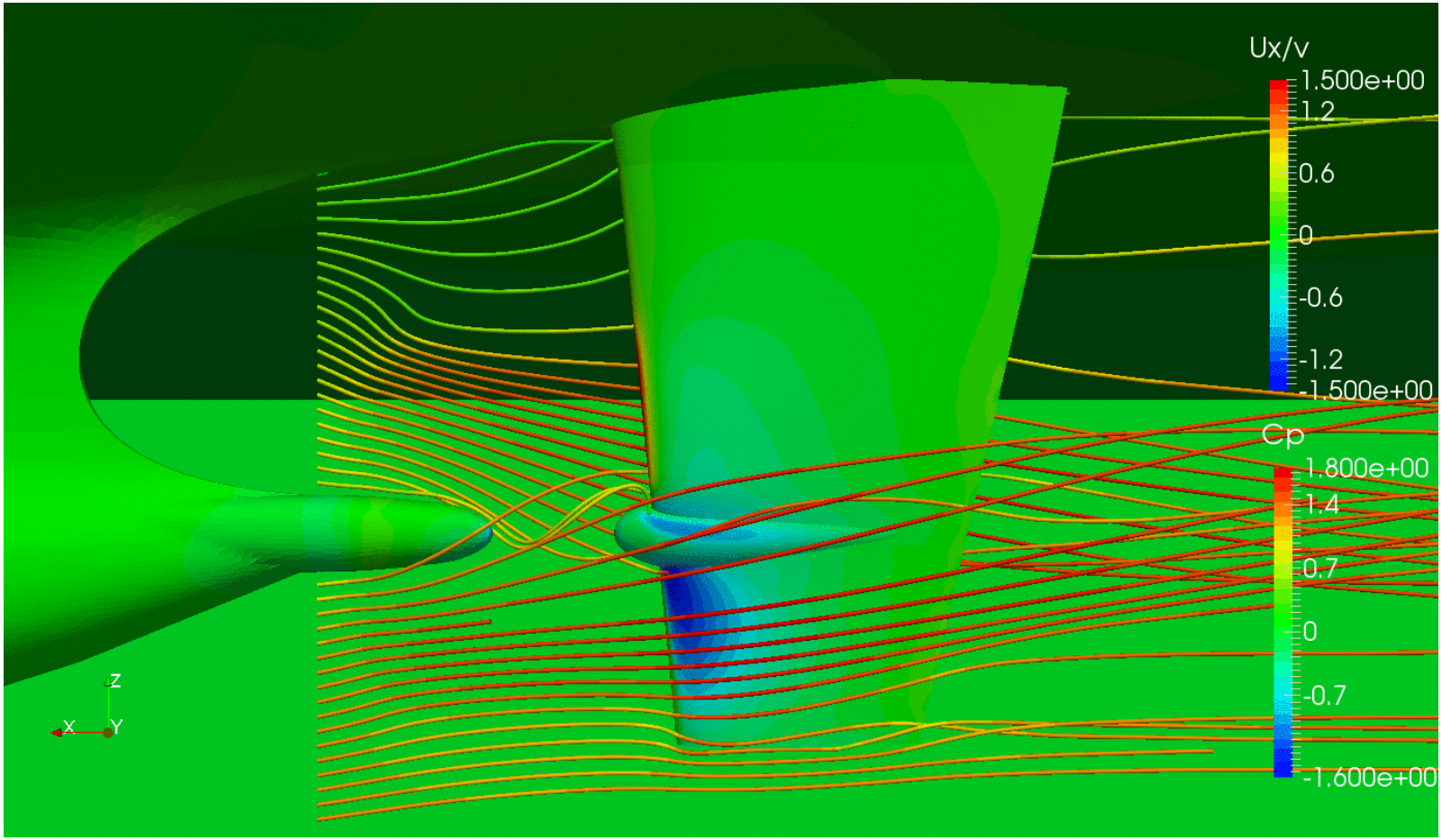
OPTIMIZATION OF TWISTED RUDDER



Rostock, Germany

February 2, 2016

Motivation

- EEDI: 30% more efficient ships by 2025
- Twisted rudders with bulb gain up to 4%
- Developed after construction is started
- RANS-BEM reduces computational time
- Inhouse software

Outline of the presentation

- Coupled RANS-BEM method
- Parametric Model
- Meshing Procedure
- Optimization Overview
- Optimization Results
- Conclusion

