Model- and full-scale power prediction of a tugboat

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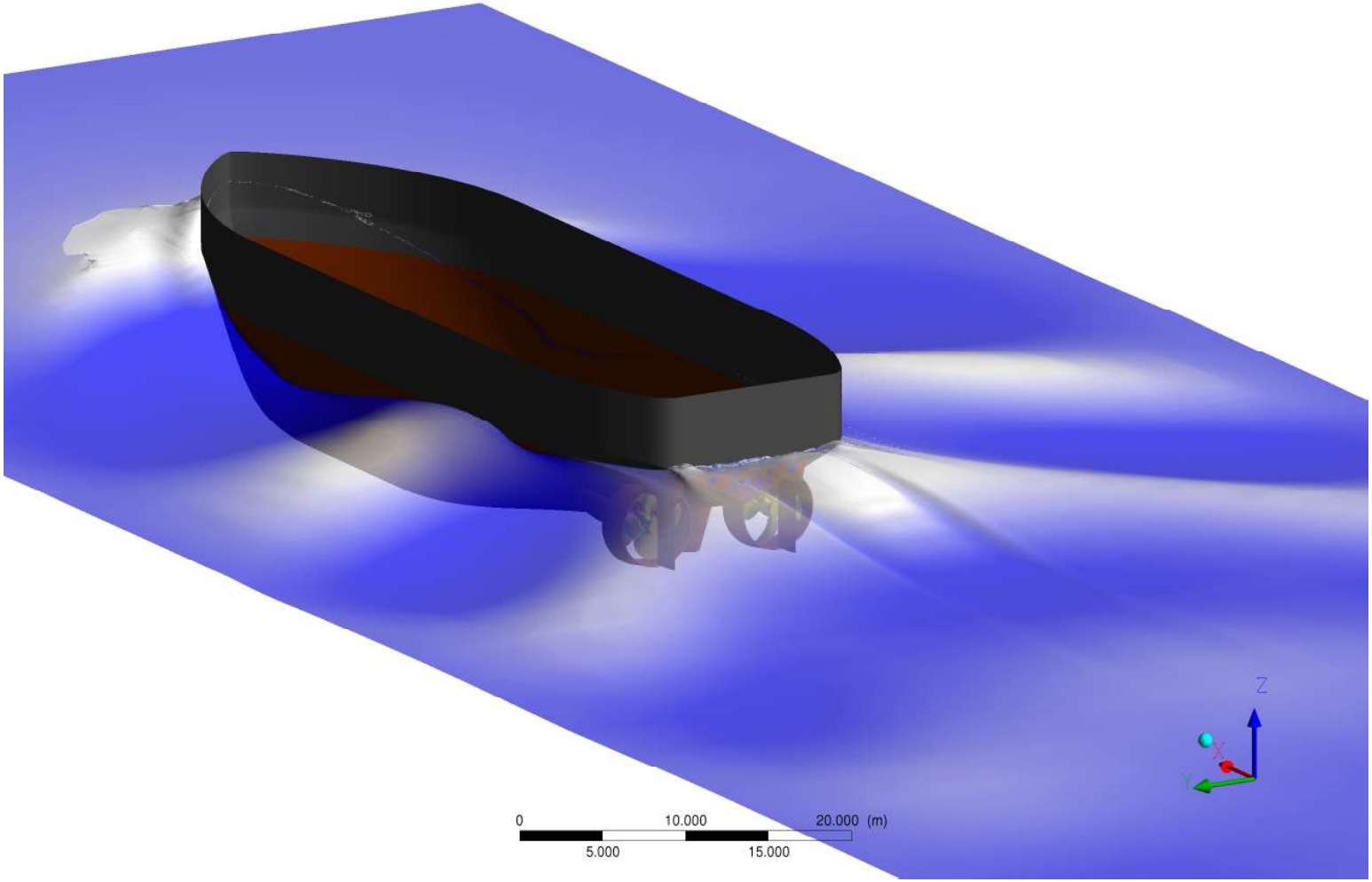
0
10.000
20.000 (m)
5.000
15.000
Z
X
Y

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- Introduction
- Power prediction assumptions
- Calculated power prediction
- Calculations to evaluate the model error
- Summary

1.0 - Introduction

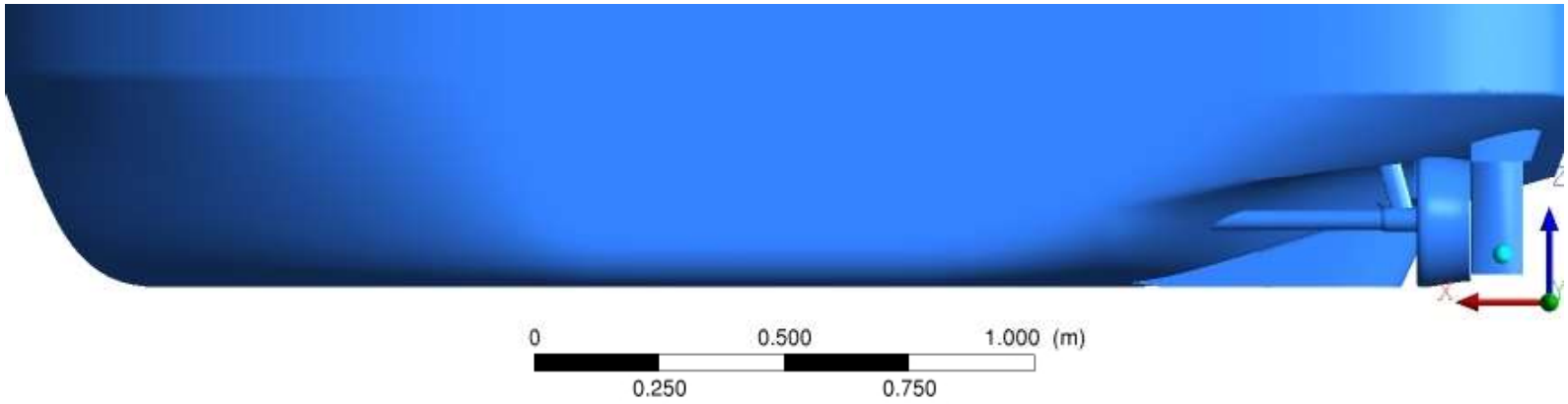
- **Motivation**:
  - power prediction of tugboats with ducted propeller
  - prediction show difference to sea trial results
- **Approach**:
  - SVA research project, funded by “Euro Norm GmbH“
  - model basin tests, CFD calculations, sea trials

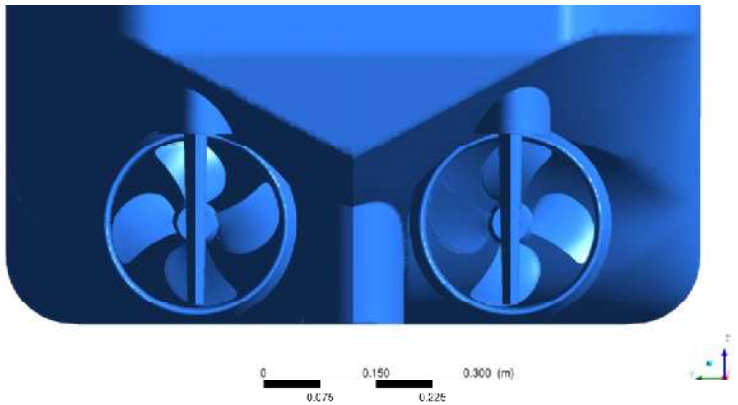
- Calculation results show the correctness of the SVA modified ITTC power prediction procedures

1.1 - Tugboats

- boats to pushing, towing and maneuvering vessels
- the calculated “Anchor handling tug supply vessel” (AHTS) is used to move offshore platforms
  - Length over all 65.00 m
  - Breath 18.50 m
  - Draft 6.80 m
  - Bollard pull 220 t

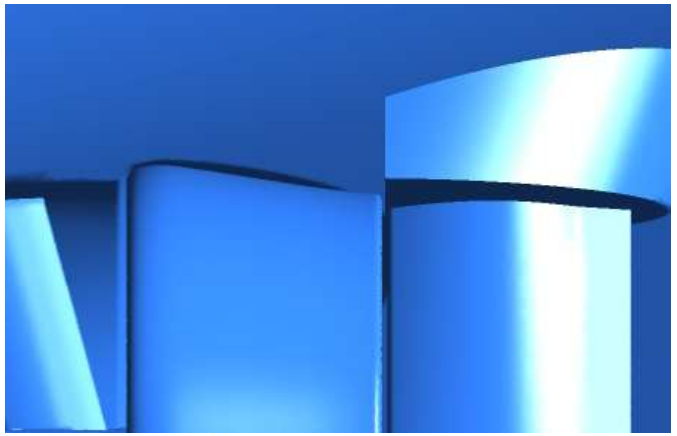
1.2 - Geometry



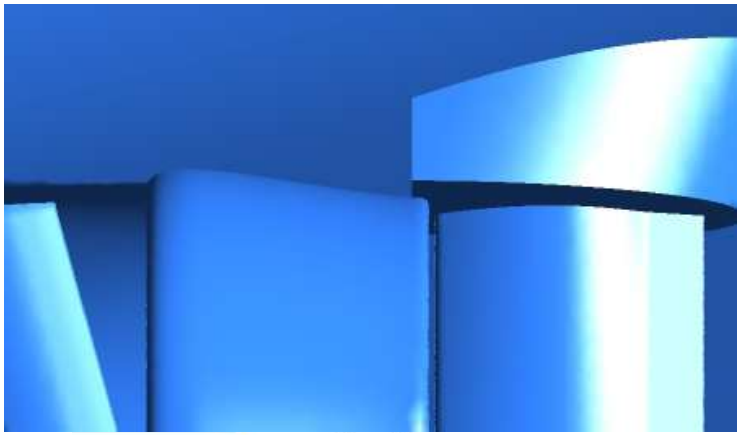


1.3 - Model-scale test geometry

- duct in model-scale geometry is not connected to the ship hull
- gap necessary to measure the duct forces



