High block coefficient ship aft body shape optimization

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Content of presentation

- Background
- Optimization study
  - Shape variations
  - Objective function
  - Optimization
  - Case study
- Comments
- Conclusions

Background
Scope and goals

- Scope
  - Shape optimization of the aft body
  - Full ships
    - High block coefficient
    - Low Froude numbers
- Goals
  - Minimize the delivered power
  - Show that it can be done in a short time with moderate computer resources.

Background
Resistance and propulsive efficiency

- Minimizing the power means the following
  - Minimize resistance, wave and viscous
  - Maximize hull efficiency, high wake fraction
- In most cases increasing wake fraction for efficiency will cause higher resistance – a trade-off is necessary to find best performance.

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Background
Resistance and propulsive efficiency

- Optimum balance between Rt and w is very difficult to find based on resistance and wake results
- Self-propulsion is the best way to achieve optimum solution.

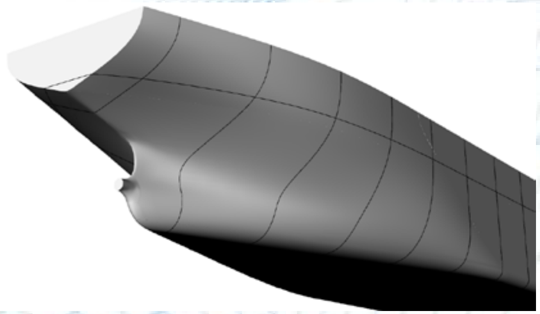
Case study based on Japan Bulk Carrier (JBC)

- JBC is a capesize bulk carrier designed jointly by National Maritime Research Institute (NMRI), Yokohama National University and Ship Building Research Centre of Japan (SRC).
- Towing tank experiments are available from NMRI, SRC and Osaka University, which include resistance tests, self-propulsion tests and PIV measurements of stern flow fields.
- Validation and Verification results using SHIPFLOW presented at Tokyo 2015 Workshop on CFD in Ship Hydrodynamics, Dec. 2-4, 2015

Case study based on Japan Bulk Carrier (JBC)

Main particulars		Full scale
Length between perpendiculars	L_{PP} (m)	280.0
Length of waterline	L_{WL} (m)	285.0
Maximum beam of waterline	B_{WL} (m)	45.0
Depth	D (m)	25.0
Draft	T (m)	16.5
Displacement volume	∇ (m^3)	178369.9
Wetted surface area w/o ESD	S_W (m^2)	19556.1
Wetted surface area of ESD	S_E (m^2)	745.2
Block coefficient (CB)	$\nabla /(L_{PP} B_{WL} T)$	0.8580
Midship section coefficient (CM)		0.9981
LCB (%L_{PP}), fwd+		-2.5475

Service speed	
U (knots)	14.5
Fn	0.142



Shape variations
Resistance

- To minimize viscous resistance it is necessary to minimize wetted surface

- but without:
    - increasing wave resistance by e.g. too blunt bow
    - viscous pressure resistance by too full stern causing separation.

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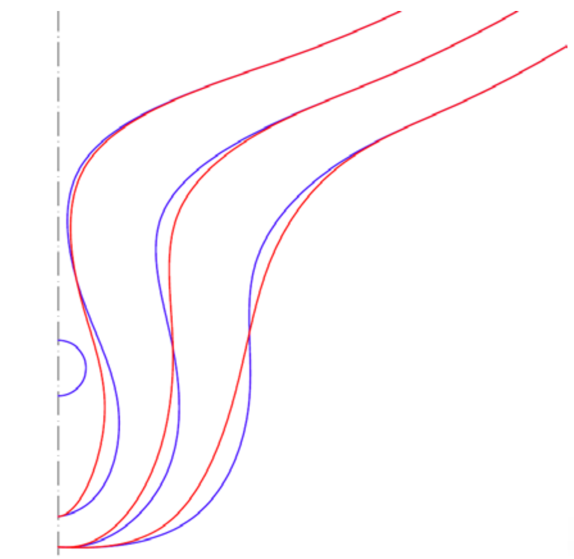
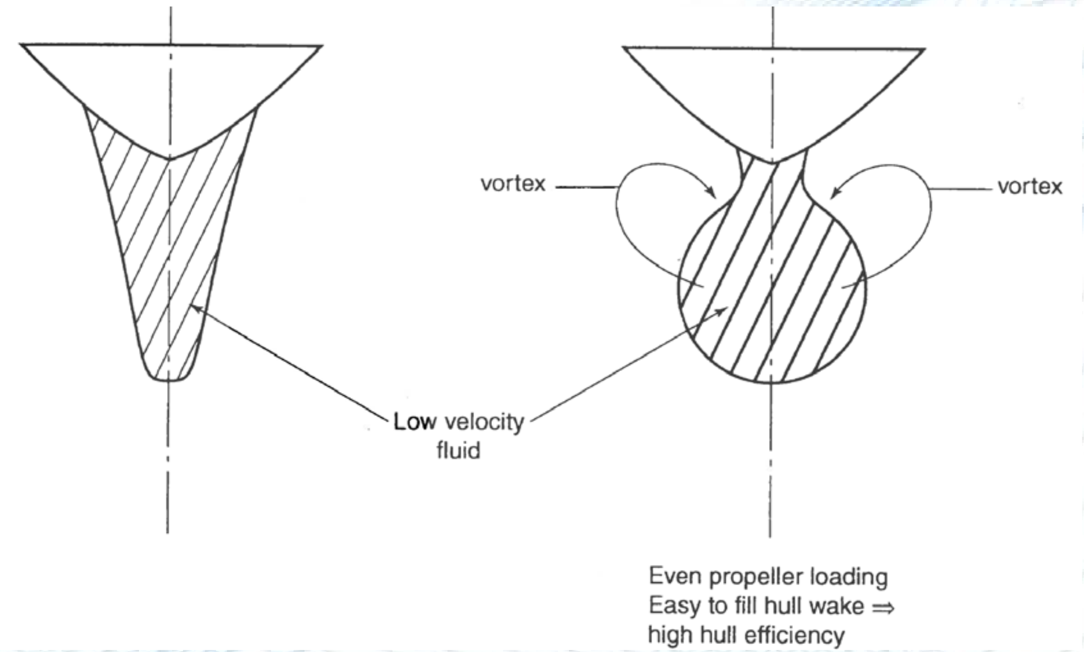
Shape variations
Wake

- To increase hull efficiency and avoid sudden changes of propeller loading the wake should be more circular and concentrated in propeller disc



U- or V-shaped sections



Utilize the bilge vortices

Tools

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made by FRIENDHSHIP SYSTEMS

- Shape variations
- Optimization methods
- Resource management

+

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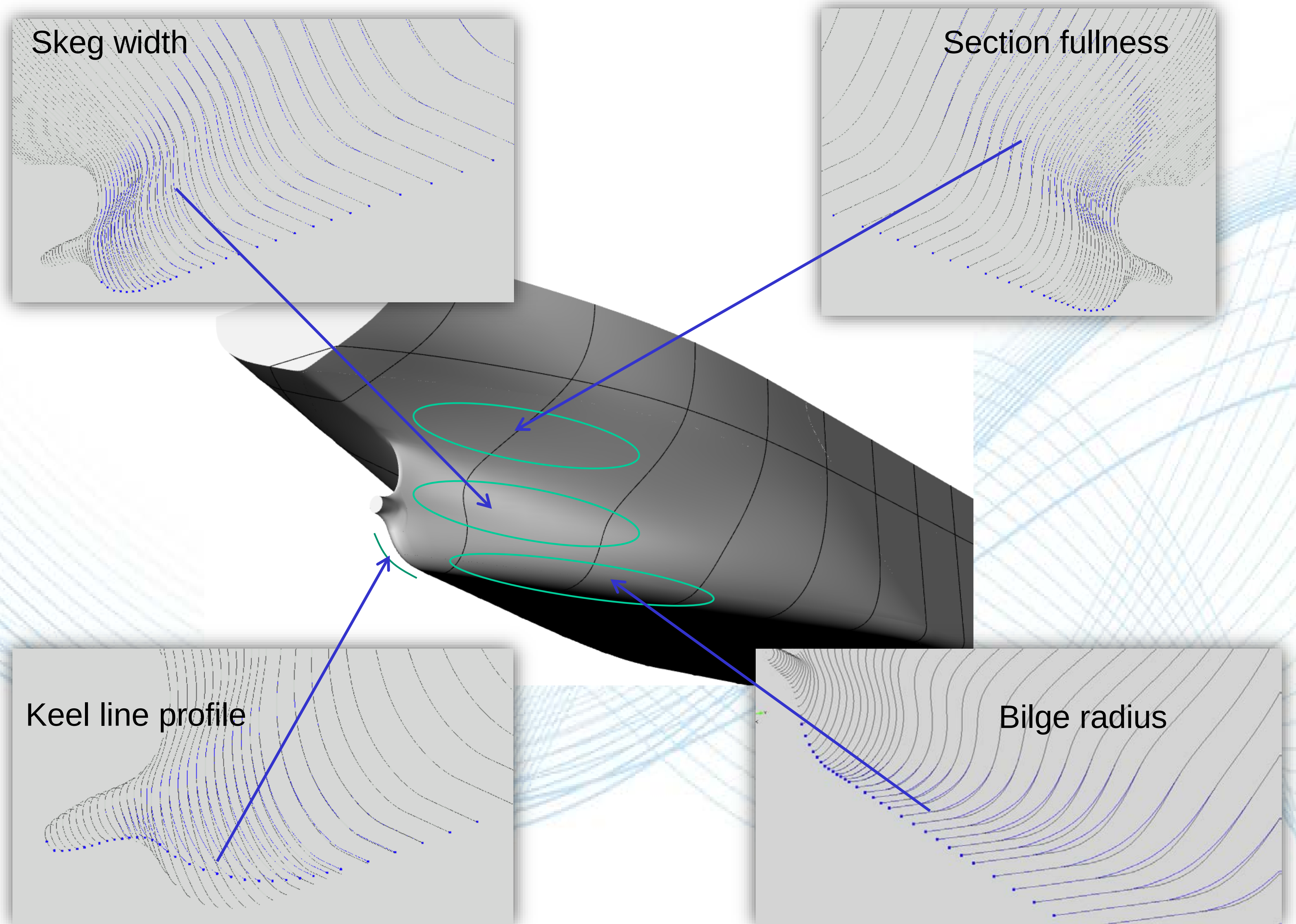
- Grid Generation
- Flow simulations
- Result processing