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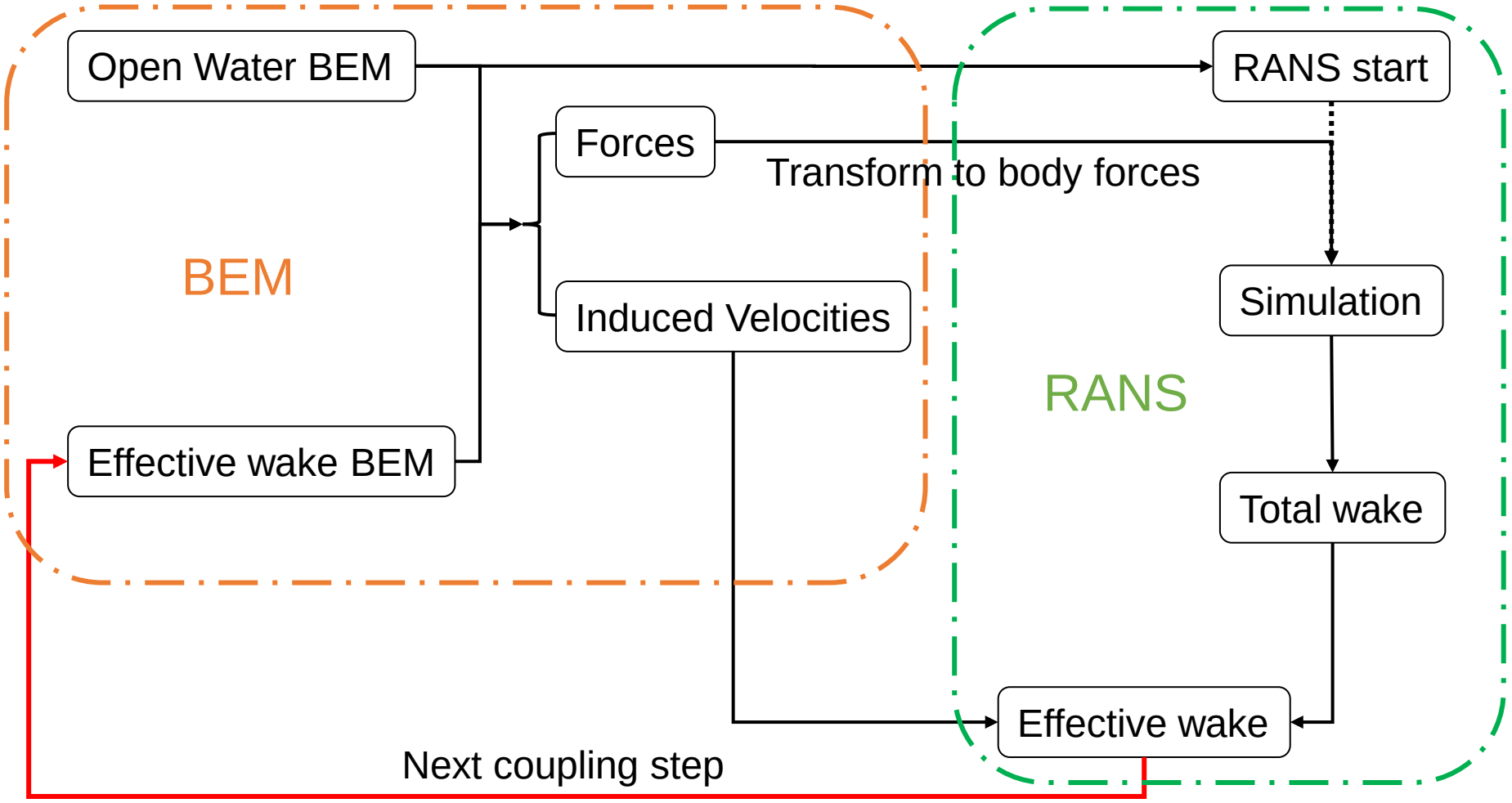
Coupled RANS-BEM Method



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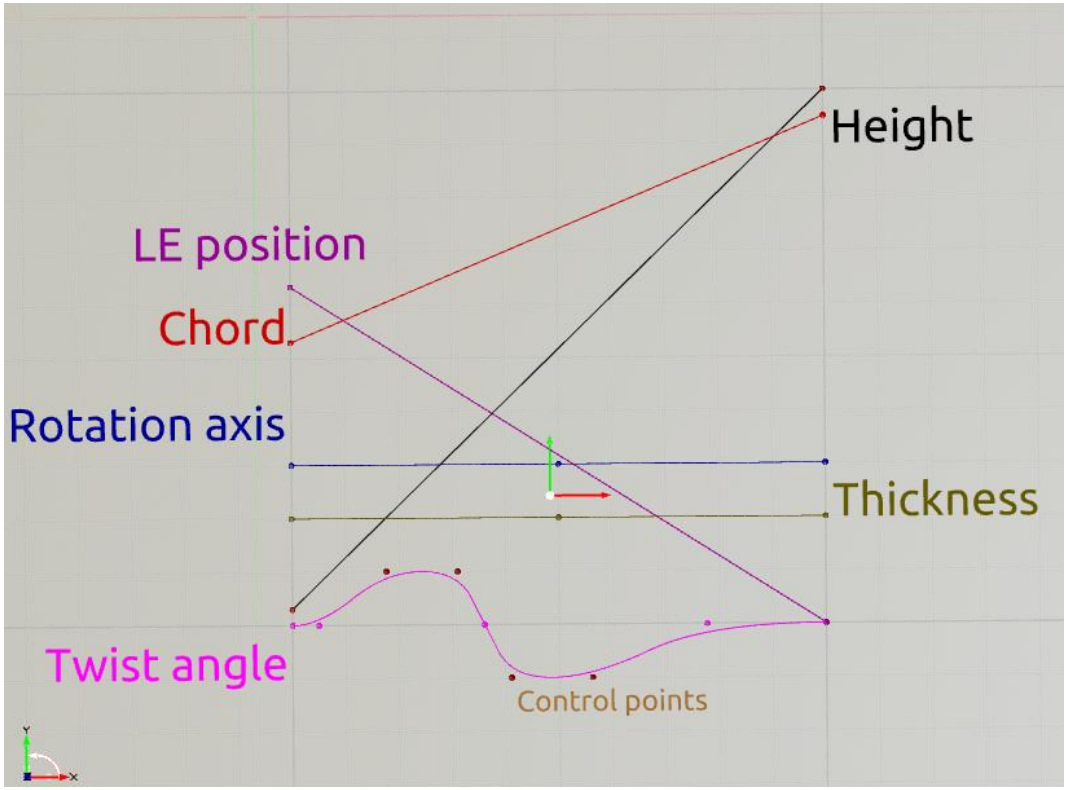
Rudder Model

