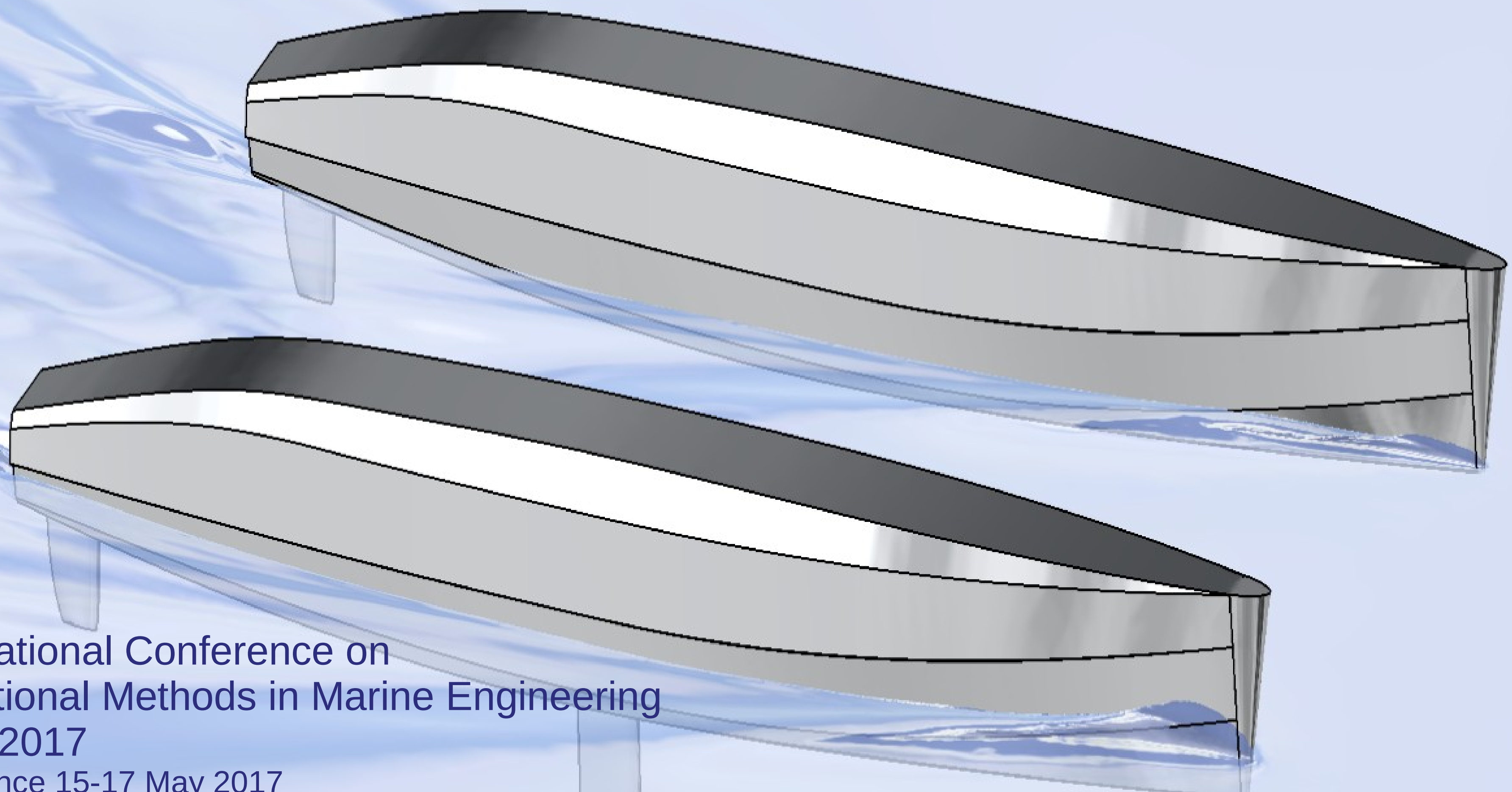
Simulation-Driven Design of Sailing Yachts and Motor Boats



VII International Conference on
Computational Methods in Marine Engineering
MARINE 2017
Nantes, France 15-17 May 2017

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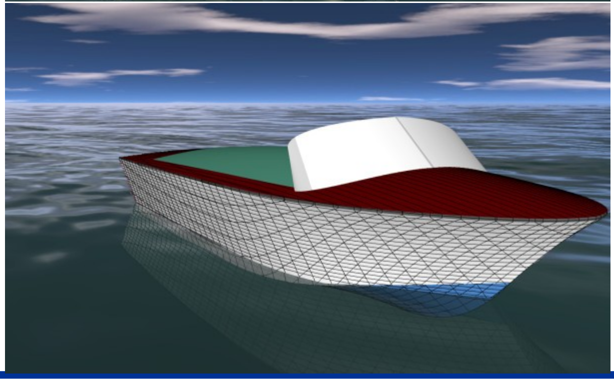
Overview

- Motivation
- Designs and Design objectives
- Parametric models
- Interfacing with CFD codes
- Optimization strategies
- Results

Motivation

- Yacht design is traditionally based on previous designs and systematic hull series (e.g. Delft series)
- The data base for catamaran designs and planing hulls is rather limited
- Model tests are prohibitively expensive
- The Simulation-Driven-Design approach allows to relate small design changes to performance



The Designs

DreamCatcherOne

- New Design
- Sailing catamaran (LWL ~20m)
- 36t displacement
- Displacement speeds
- Two speed optimization
  (Fn = 0.3 (8.2kts) and Fn = 0.44 (12kts))
- Different CFD codes used (SHIPFLOW®, FINE™/Marine)
- > 4500 models investigated
- **Design objective:**
  Good light wind performance

Riva Junior

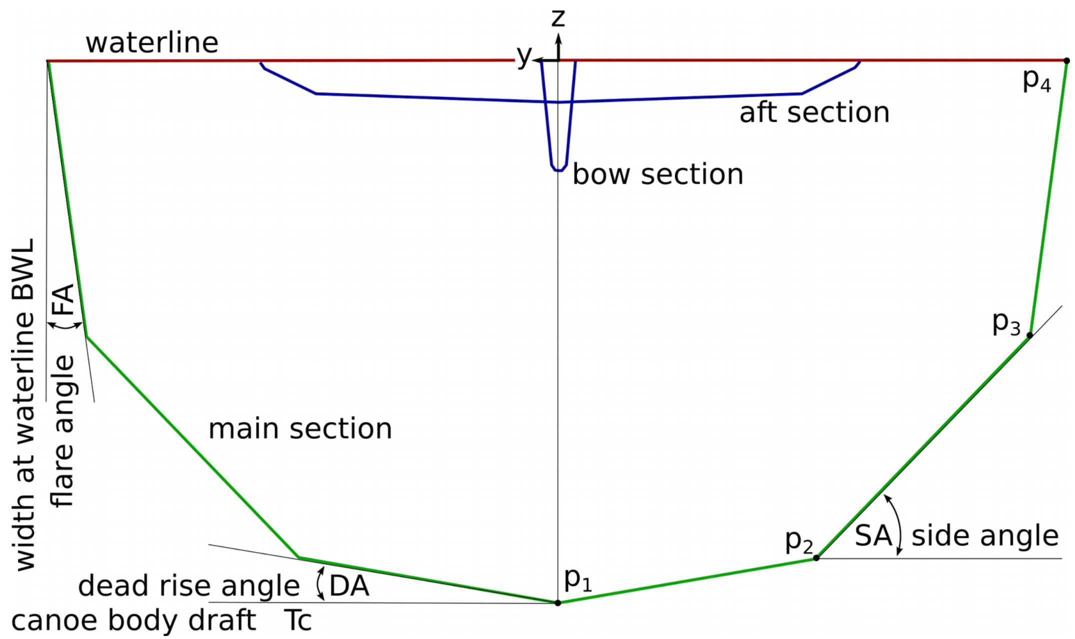
- Classical Design
- Motor boat (LWL ~5.66m)
- 1.3t displacement
- Plaining speed
- One speed optimization
  (Fn = 1.32 (18kts))
- One CFD codes used (FINE™/Marine)
- ~ 100 models investigated
- **Design objective:**
  Min. resistance at design speed