Shape variations

- Hull shape modifications with Surface Delta Shift*
  - Bilge radius
  - Keel line profile of bossing
  - Skeg (gondola) width
  - Section fullness above skeg

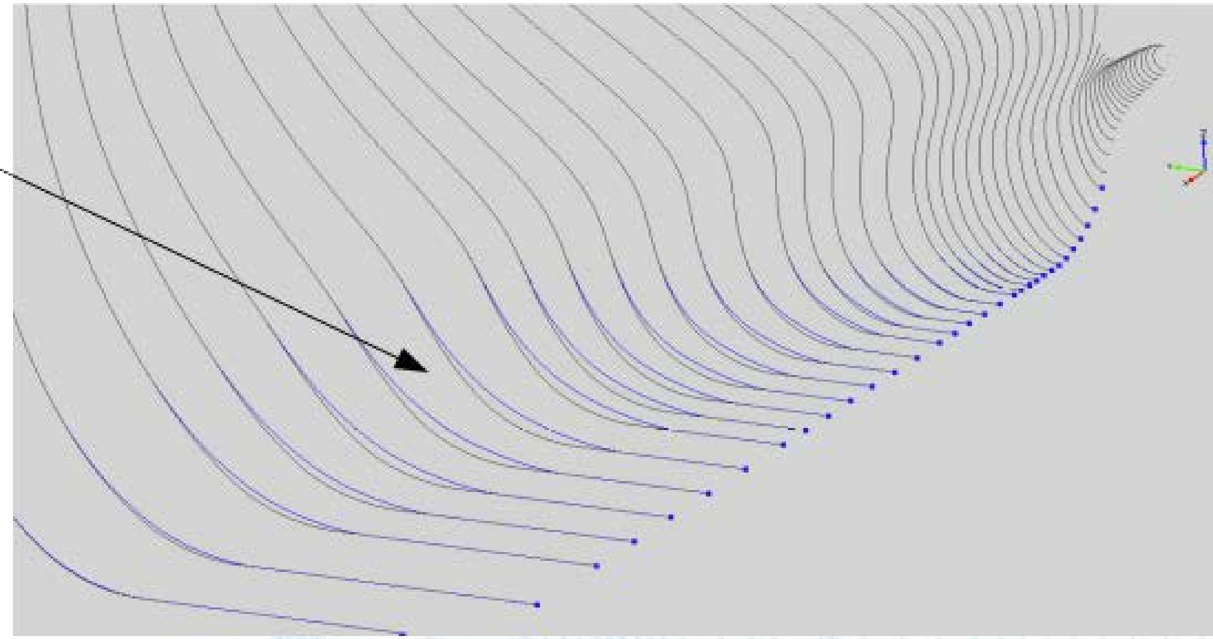
* - partially parametric modelling

Shape variations

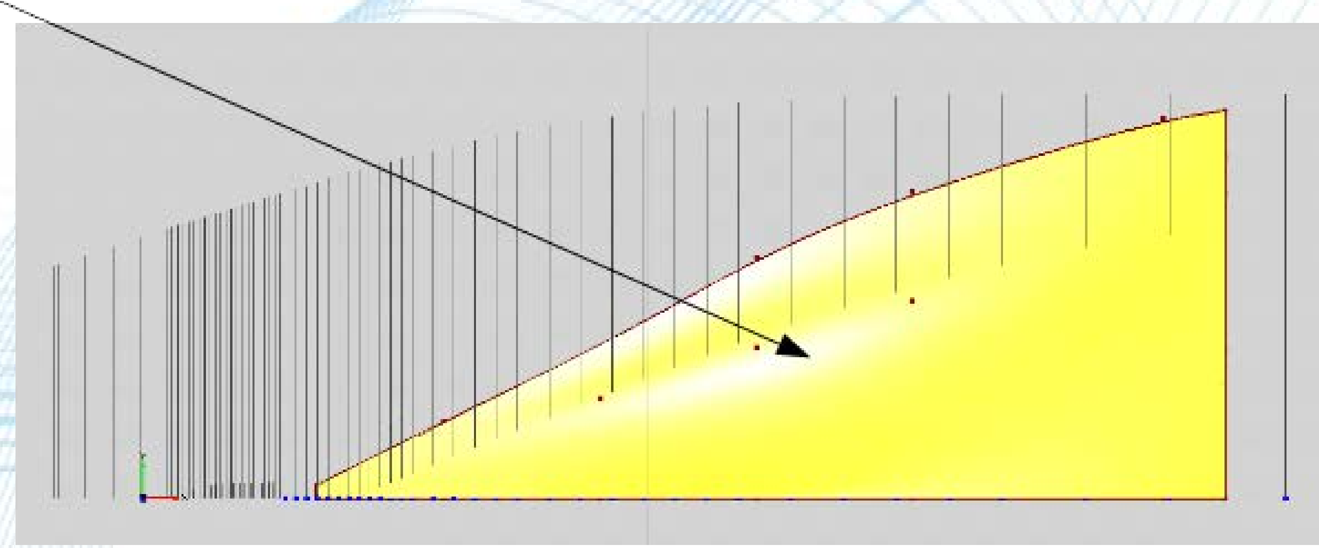


Shape variations

- Bilge radius



- Delta surface



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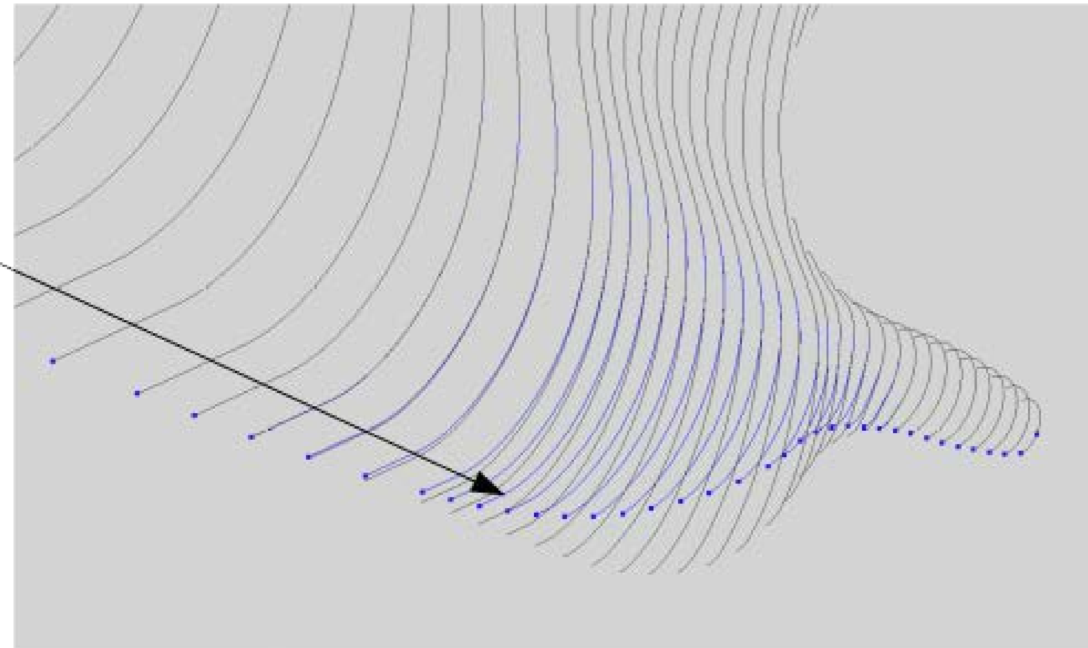
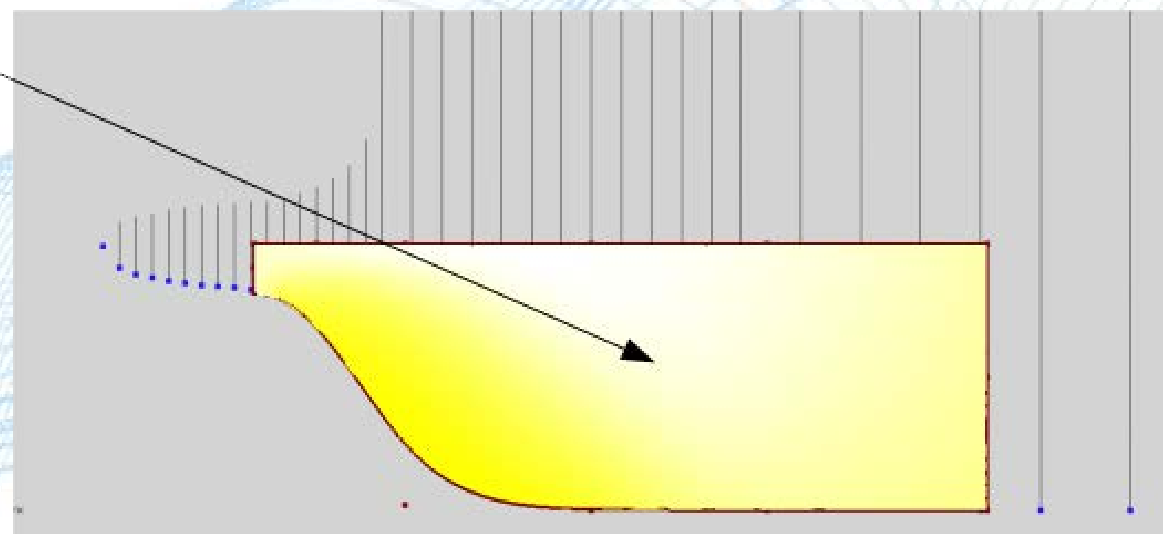
Shape variations

