Design of ships in waves using CAESES and SHIPFLOW

presented by
Leif Broberg FLOWTECH International

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Content

- Overview of the tools
- Case study
  - Optimizations
  - Cross-check
- Summary

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Overview of

SHIPFLOW and CAESES

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Integration of tools

Shape variations

Optimization methods

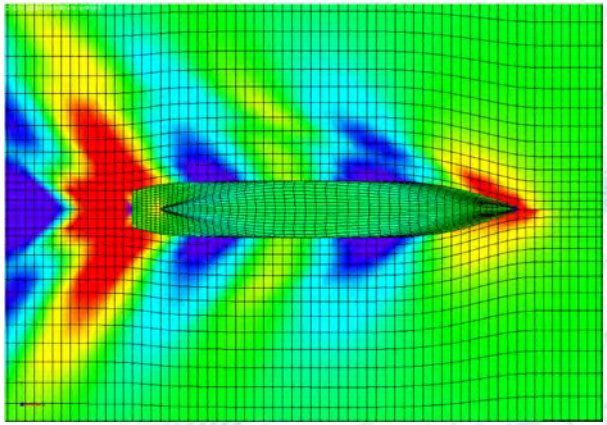
Resource management

- Grid Generation
- Flow simulations
- Result processing

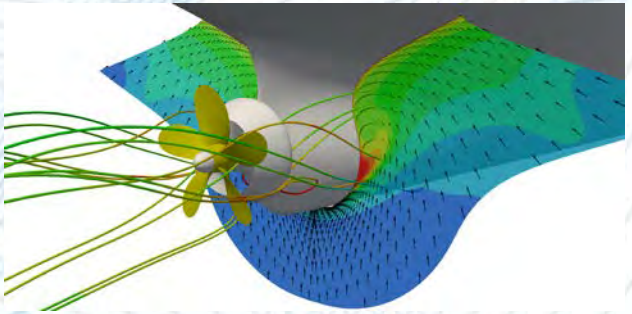
The SHIPFLOW system

Flow solvers

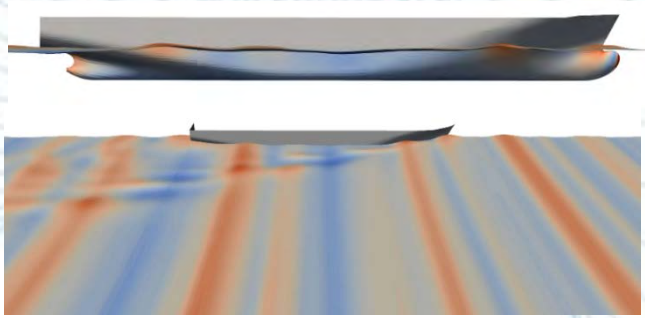
- BASIC
  - XPAN potential flow solver.
    wave pattern, wave resistance, pressure, sinkage&trim
  - XBOUND thin boundary layer method
    surface streamlines, friction drag, b.l. thickness
  - **Best suited for wave resistance optimizations**



- RANS
  - XCHAP RANS equations solver
    flow field, viscous resistance, self-propulsion, free-surface
  - **Applied successfully to delivered power optimizations**



- MOTIONS
  - time dependent potential flow solver
  - **motions and added resistance in waves**



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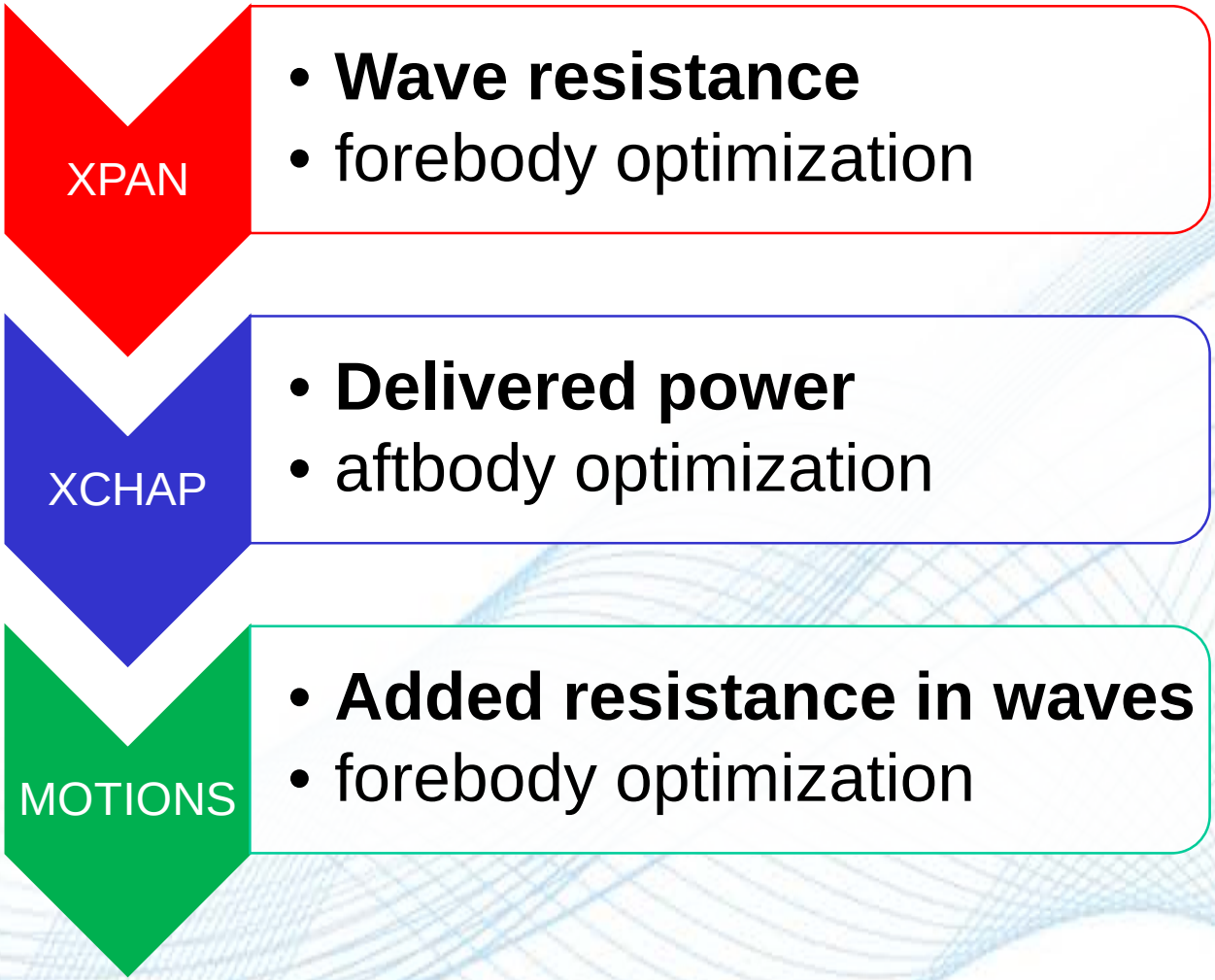
Optimization Strategy - Efficient choice of solvers



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Case Study

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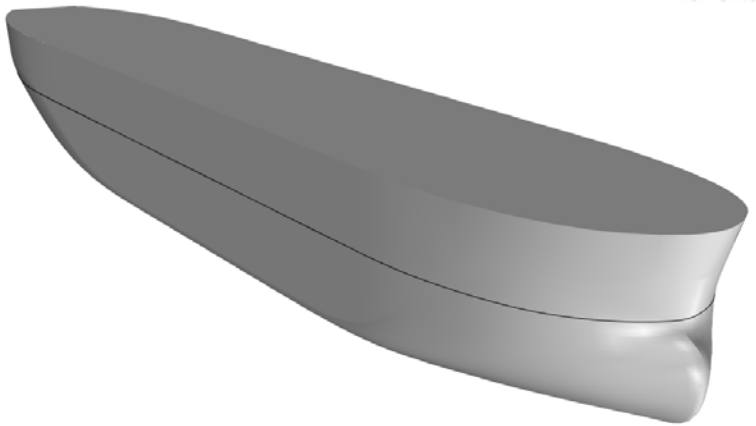
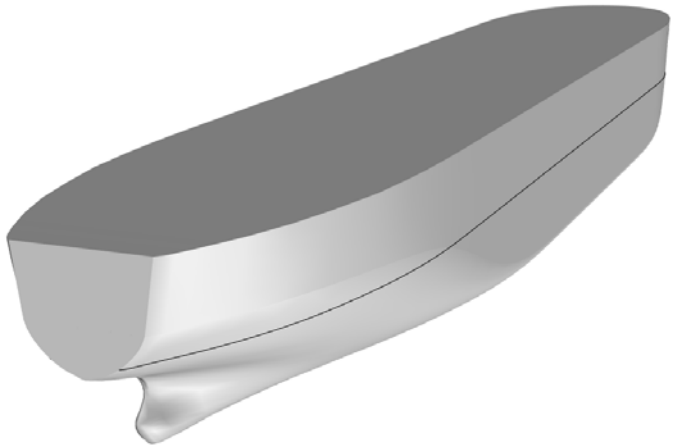
Case study provided for the NJTF optimization workshop 2018





- Particulars:
  - Loa(m) 322.5 m
  - Lpp(m) 314.6
  - B(m) 52.5
  - T(m) 18.1
  - Displacement (m^3) 252045.4
  - Propeller diameter: 9.6m
- Conditions:
  - Vs=15kn
- Optimization target:
  - Resistance
- Constraints:
  - Lpp, ship width B, draught T remain unchanged;
  - Lcb (Lpp%) ≥ 3%
  - Displacement change less than 1500m^3;

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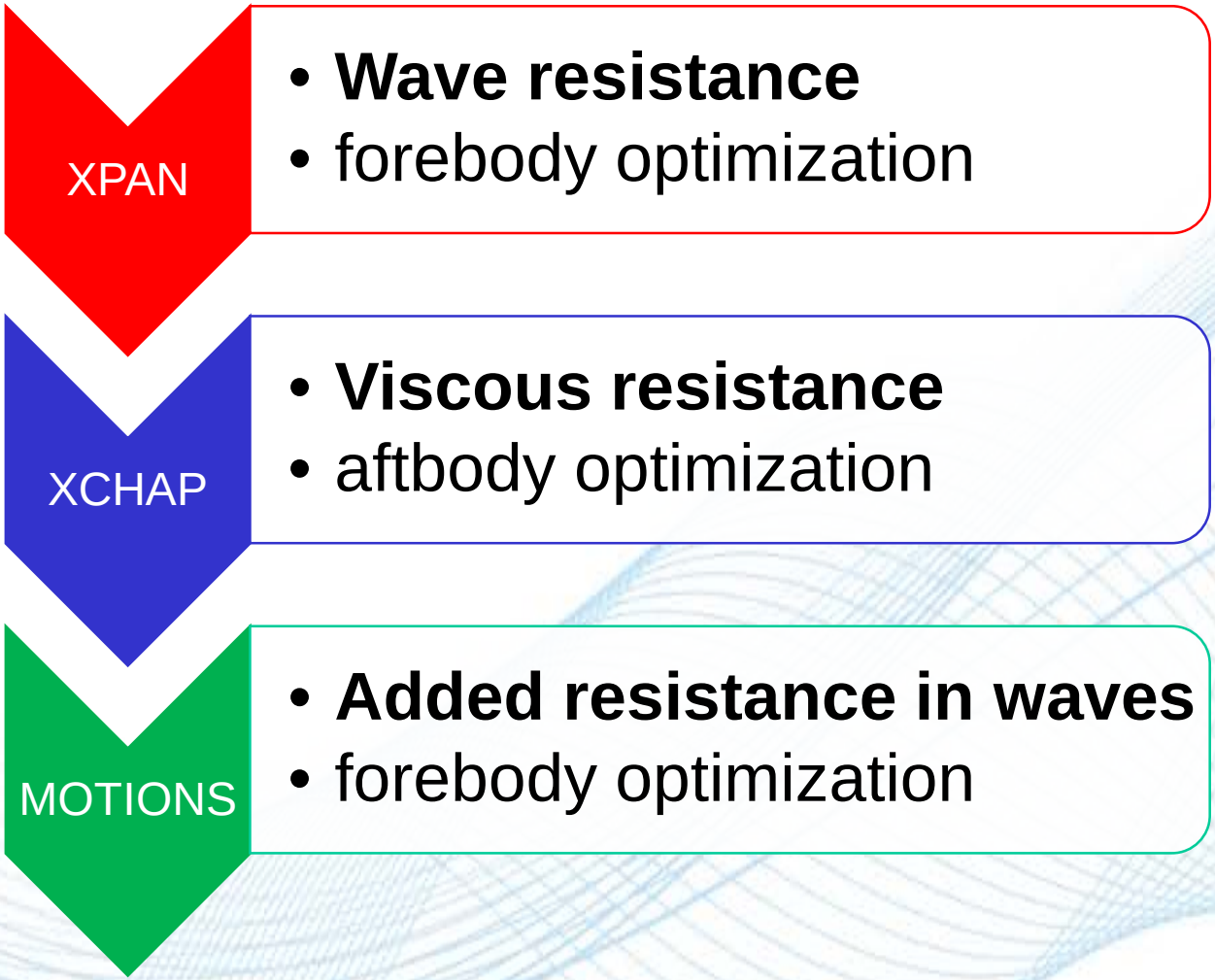
Optimization Strategy



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Added resistance in waves optimization

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Added resistance in waves optimization with MOTIONS

- Baseline analysis and target conditions
- Transformation and design variables
- Optimization process
- Comparison of variants