Parametric model in Yacht Design

- Key success factors
  - Reduce the number of independent parameters
  - Parameters should influence known performance aspects as directly as possible
  - Large parameter ranges to cover “unusual” designs
  - Provide suitable constraints
- CAESES® parametric CAD system
  - define complex geometric shapes based on mathematical models
  - integrates well with a many CFD solvers such as SHIPFLOW®, FINE™/Marine, STAR-CCM+ or OpenFOAM

DCOne: Three-/Four plate models

- All parametric hull designs used here use a section engine
- Shape parameters
  - waterline curve, center line curve, dead rise angle curve and flare angle curve, sectional area, longitudinal position
- Dependent parameters
  - side angle is derived using a quadratic equation minimizing the length $p_1p_2p_3p_4$
  - displacement by variation of sectional area



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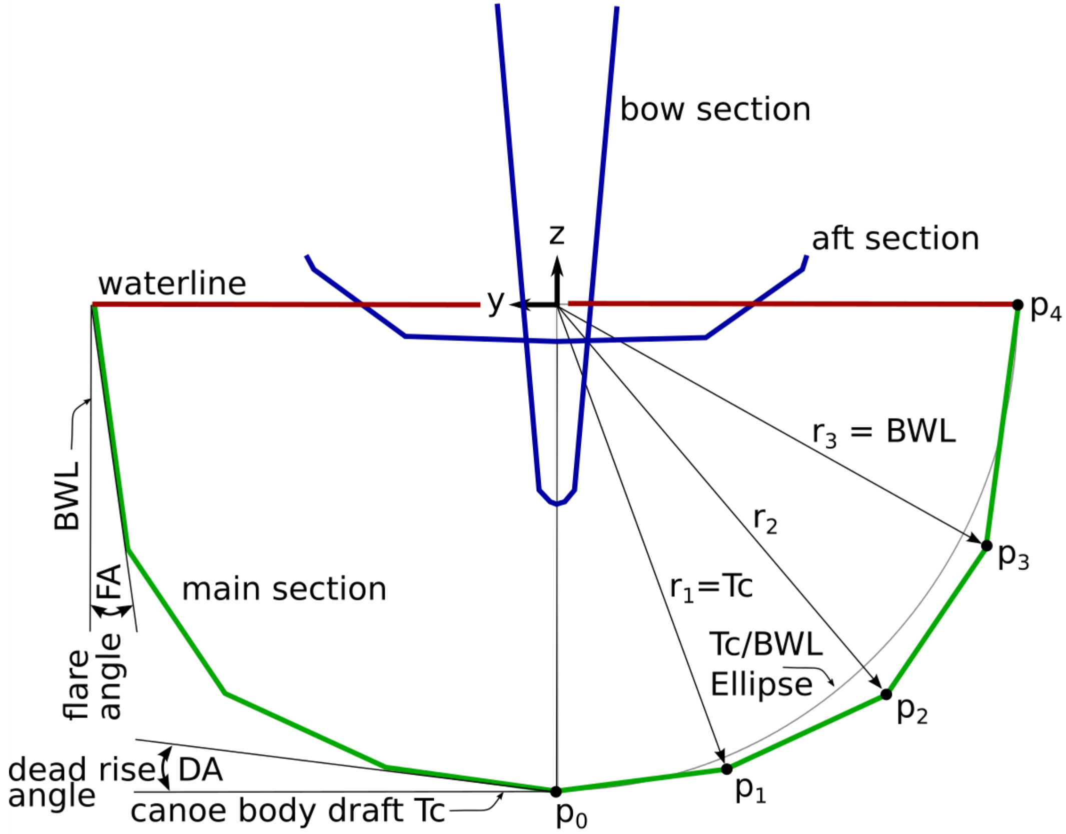
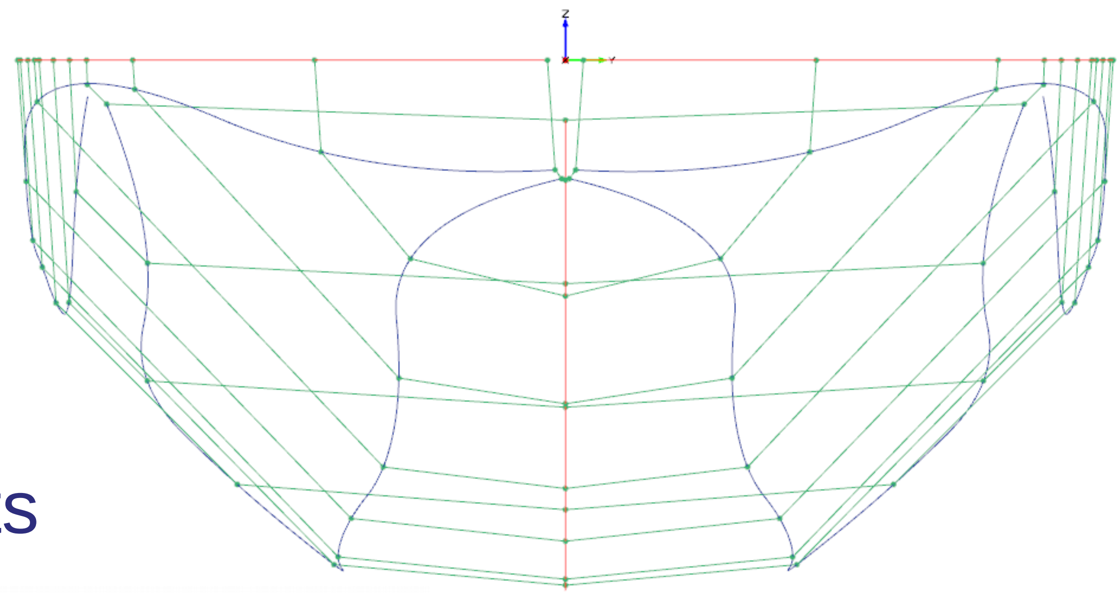
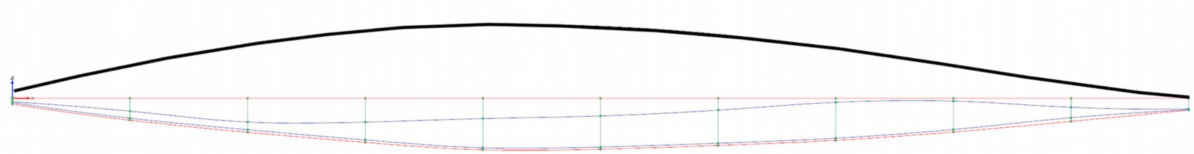