- Keel line profile of bossing



- Delta surface



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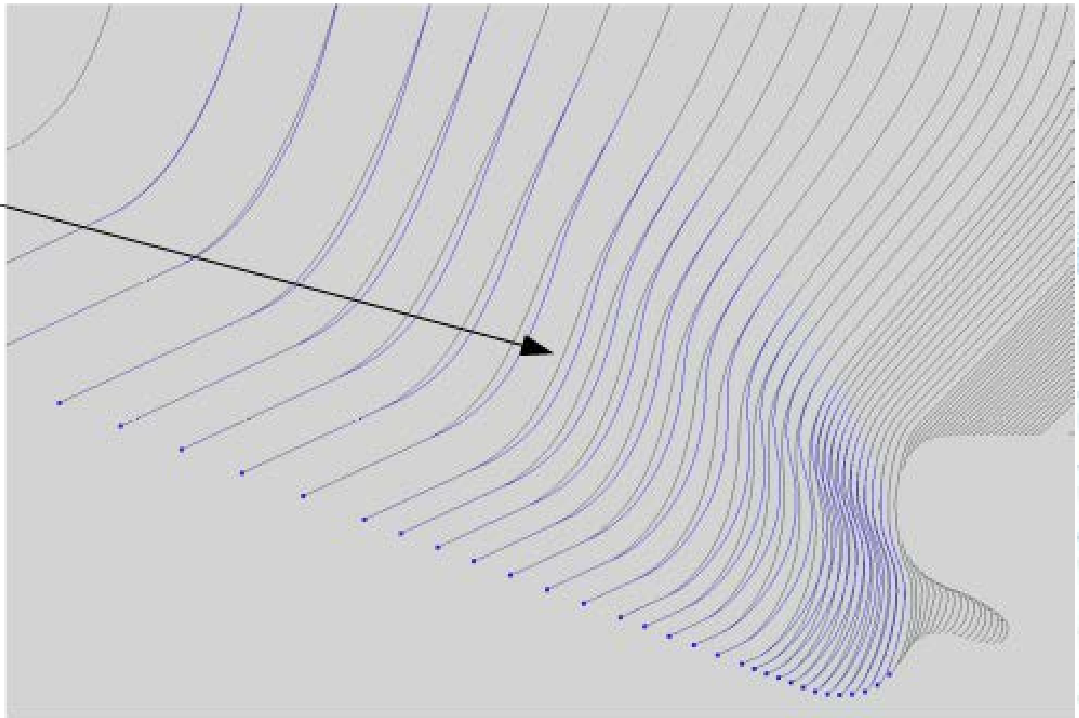
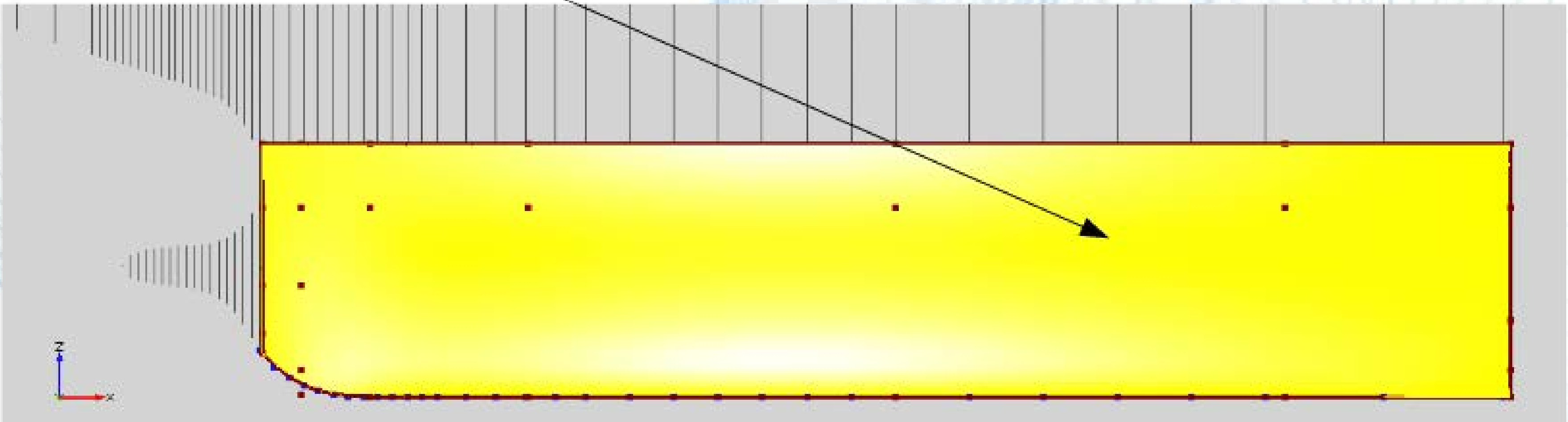
Shape variations