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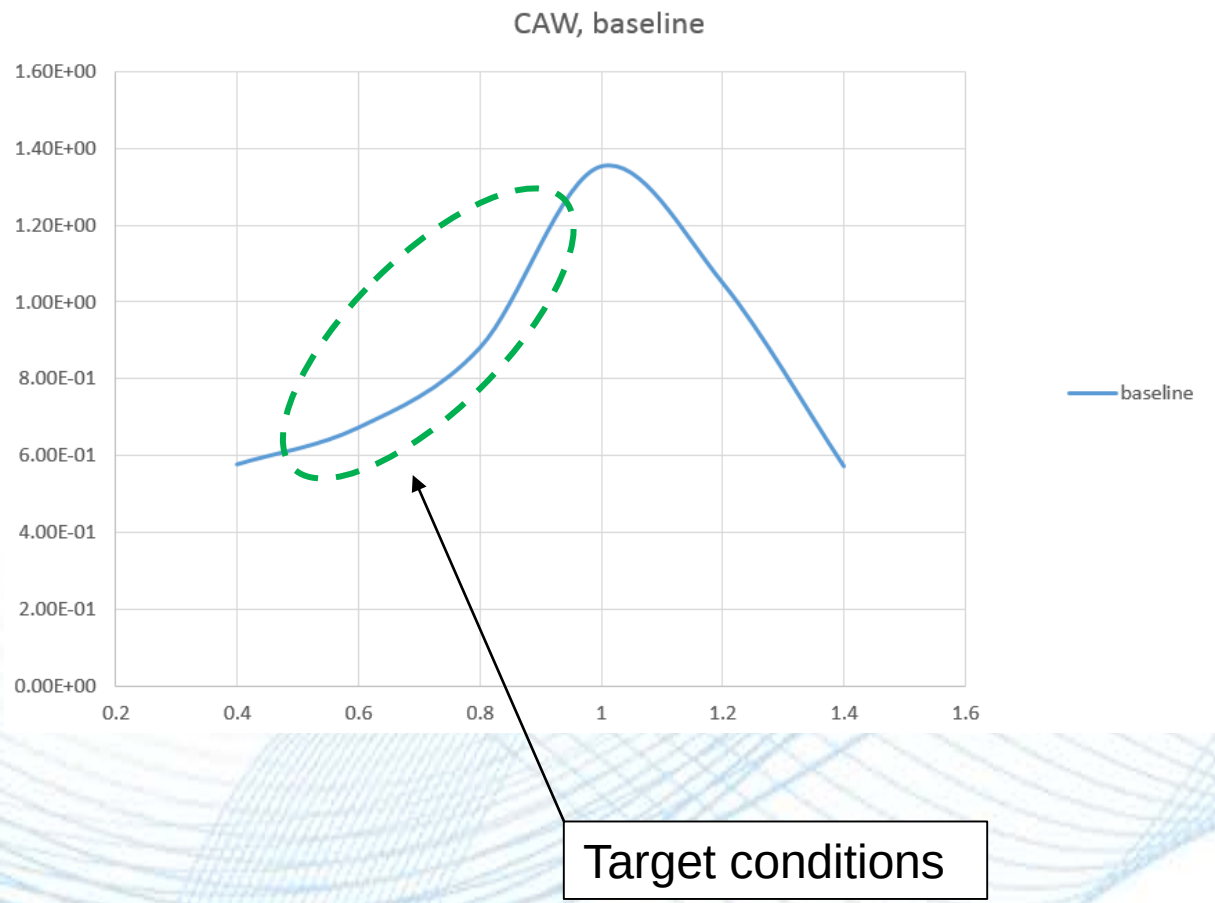
Added resistance in waves optimization with MOTIONS

- Baseline analysis



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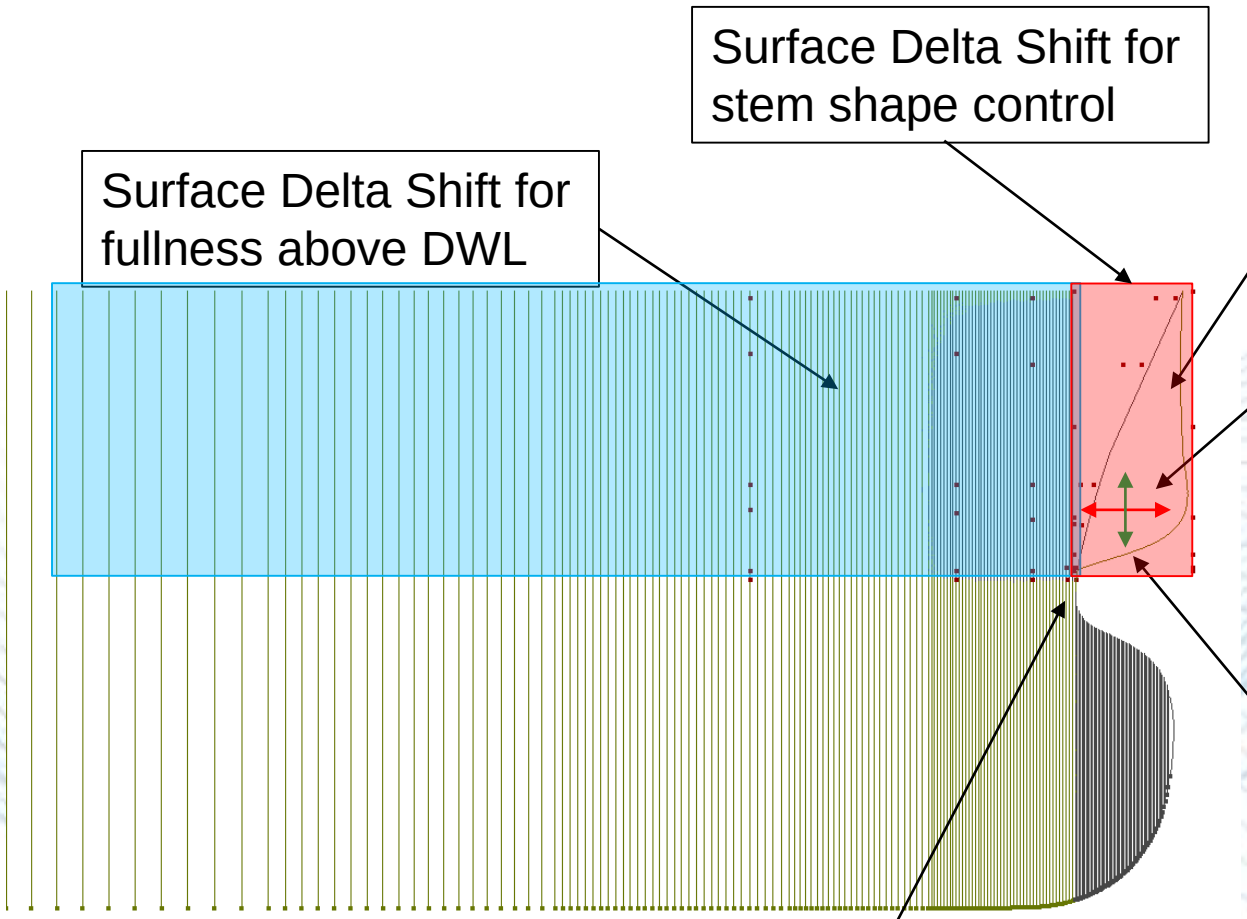
Added resistance in waves optimization with MOTIONS

- Transformation and design variables



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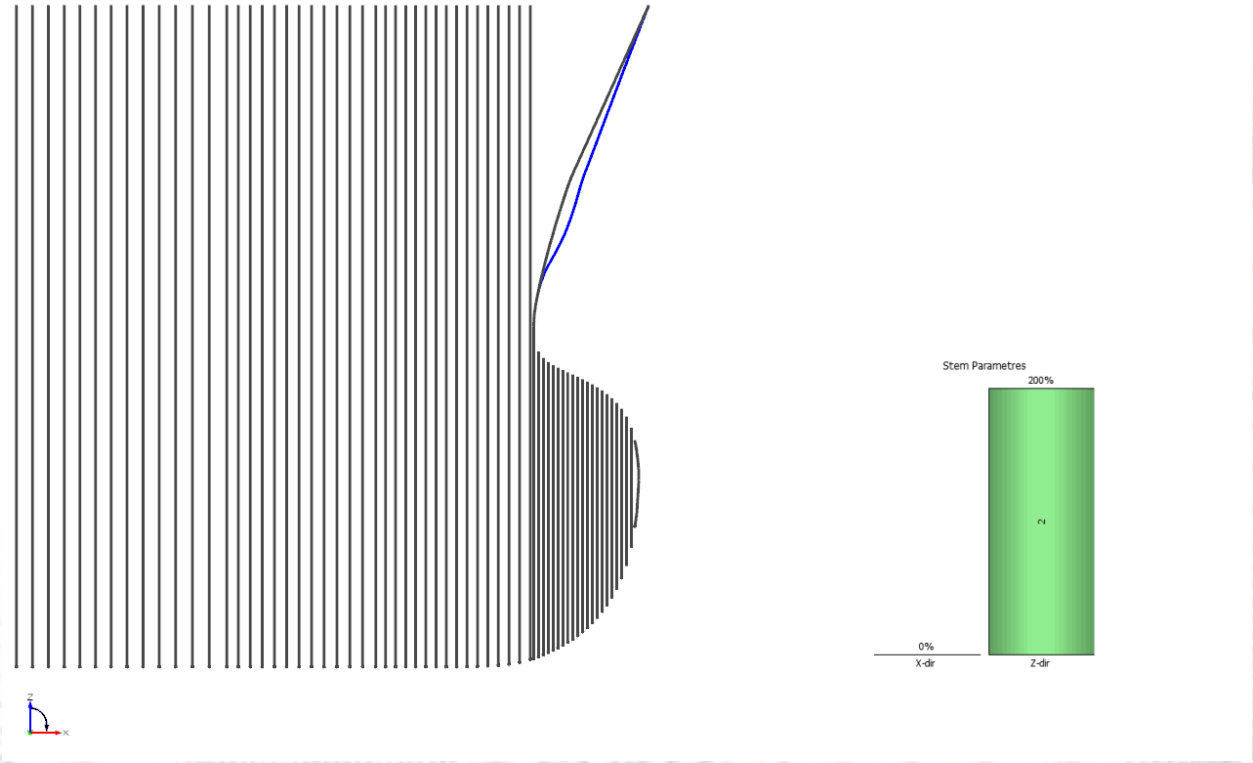
*) patented by VARD, Norway

Added resistance in waves variant comparison



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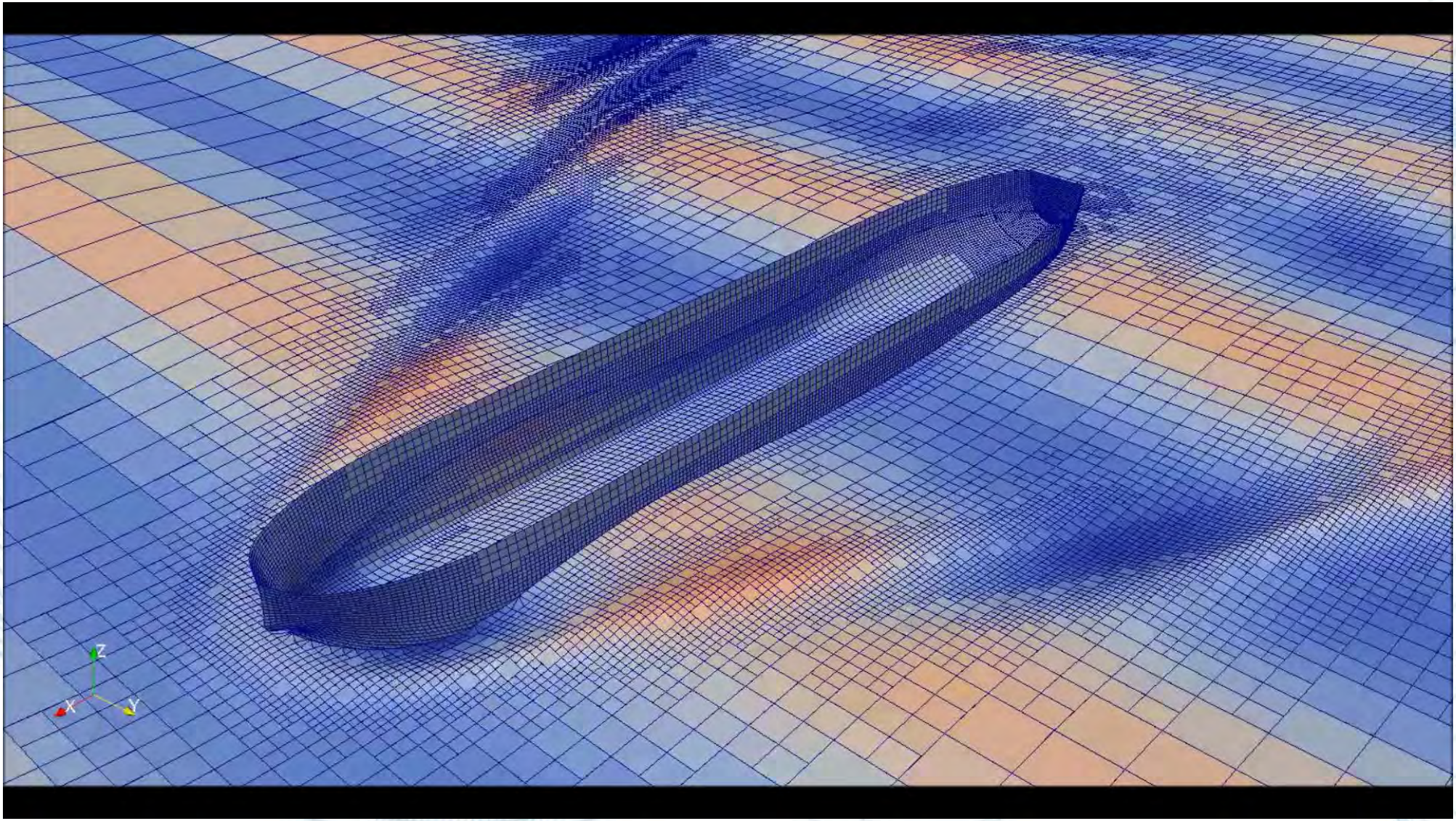
SHIPFLOW MOTIONS