DCOne: Modeling Pitfall

Choosing parameters that directly influence performance does not always work:

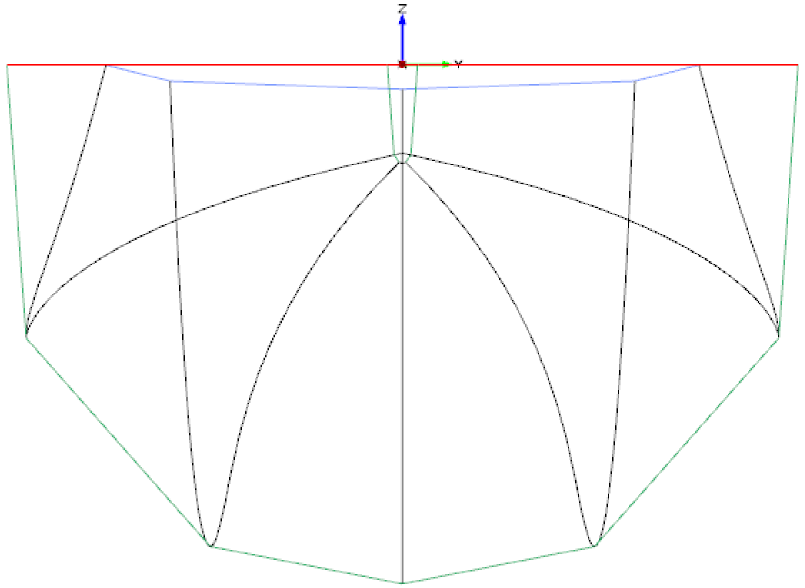
- Sectional area curve is translated into a multitude of hard chined sections
- The curves connec-ting the corner points are not fair but show wave-like shapes
- Too many constraints

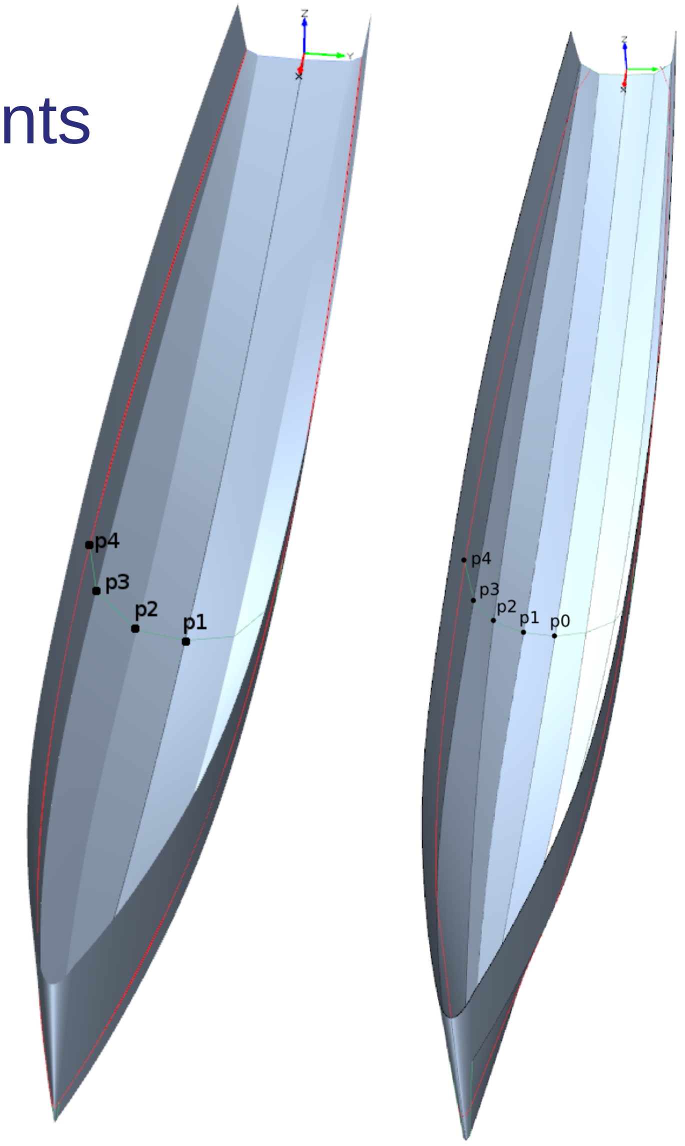




DCOne: Fair chines

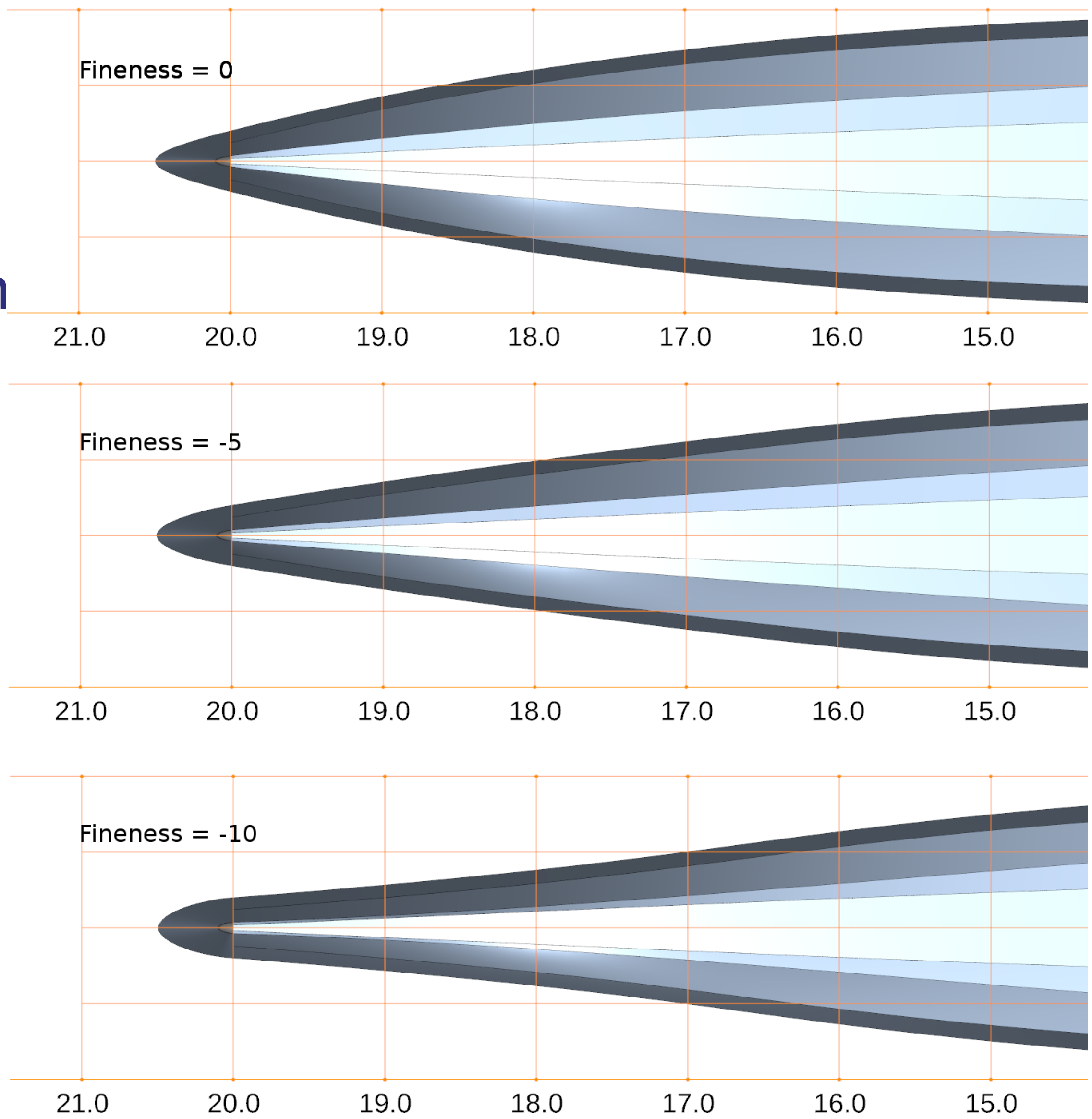
- Three section only: stern,main, bow
- The chines depend on the section points which are connected by C2-continous splines
- The chine-curves are used as rail curves for developable surfaces