- Few parameters
- Flexible
- Lot of posibilities



How it works

Parameters:

Video

-Twist angle

-Twist Axis

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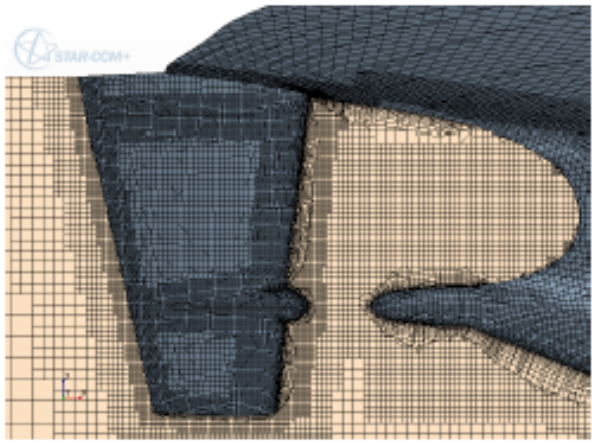
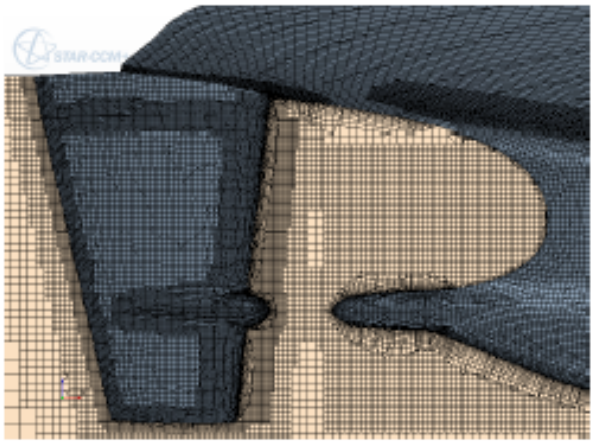
Meshing Procedure

- Mesh geometry Surface
- Extrude prism layers
- Intersect subsurface with background mesh
- Refinement splitting cells uniformly in all directions
- Divide reference length by *RefCells*
- Quality statistics