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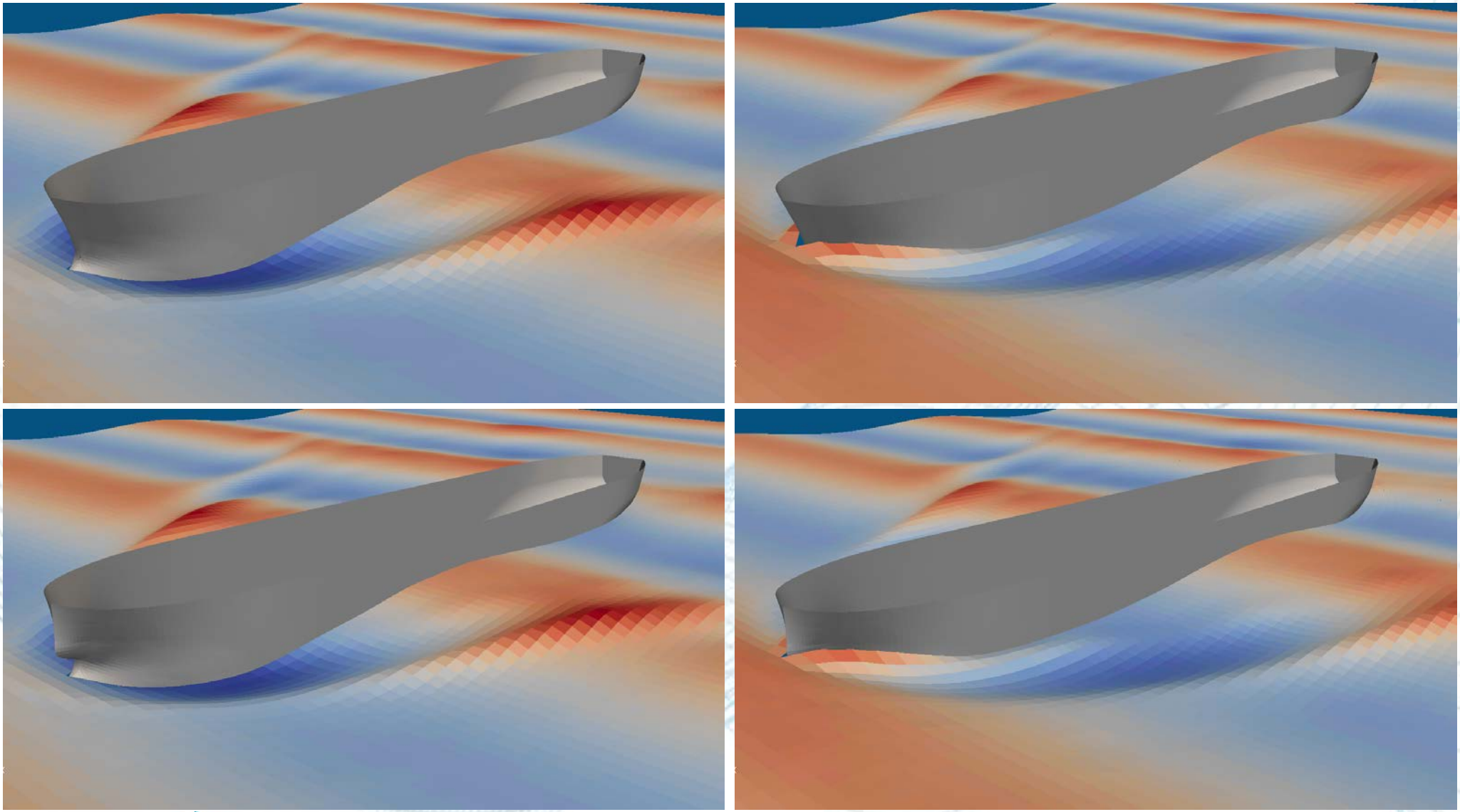
Added resistance in waves optimization with MOTIONS



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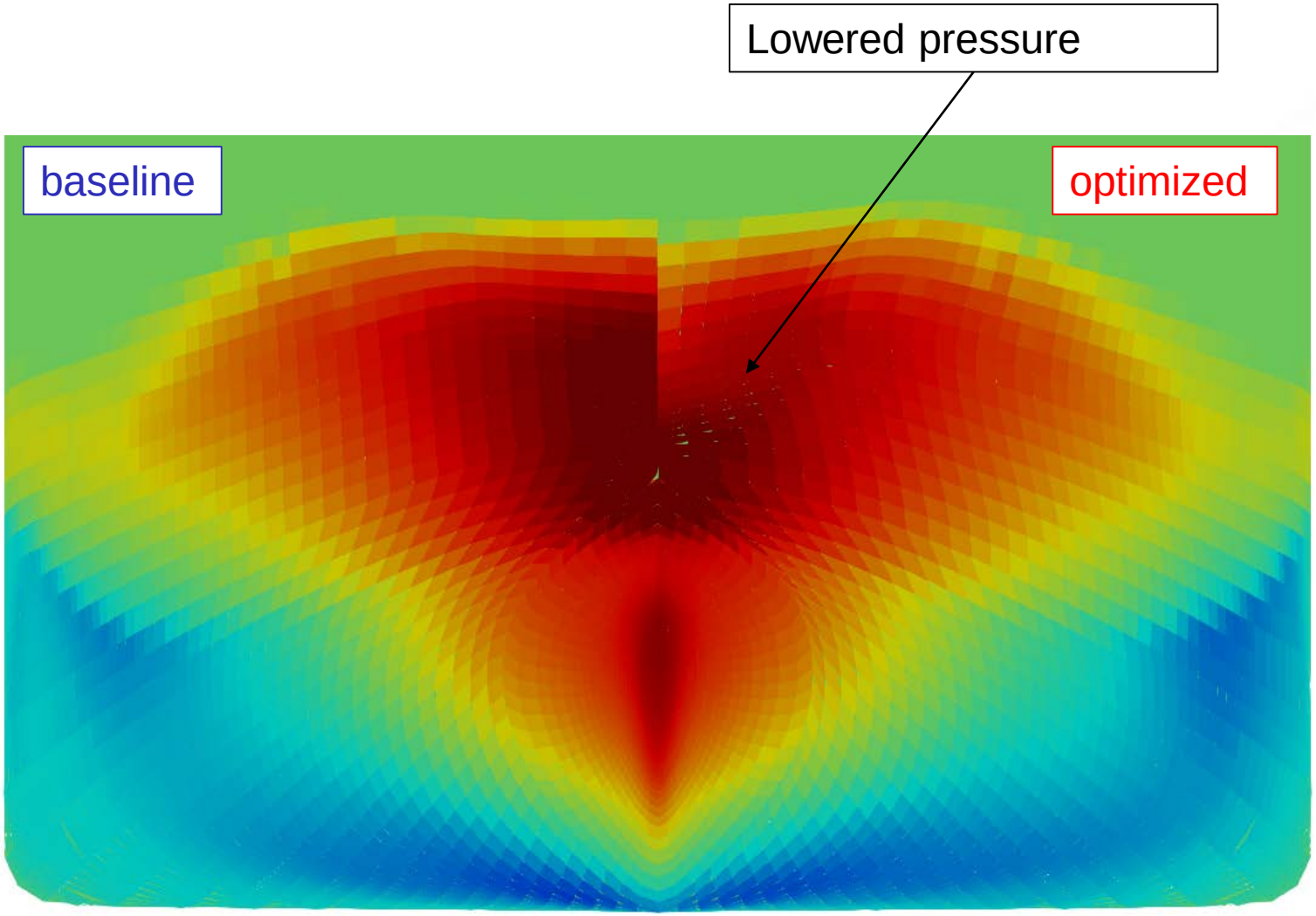
Averaged pressure distribution (over one wave period) - bow



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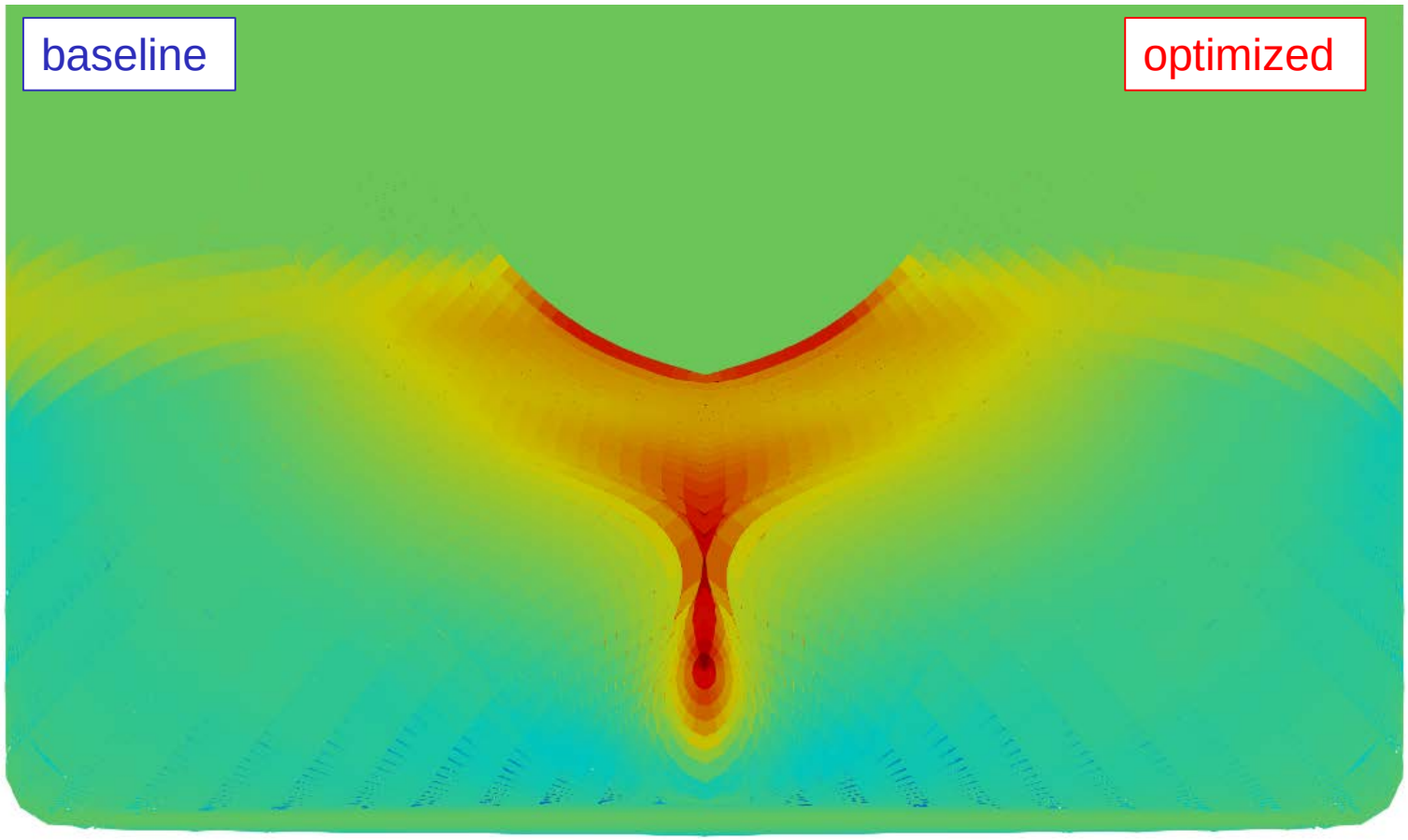
Averaged pressure distribution (over one wave period) – stern

No noticable difference



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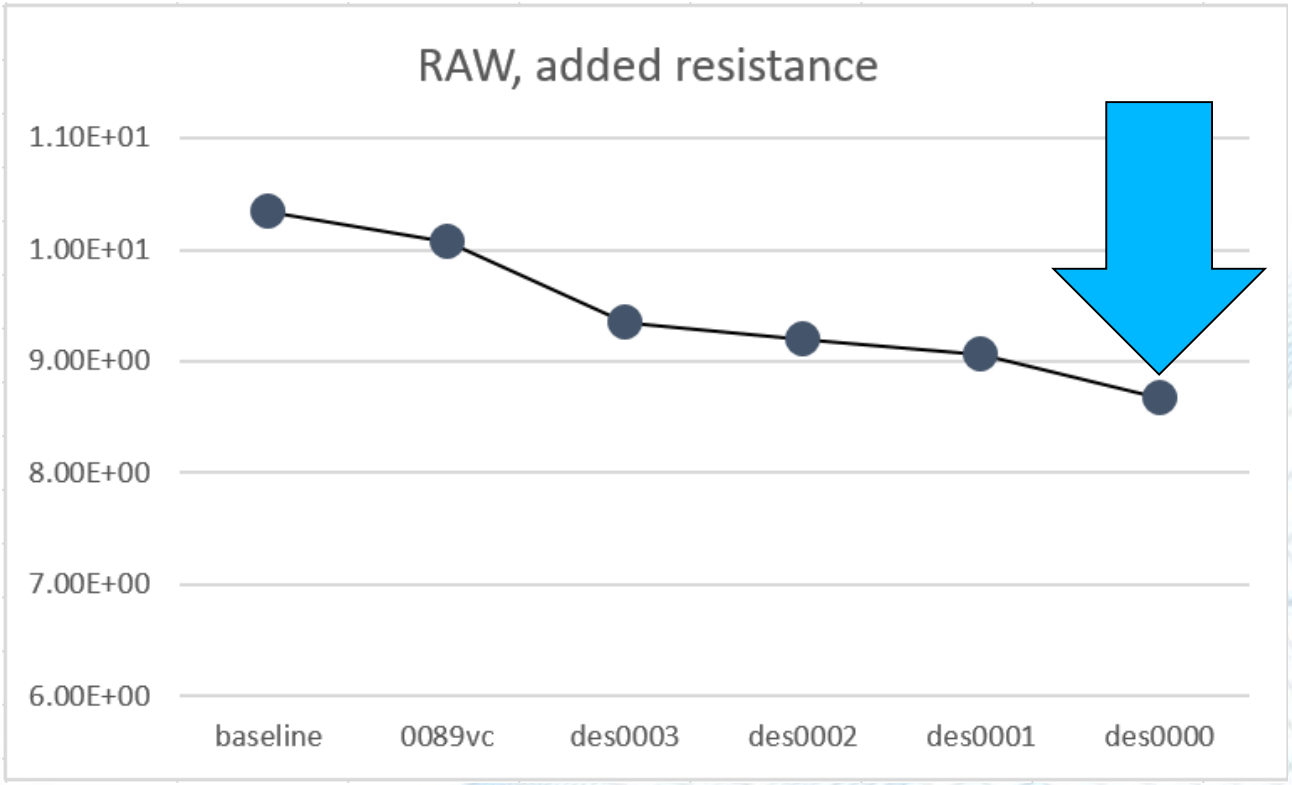
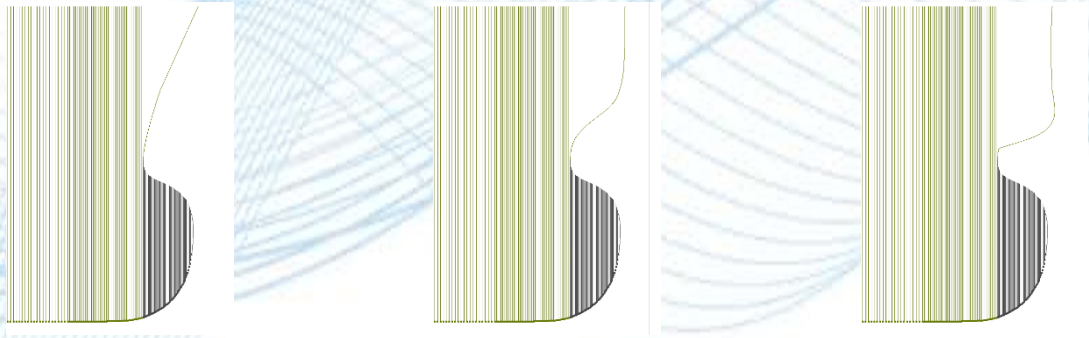
Added resistance in waves: λ= 0.6Lpp