DCOne: Design parameters

- Maximum Beam
- Beam at stern
- Bow Fineness
- Rocker angle at the stern
- Draft at stern
- Area of stern section
- Flare angle at stern
- Beam-to-Draft ratio
- Dead rise angle curve
- Flare angle curve
- Draft at bow
- Longitudinal position of the main section
- ...

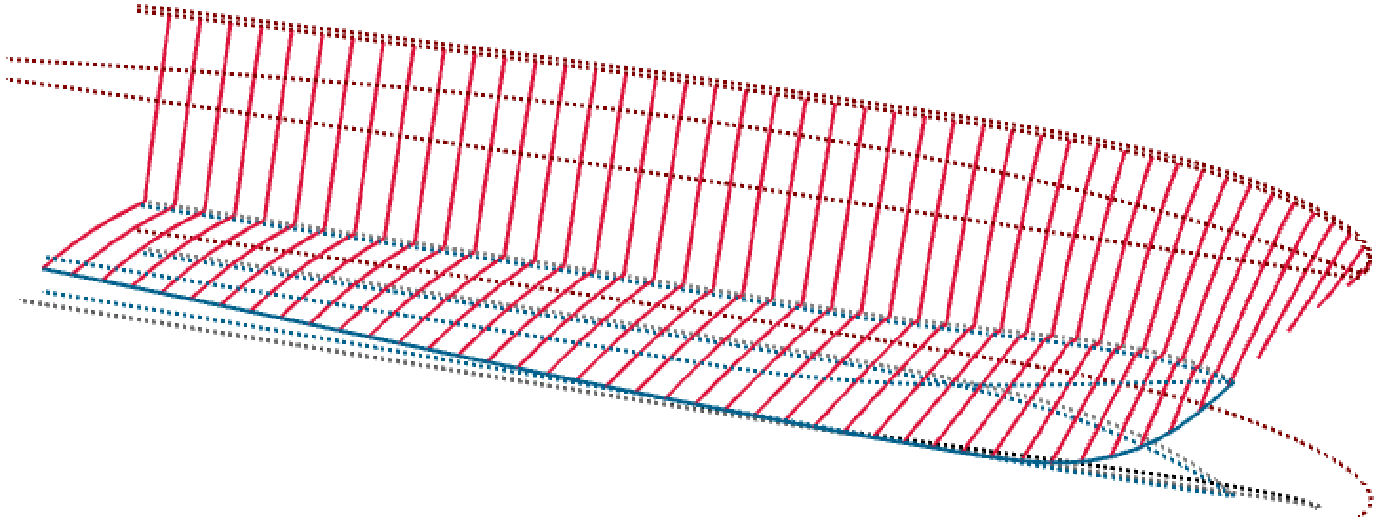


Riva: Parametric model

- Different approach:

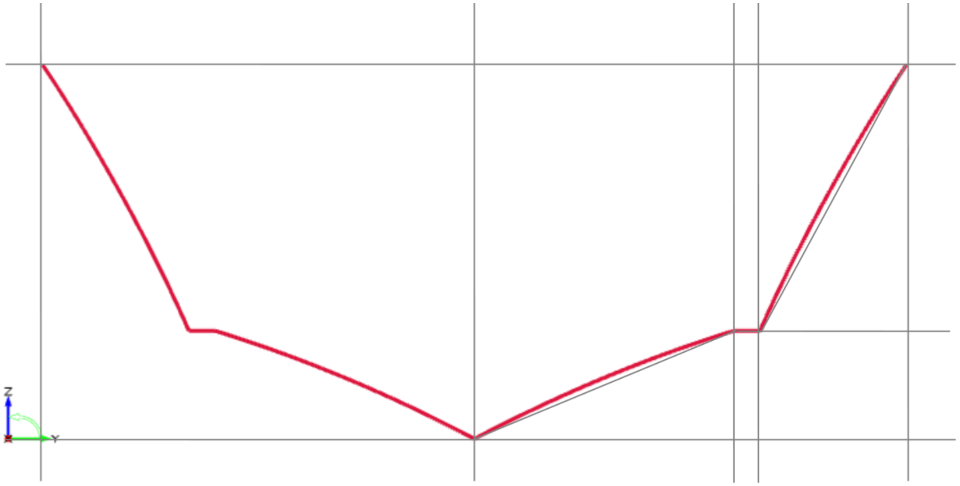
  Define hard chines first, then sections

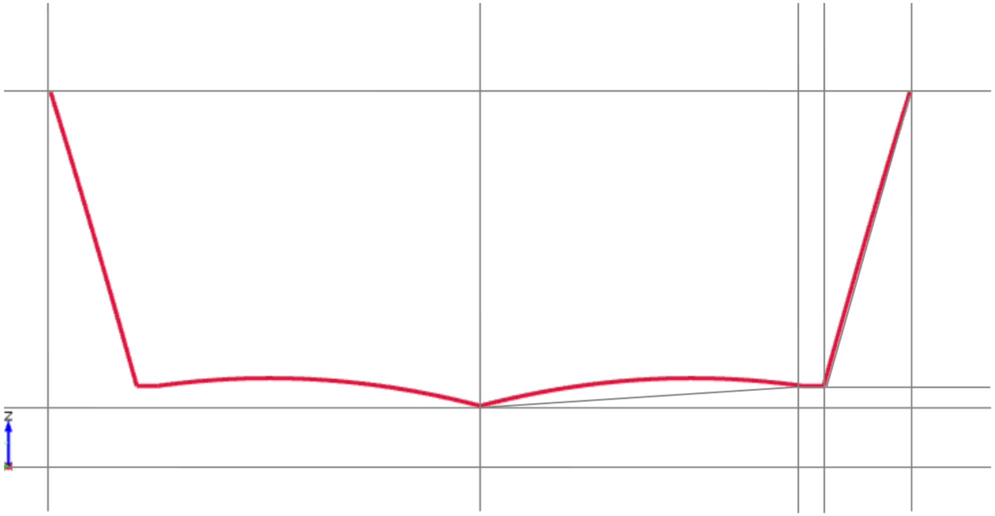
- Chines are defined by generic curves in 3D that are based on two planar curves in the XY and XZ planes
- Skinning by a mix of ruled surfaces and metasurfaces



