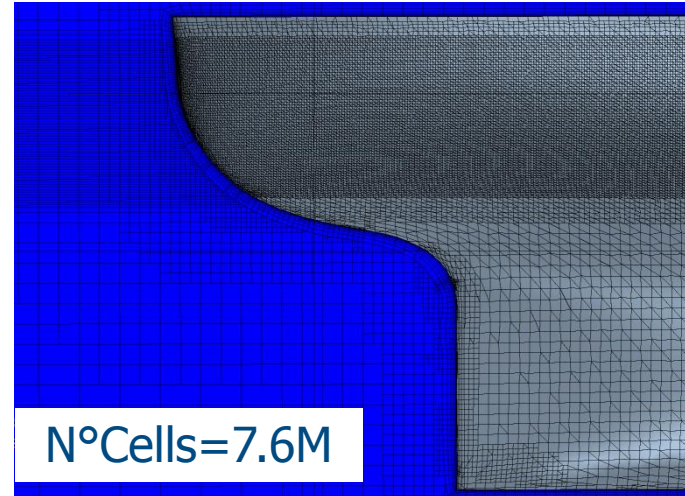
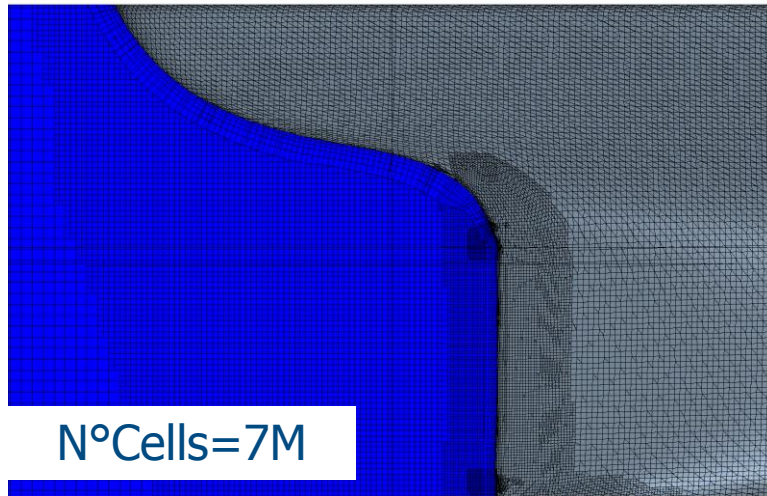


- ▶ Elevated time to achieve steady state

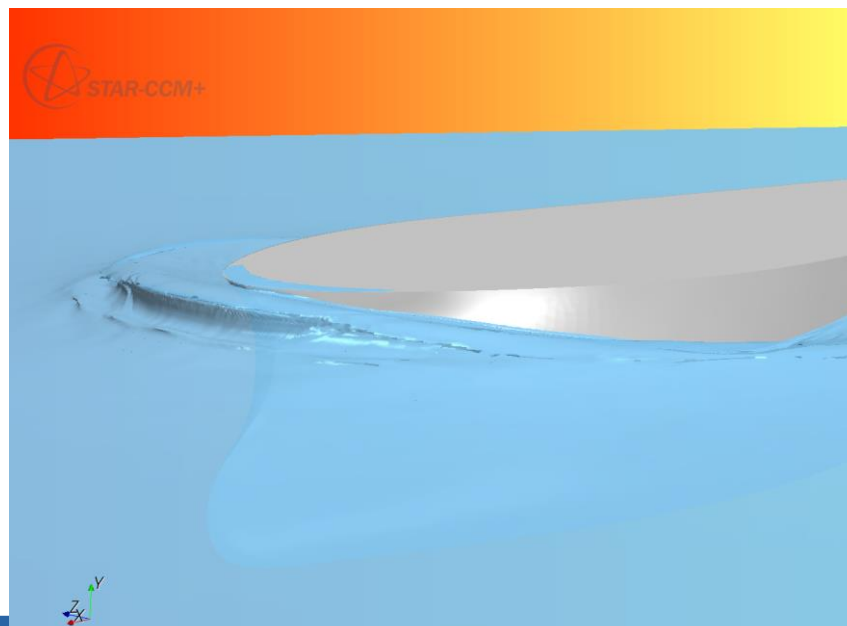


## Free Surface Effect (Drawback)

- ▶ Different Mesh refinement

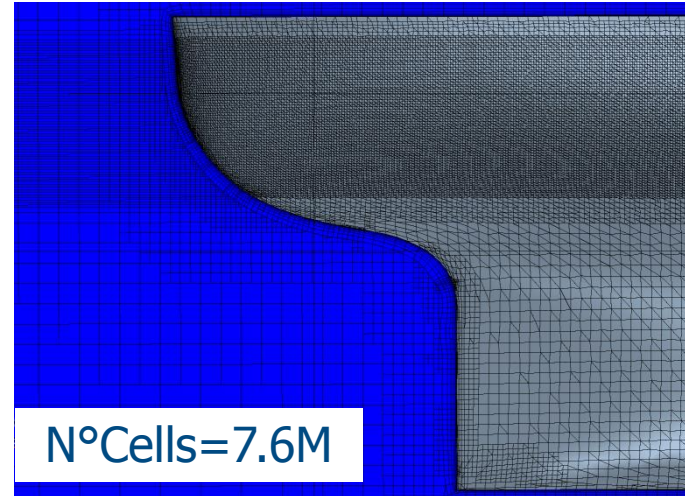
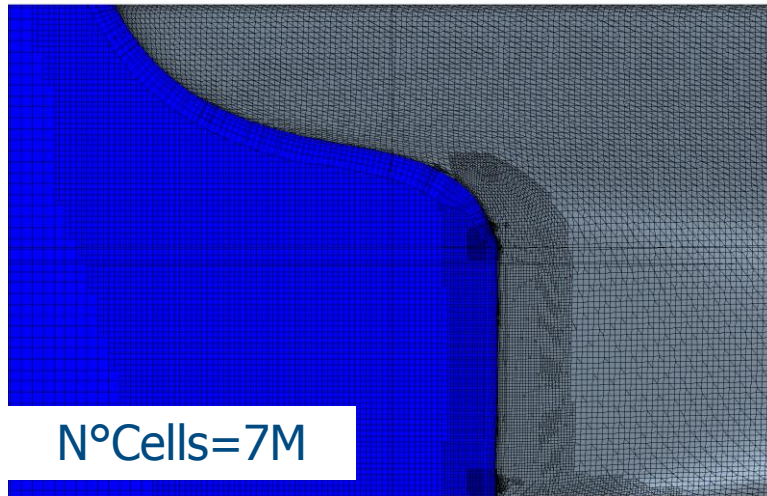