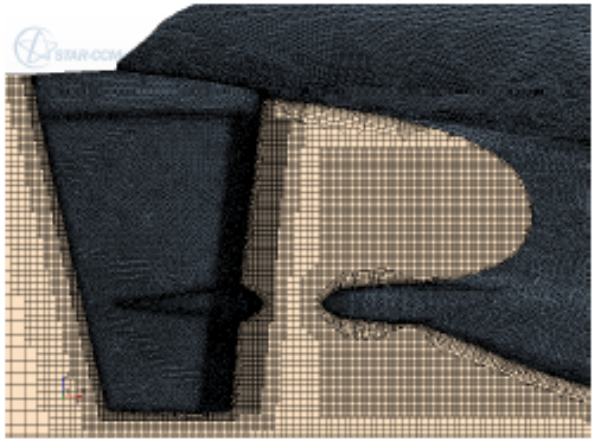
Meshing Procedure



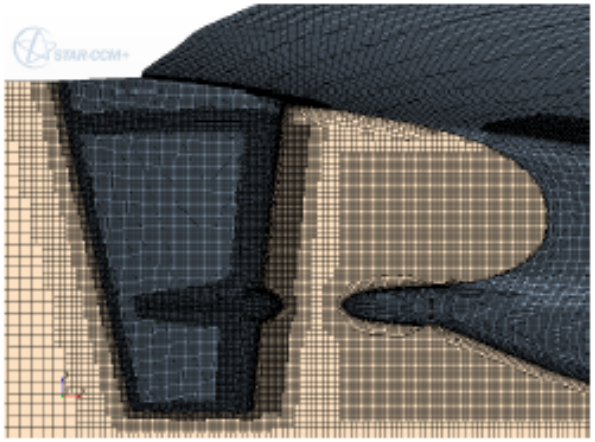
a) Coarse 12



b) Fine 16n

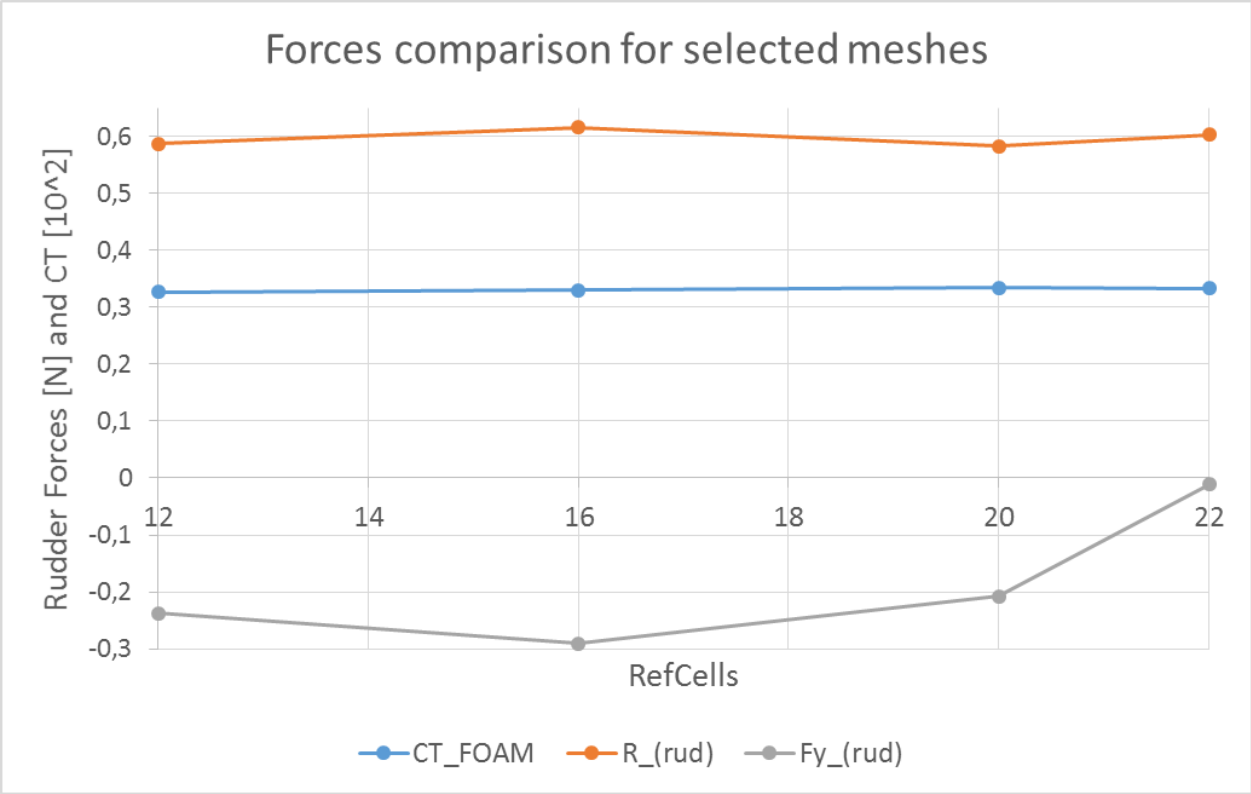


c) Fine 20



d) Fine 22

Mesh Convergence