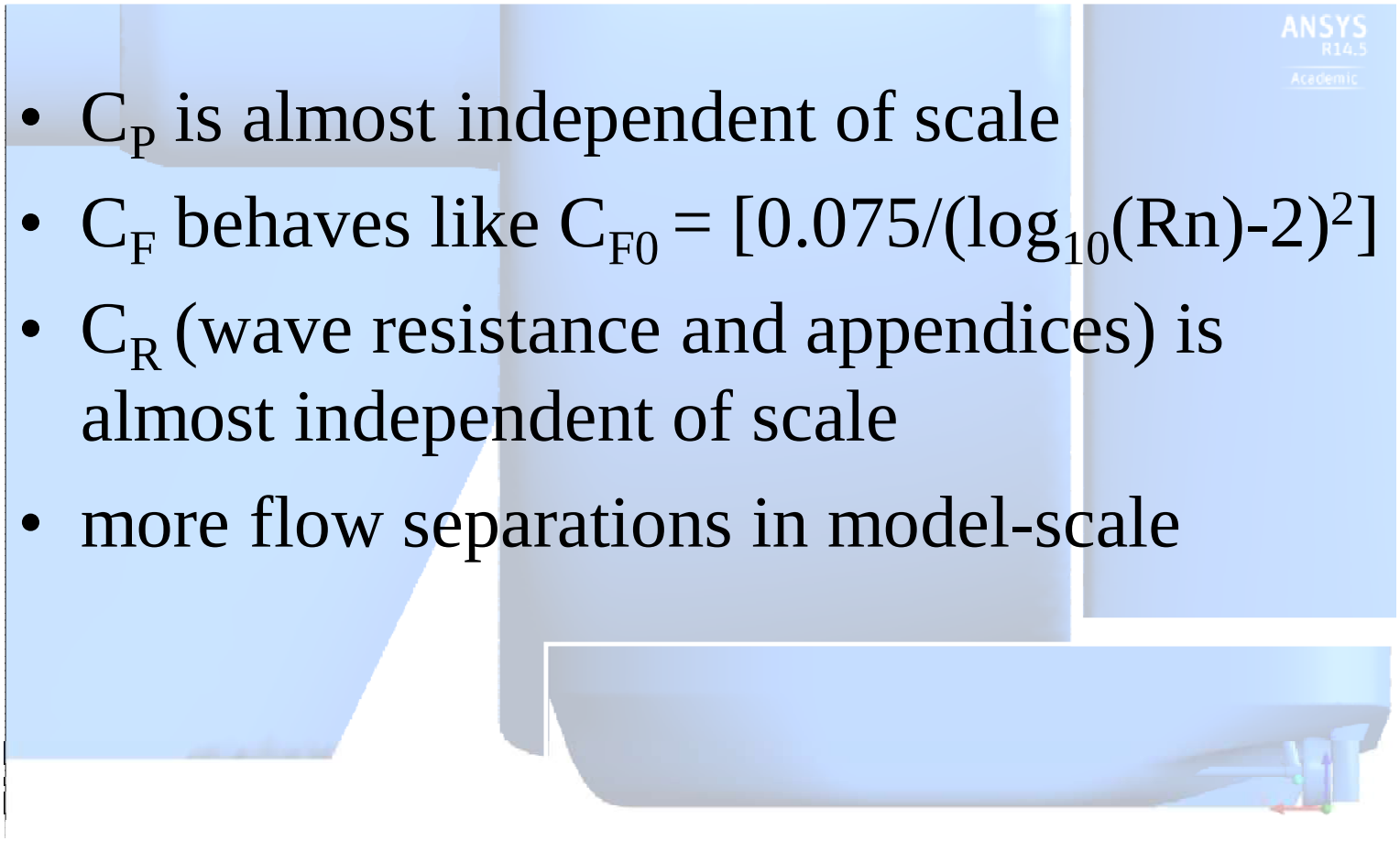
model ship geometry



full-scale ship geometry

2.0 – Power prediction assumptions

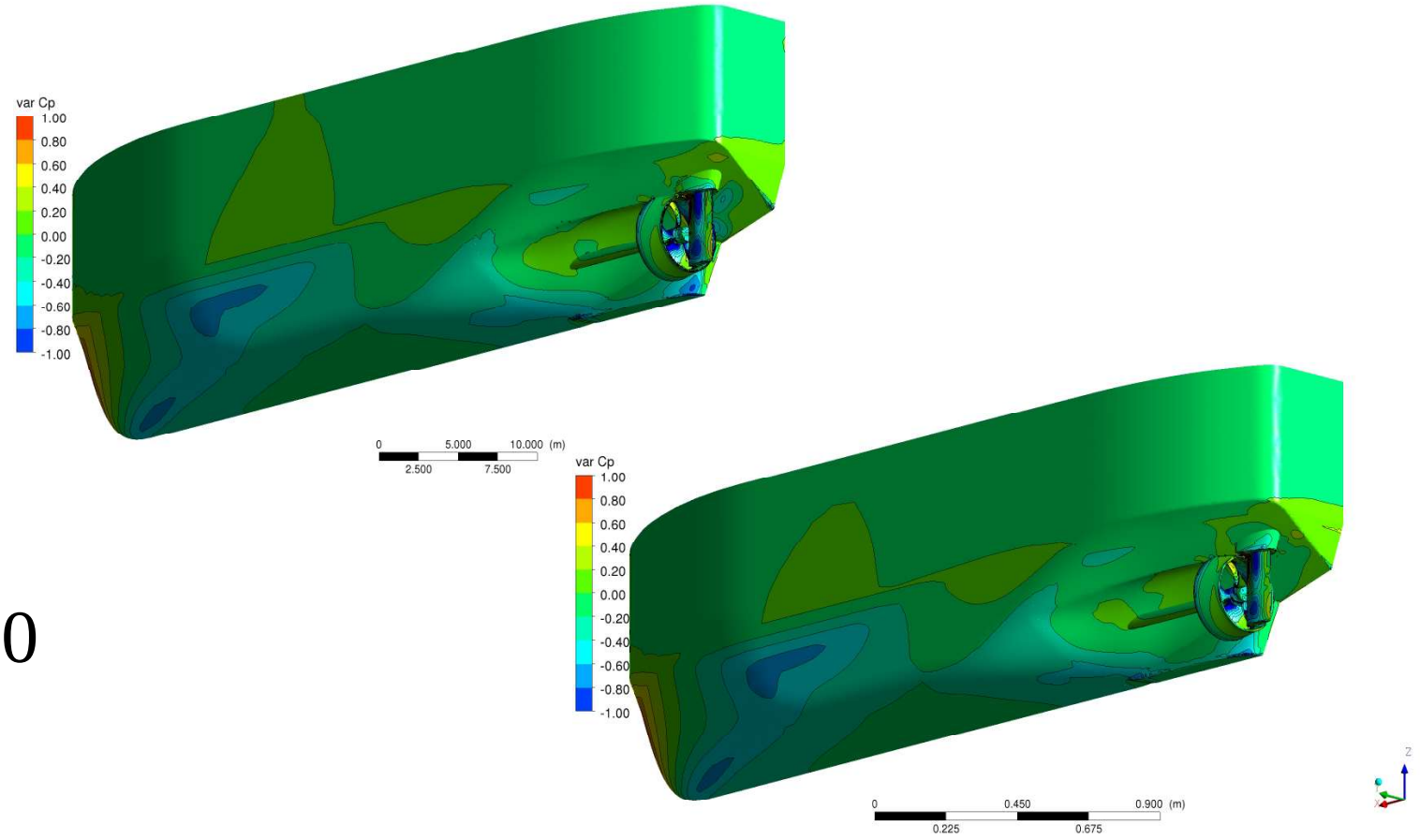
- C_P is almost independent of scale
- C_F behaves like $C_{F0} = [0.075/(\log_{10}(Rn)-2)^2]$
- C_R (wave resistance and appendices) is almost independent of scale
- more flow separations in model-scale