- ▶ Elevated time to achieve steady state

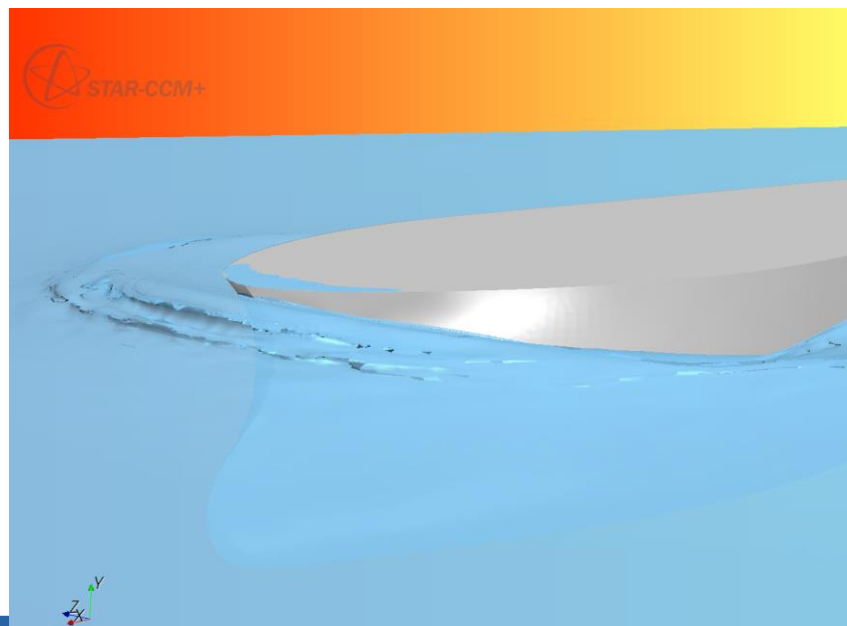


## Free Surface Effect (Drawback)

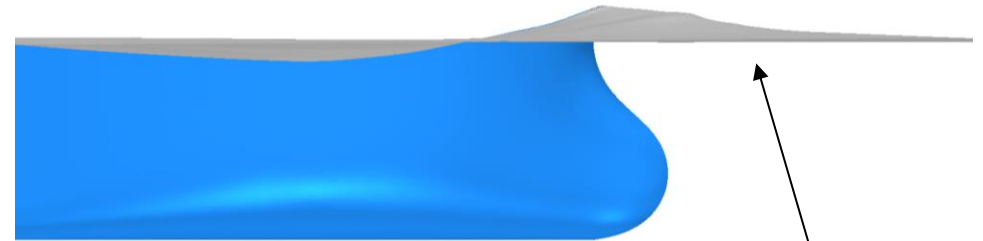
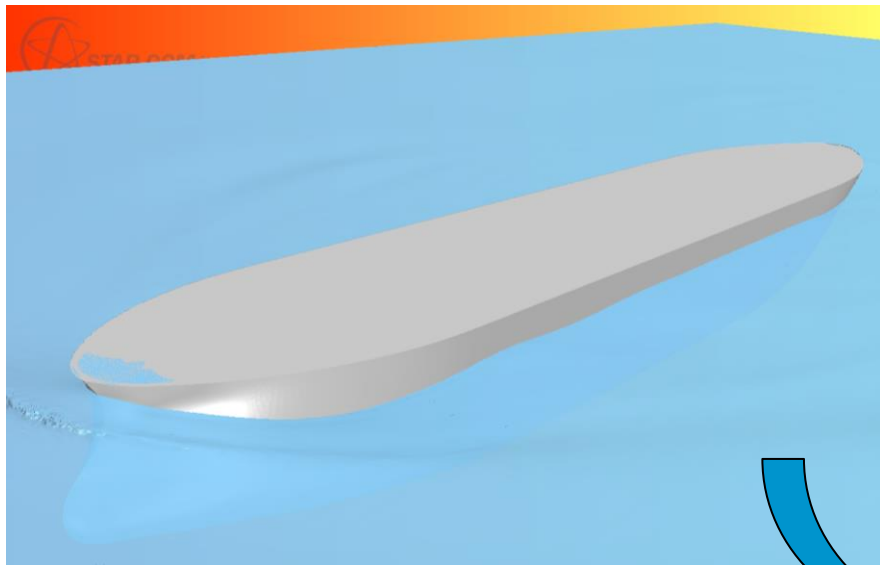
- ▶ Different Mesh refinement