Riva: Parametric model

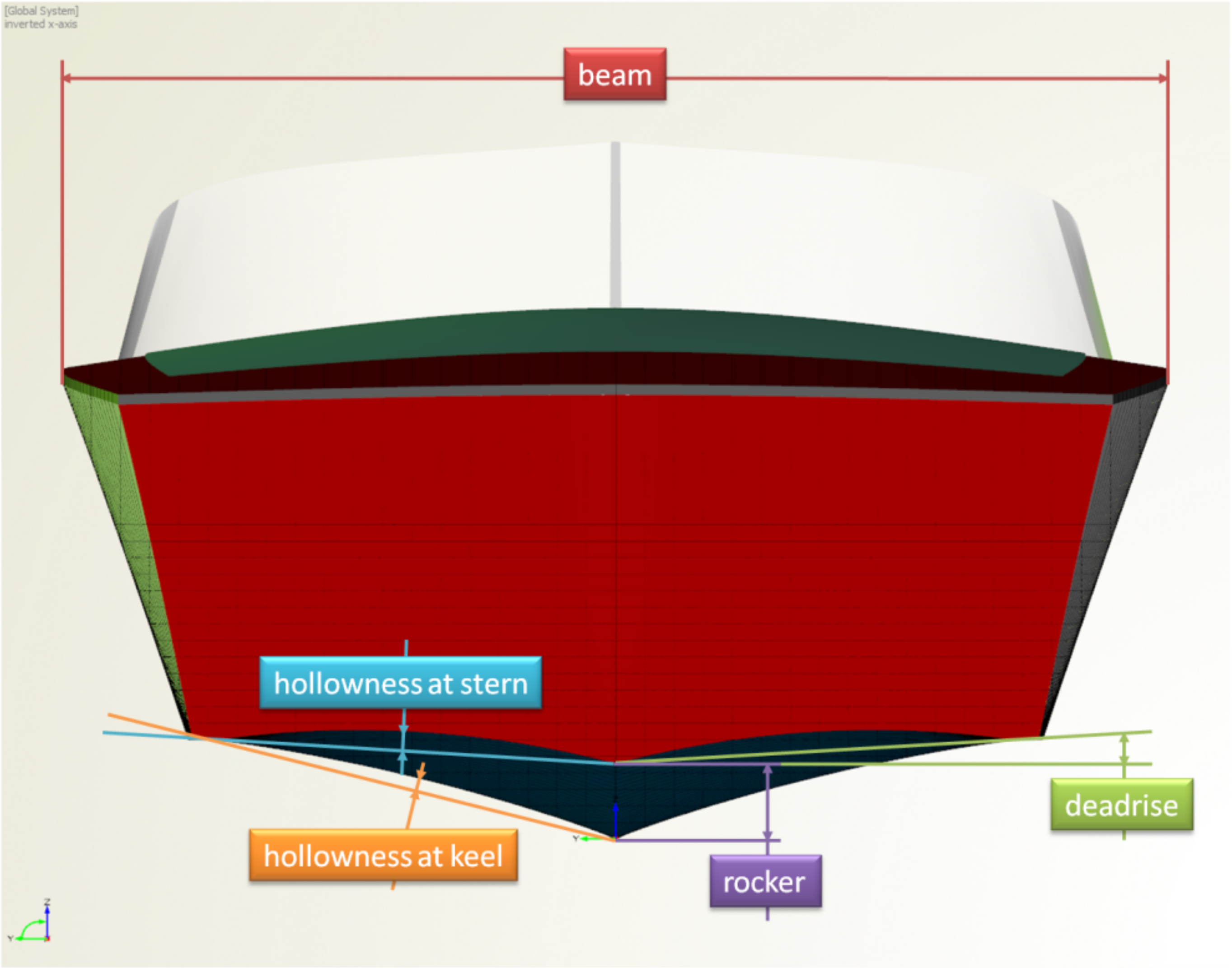
- Hull is composed of different parts that seamlessly connect at the chines
- Each part can be separately varied based on separate parameter curves
- In longitudinal direction the sections are varied based on a mathematical model of the section (i.e a program written within the CAD environment (CAESES®) to generate the meta surfaces