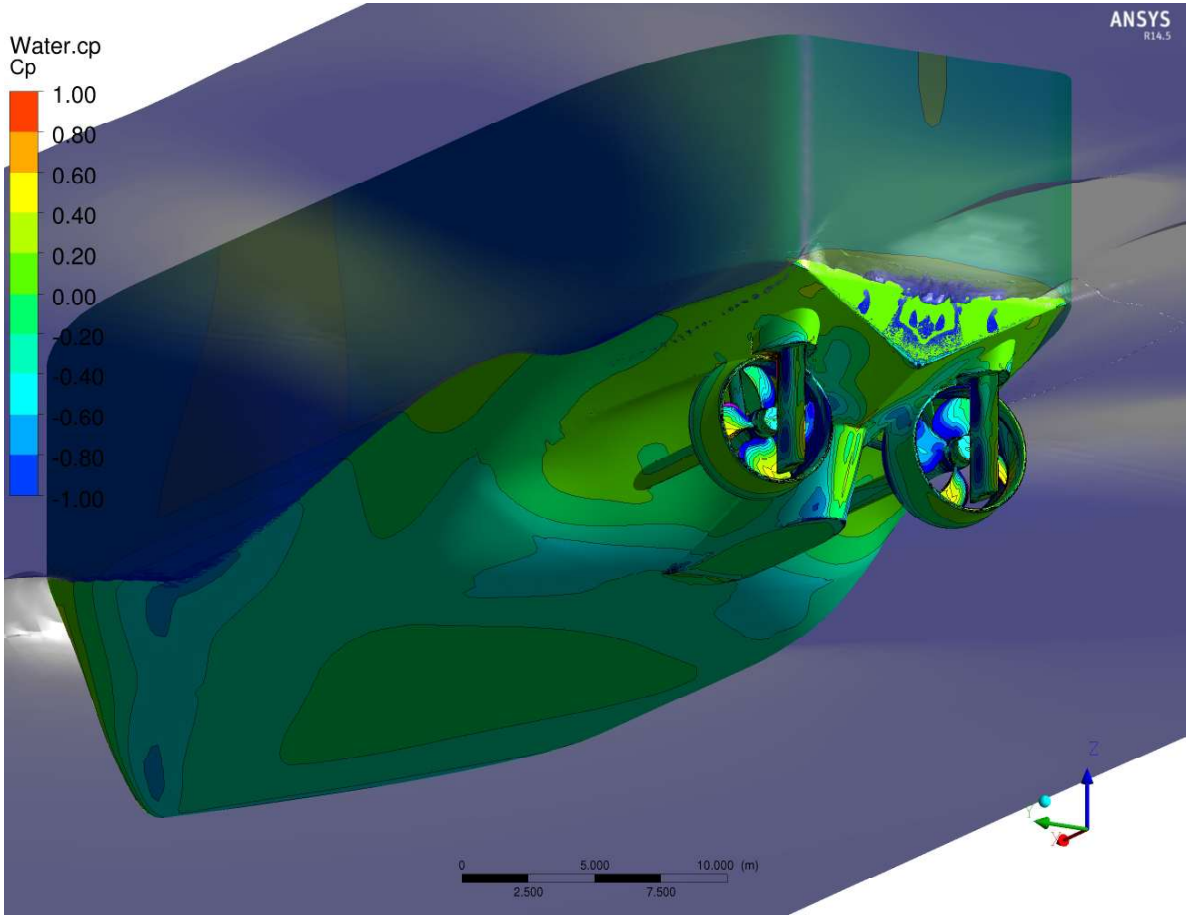
2.1 - C_P distributions at 16 kn

$\lambda = 1$

$\lambda = 20$



2.2 - C_P unsteady, full-scale Ship

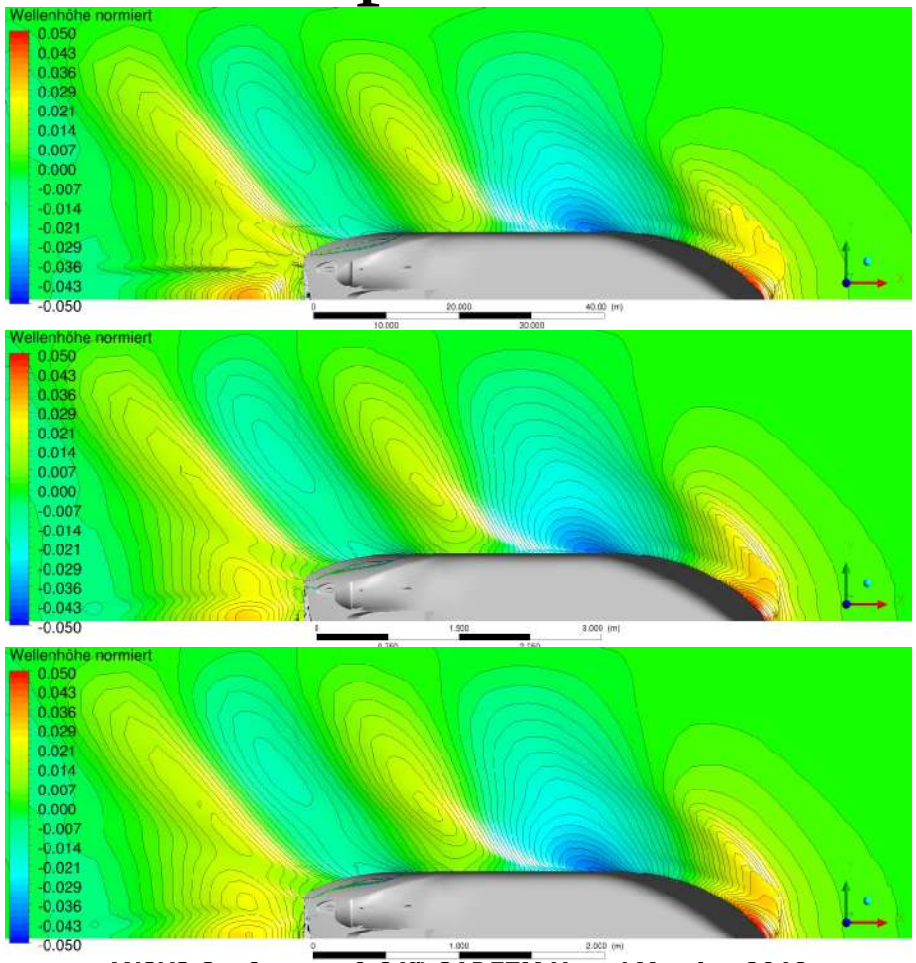


2.3 - Wave patterns at 16 kn

$\lambda = 1$

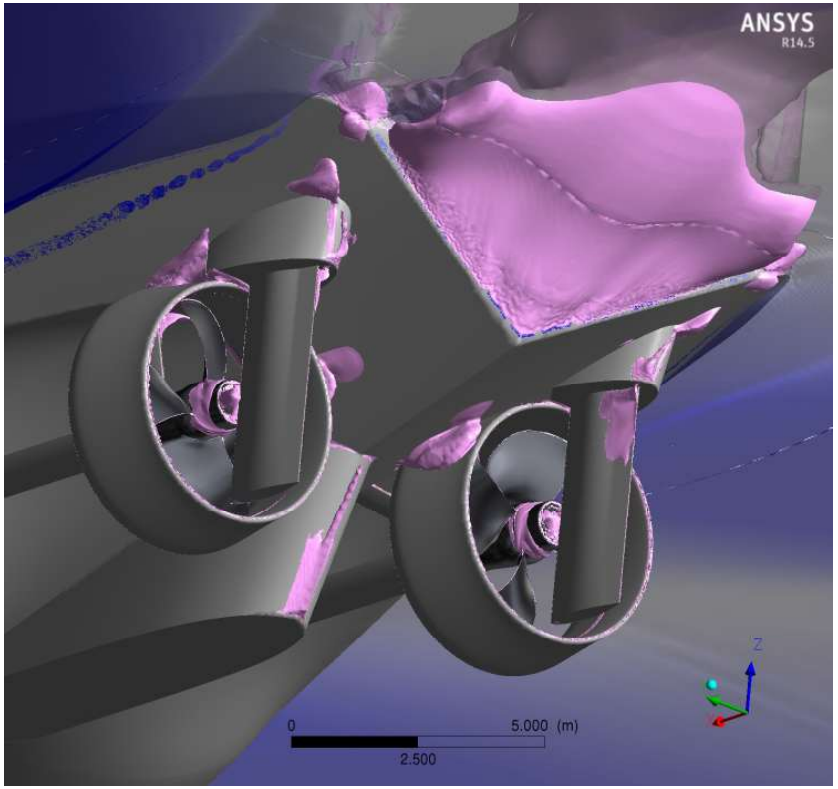
$\lambda = 13$

$\lambda = 20$

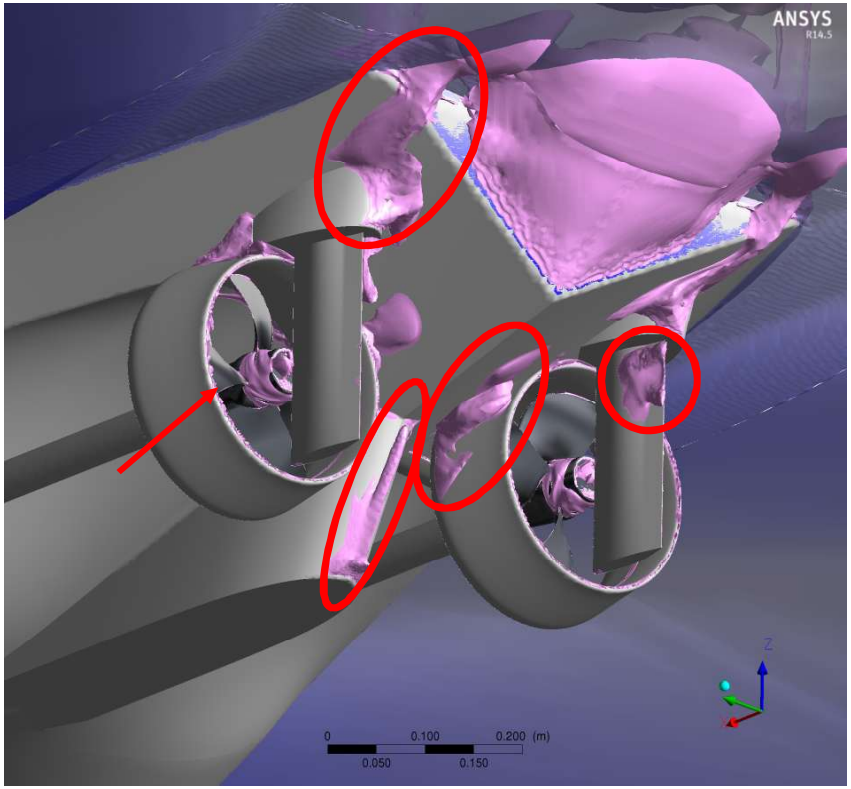


$$V_M = V_S / \sqrt{\lambda}$$

2.4 - Flow separations at 16 kn



$\lambda = 1$

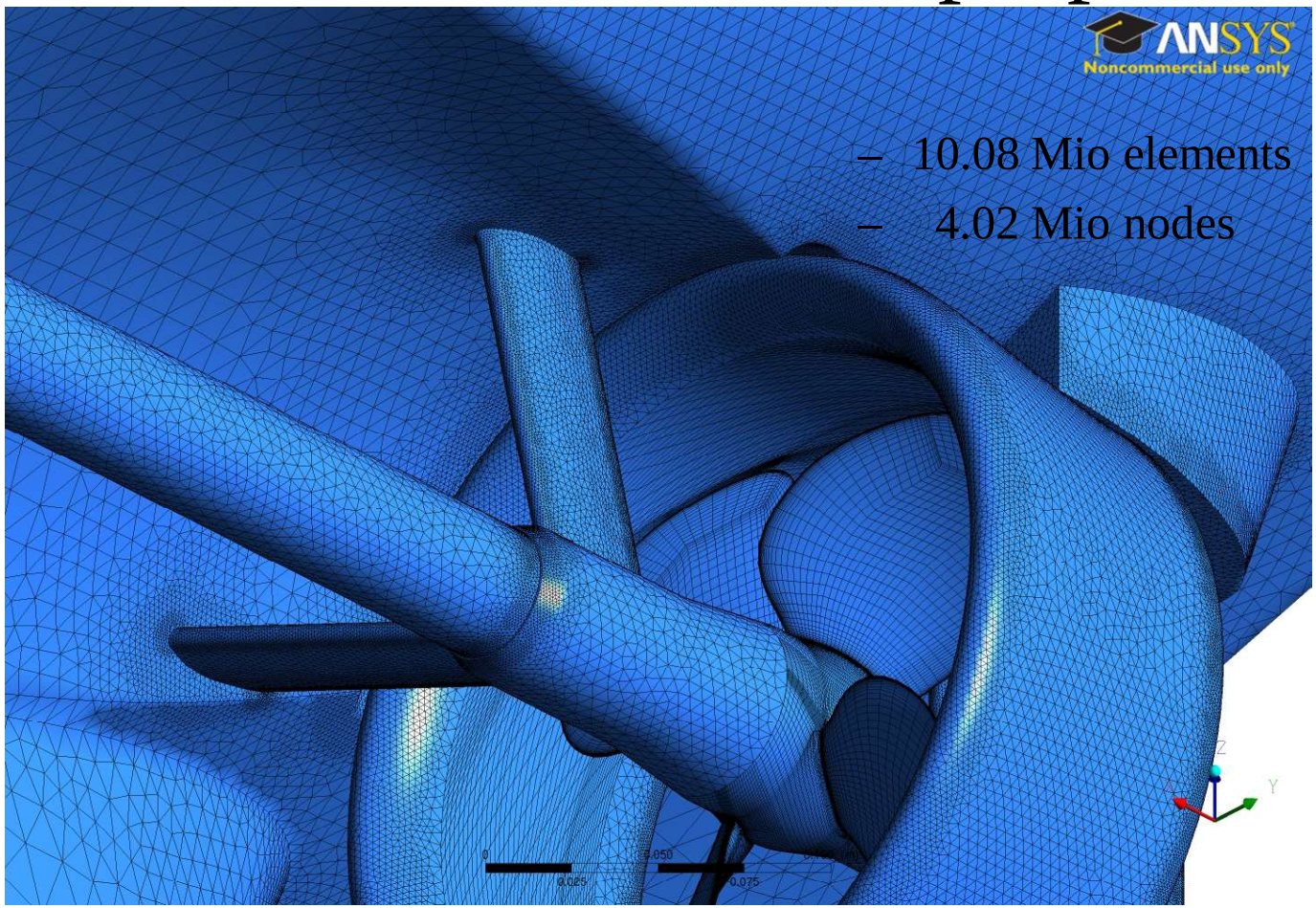


$\lambda = 20$

3.0 - Simulation Tools

- Mesh generation with ANSYS ICEM CFD
  - hexahedra mesh is used at bow, in the outside region and in propeller region
  - tetrahedral mesh is used for the complex aft ship geometry
- calculations are made with ANSYS CFX
  - two-phases with free water surface
  - unsteady with real rotating propeller
  - SST k-omega model
  - single calc. with Gamma-Theta transition model
  - single calc. with three-phases (free surface + cavitation)