- ▶ Elevated time to achieve steady state

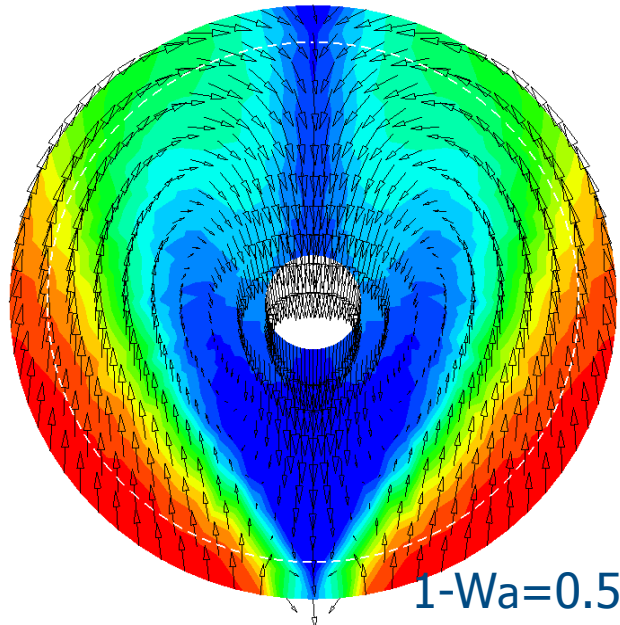


# Free Surface Effect



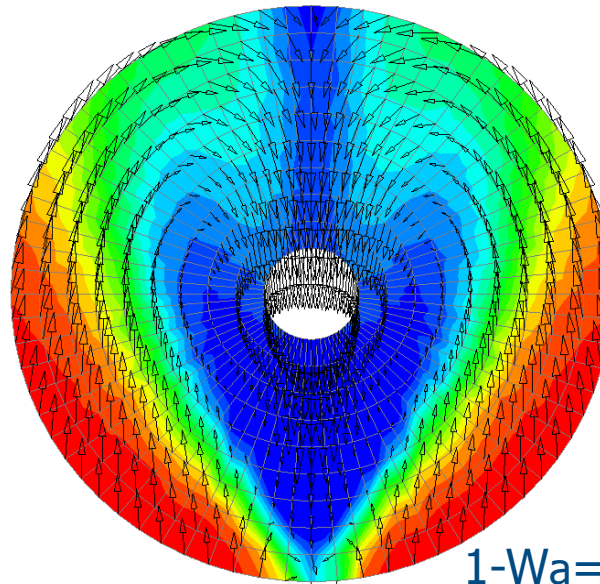
Solid Boundary

No Free Surface



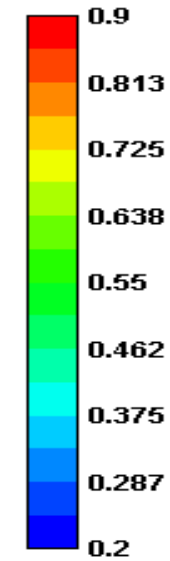
$1-Wa=0.504$

Free surface