Riva: Design Parameters

- Beam
- Hollowness
- Rocker
- Deadrise

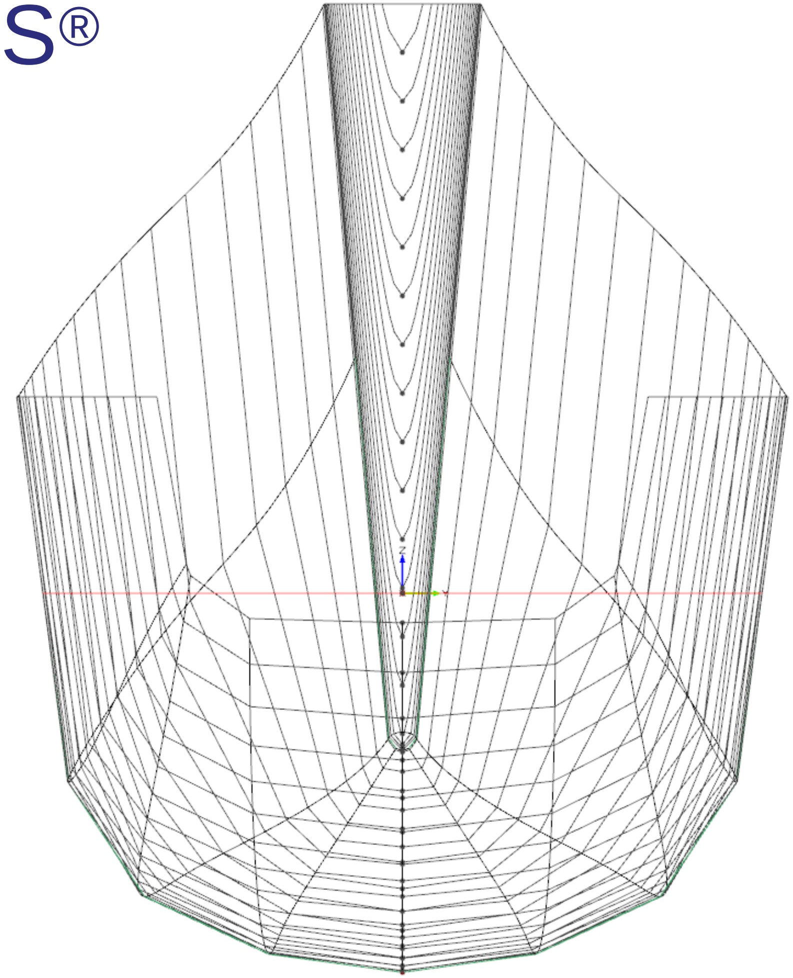


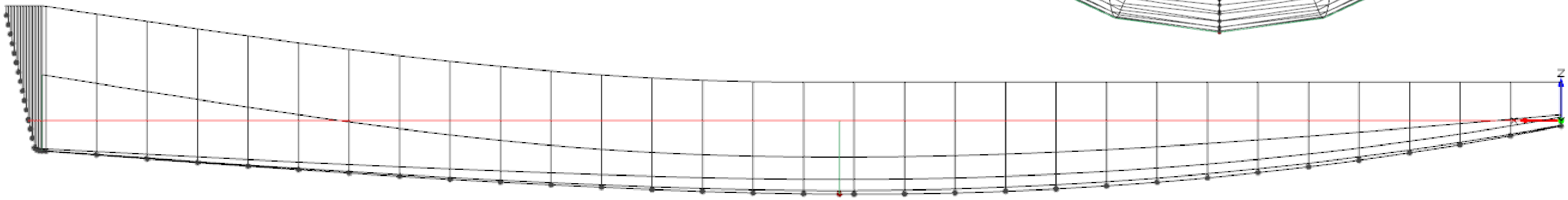
See:

webapps.caeses.com

DCOne: CFD Model setup 1

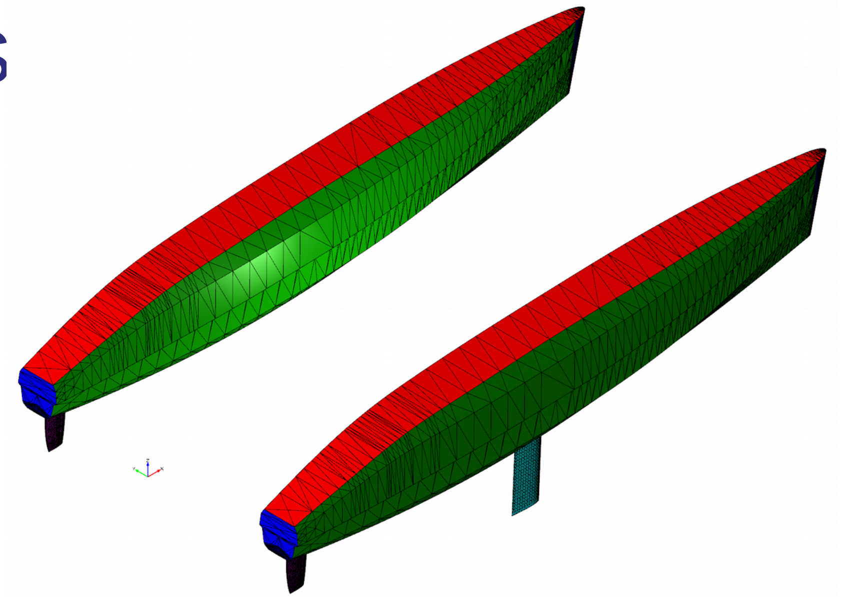
- Parametric model in CAESES®
  - Hull geometry
  - Fixed displacement
- Interface to SHIPFLOW®
  - Section created in CAESES®
  - Section resolution adjusted for best meshing results

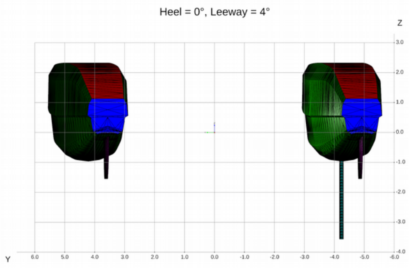


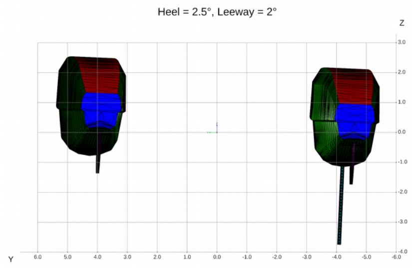


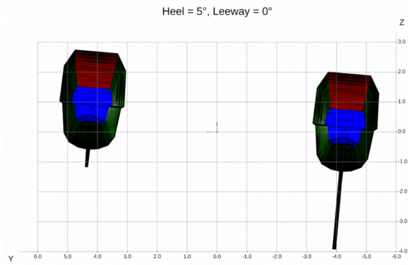
DCOne: CFD Model setup 2

- Parametric model in CAESES
  - Heel / Leeway transformations
  - Fixed displacement
  - Variable rudder angles and daggerboard sweep angles
- Interface to FINE™/Marine
  - Triangulation in CAESES®
  - Water-tight STL body
  - STL-triangulation exported (multibody STL)
- Different colours for different parts for automatic recognition in FINE™/Marine's "C-Wizard"