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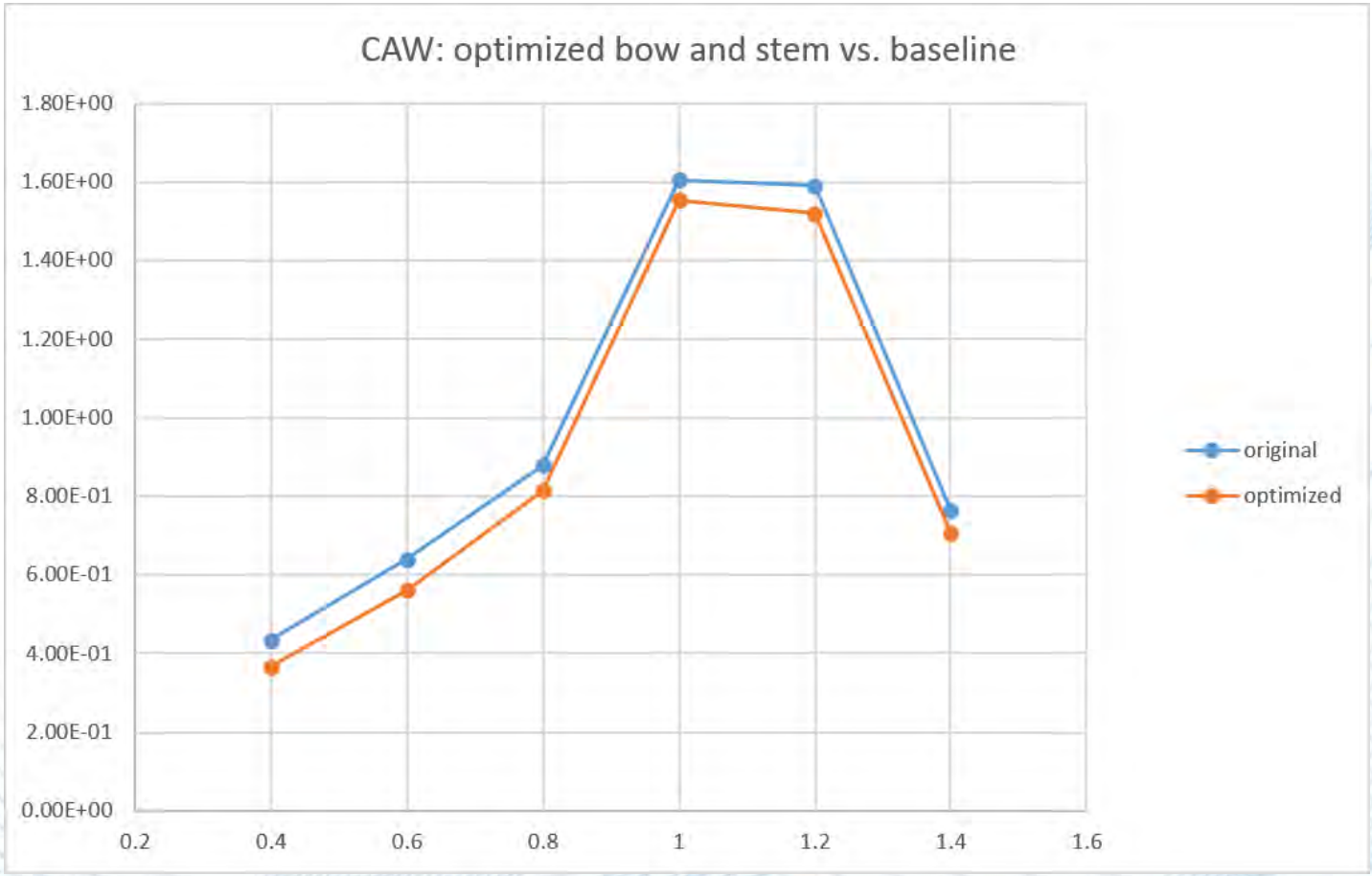
Added resistance in waves variant comparison



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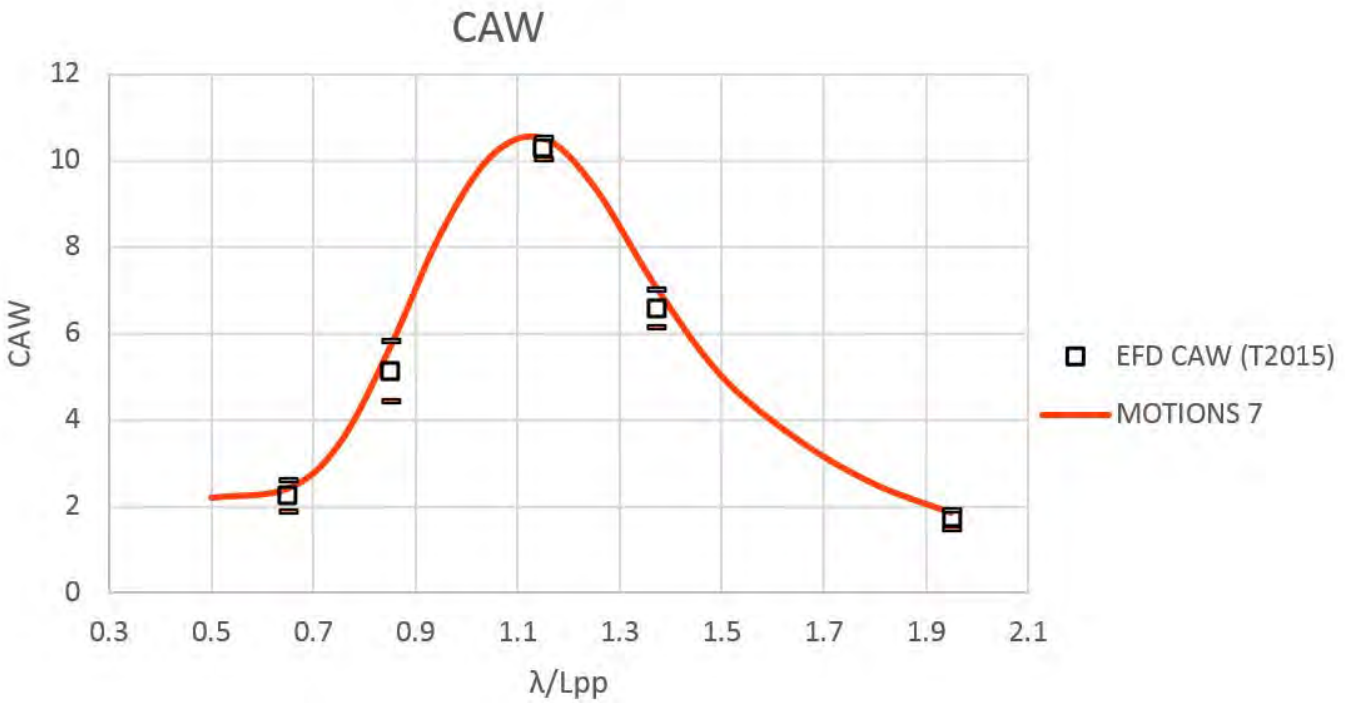
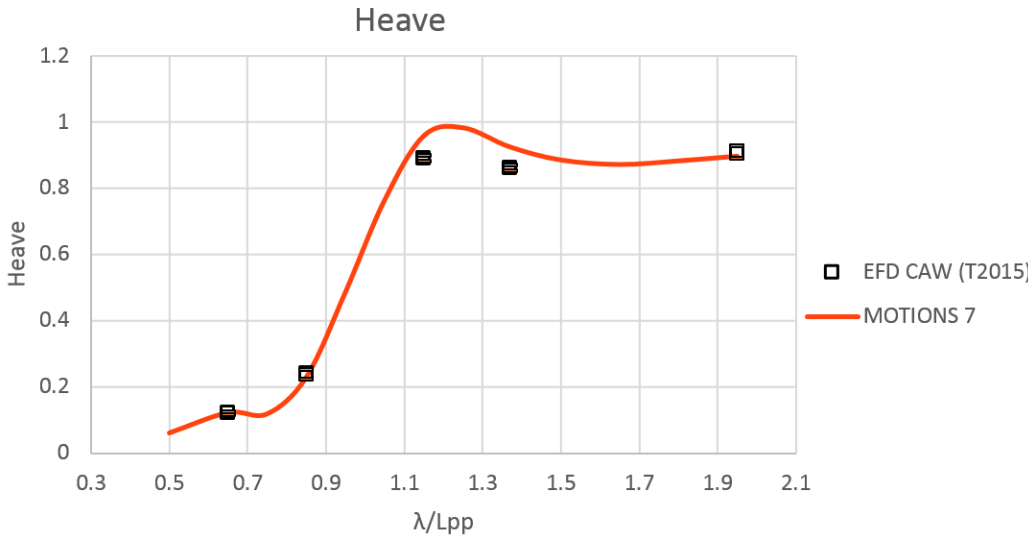
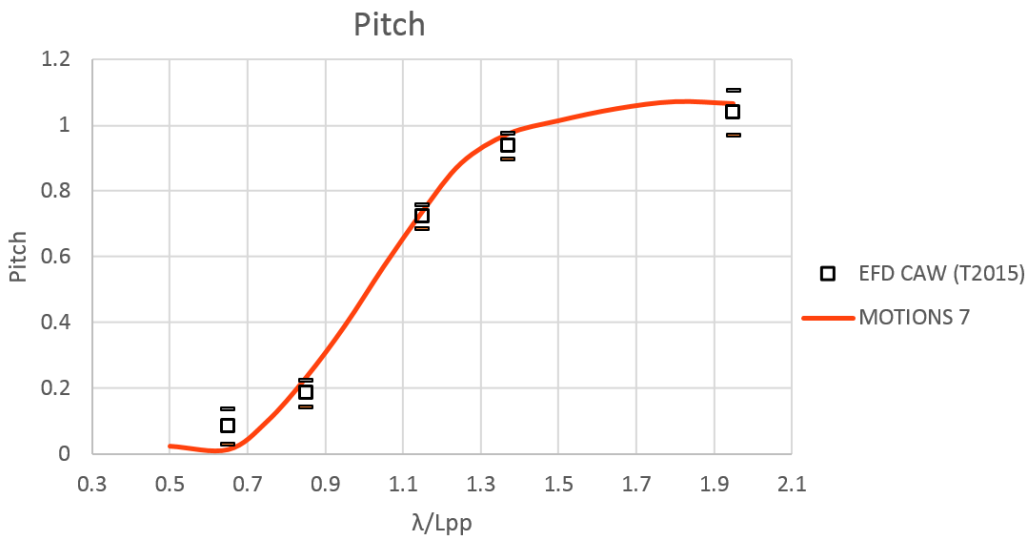
KCS results - comparison with experiments



- experimental data taken from Tokyo 2015 Workshop summary
- Average of FORCE, IIHR and OU measurements including standard deviation bars