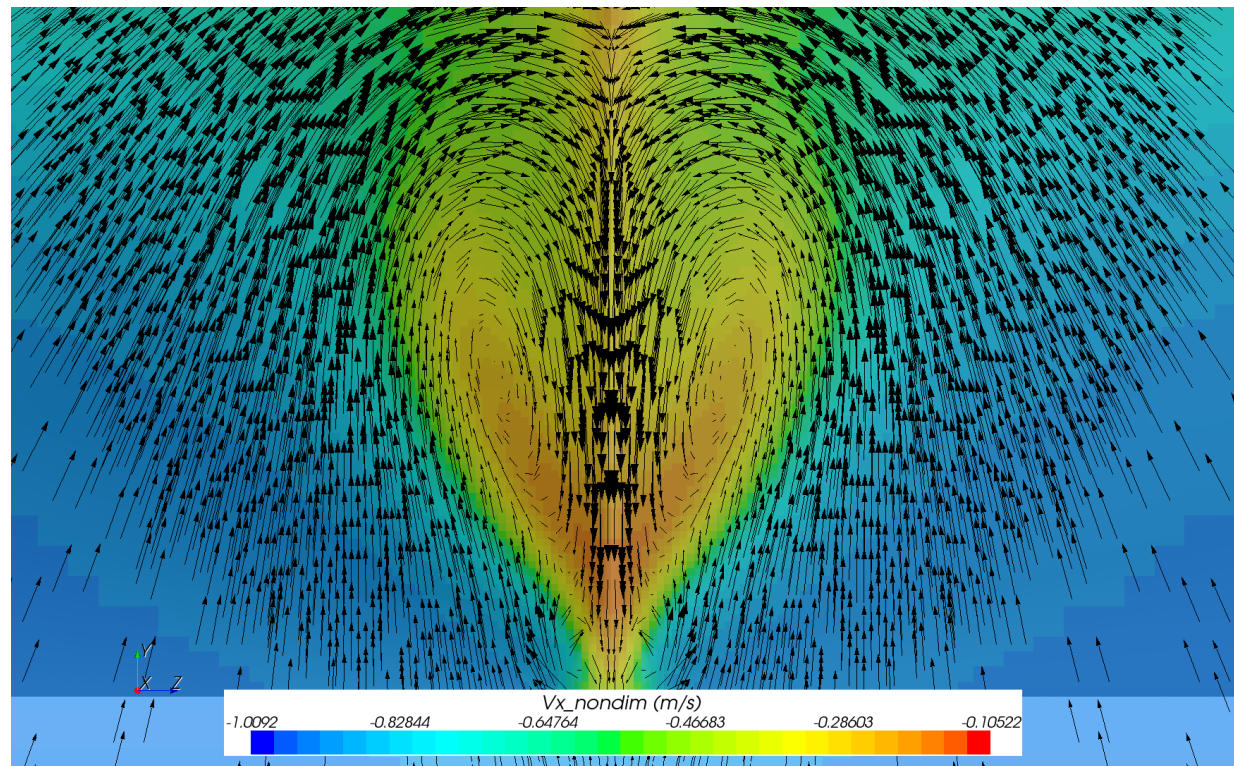


$1-Wa=0.502$

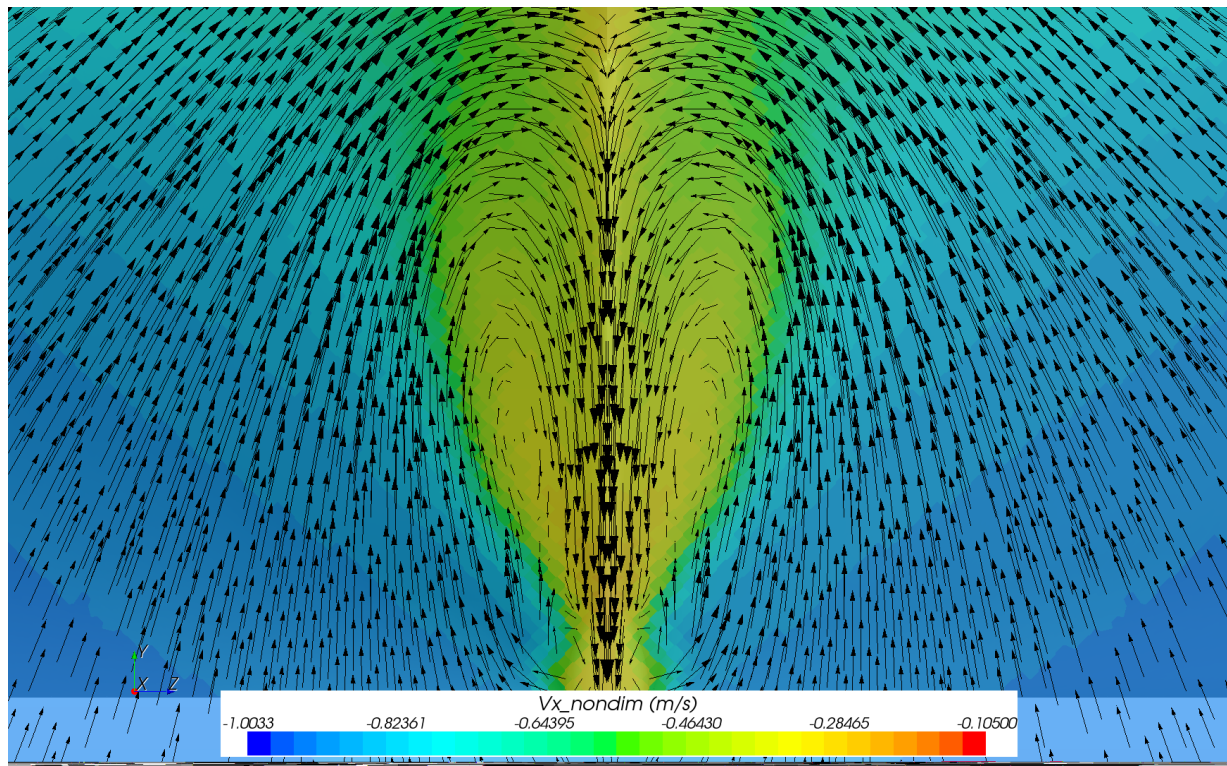
$V_x/V_{Ship}$



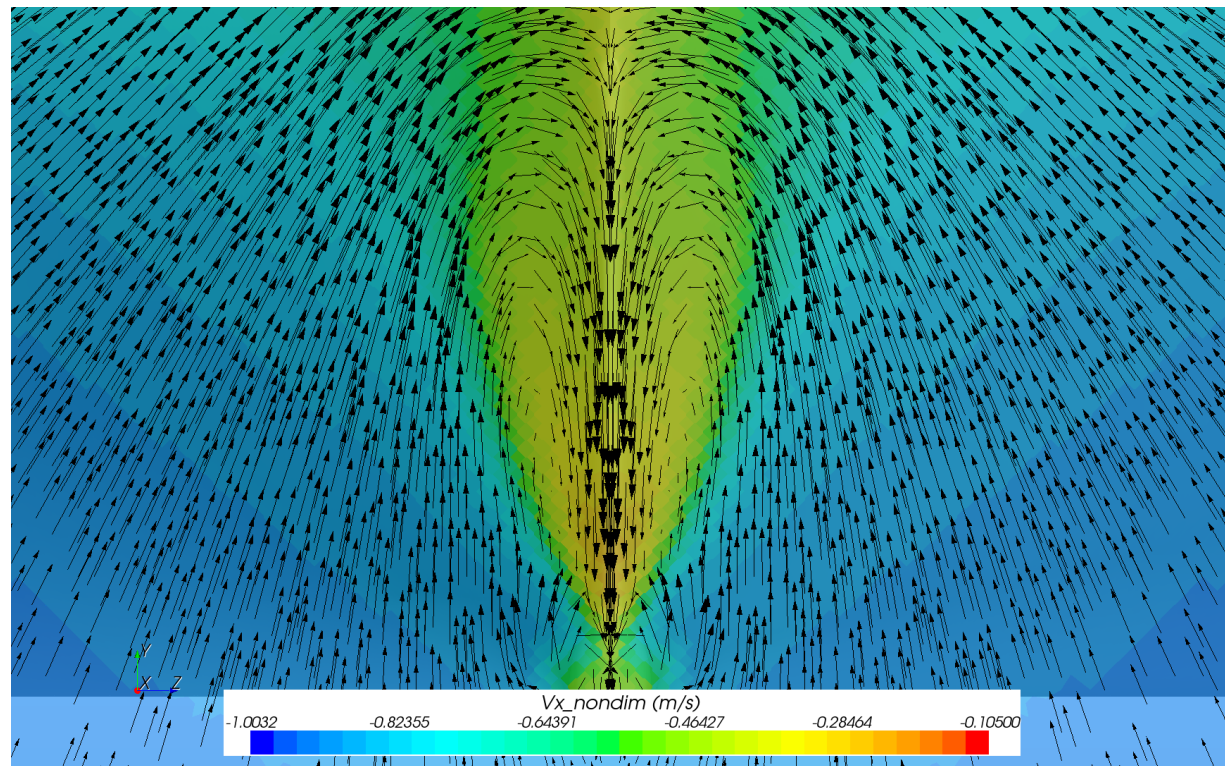
## Model Scale 7m



Length=30m

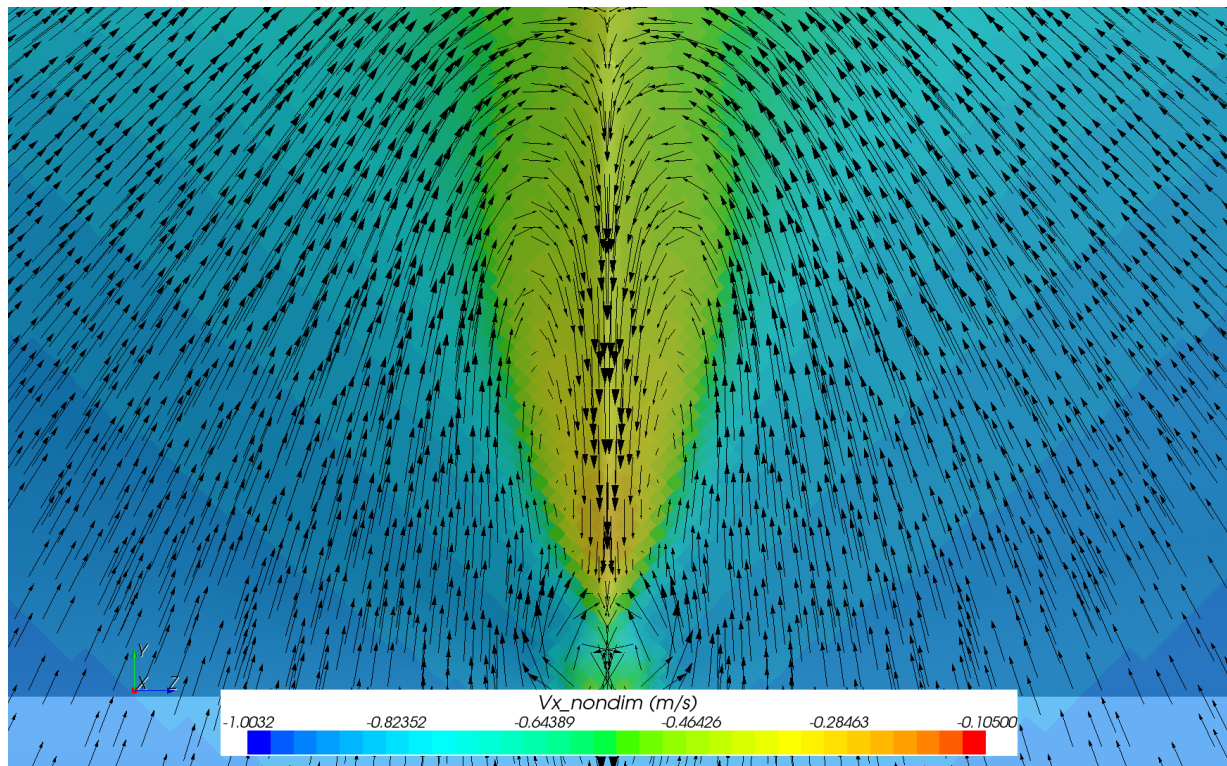


Length=120m



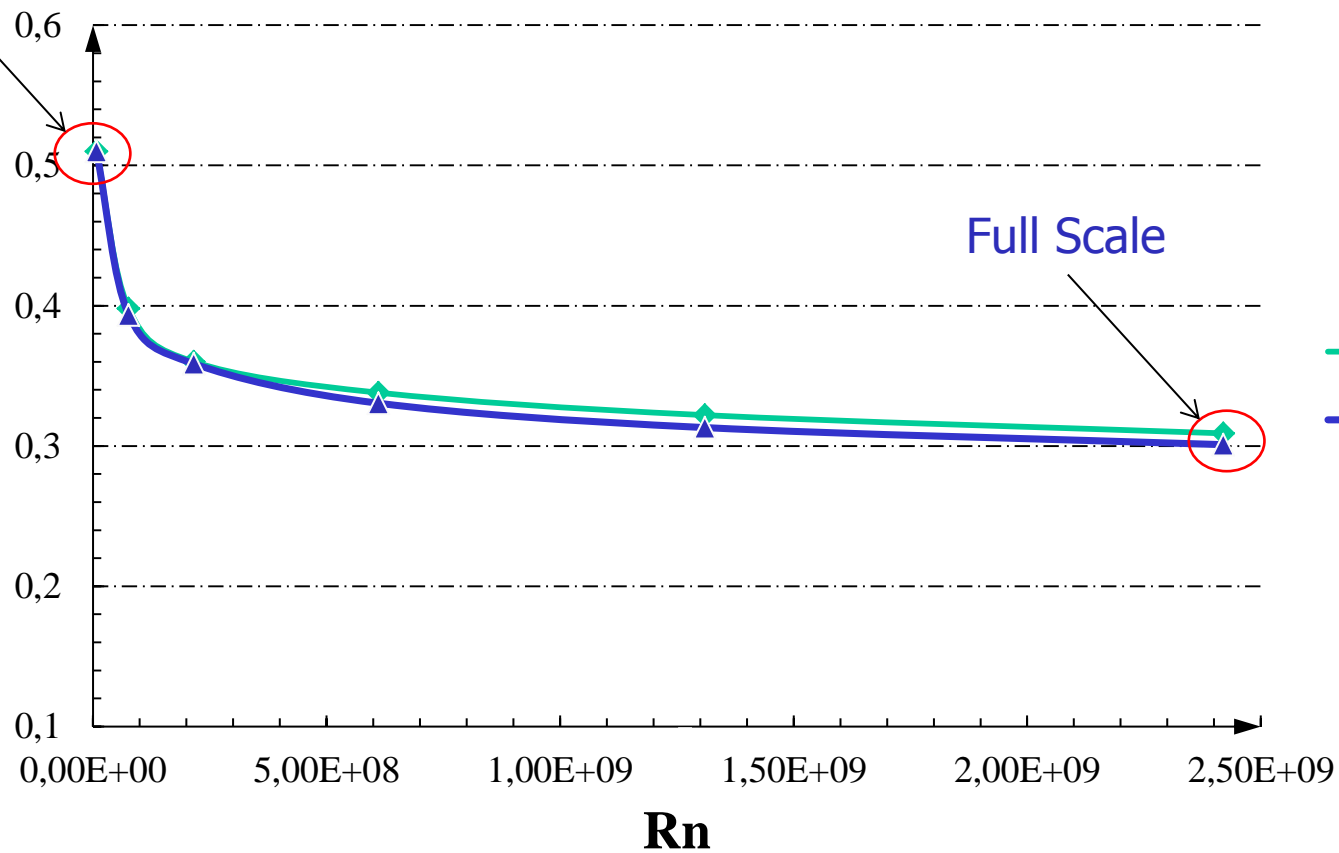