- CT_FOAM: resistance coefficient from OpenFoam
- R_(rud): rudder resistance
- Fy_(rud): rudder lateral force

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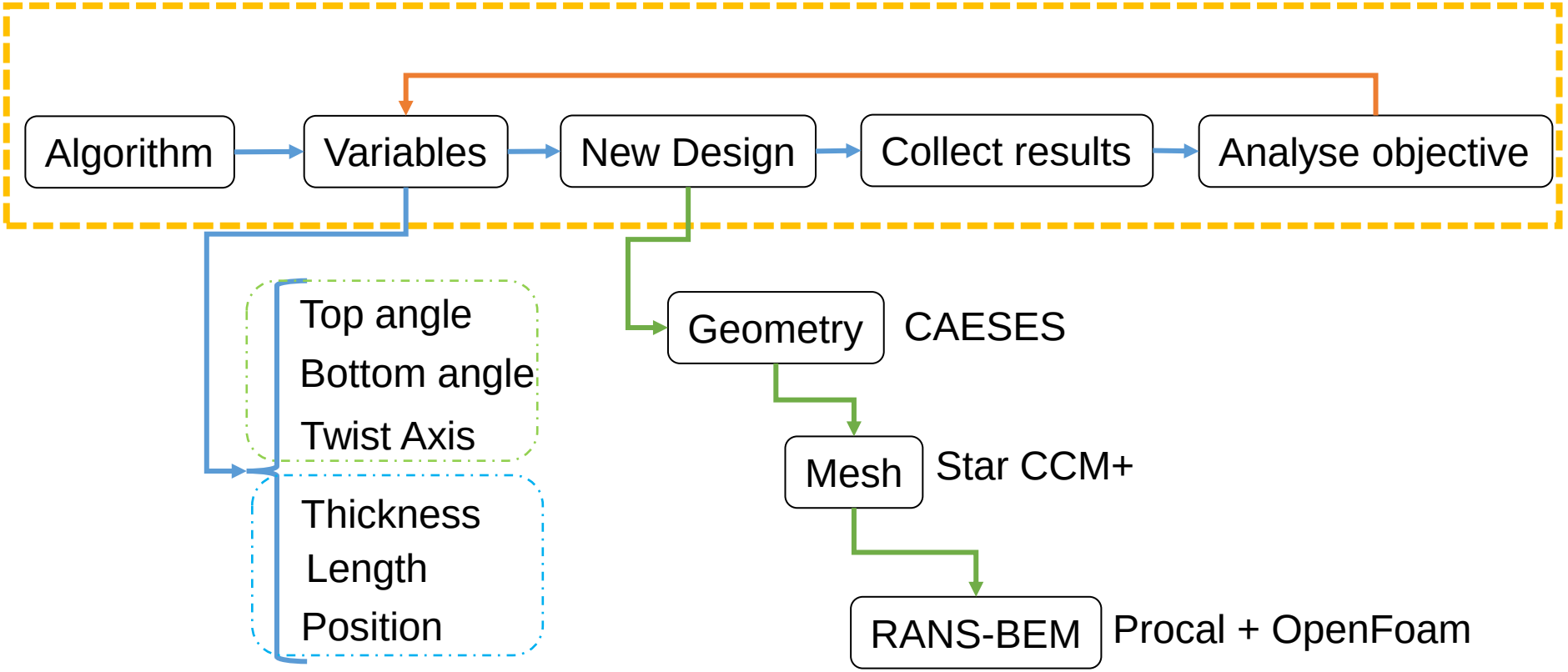
Optimization Flow