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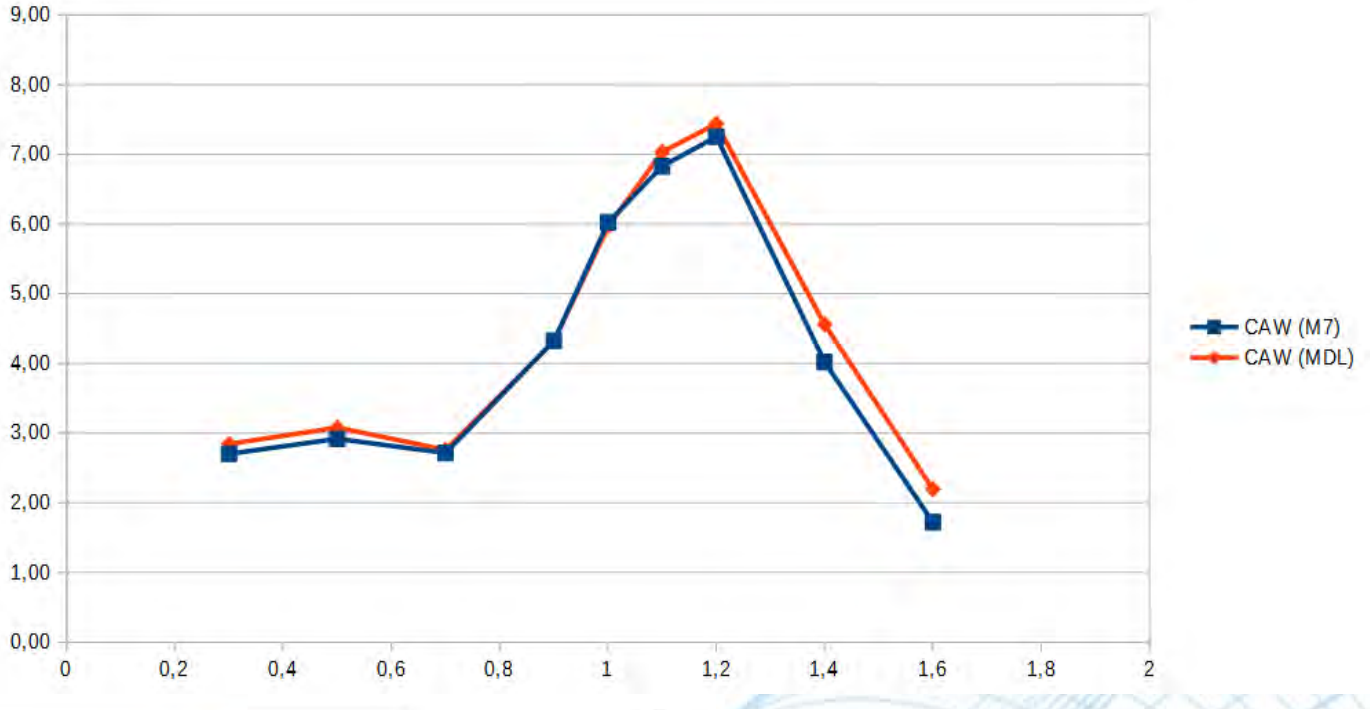
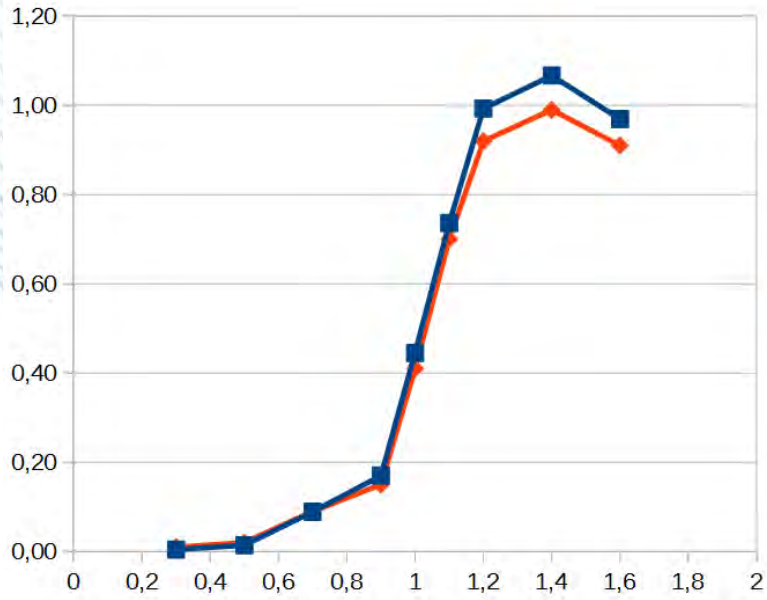
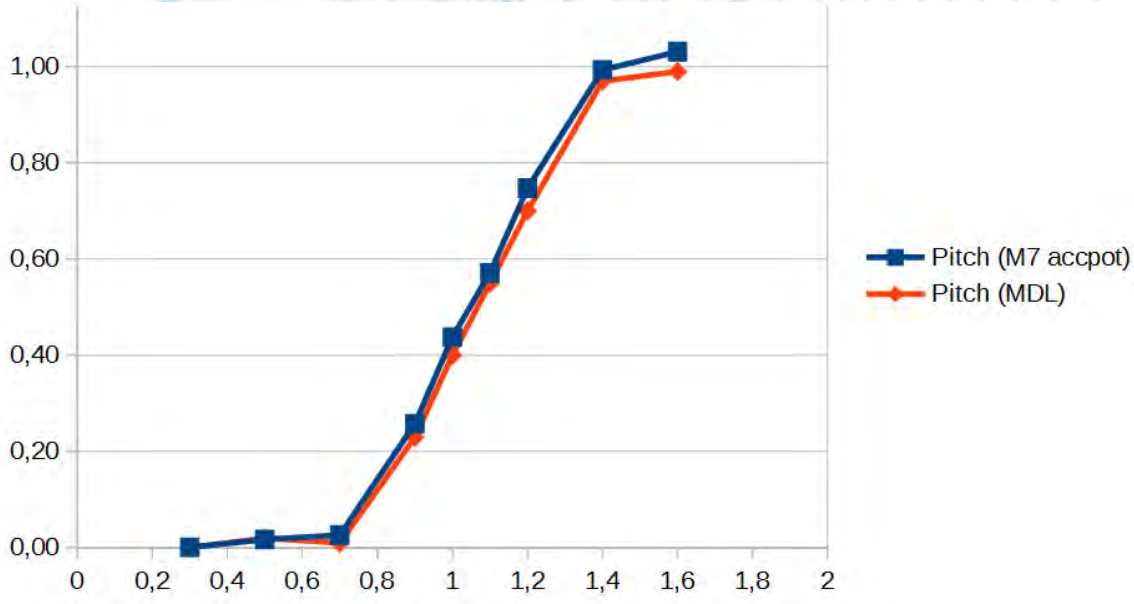
KVLCC2 results - comparison with experiments







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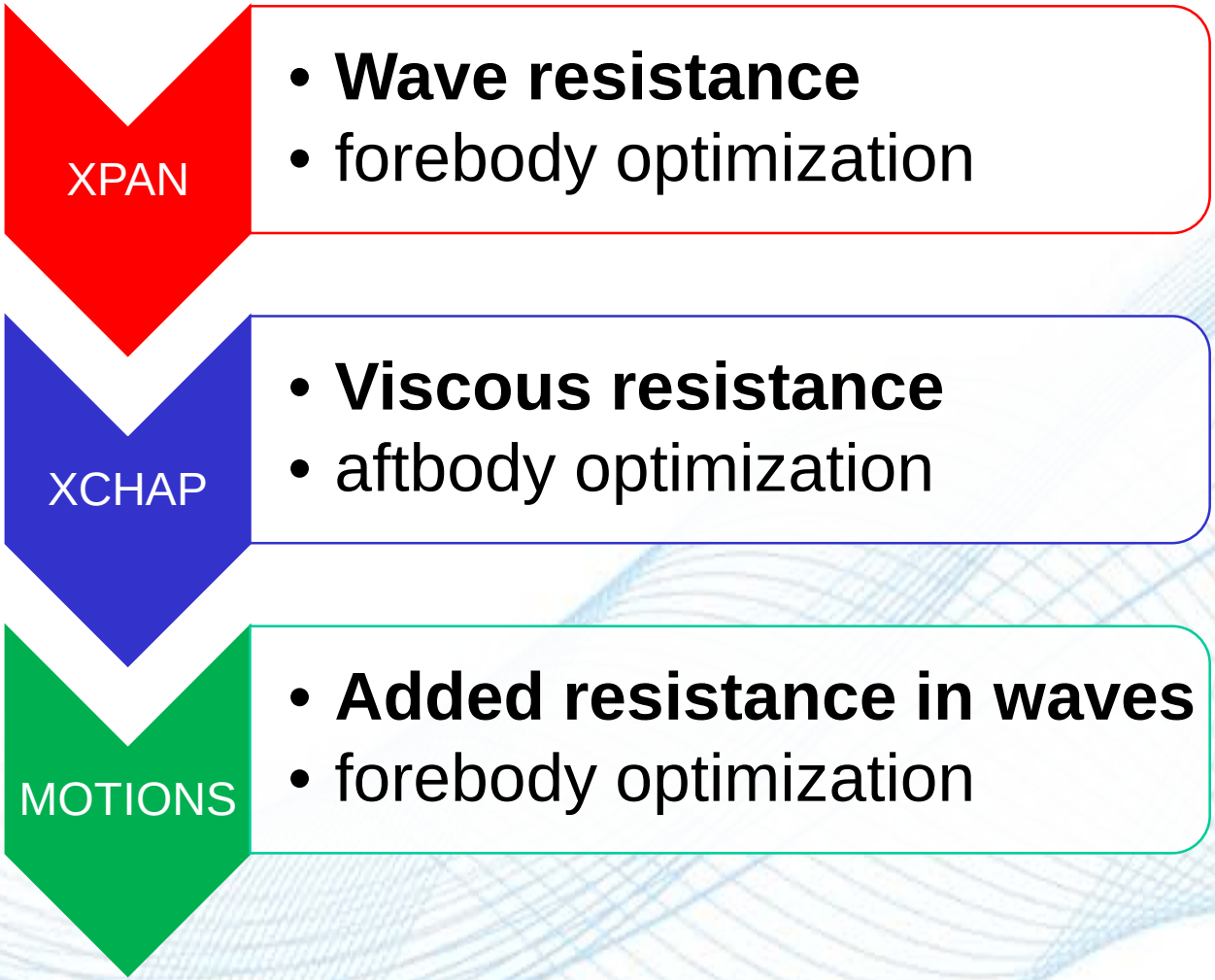
Optimization Strategy



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Wave resistance optimization

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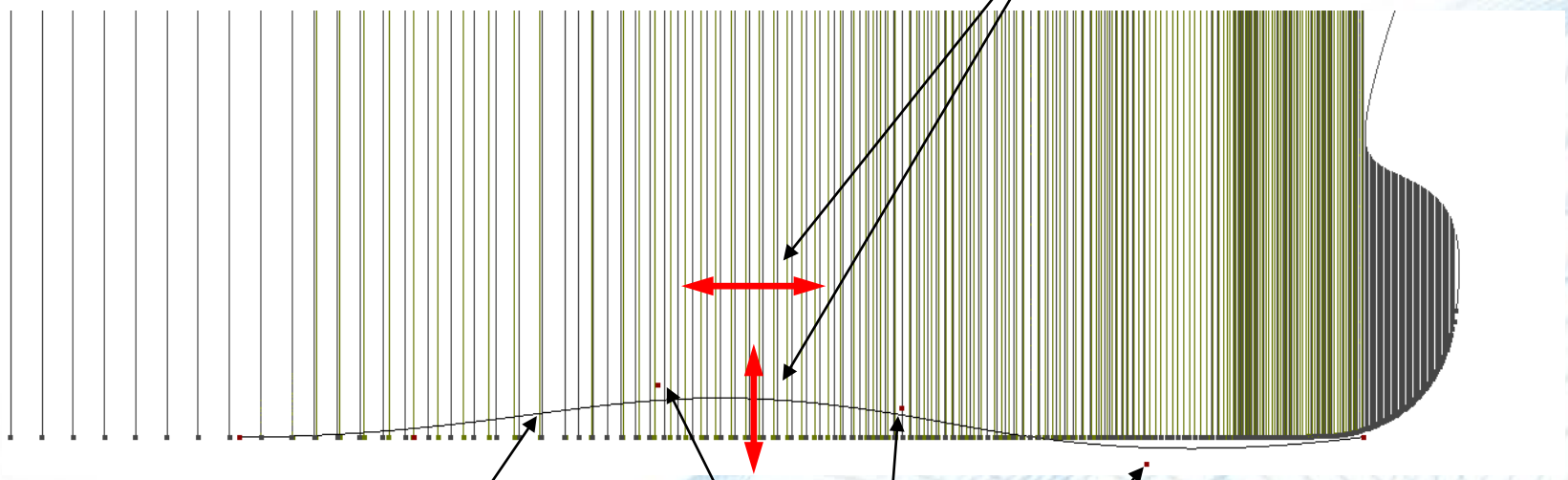
Transformation method – Delta Shift



Vertical deformation of Delta curve results in longitudinal translation of stations

Delta Curve

Control points,
3 design variables

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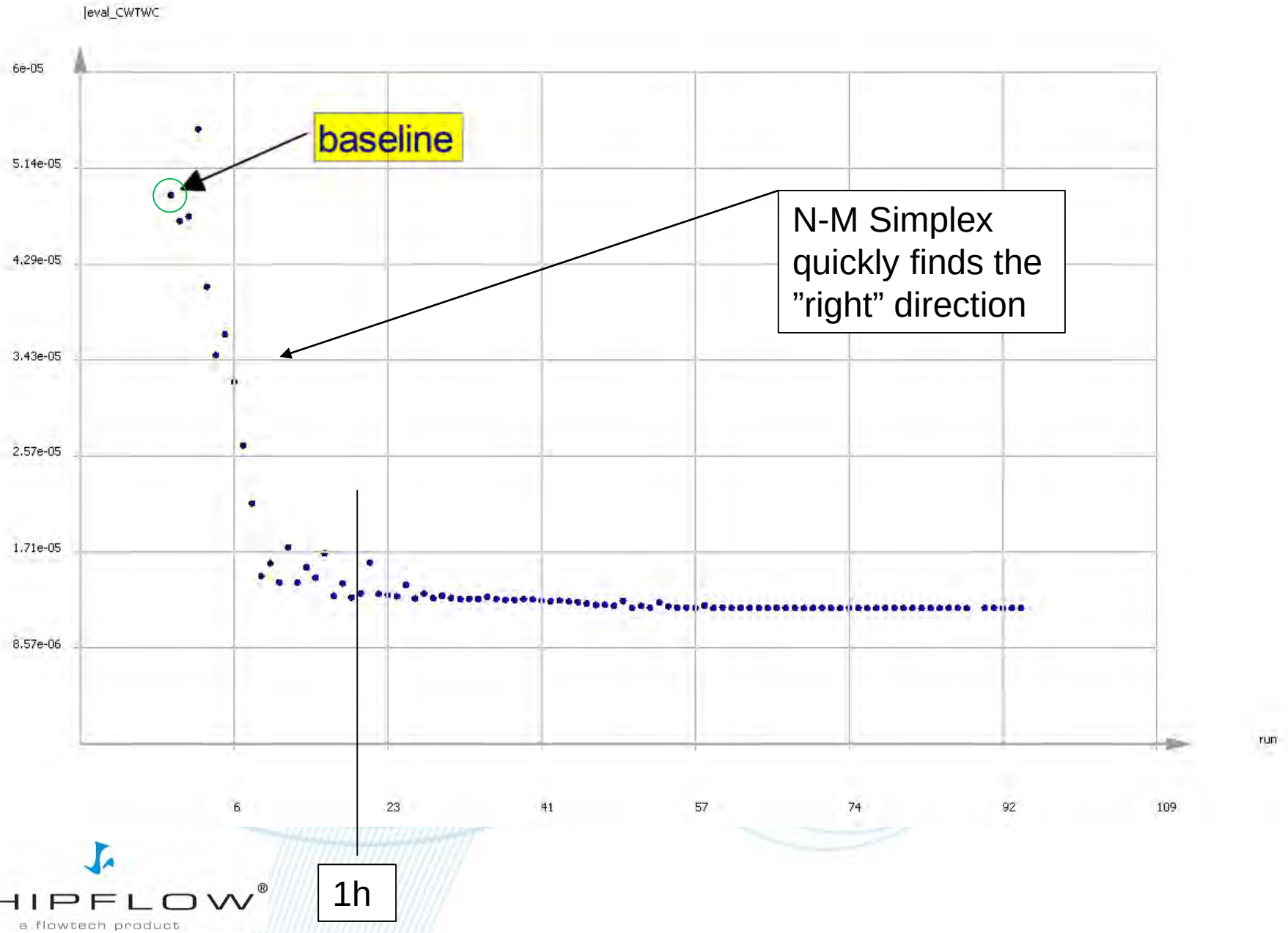
Optimization history