## Full Scale 300m



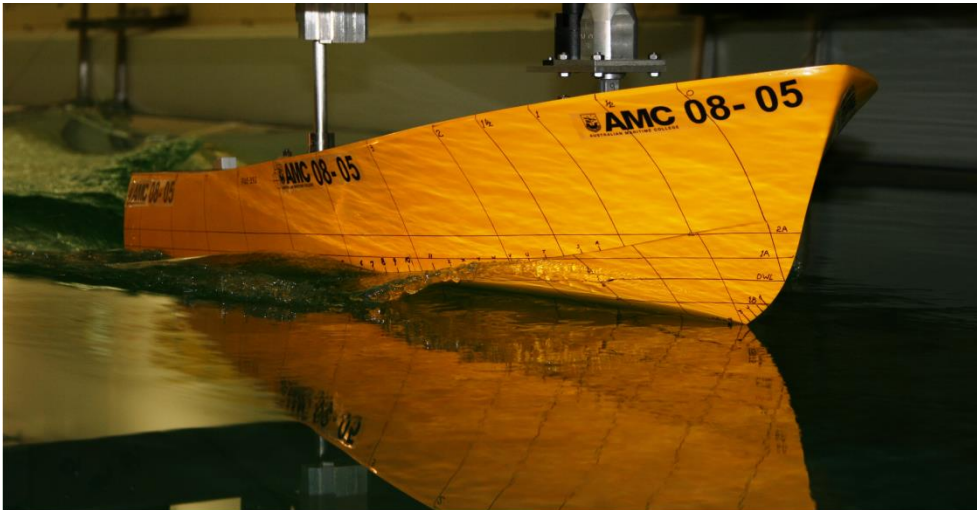
## W Comparison

Model Scale

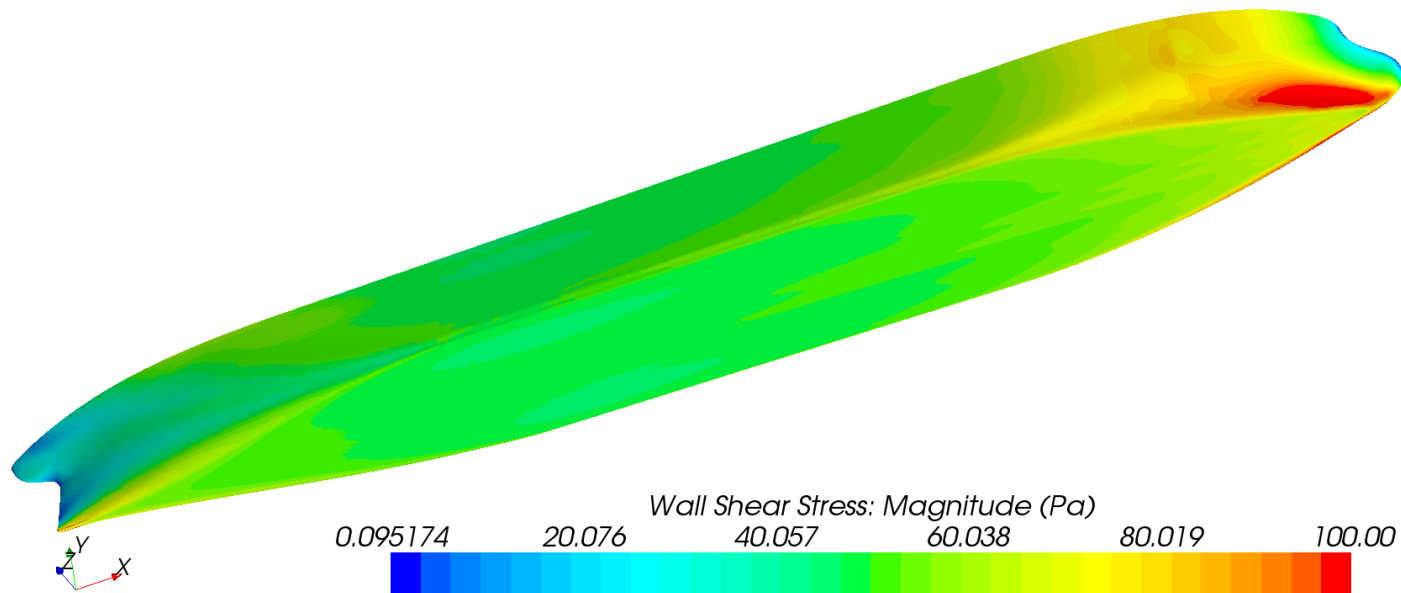


- ◆ w Computed
- ▲ w Sasajima

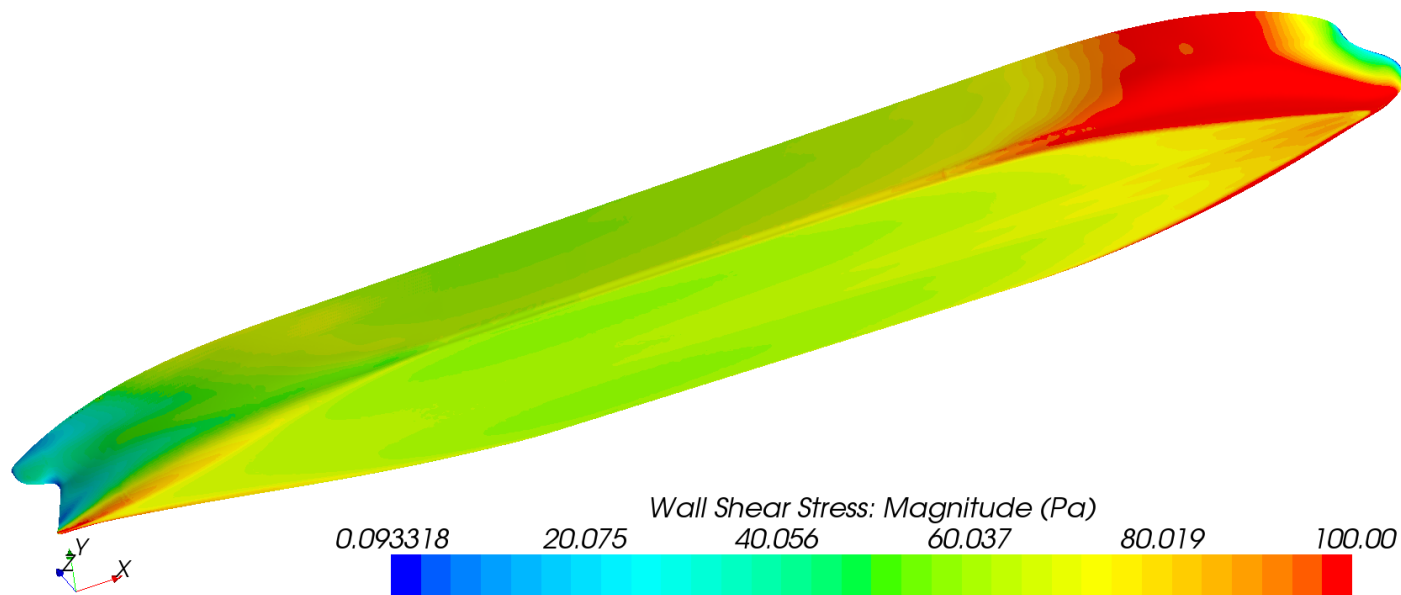
$$W_S \propto W_M \frac{C_{FS}}{C_{FM}}$$