- Skeg (gondola) width



- Delta surface



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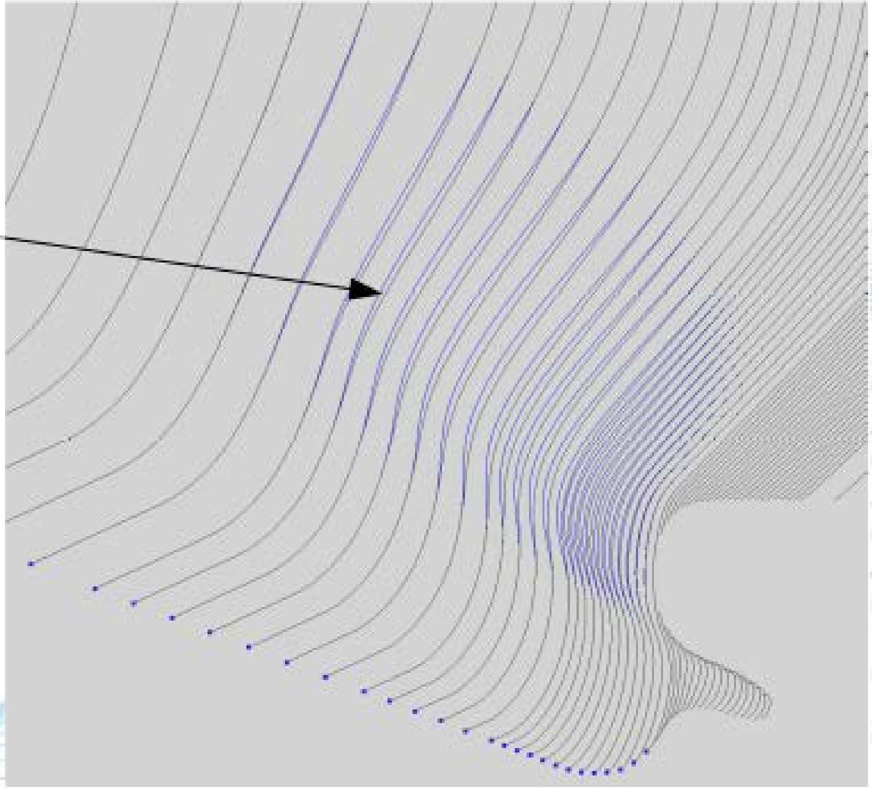
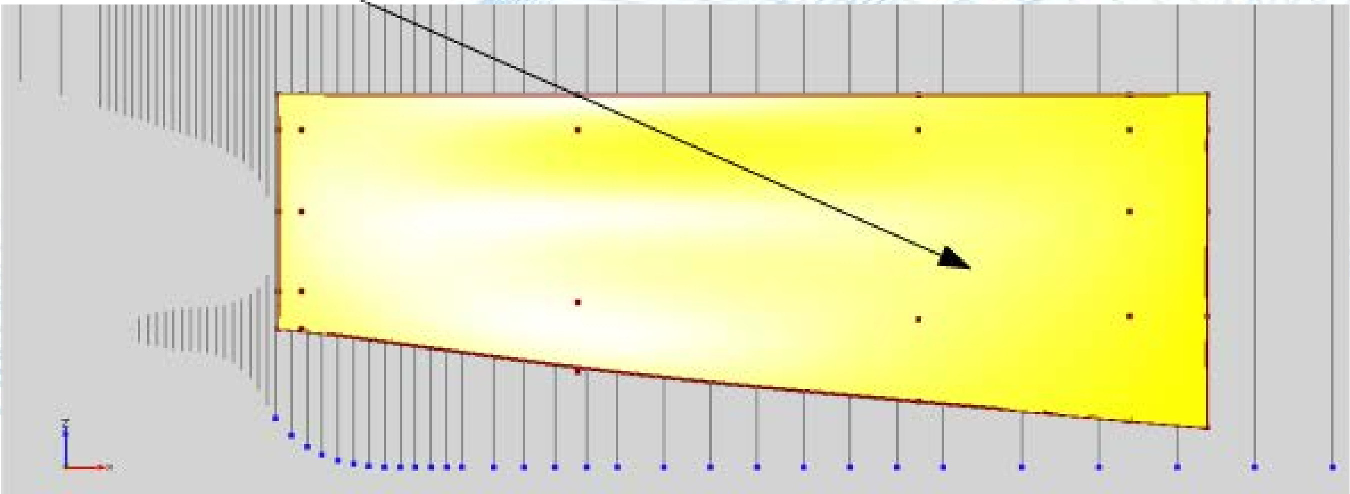
Shape variations

- Section fullness above skeg



- Delta surface



Objective function / Optimization method

- Objective – Minimize the delivered power PD
  - Self-propulsion simulation
  - Scale effects
- Constraints
  - No loss of displacement
- Optimization method: Genetic Algorithm (NSGA-II)

Aft-body optimization of Japan Bulk Carrier (JBC)

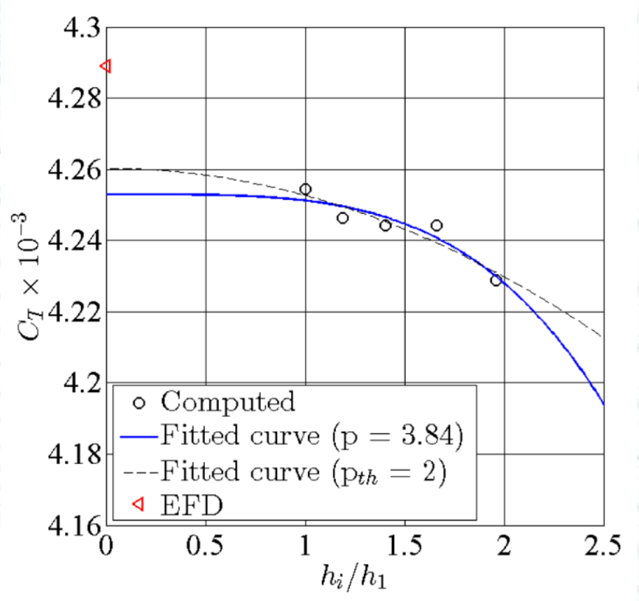
- Tools:
  - SHIPFLOW and CAESES work environment
  - Direct self-propulsion optimization with SHIPFLOW
  - Partially parametric modelling with CAESES tools for good control and flexibility of hull modifications
- Conditions:
  - Self-propelled bare hull computations
  - Propeller pitch adjusted to find propulsion point
  - RPM fixed to desired engine
  - Design speed and design draught
- Optimization:
  - 4 independent variables
  - Delivered Power objective function
  - Displacement constraint (not less than baseline)
  - NSGA2 optimization algorithm
  - 12 generations, 24 individuals

<u>CASE A</u> – BASELINE hull

- Verification and Validation in:

KORKMAZ, K. B., ORYCH, M., LARSSON, L., 'CFD Predictions Including Verification and Validation of Resistance, Propulsion and Local Flow for the Japan Bulk Carrier (JBC) with and without an Energy Saving Device', *Proceedings, Tokyo 2015 Workshop on CFD in Ship Hydrodynamics.* 2015.

- The resistance maximum comparison error of about 1.2%. The delivered power was underpredicted by 6% which was thought to be a result of a slight wake overestimation



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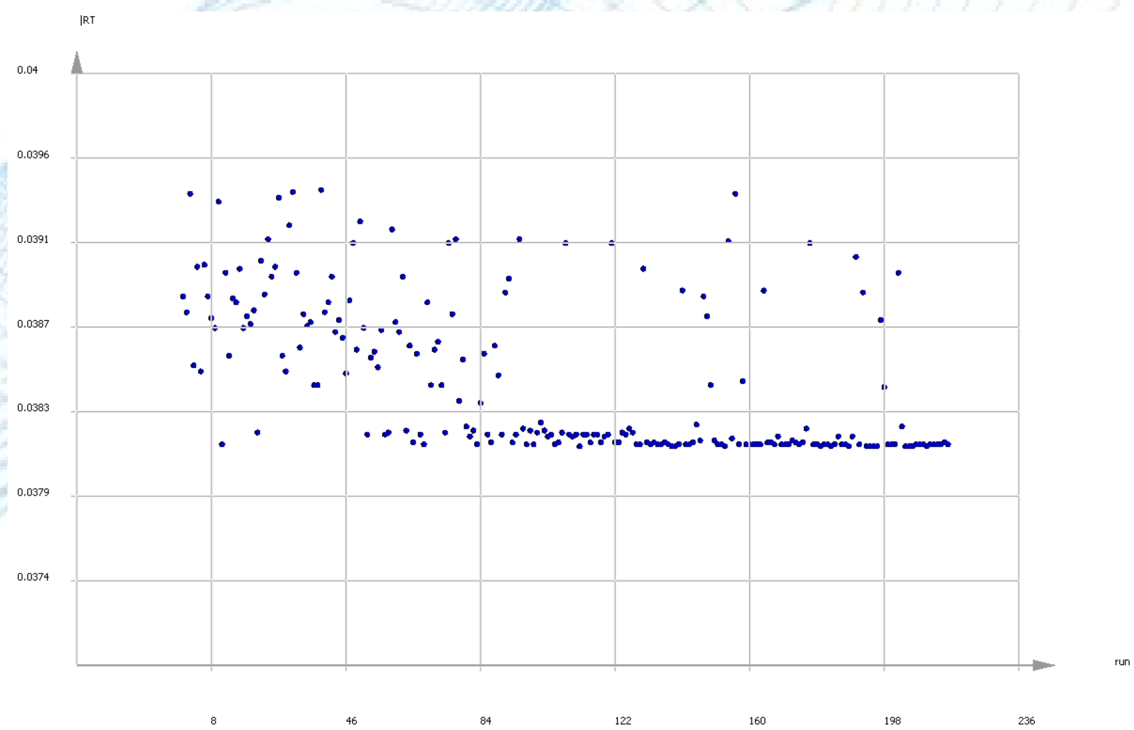
CASE B - Resistance optimization at model scale