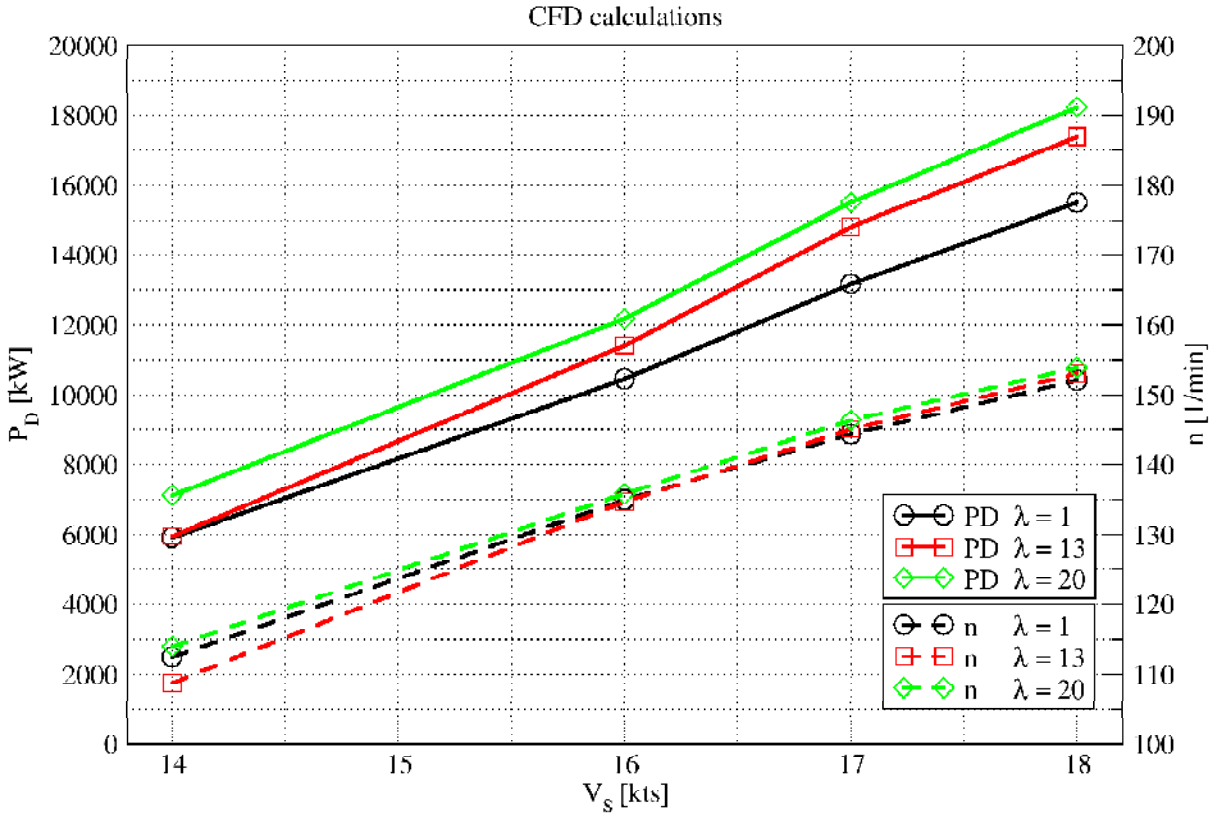
3.1 - Mesh, model-scale, propulsion



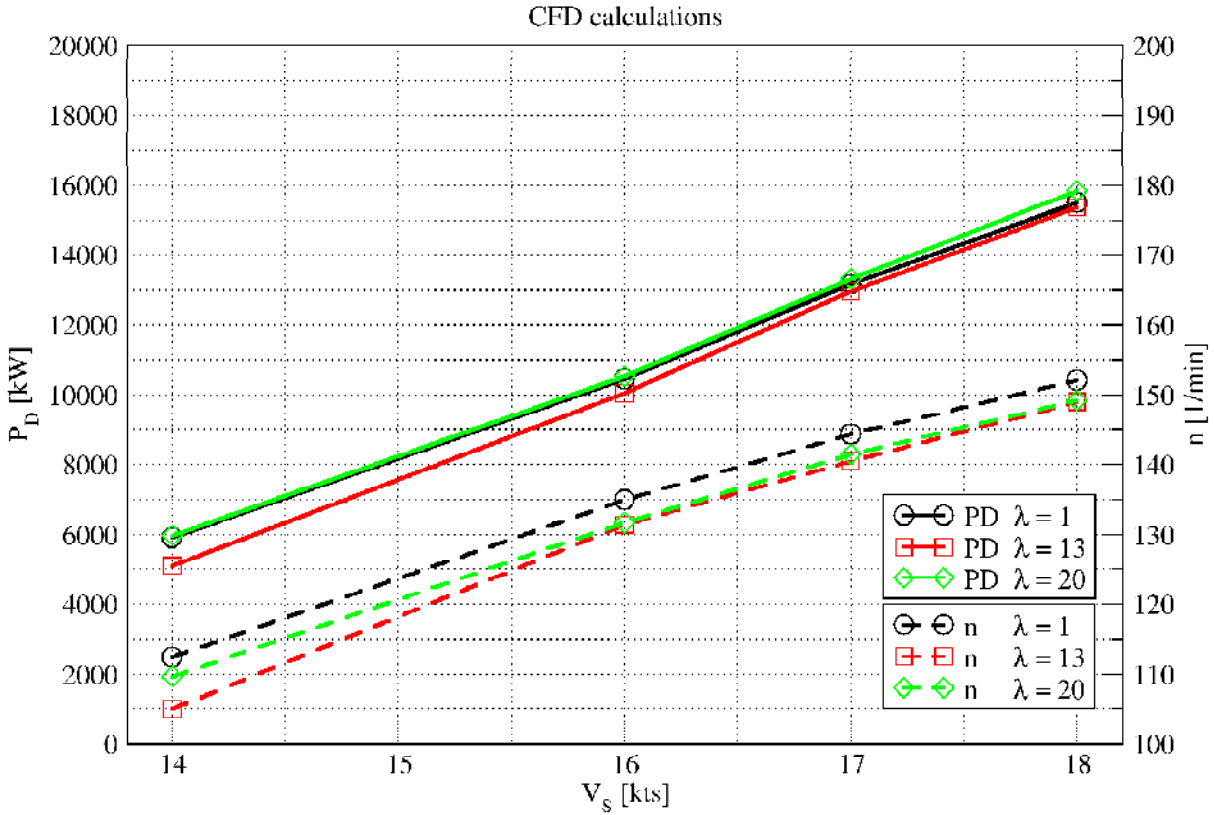
3.2 - Power prediction

- Calculations at different ship speeds
  - full-scale calculations
  - model-scale calculations with $\lambda = 13$ and $\lambda = 20$
  - gap effect calculations with $\lambda = 20$
- power prediction prognosis with the calculated results

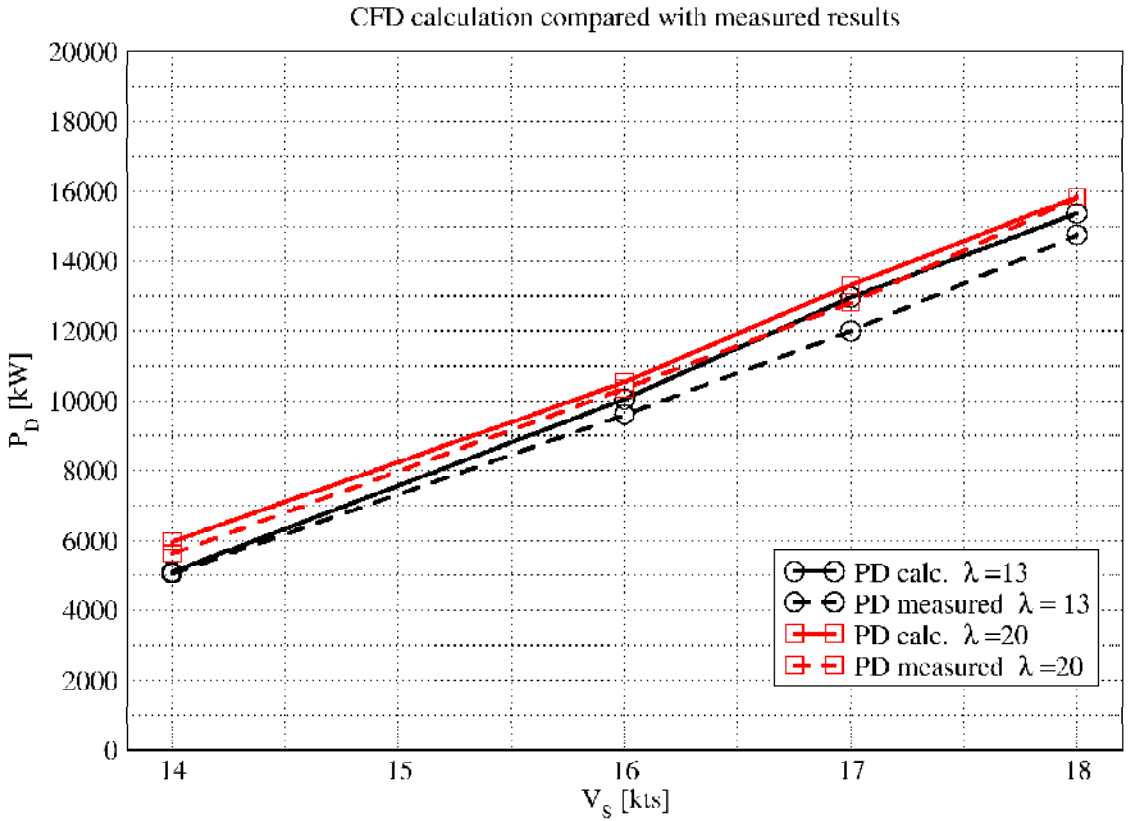
3.3 - Power prediction without R_n correction



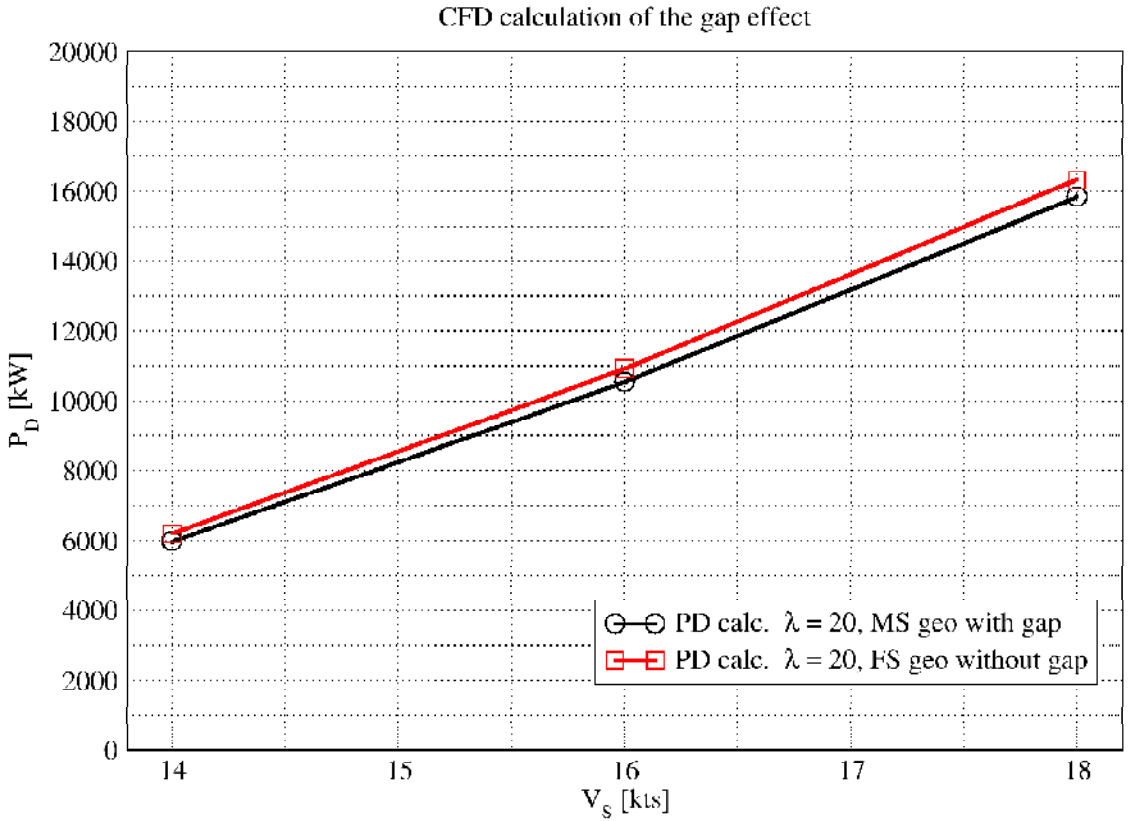
3.4 - Power prediction with R_n correction