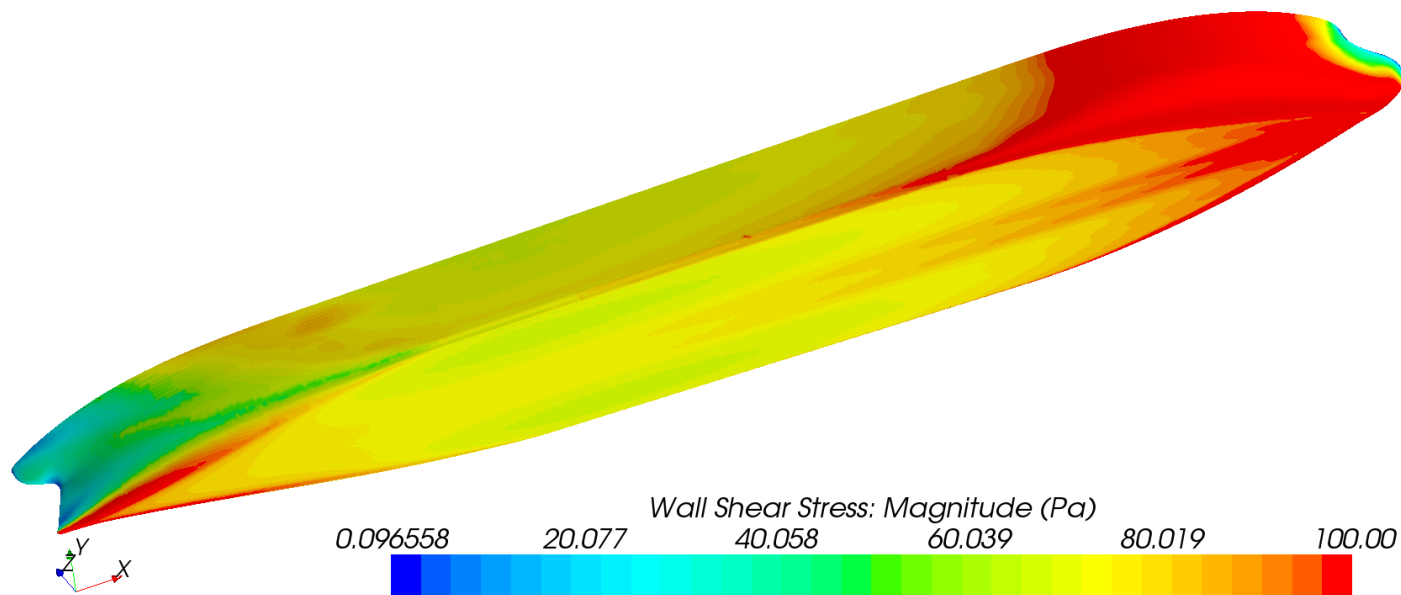
## ► Increase of shear stress (smooth)



- ▶ Increase of shear stress (New ship=200 $\mu\text{m}$ )

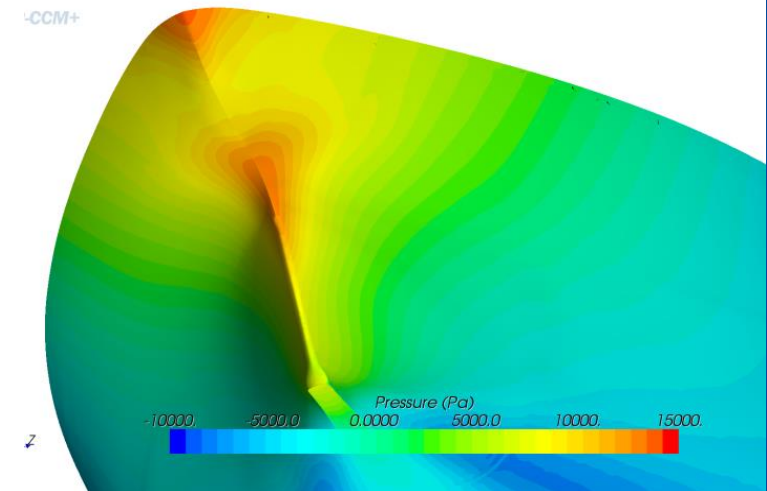
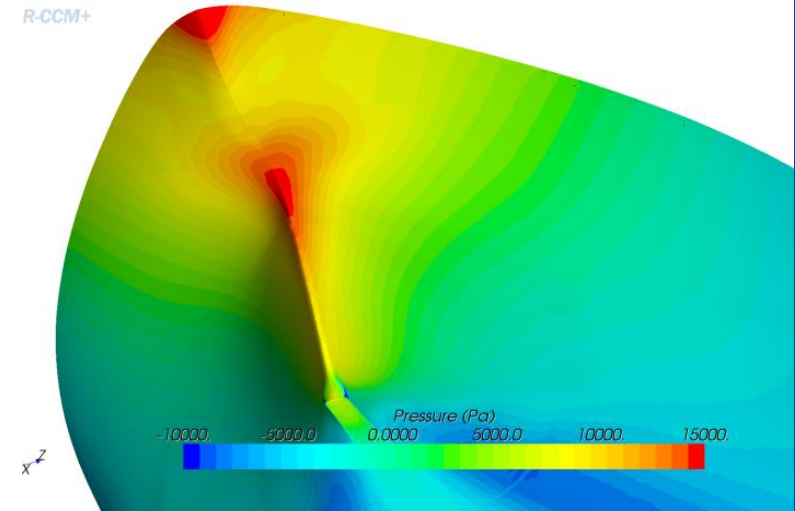
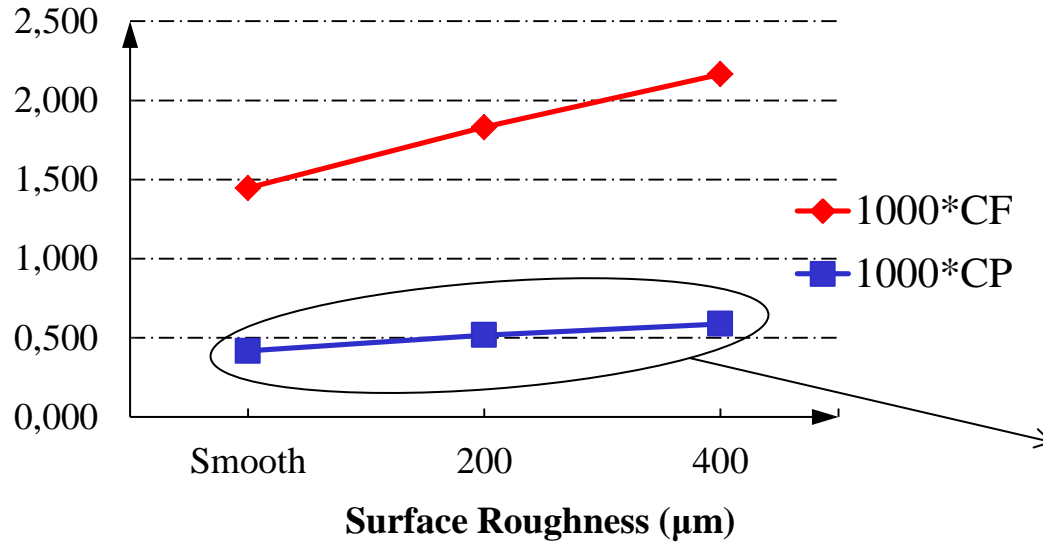