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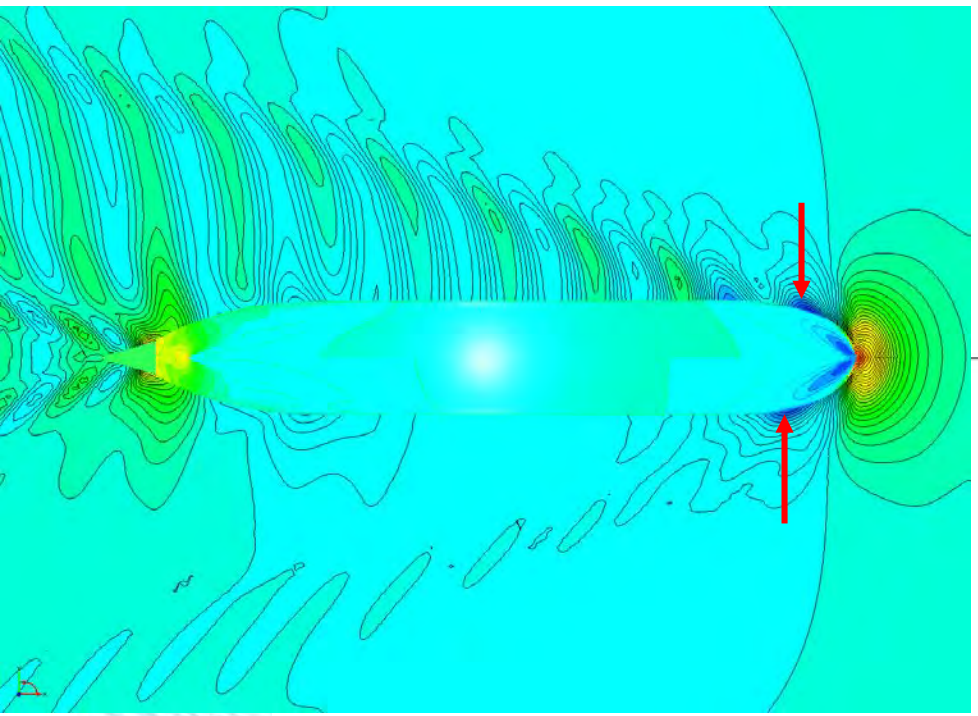
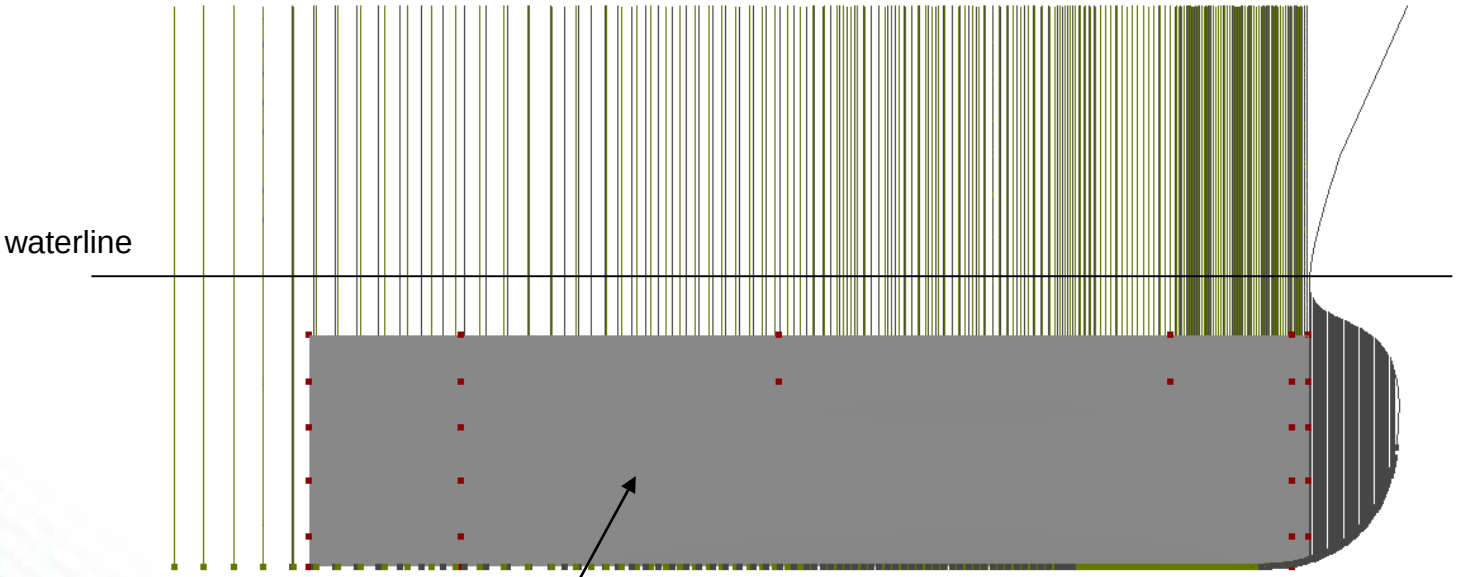
Waterline shape – deviation and curvature



Forebody – Displacement correction



Surface
Delta Shift

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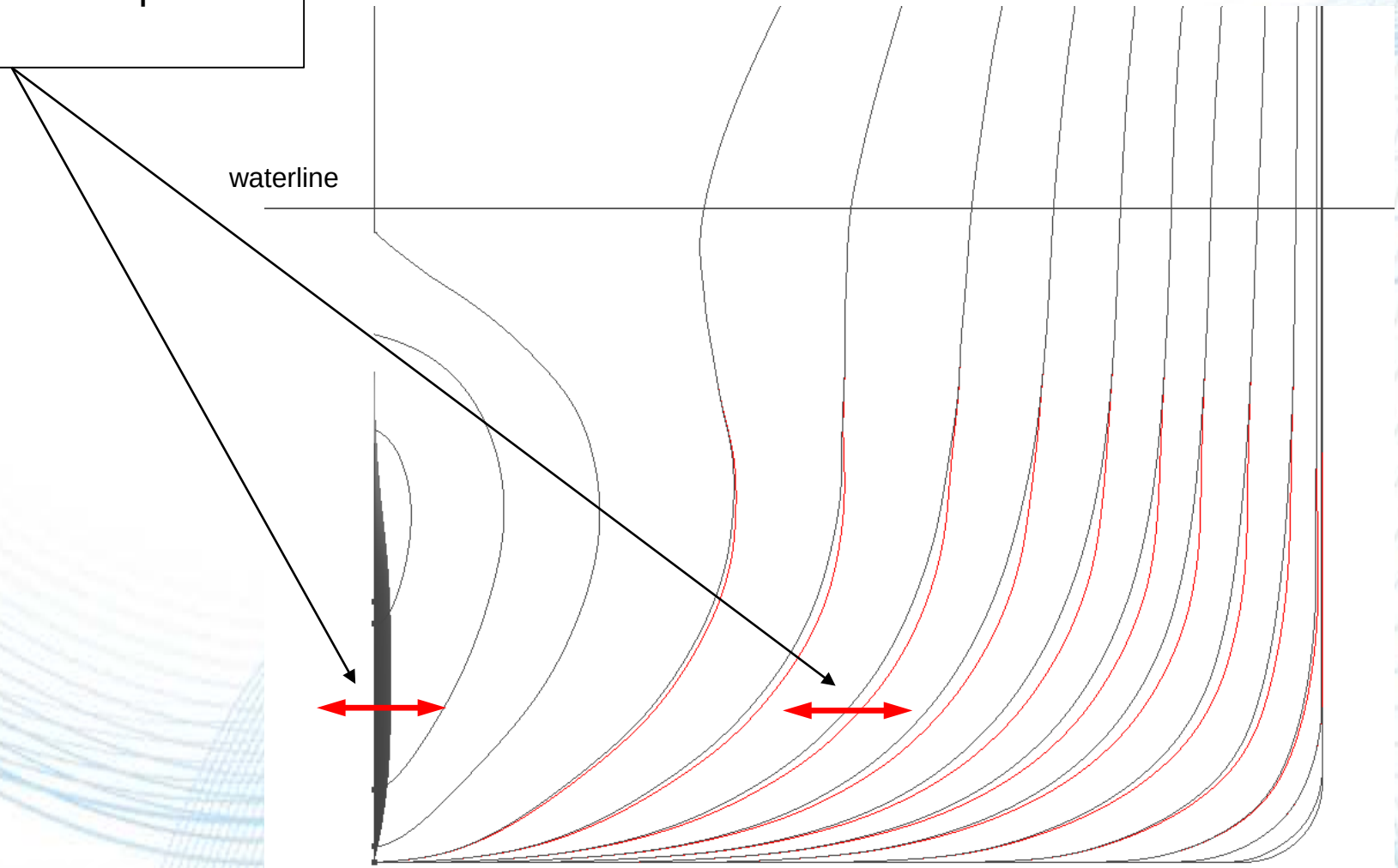
Forebody – Displacement correction

Transverse deformation of Delta surface results in transverse station shape modification



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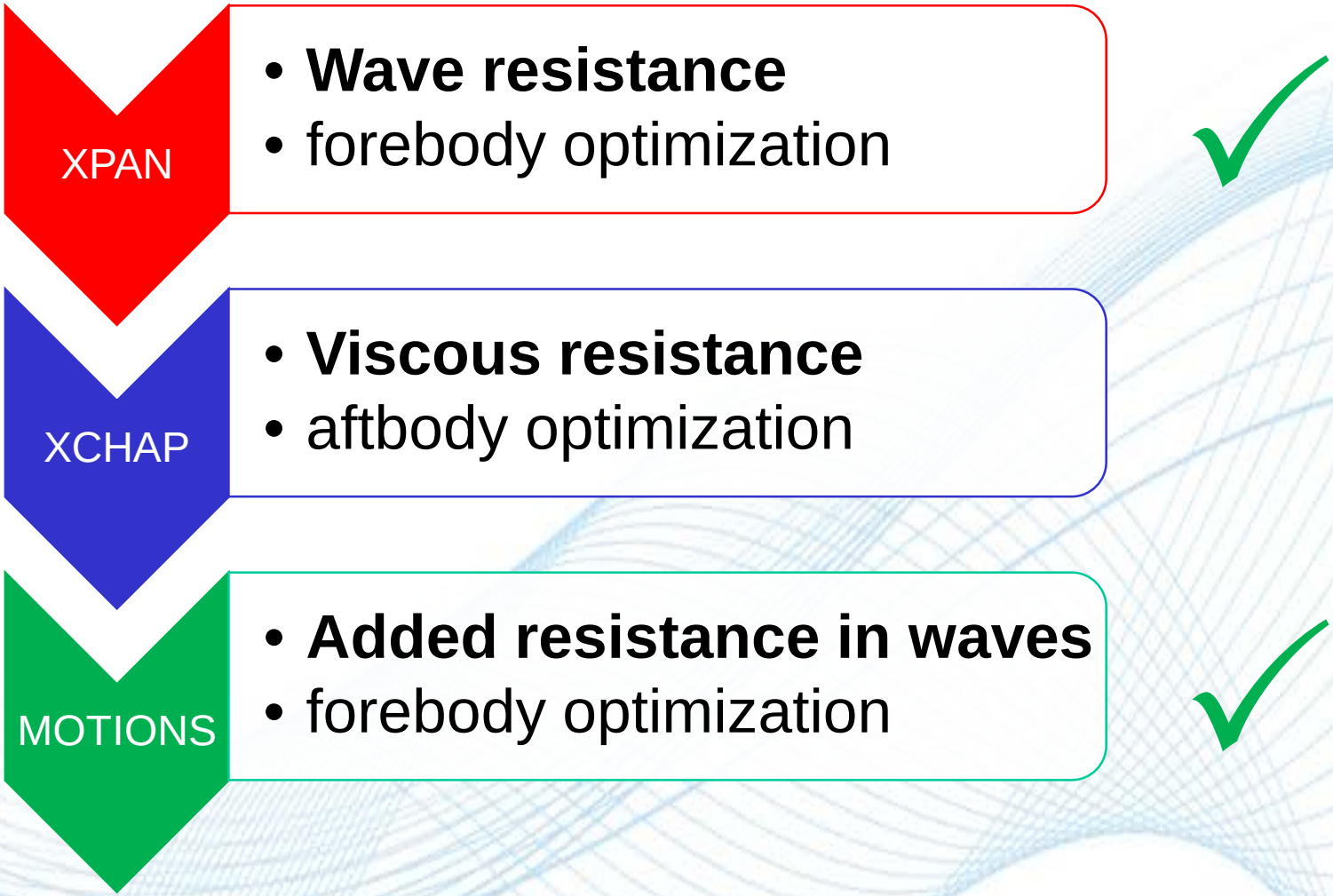
Optimization Strategy



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Viscous resistance optimization