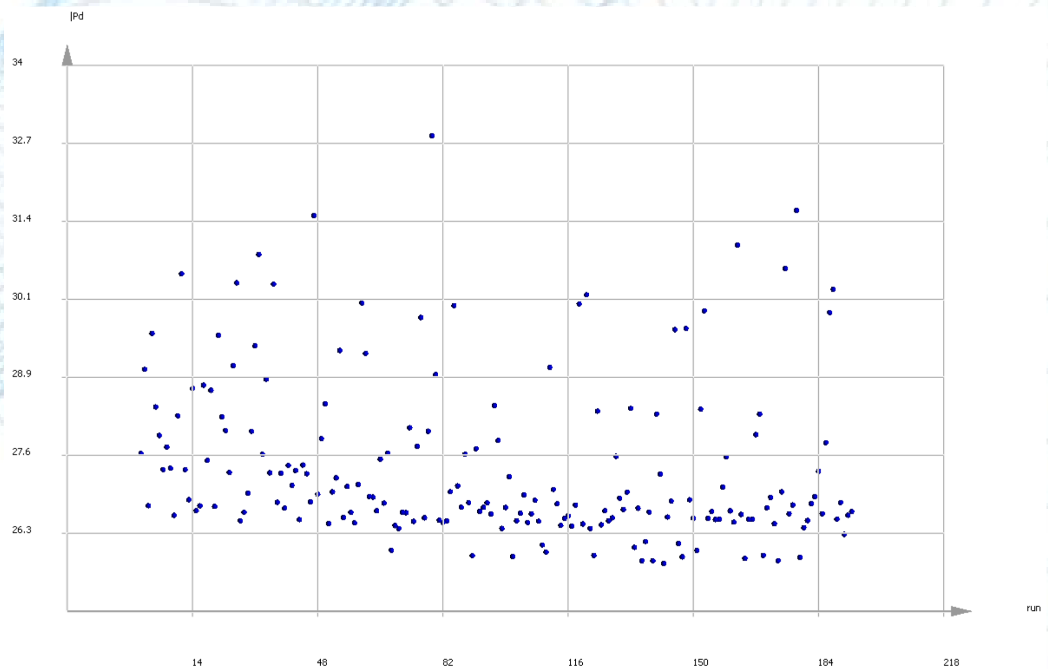
- Reynolds number: 7.46e6
- Module: XCHAP using Krylov solver (SHIPFLOW 6.3)
- Fine grid, zonal approach, 1.2M cells (automatically generated from iges)
- 15 minutes per case (Intel i7 5960X)
- 288 designs investigated
- 1.2% decrease in RT at model scale (w.r.t. baseline)



<u>CASE C</u> - Self-propulsion optimization at model scale

- Reynolds number: 7.46e6
- Module: XCHAP using Krylov solver (SHIPFLOW 6.3)
- Medium grid with refinement, zonal approach, both sides, 3.0M cells (automatically generated from iges)
- Self-propulsion with integrated lifting line propeller model
- 4 cases per hour on a 4 node cluster (Intel Xeon X5675)
- 288 designs investigated
- 3.7% decrease in PD at model

  scale (w.r.t. baseline)



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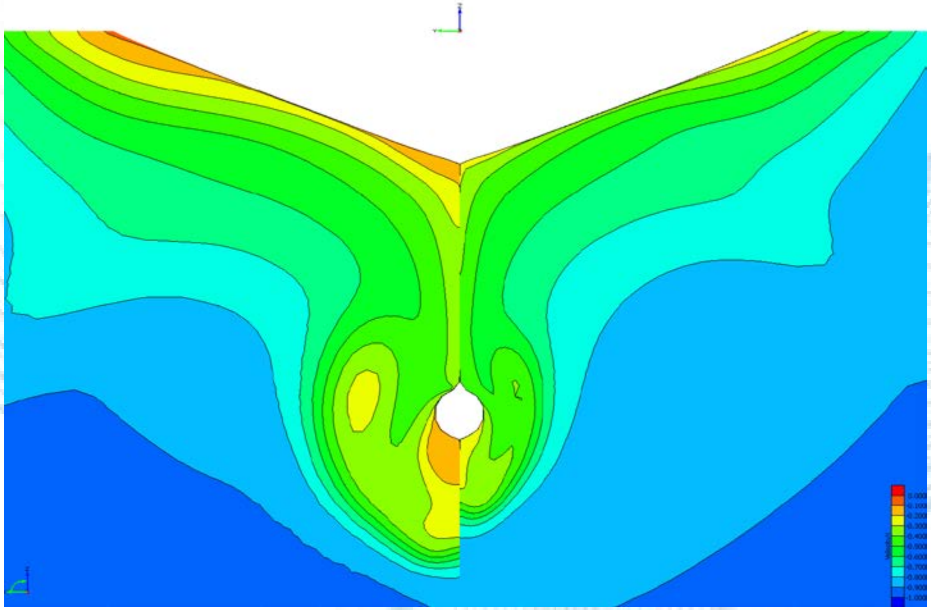
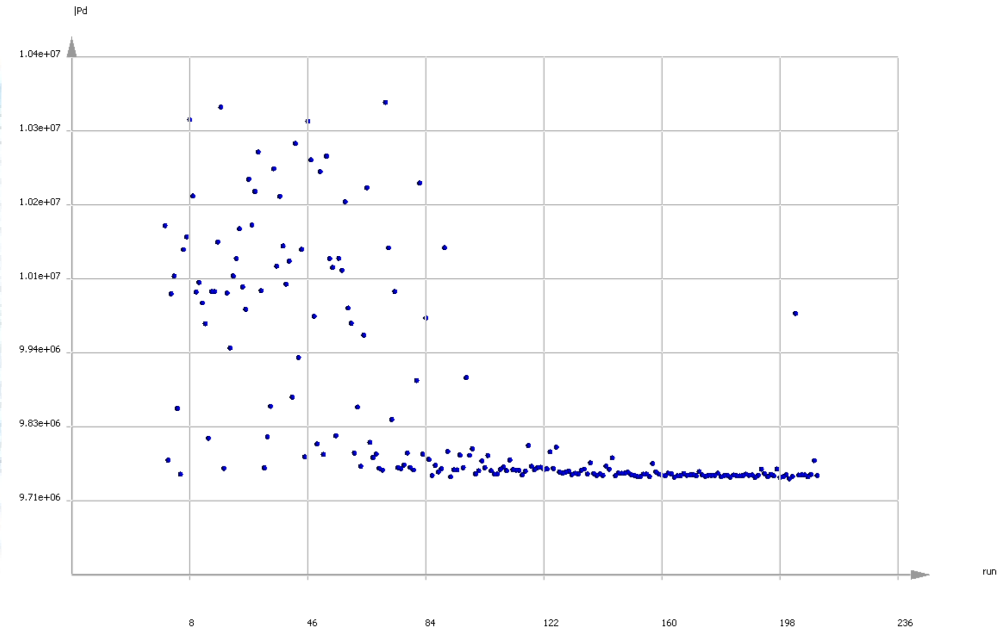
<u>CASE D</u> - Self-propulsion optimization at full scale

- Reynolds number: 2.10e9
- The same as the setup for “C” but with additional cells in normal direction (50% extra)
- 0.35% decrease in PD at full scale

  (w.r.t. baseline)





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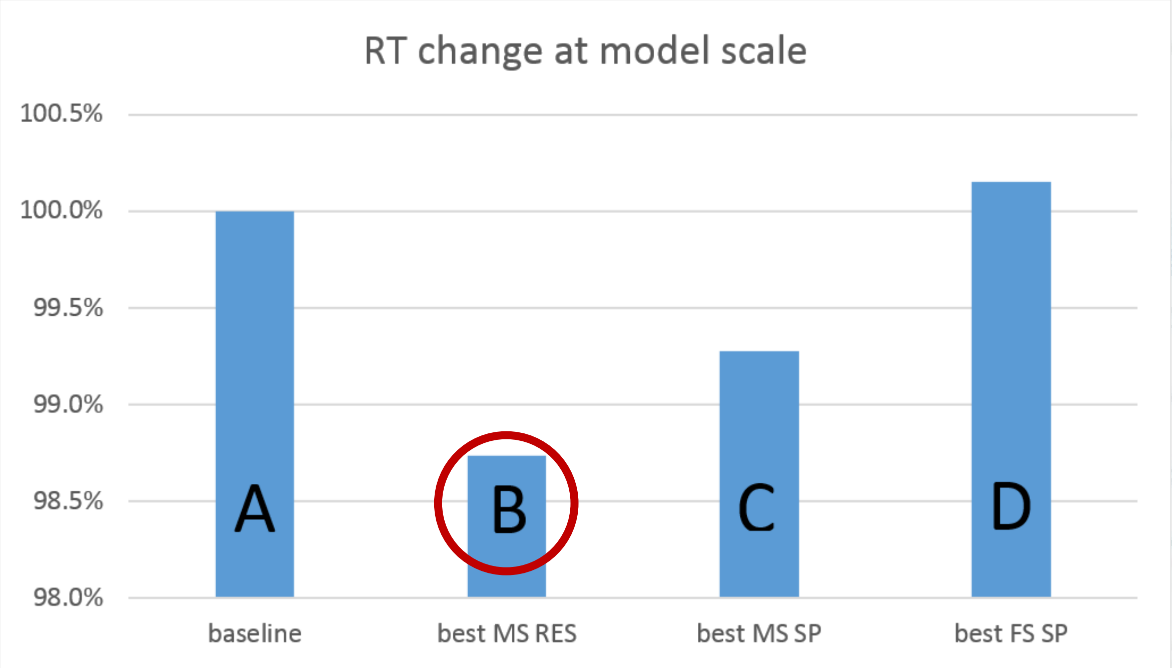
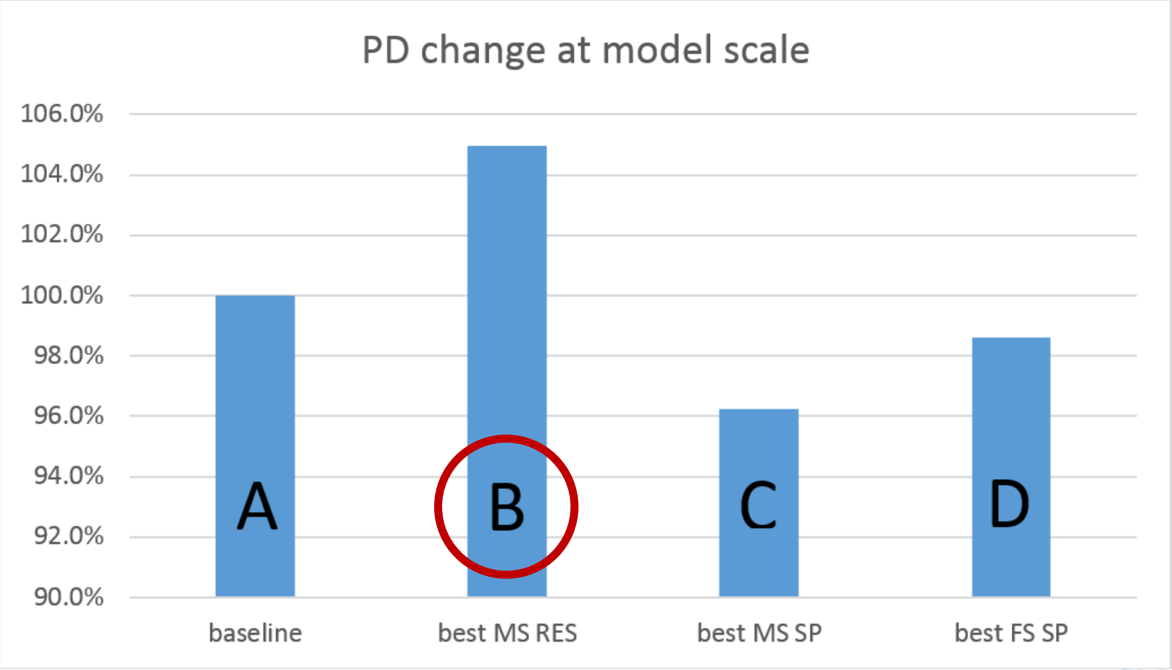
Cross-comparisons: model scale RT vs PD