- ▶ Increase of shear stress (6 years ship  $\Rightarrow r=400\mu\text{m}$ )

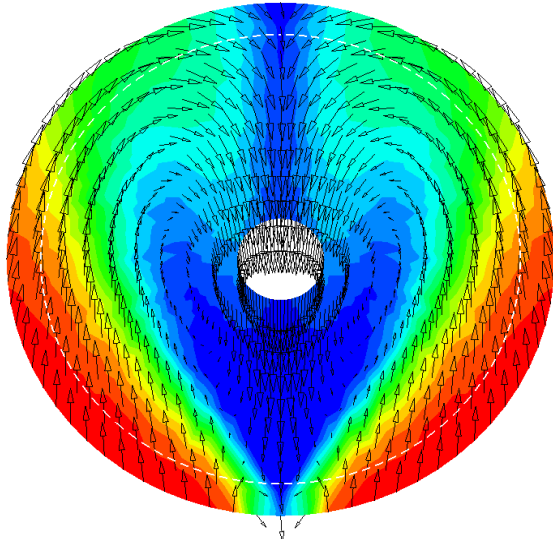


# Roughness Effect

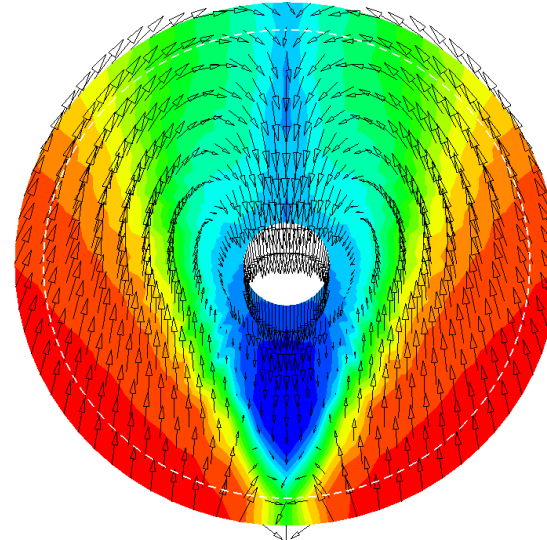
## Roughness effect on the Resistance



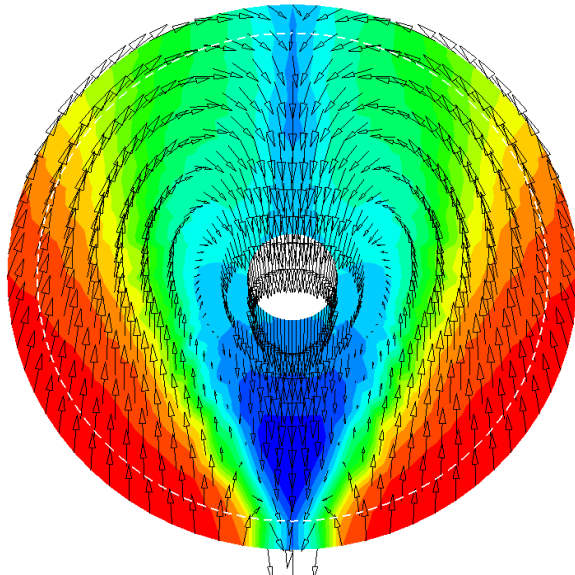
Model Scale 7m



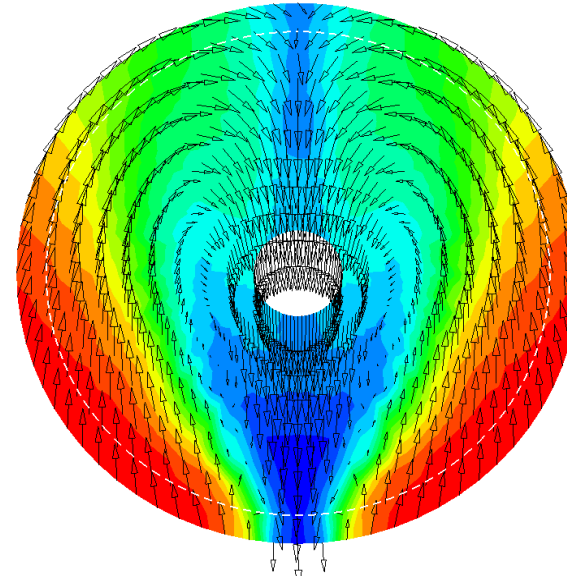
Full Scale Smooth



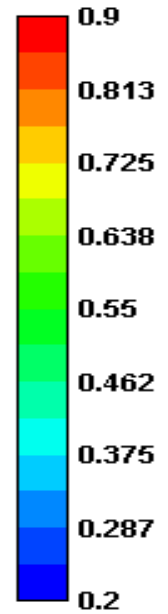