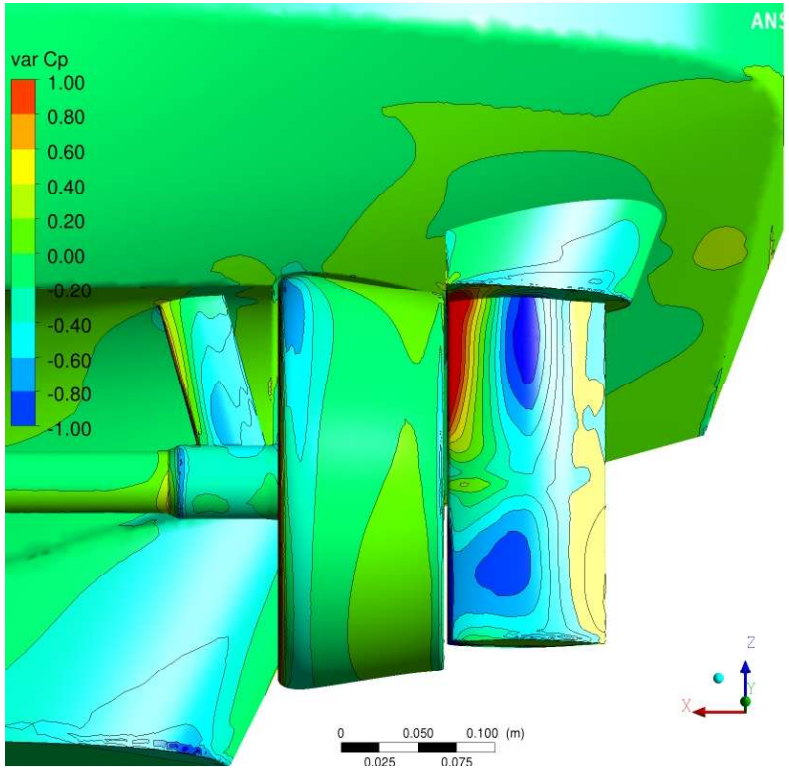
3.5 - Comparison with test results



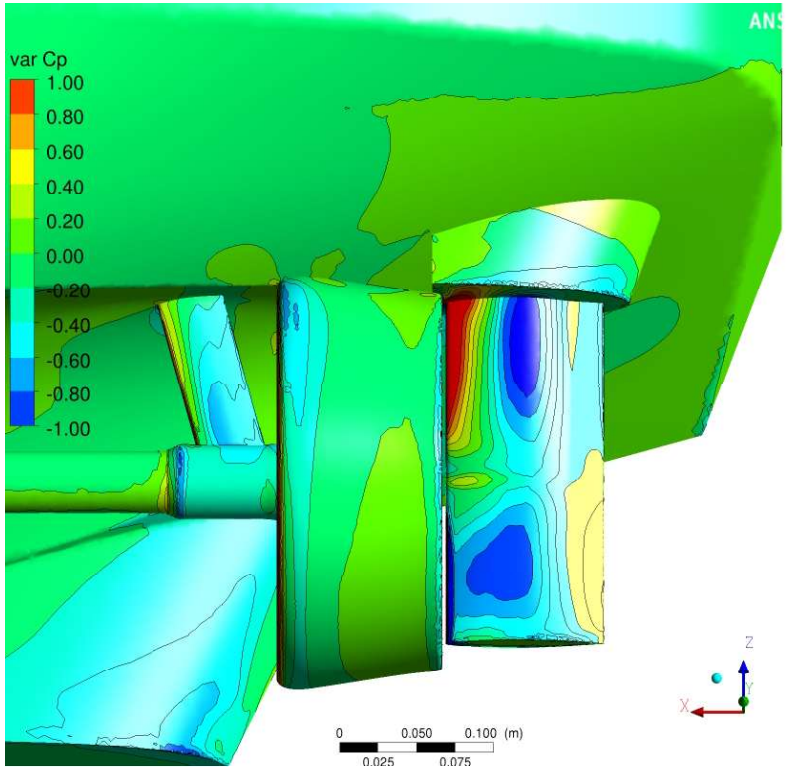
3.6 - Model geometry gap effect



3.7 - Duct gap effect, C_P at 16 kn

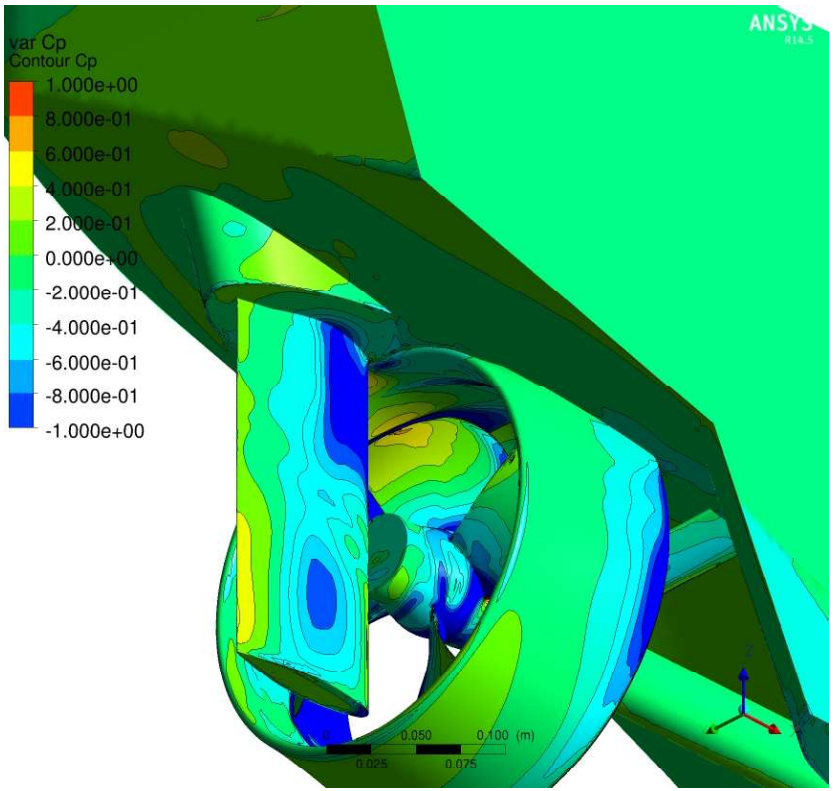


model ship geometry, with gap

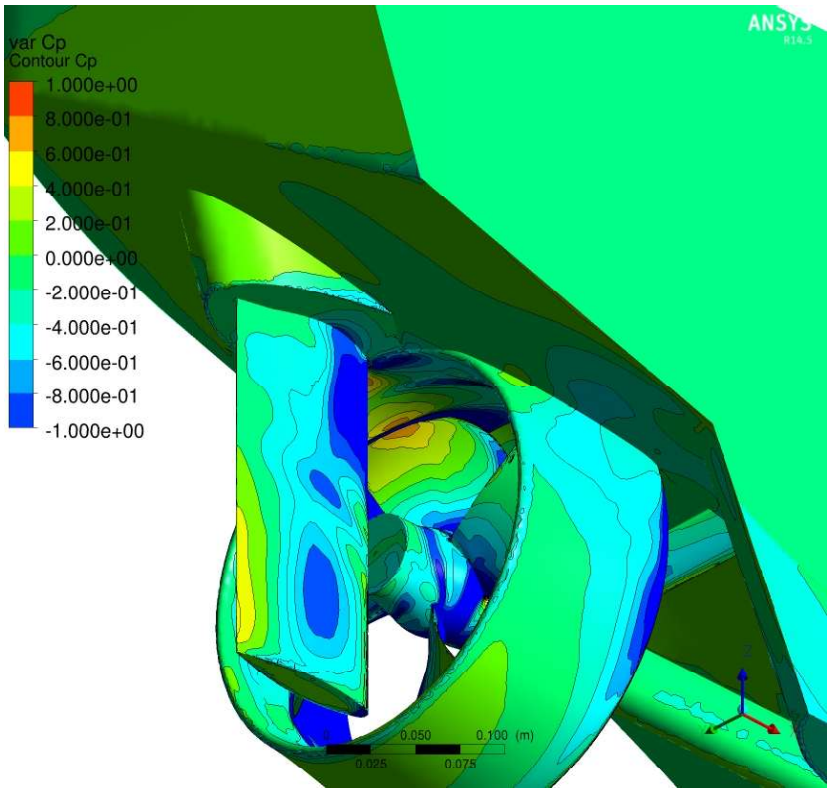


full-scale ship geometry, without gap

3.8 - Duct gap effect, C_P at 16 kn



model ship geometry, with gap



full-scale ship geometry, without gap

3.9 - Predicted ship speed

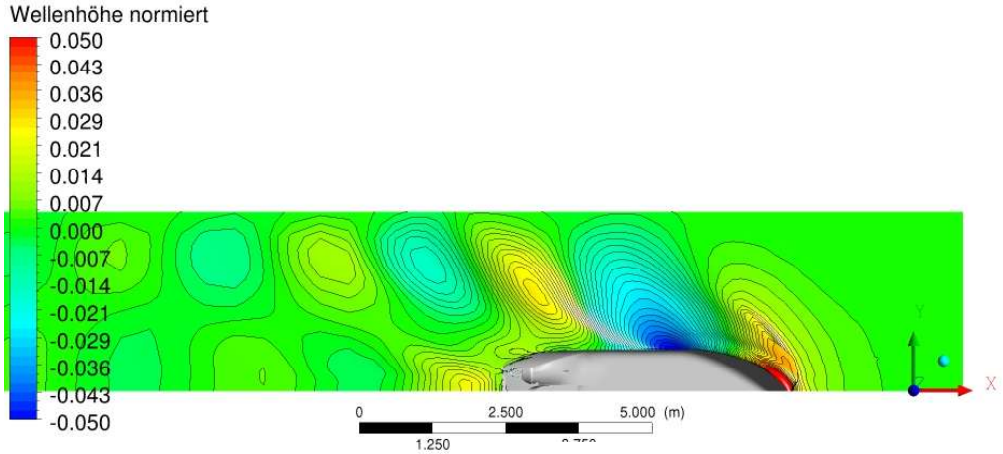
	V_S [kts]	n [1/min]
full-scale $\lambda = 1$	17.18	145.7
model-scale $\lambda = 13$	17.23	142.5
model-scale $\lambda = 20$	17.10	142.3
model-scale $\lambda = 20$, without gap	17.01	142.9

$P_D = 13580$ kW

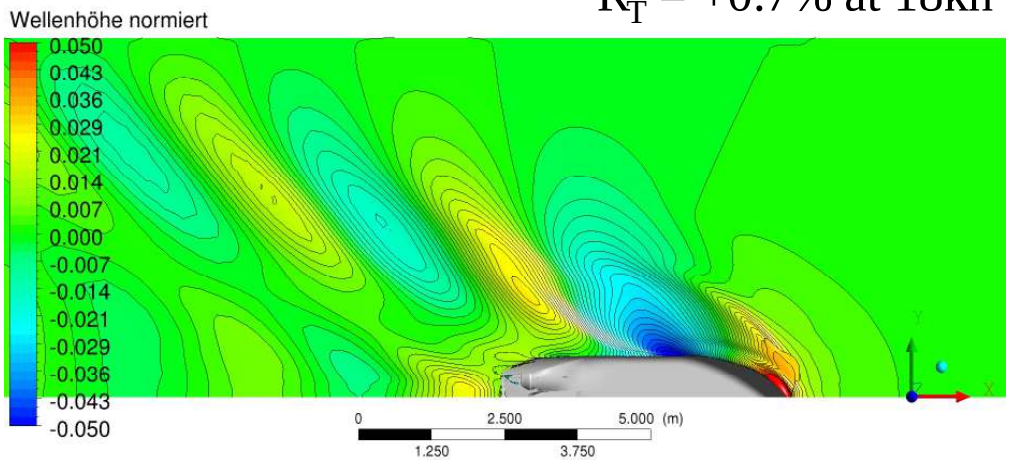
4.0 - Calculations to evaluate the model error

- use of a larger domain
- bow wave refinement
- influence of laminar-turbulent transition
- influence of propeller cavitation