FS-optimizer



Algorithm Selection

Sobol

- Uniform sampling of the design space
- Quasi-random sequence
- Deterministic algorithm

NSGA II

- Stochastic population-based
- Natural evolution: fittest individuals over generations
- Genetic operations: crossover and mutation

Objective definition

Propulsive efficiency

Efficiency comparison

Effective power

$$\eta_D = \frac{P_E}{P_D} = \frac{(R_T - F}{2\pi Q} \quad eff_0 = 1 - \frac{2\pi Qn}{P_{D0}}$$

Delivered power

Non-twisted rudder P_D

v_s: model speed

R_T: measured resistance

F_D: friction deduction

Q: propeller torque

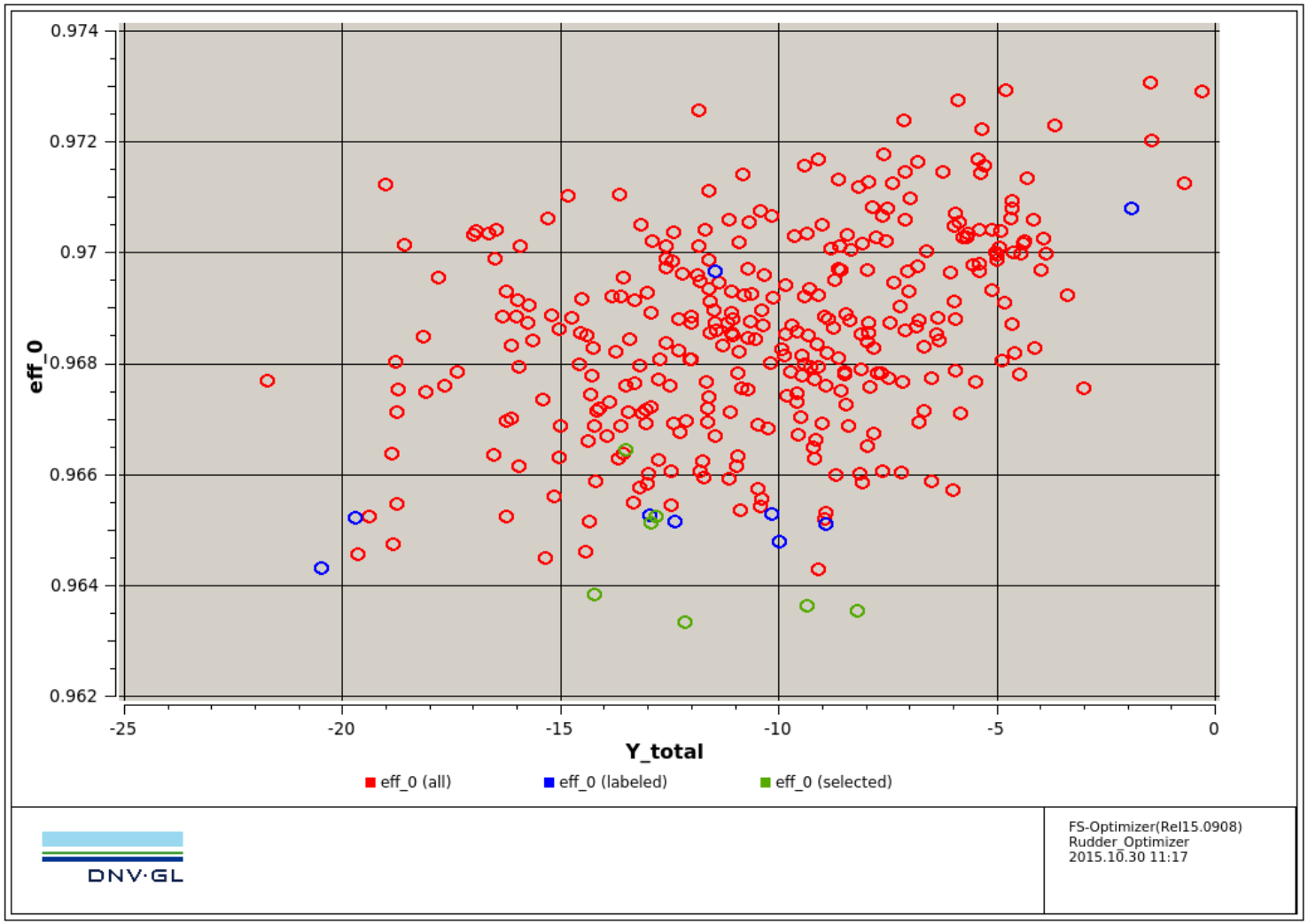
n: propeller rotational rate

$$Y_{total} = Y_{Top} - Y_{Bottom}$$

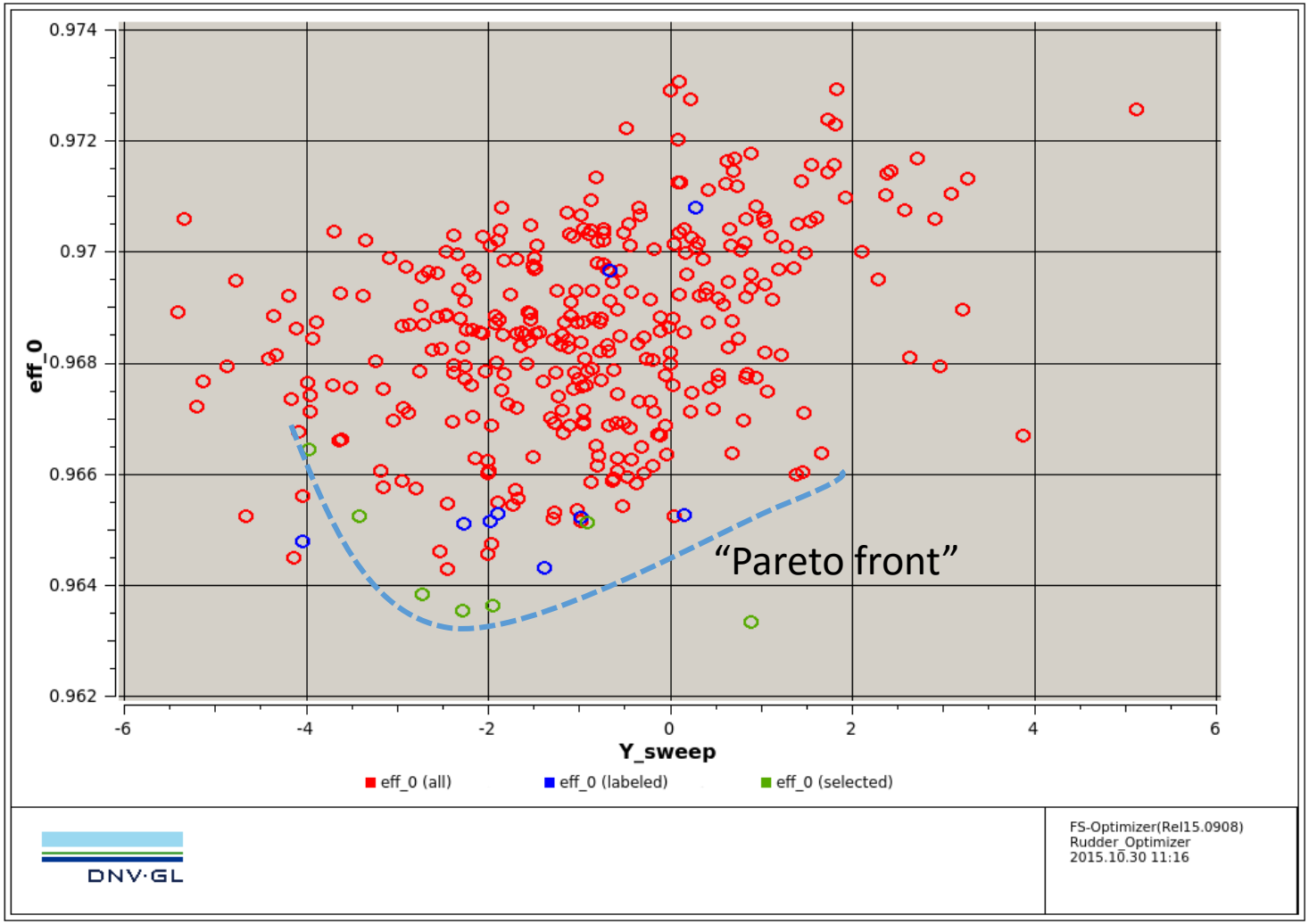
$$Y_{sweep} = \frac{Y_{Top} + Y_{Bottom}}{2}$$