Full Scale 200 $\mu$ m



Full Scale 400 $\mu$ m

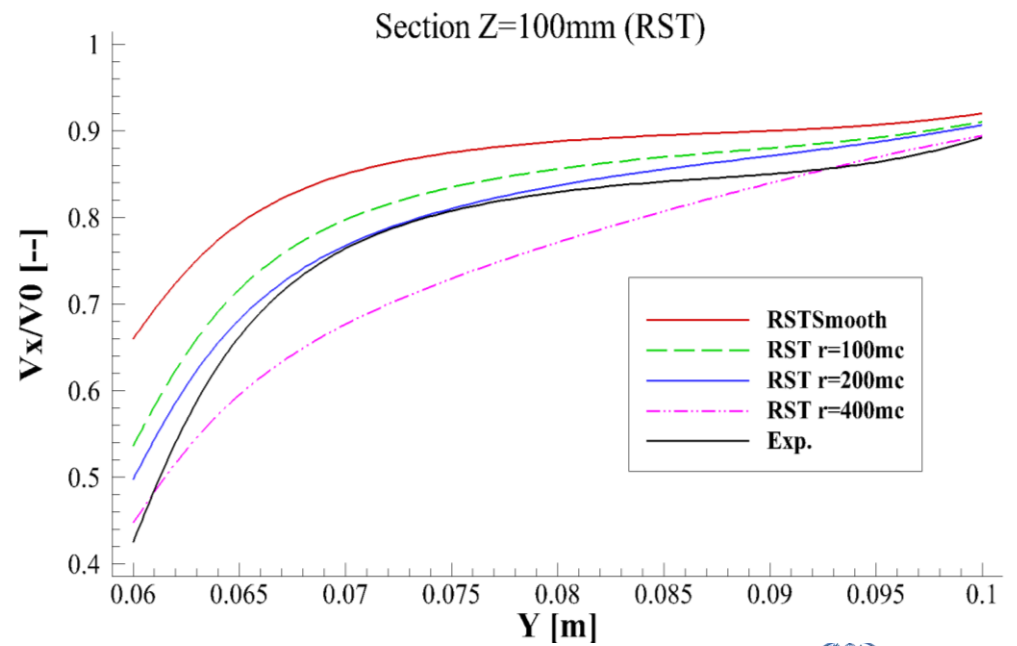
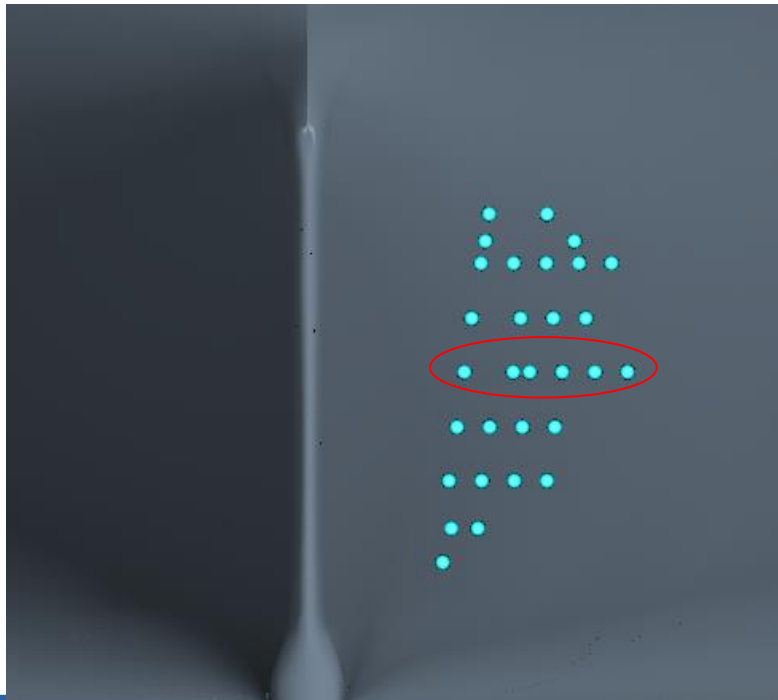
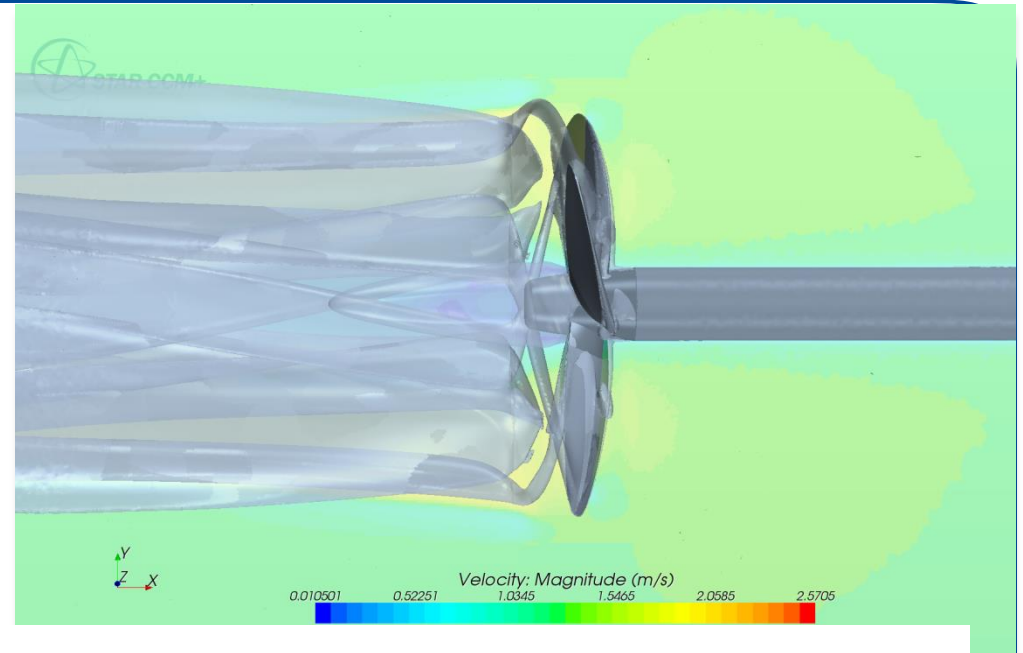
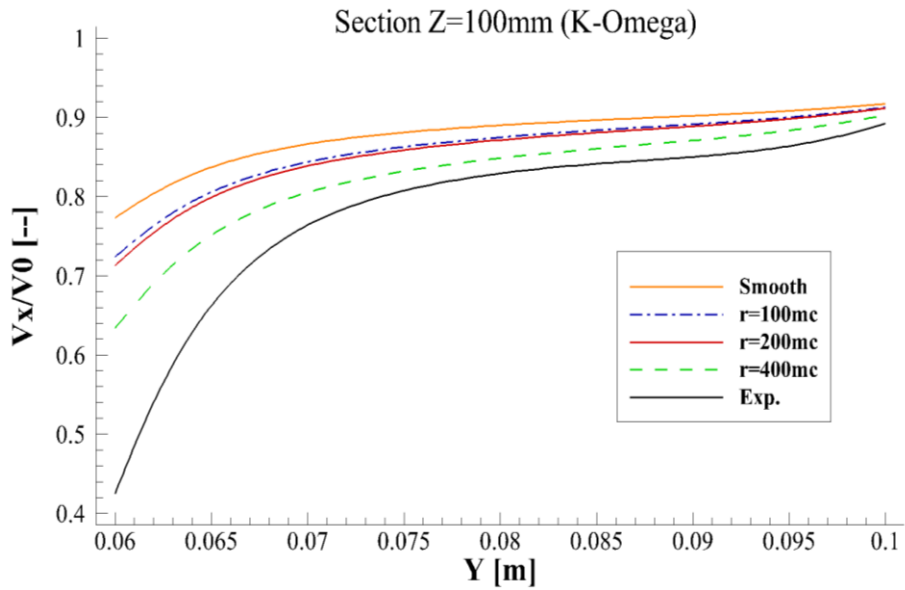


$V_x/V_{Ship}$





# Final Comparison



- ▶ RST most reliable model
- ▶ Free surface negligible for low  $Fn$
- ▶ Indispensability of Roughness model