- **Hull B** (optimized for min. RT at model scale):
  - has the lowest RT
  - But at the same time highest PD
  - Lower nominal wake than A (baseline)
  - Streamlined but not efficient





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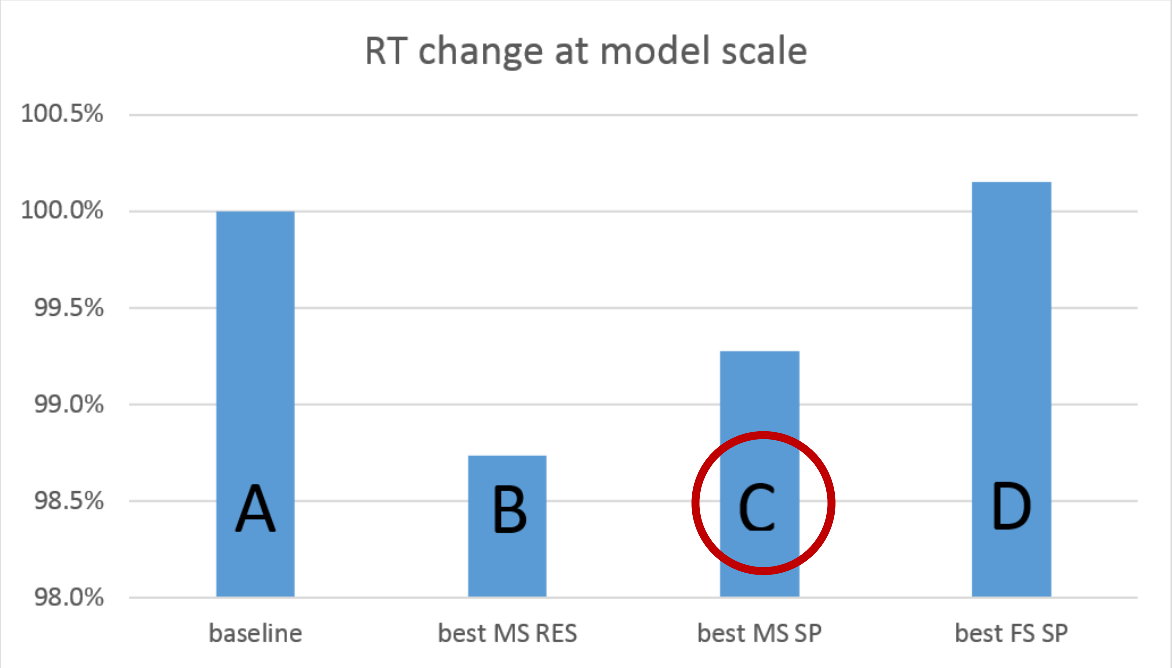
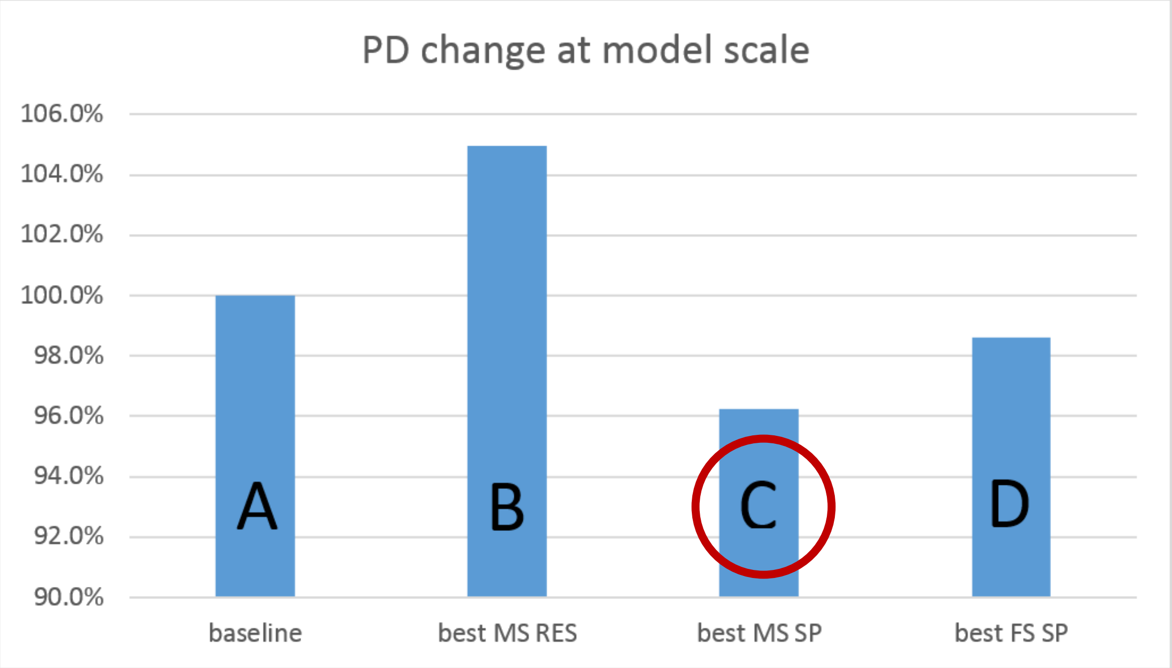
Cross-comparisons: model scale RT vs PD

- **Hull C** (optimized for min. PD at model scale):
  - Higher RT than hull B
  - But at the same time Lower PD