Twist monitor

DOE-Design of Experiments



DOE-Design of Experiments



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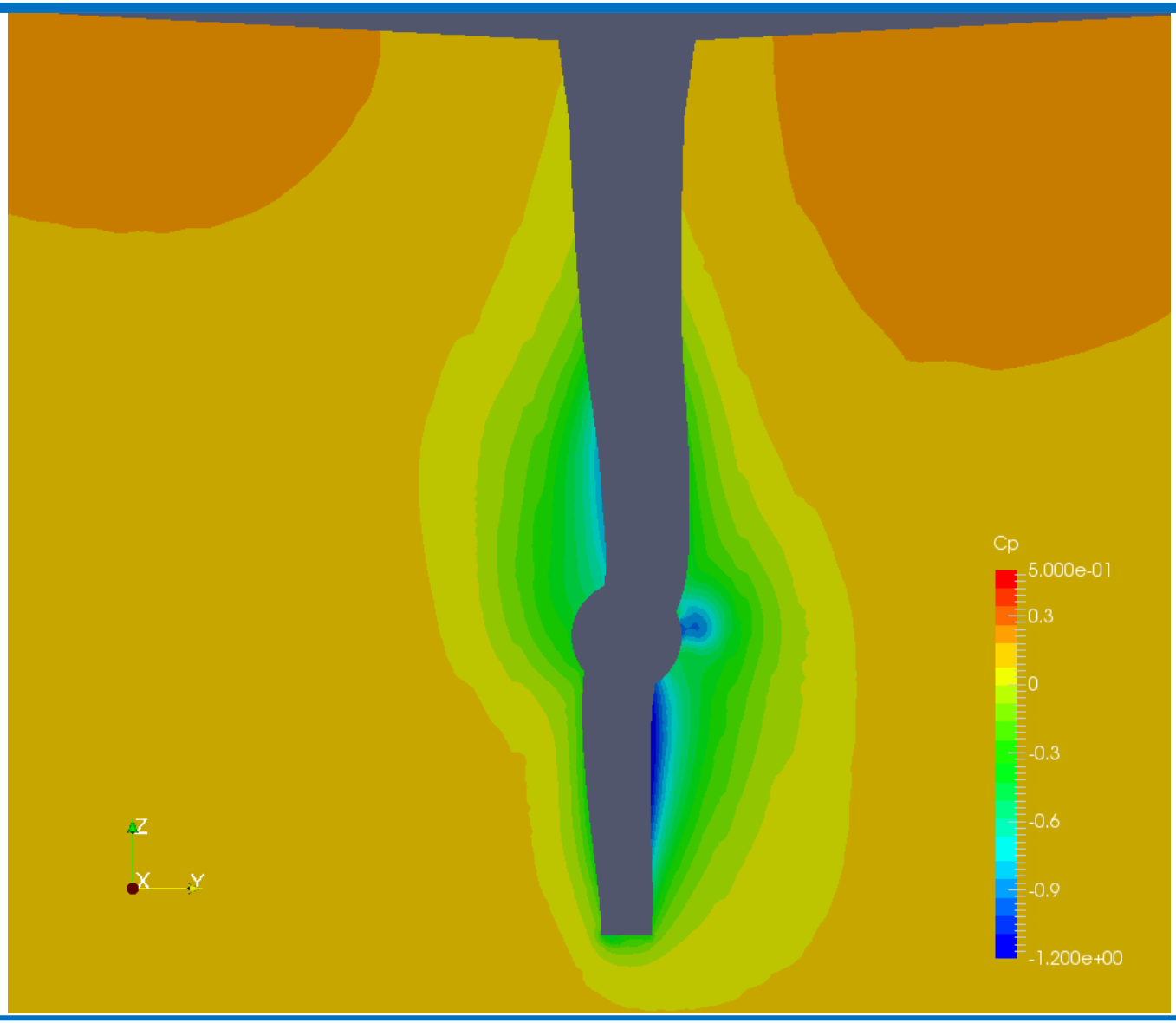
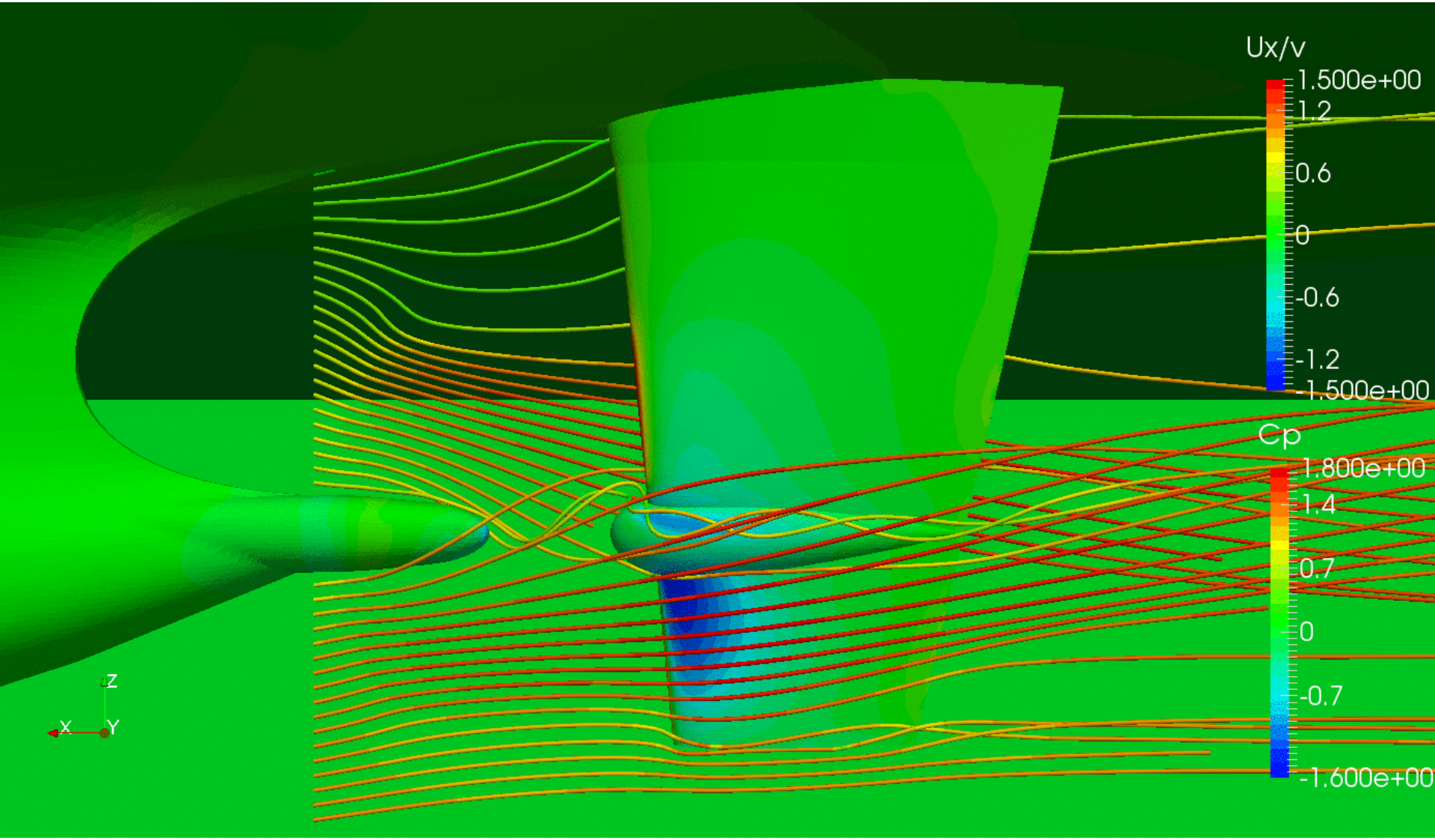
Twisted Rudder results