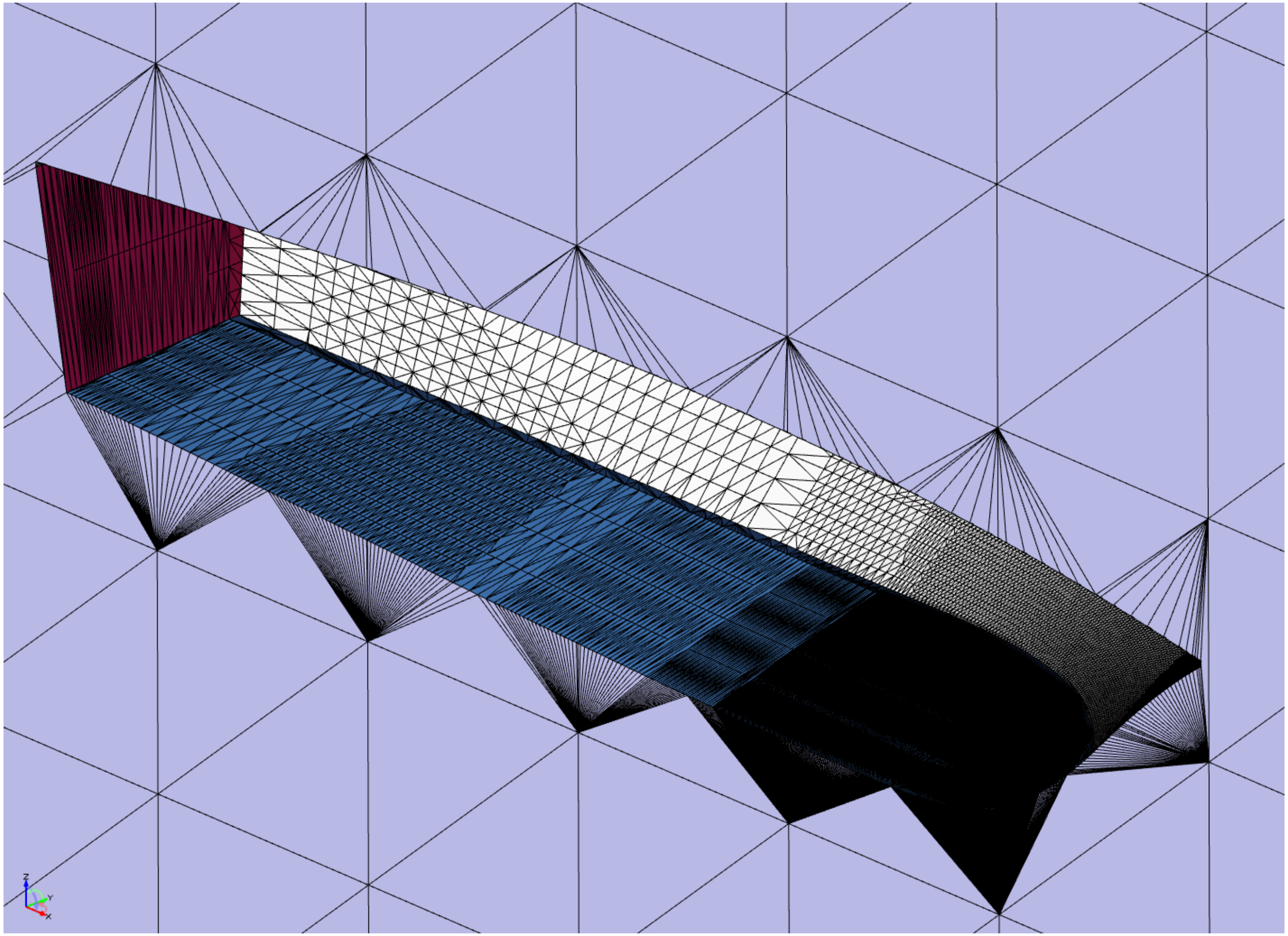








Riva: CFD Model setup



- Triangulation of hull and simulation domain
- Colored STL Export as in DCOne Case 2

Optimization strategies

DreamCatcherOne

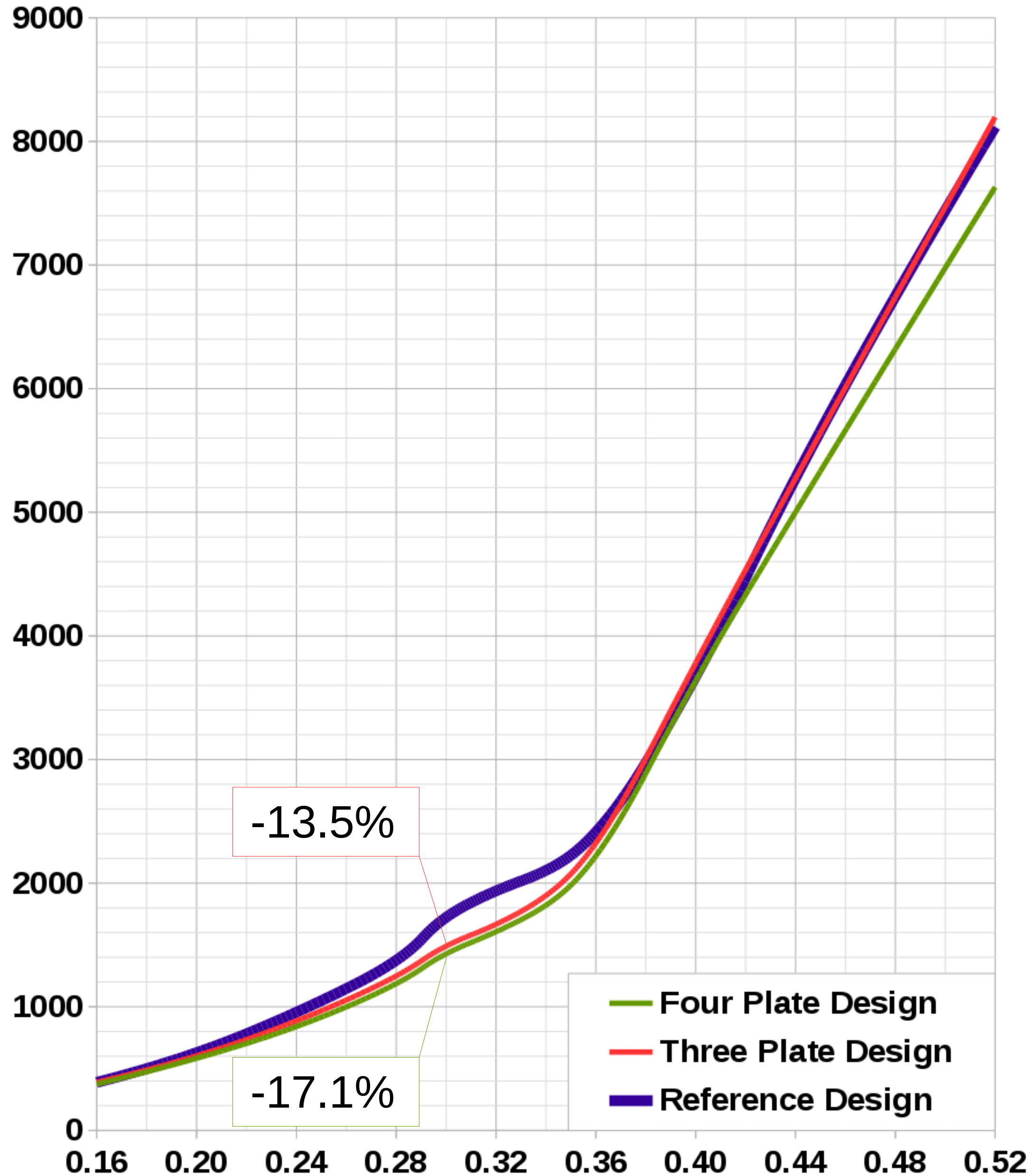
- Wave resistance single hull
  - "Design of Experiments"
  - ~4000 models, 8000 calculations
- Total resistance, zonal approach
  - ~500 models, 1000 calculations
  - Selection criterium: Weighted sum of resistances at Fn= 0.3 and Fn=0.44
- Total resistance appended catamaran model (RANSE solver)
  - ~200 simulations
  - Verification of best single hull designs, hull distance, ...

Riva Junior

- Total resistance (RANSE solver)
  - "Designs of Experiments"
  - Evaluation of the design space
  - ~100 models
  - Selection criterium: Lowest resistance at design speed
- Tseach
  - automatic using deterministic gradient-free search strategy to find the best model in a limited design space