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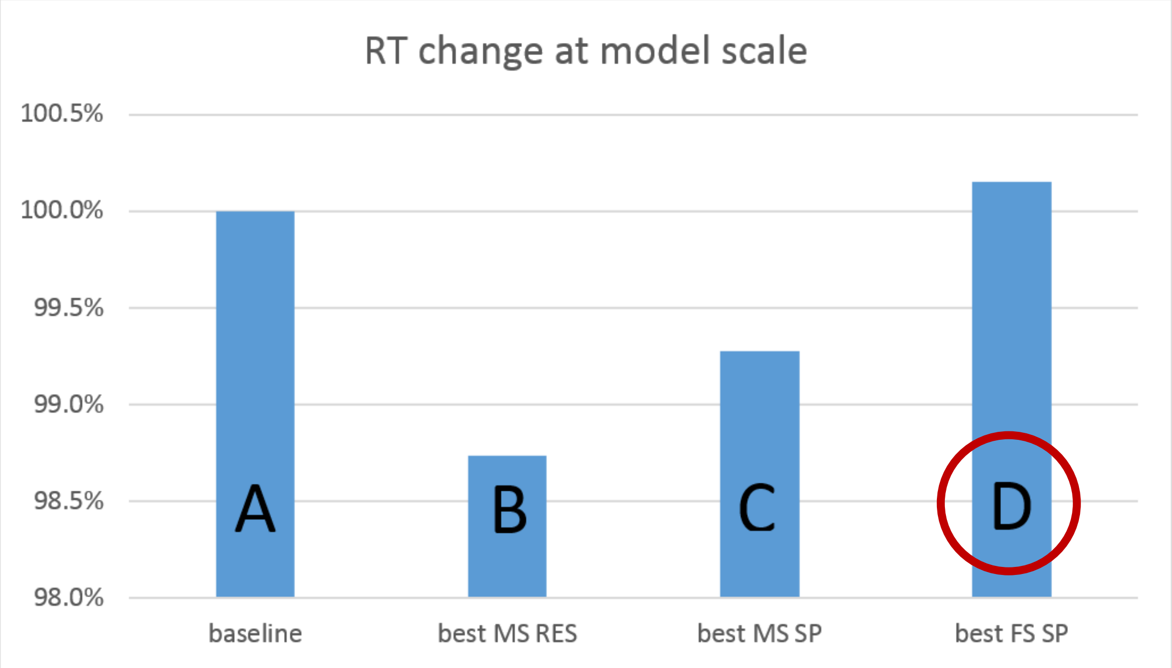
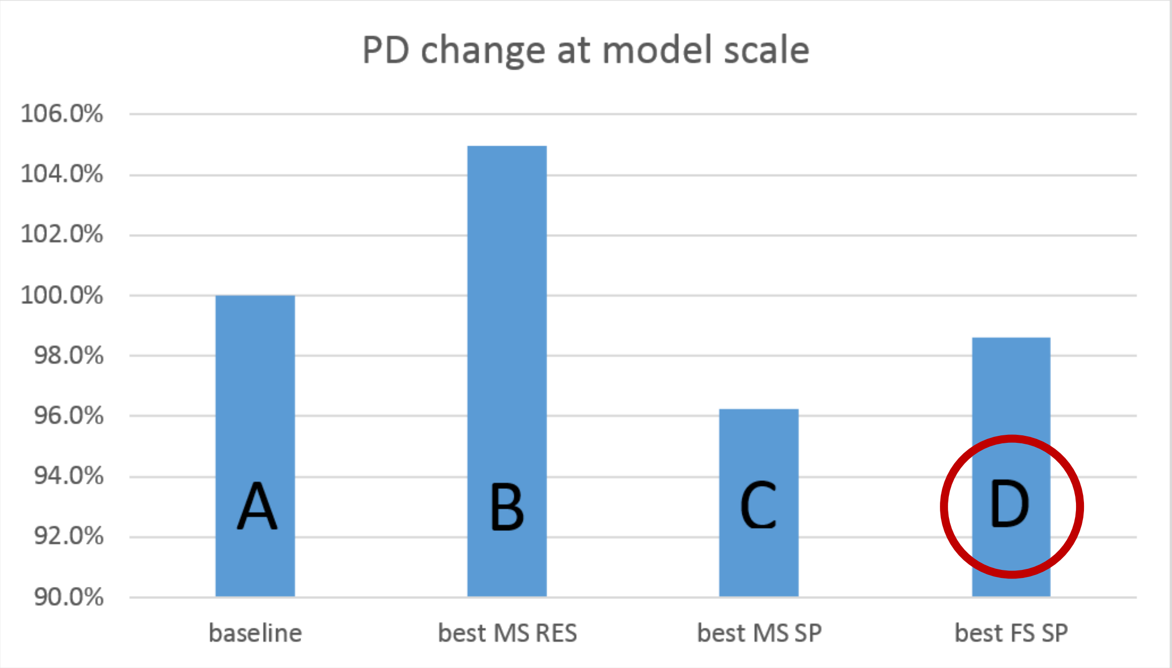
Cross-comparisons: model scale RT vs PD

- **Hull D** (optimized for min. PD at full scale):
  - Higher RT than hull C
  - and Higher PD at model scale





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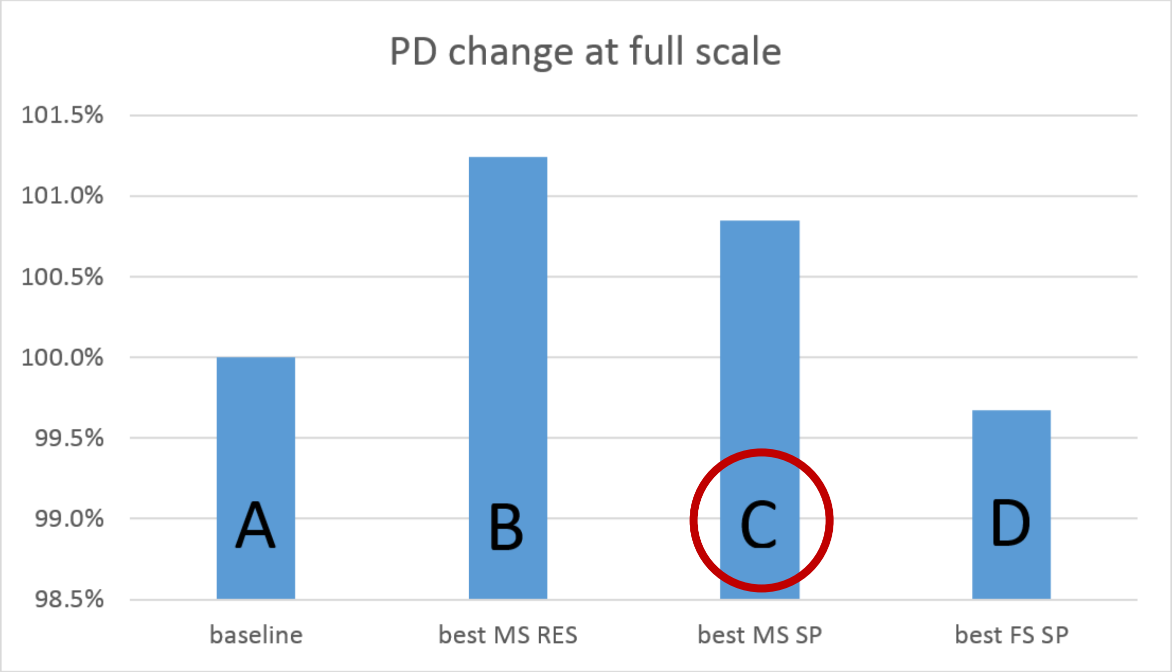
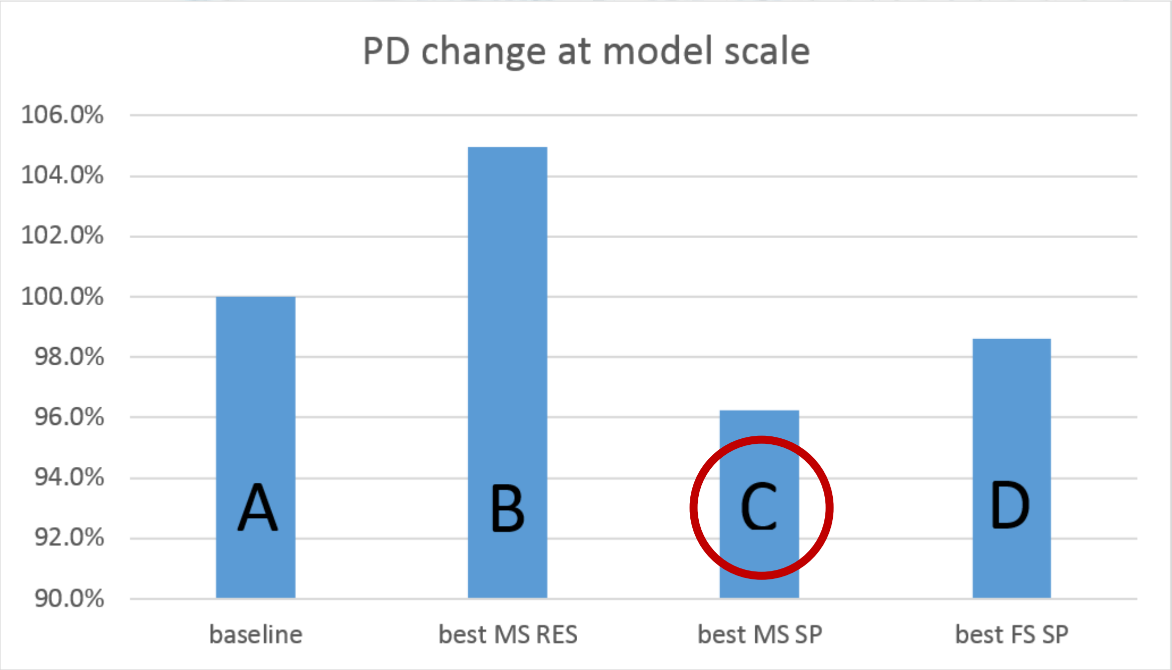
Cross-comparisons: model scale PD vs full scale PD