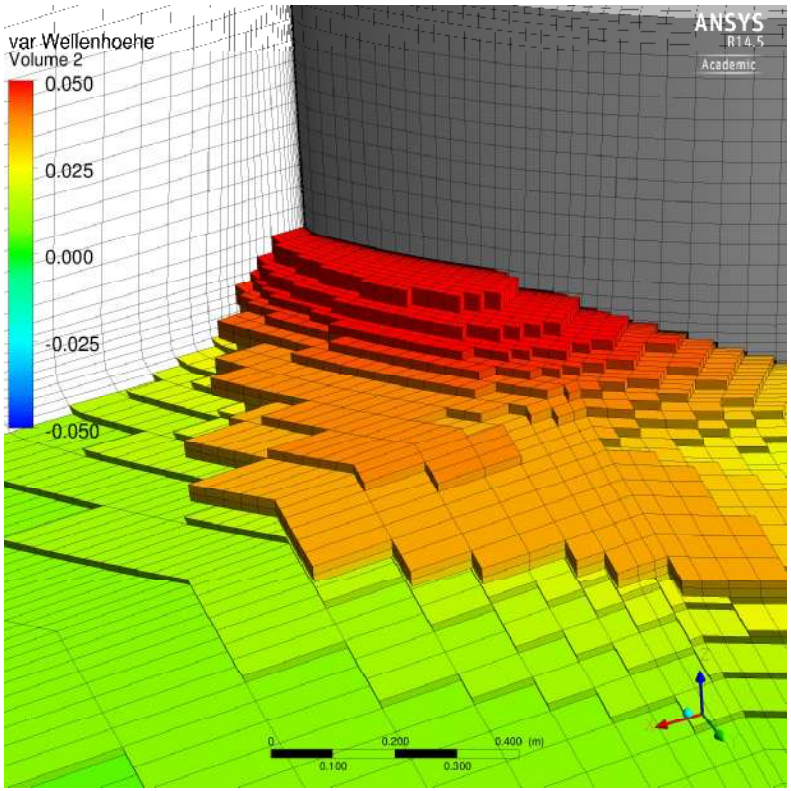
4.1 - Calculations in a larger domain



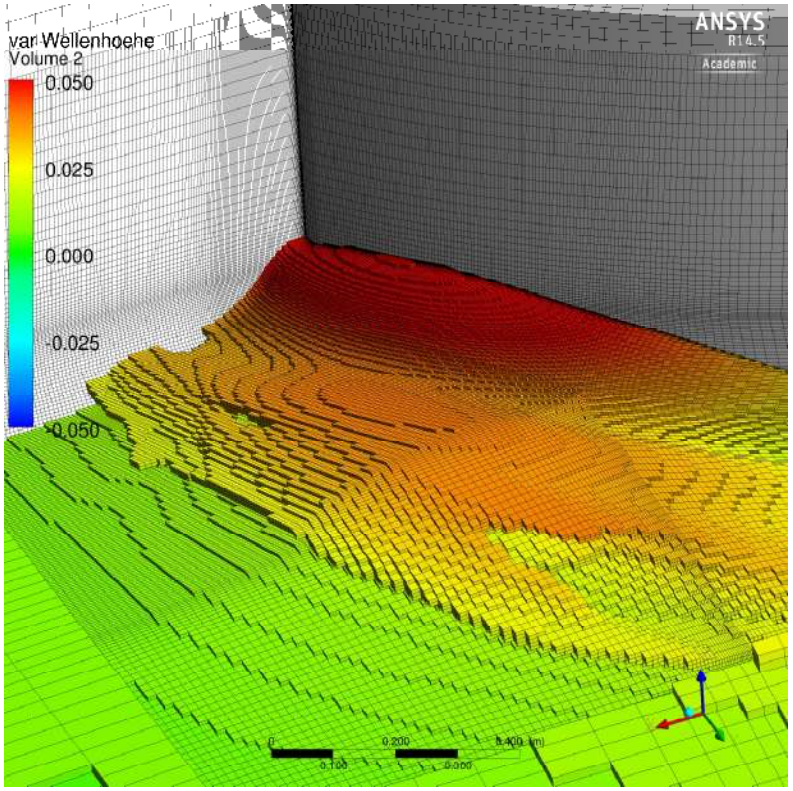
R_T = +0.7% at 18kn



4.2 - Bow wave mesh refinement



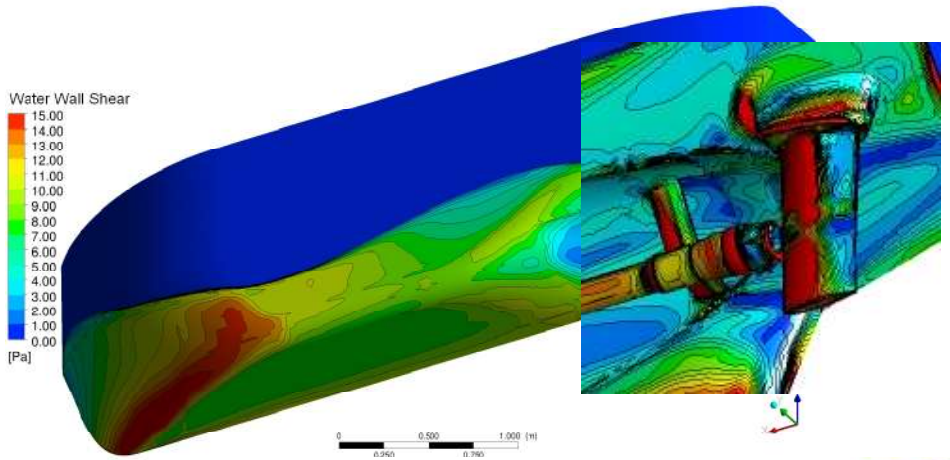
coarse bow mesh



fine bow mesh, R_T = -2.8% at 18kn

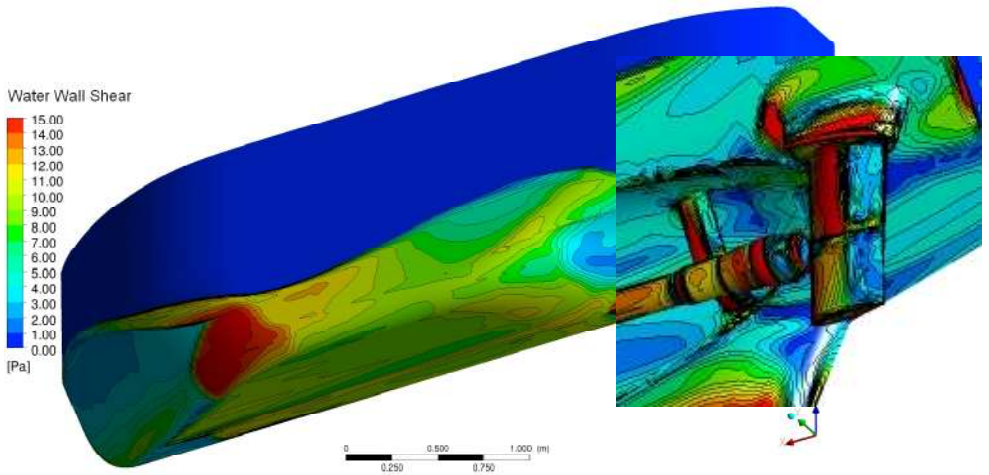
4.3 - Gamma Theta transition model

SST fully turbulent

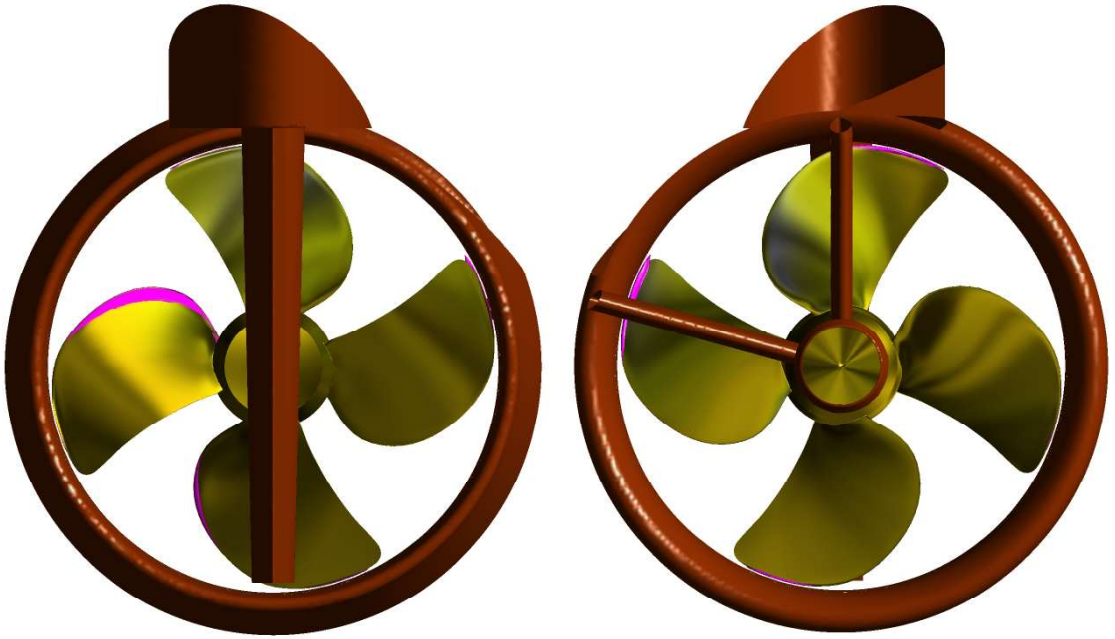


SST Gamma Theta transition model