.gif

Bulb results

.gif



Best Twisted Rudder and Bulb

Non-twisted rudder η_D=0.8044

N-356

η_D = 0.8336

η_D increased 2.93%

Eff_0 = 4.3%

N-200

η_D = 0.8337

η_D increased 2.92%

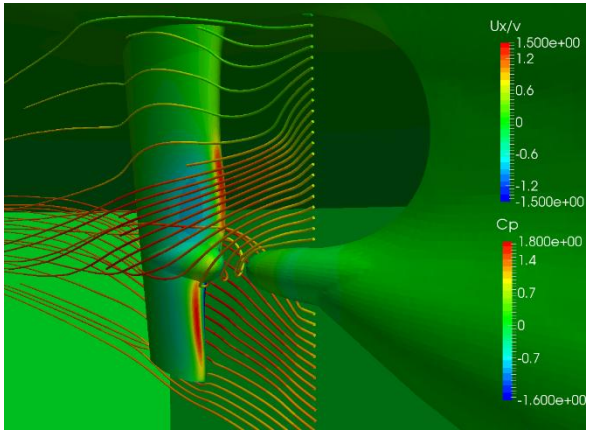
Eff_0 = 4.33%

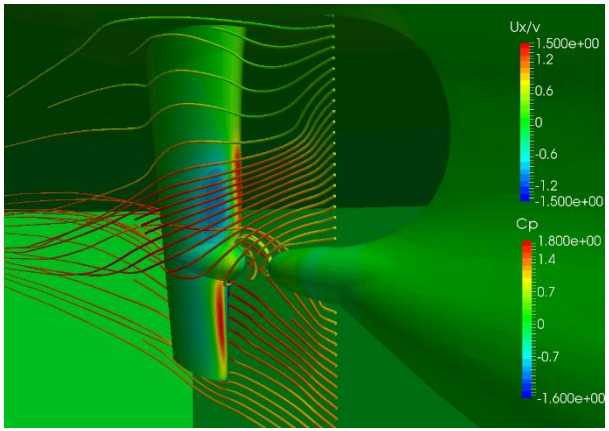
B-076

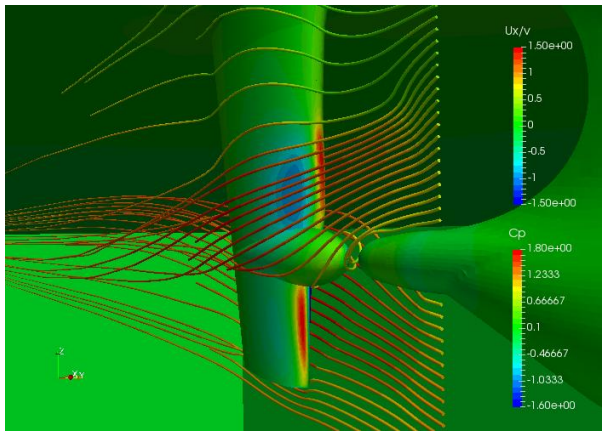
η_D = 0.8348

η_D increased 3.04%

Eff_0 = 4.55%







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Conclusion

- Appropriate selection of:
  - Mesh
  - Algorithm
  - Variables
  - Objective

- RANS-BEM computational time < fully RANS

- Reduction in delivered power of 4.55%