- **Hull C** (optimized for min. PD at model scale):
  - Higher PD at full scale than hull D





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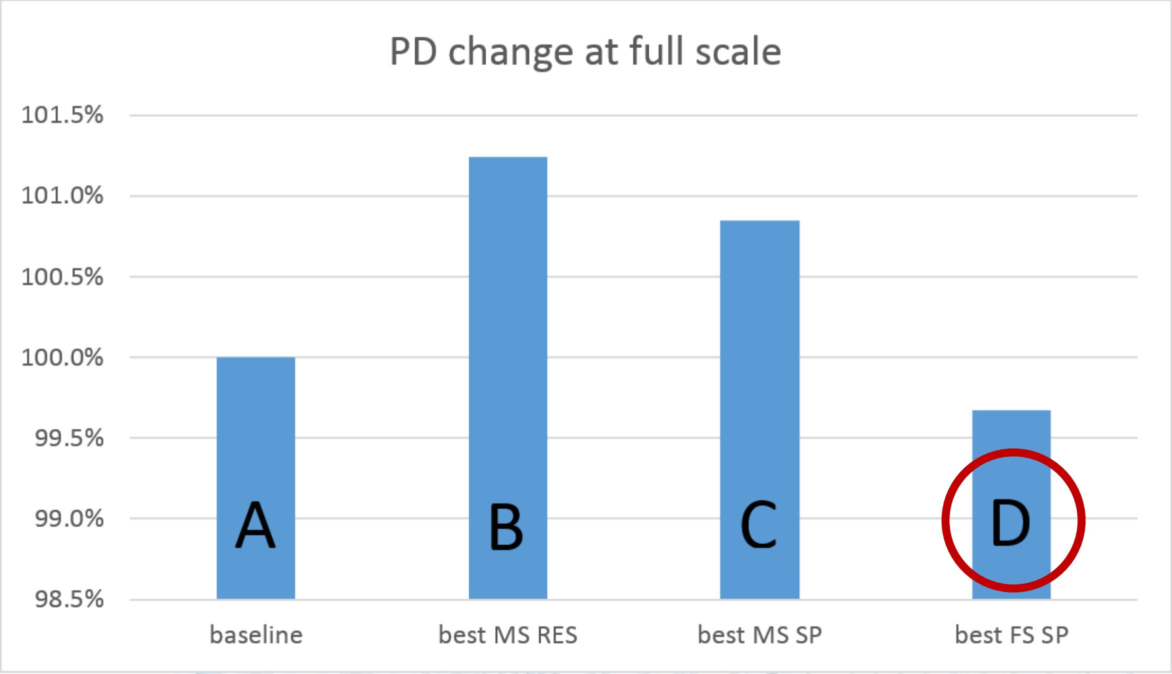
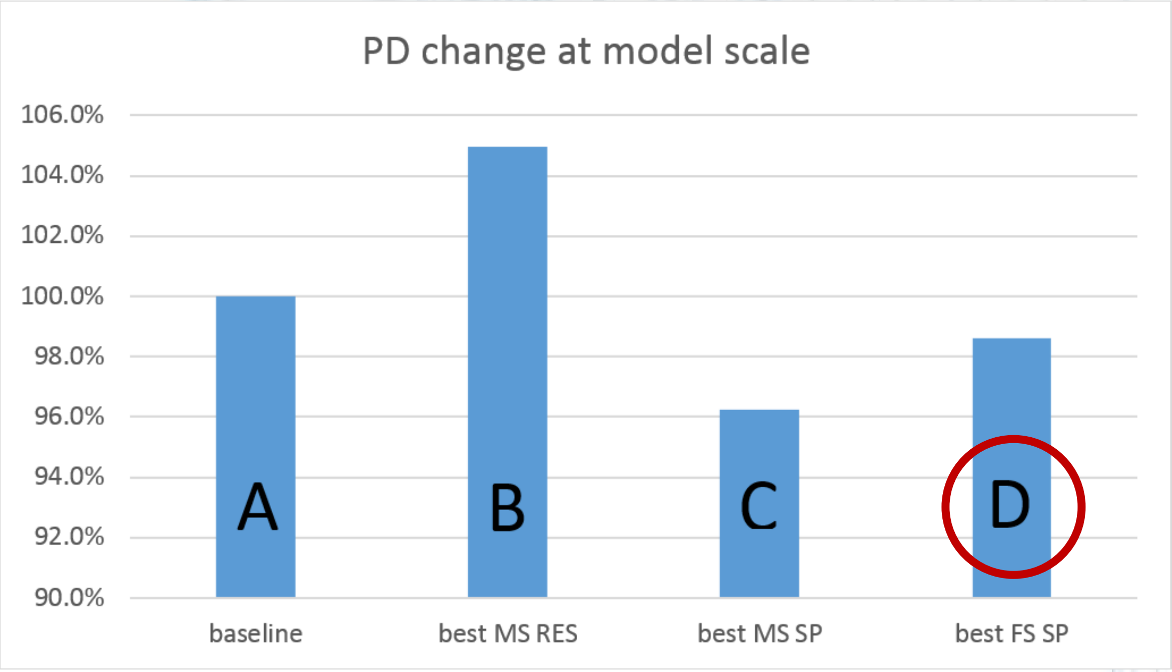
Cross-comparisons: model scale PD vs full scale PD

- **Hull D** (optimized for min. PD at full scale):
  - Higher PD at model scale
  - But Lower PD at full scale





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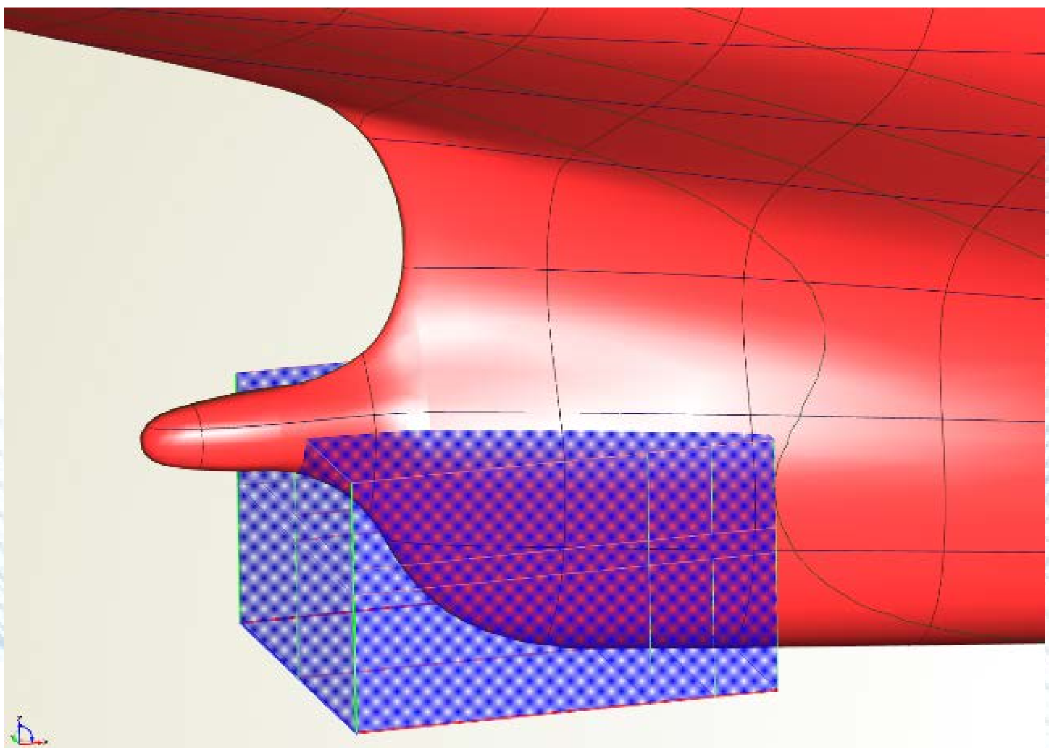
Some additional points

- Deformation techniques
  - Free box deformation can be better than delta surface shift in some cases e.g. for bulbs and skeg profile



Comments

- Constraints
  - Displacement
    - Appropriate penalty important
    - Design expected to be close to minimum displacement
- Optimization Approach
  - Wave resistance with XPAN:
    - TSearch or Sobol+TSearch if exploration is necessary
  - Viscous resistance and self-propulsion with XCHAP:
    - Genetic algorithm NSGA2
  - Note that the method selection will depend on the specific problem.

Comments

- CAESES and SHIPFLOW is an excellent environment for hydrodynamic optimizations
  - Partially parametric modelling delivered by CAESES gives very good control and flexibility of hull modifications, both global and local
  - SHIPFLOW is an efficient tool for self-propulsion simulations at model and full scale
- Aft body shape optimization of high block coefficient ship

  For best results:

  - optimize in self-propulsion condition
  - optimize directly at full scale.

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Thank You

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