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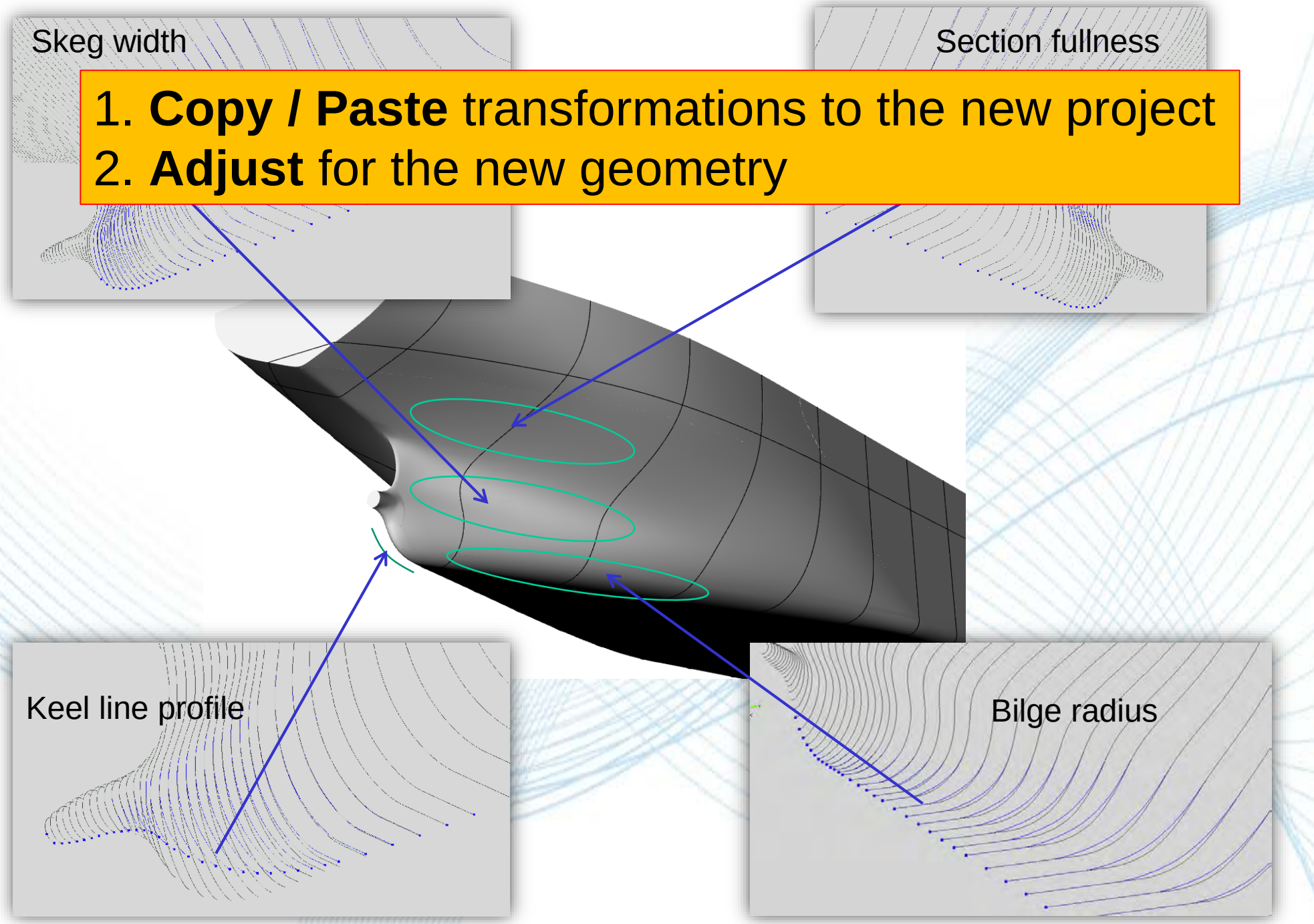
Shape variations template (used previously for JBC)



Optimization method – NSGA2

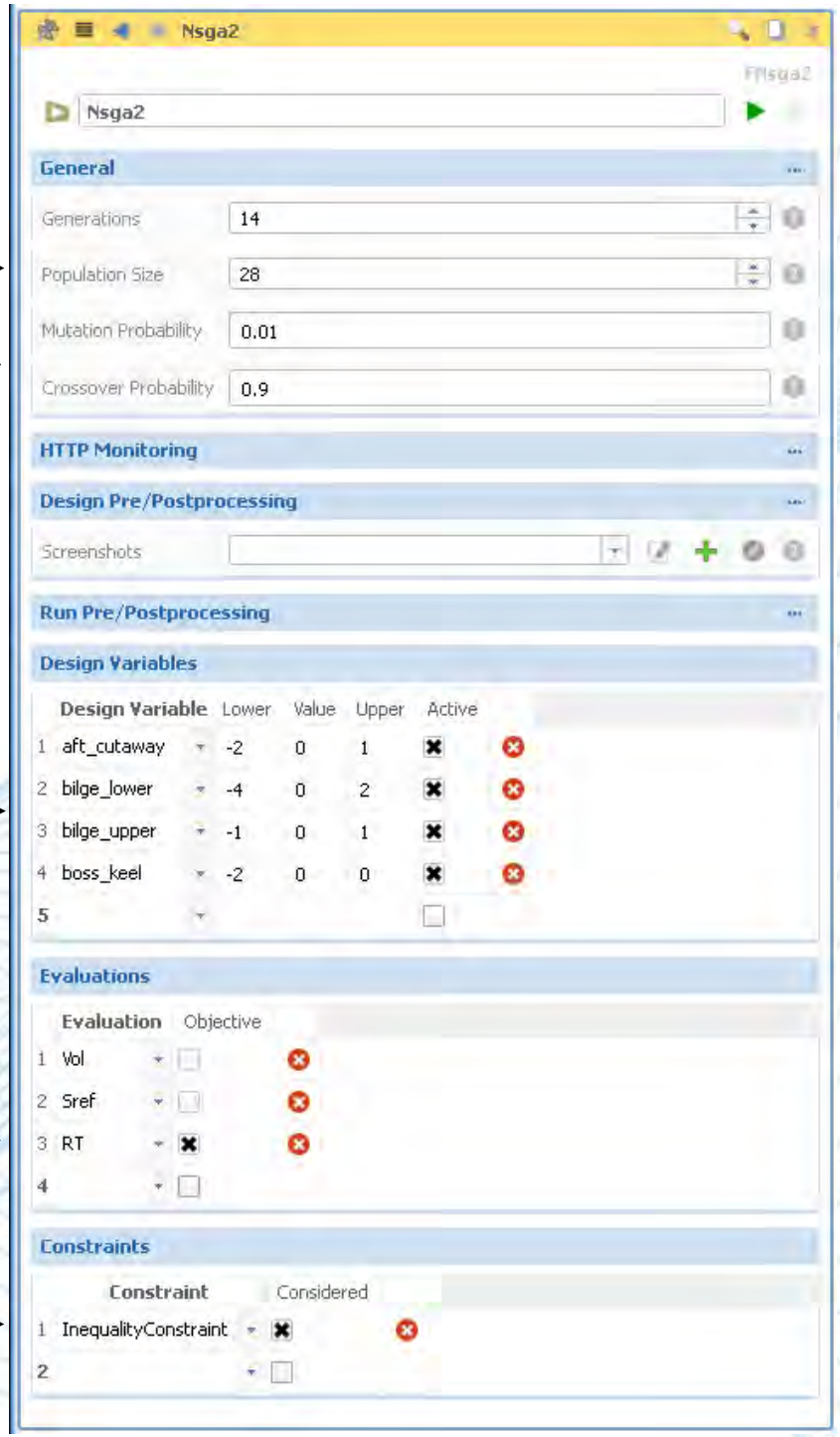
Large population size and number of generations for more design variables

For GA it is possible to run whole generation at once. After 8-10 generations the process is well converged. Total optimization time can be reduced to 6h.

4 design variables

RT as an objective

Displacement constraint



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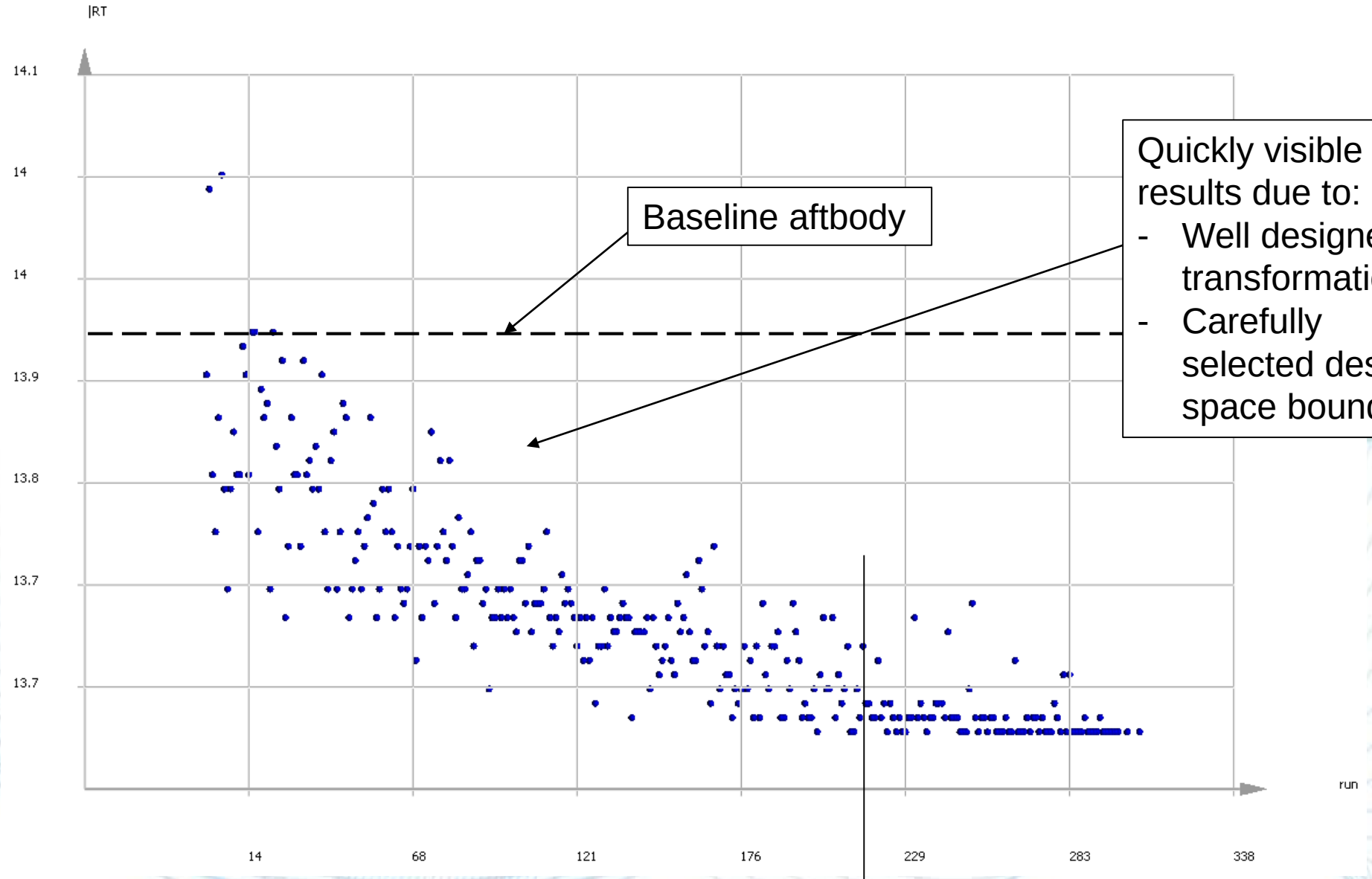
Optimization method – NSGA2



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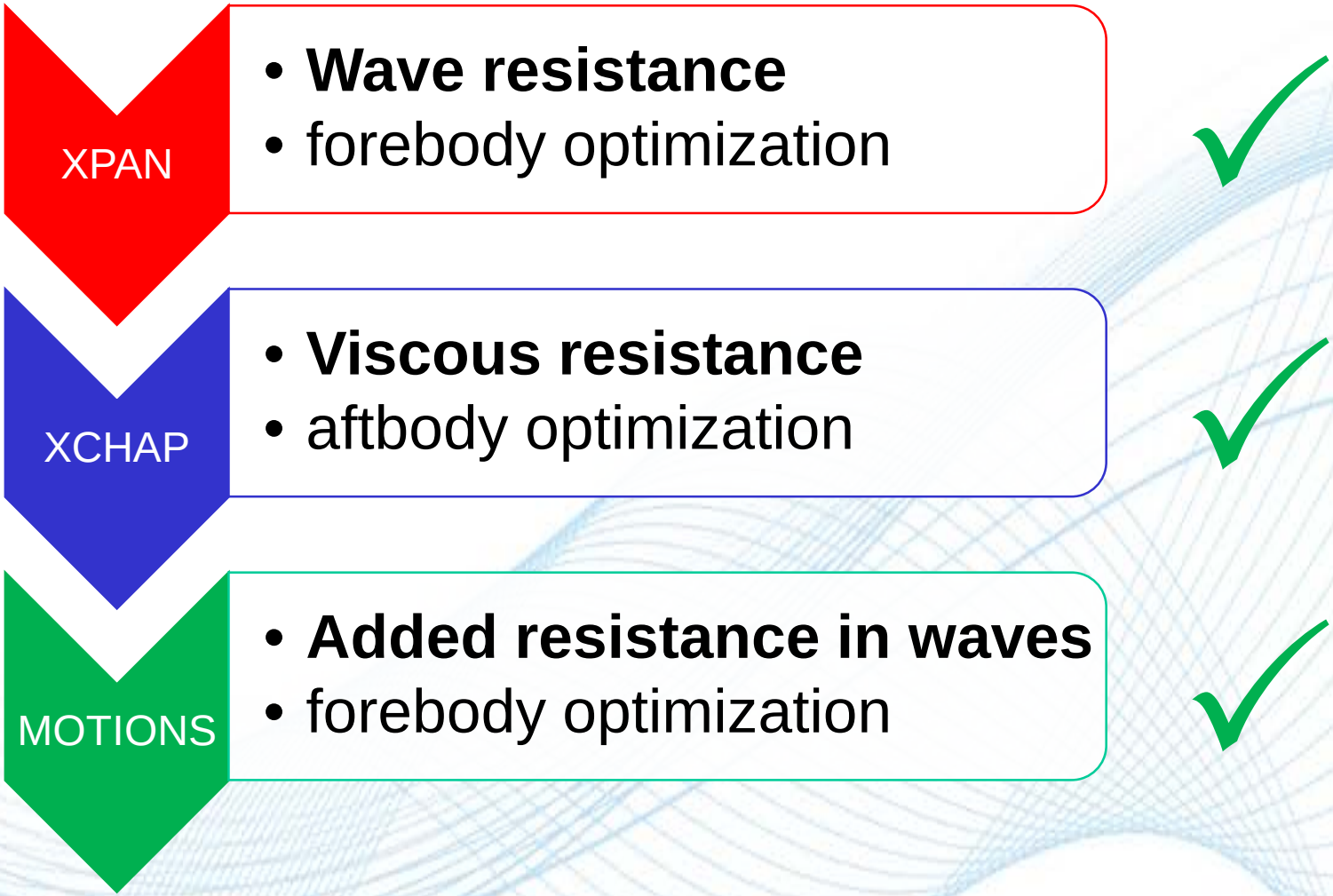
* - on a 10-node cluster

Optimization Strategy



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Cross-check of the variants with VOF