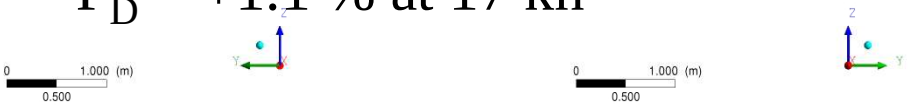
R_T (λ = 13) = -1.8% at 16kn



4.4 - Cavitation at full-scale ship

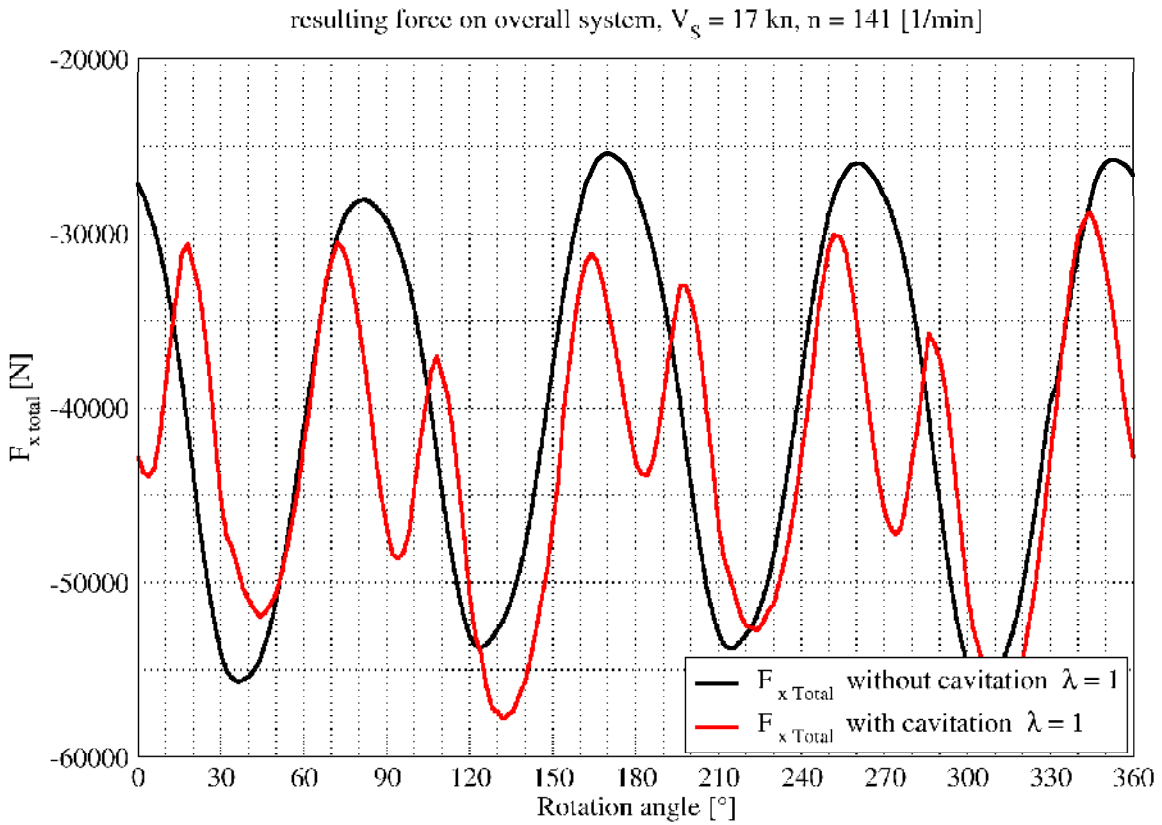


P_D = +1.1 % at 17 kn



pressure side suction side

4.5 - Influence of Cavitation



Summary

- the R_n correction work excellent for the $\lambda = 20$ model-scale ship
- the calculations of the model-scale ships are consistent with model test measurements
- there is a noticeable gap effect

Questions ?