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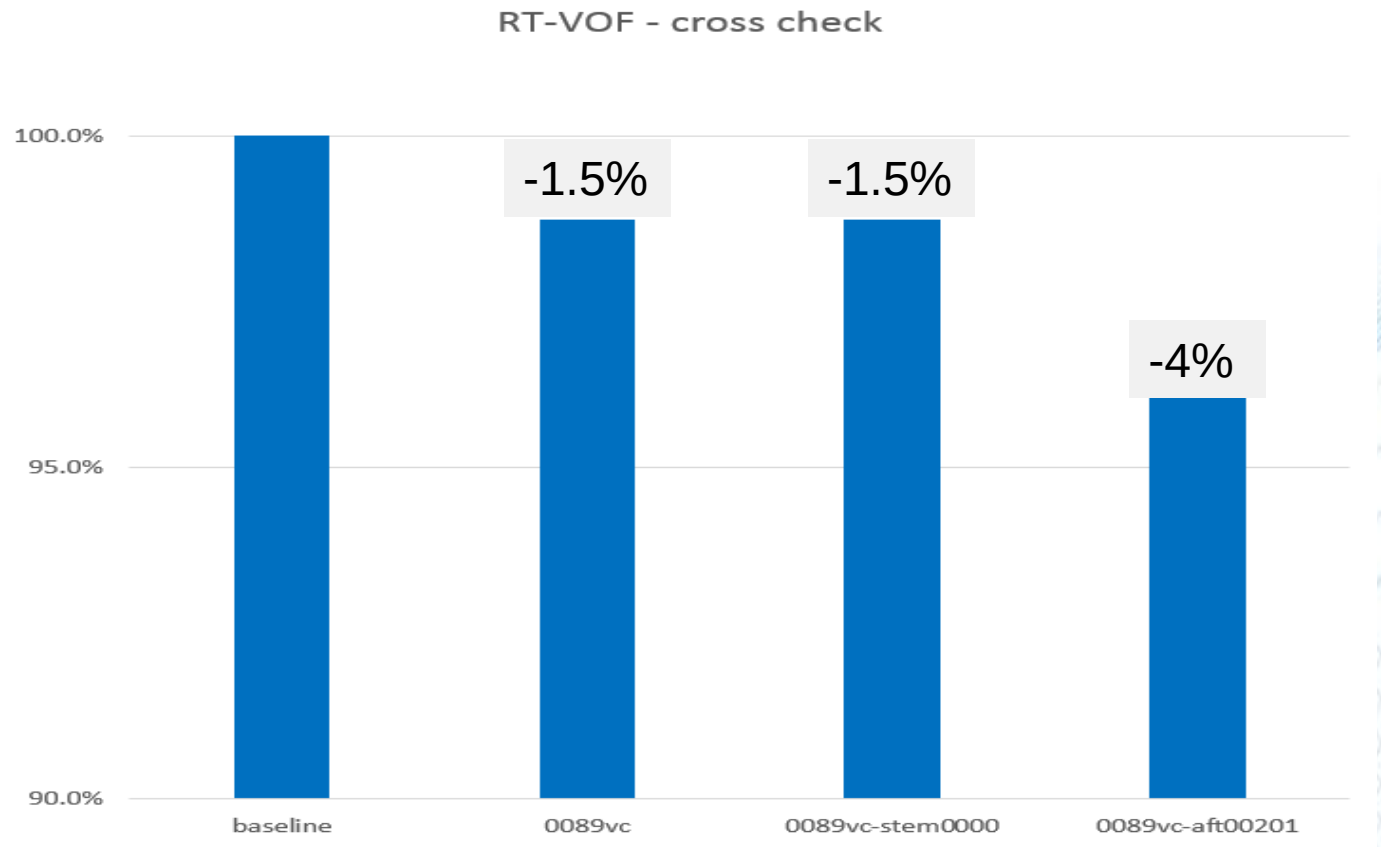
Cross-check of the variants with VOF – resistance - RTm



Optimized bow

Optimized bow + Optimized added resistance in waves (above free surface only)

Optimized bow + Optimized aftbody

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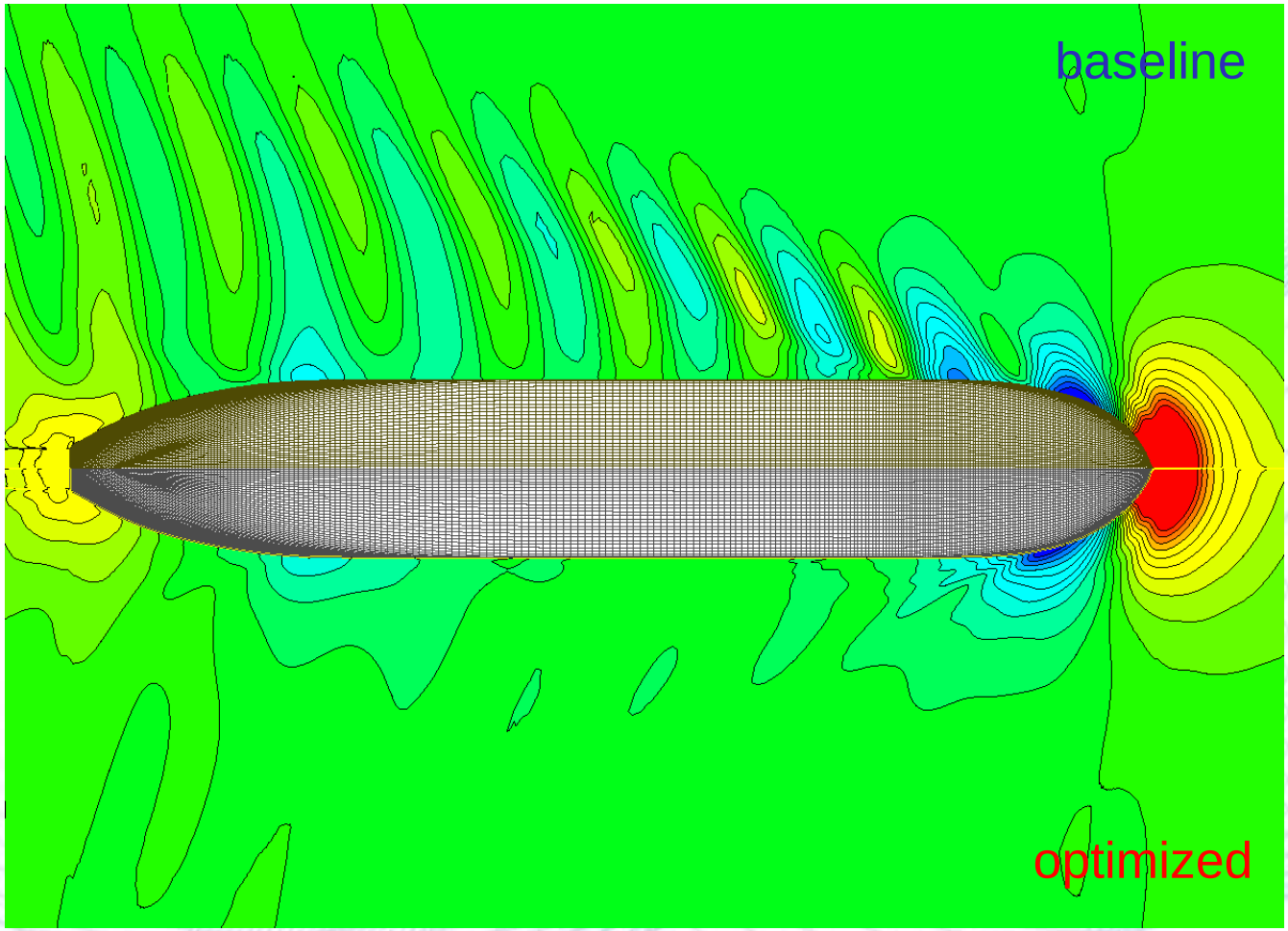
Cross-check of the variants with VOF – wave pattern



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Comments and suggestions

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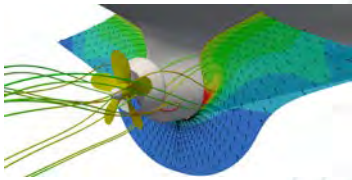
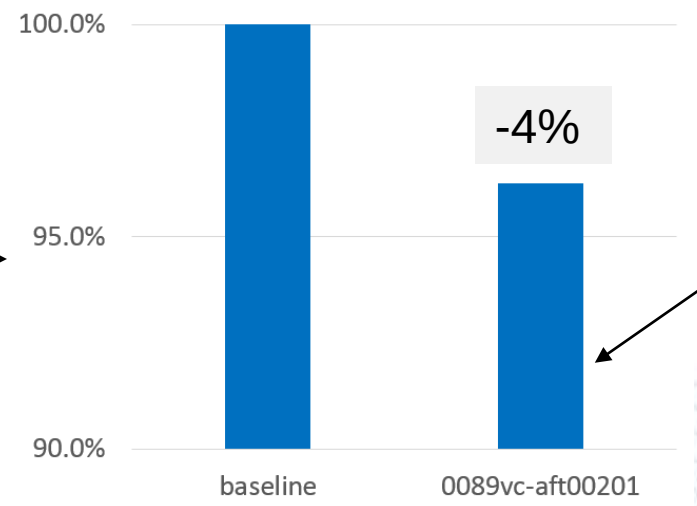
Delivered Power - model scale calculations

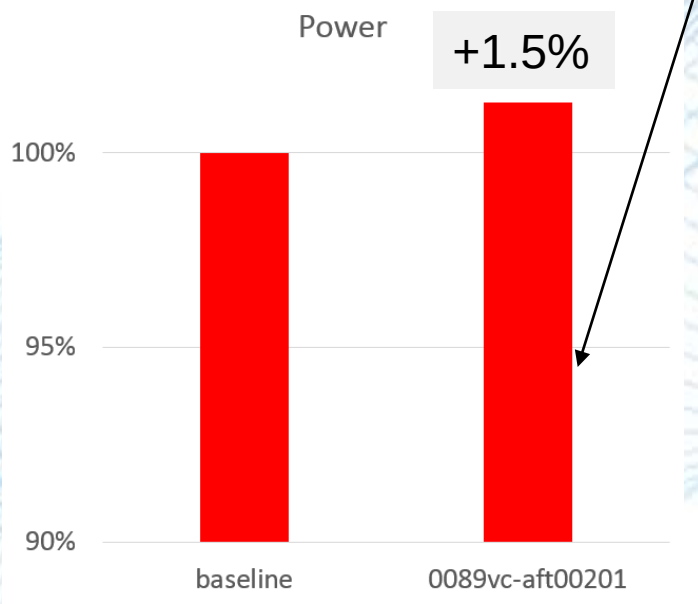


Resistance



Hull optimized for minimum RTm

Power



Optimizing high Cb ships for resistance may lead to poor propulsive efficiency!

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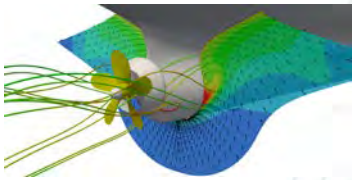
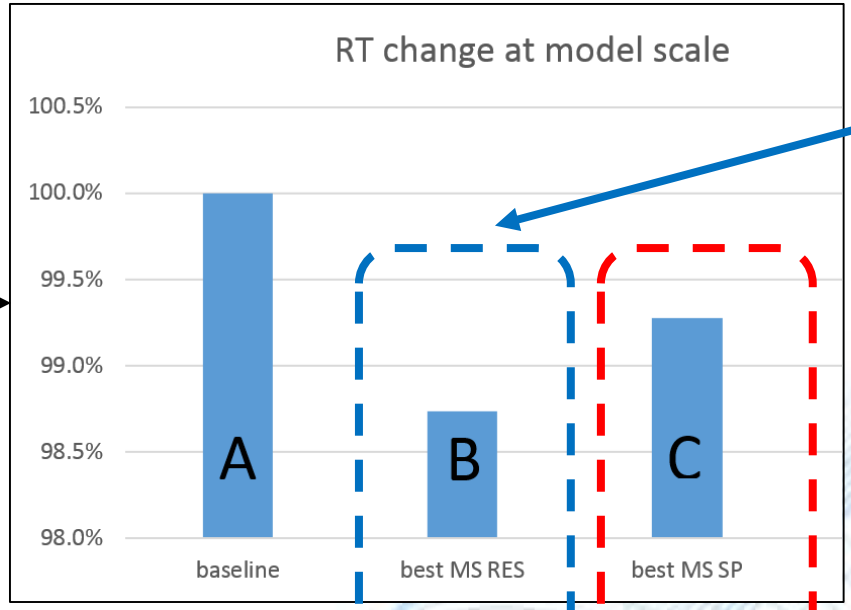
Suggestion: Use PD not RT as your objective

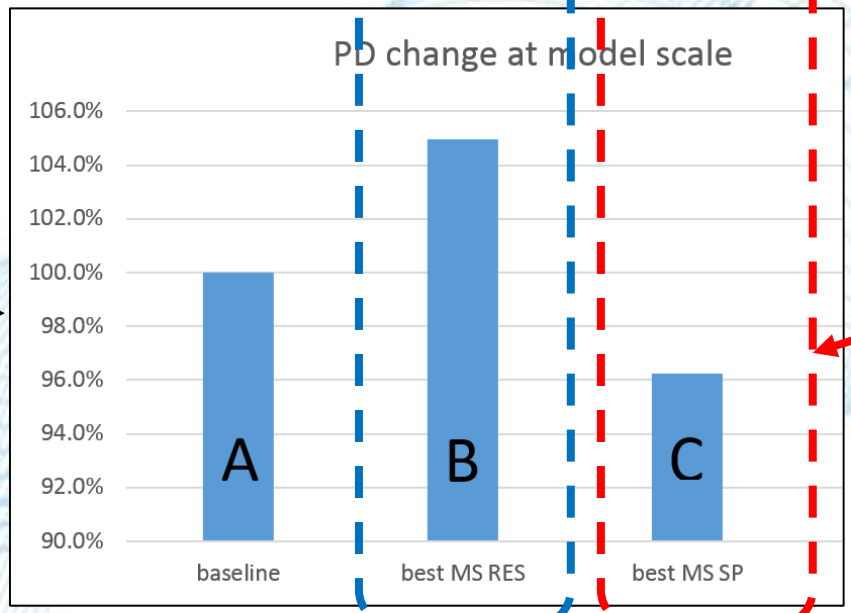


Resistance



Hull optimized for minimum RTm

Delivered Power



Hull optimized directly for minimum Pdm

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* - JBC optimization case

Comments

- Optimized hull form in 1 day!
- CAESES and SHIPFLOW is an excellent environment for hydrodynamic optimizations
- Partially parametric modelling used in CAESES is flexible, easy to apply and gives good results
- SHIPFLOW MOTIONS is feasible to use for shape optimization for minimum added resistance in waves
- SHIPFLOW RANS aftbody optimization is possible thanks to very fast solver
  - We must optimize full block coefficient hull forms for minimum delivered power using self-propulsion computations.

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Thank You

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