DCOne: Numerical Results 1

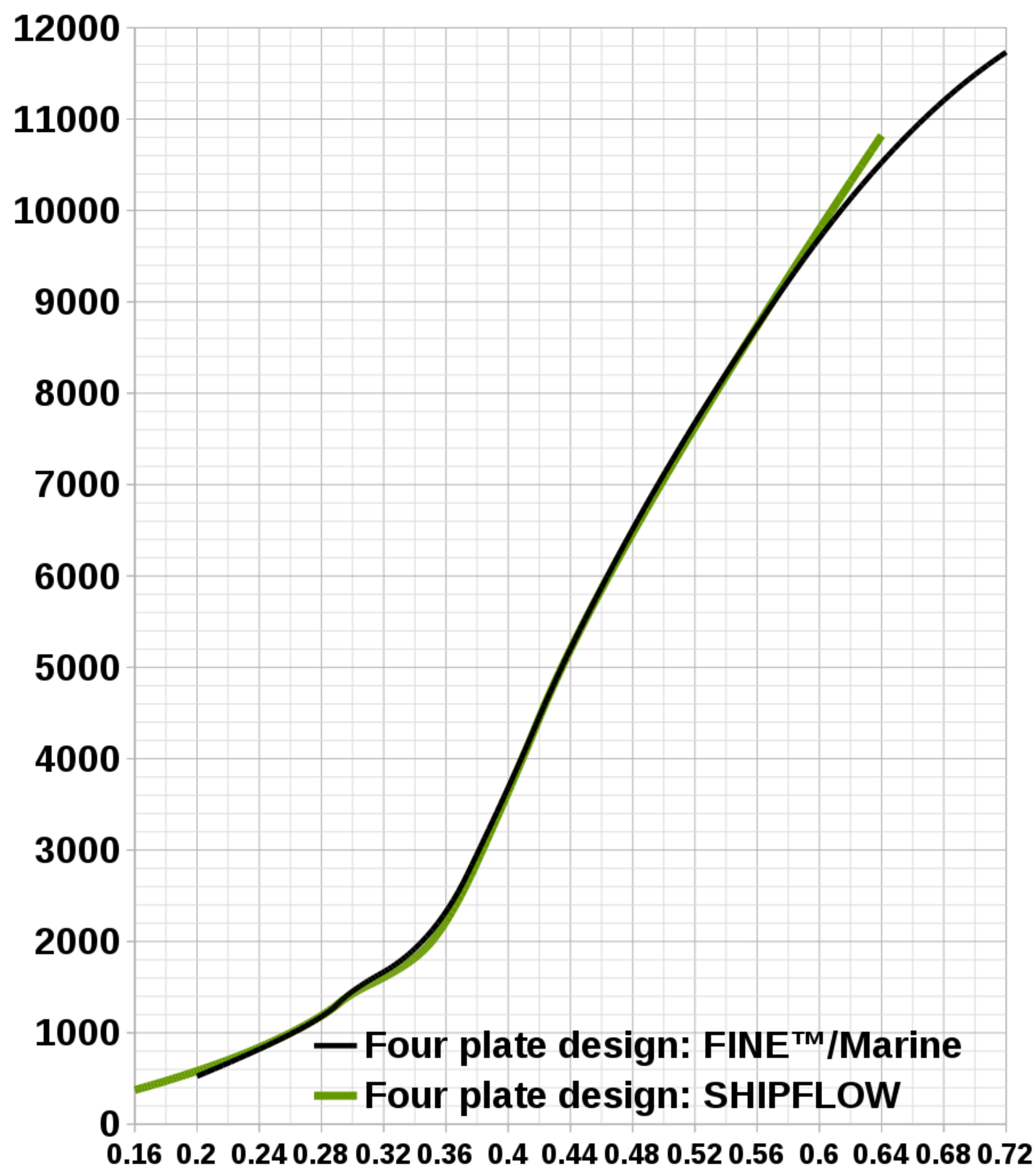
- Best three and four plate designs
- Complete speed range
- Significant improvement between F_n=0.28 and 0.36 (7.5 and 9.5 kts) (Hull speed 10.9kts)
- Four plate design better at higher velocities



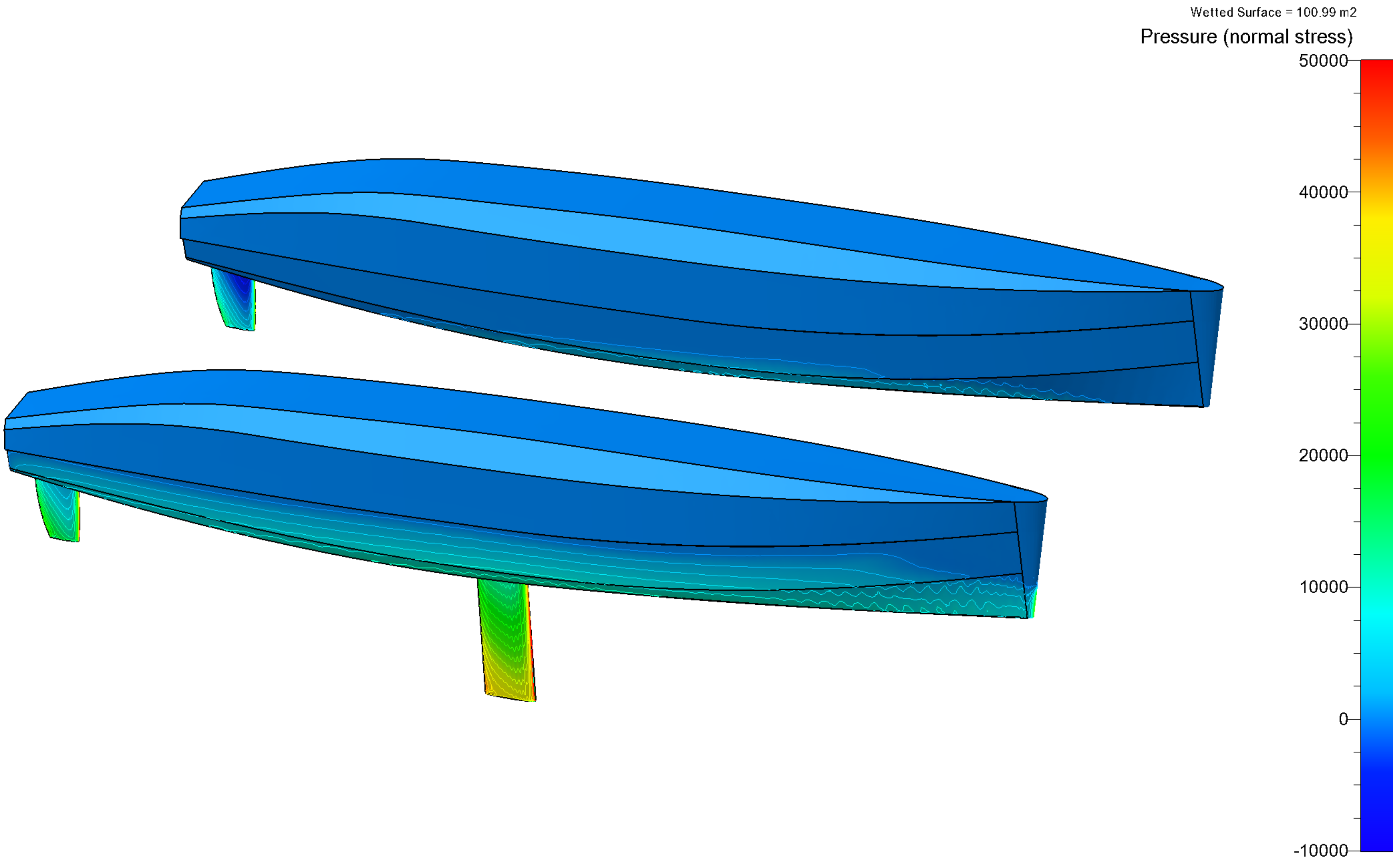
DCOne: Numerical Results 2

- Result verification using RANSE solver (FINE™/Marine)
- Maximum deviation at the optimization points
  F_n=0.30 1.8%
  F_n=0.44 0.1%
- Maximum deviation at other calculation points
  Fn=0.36 5.5%

➡ Reliable results

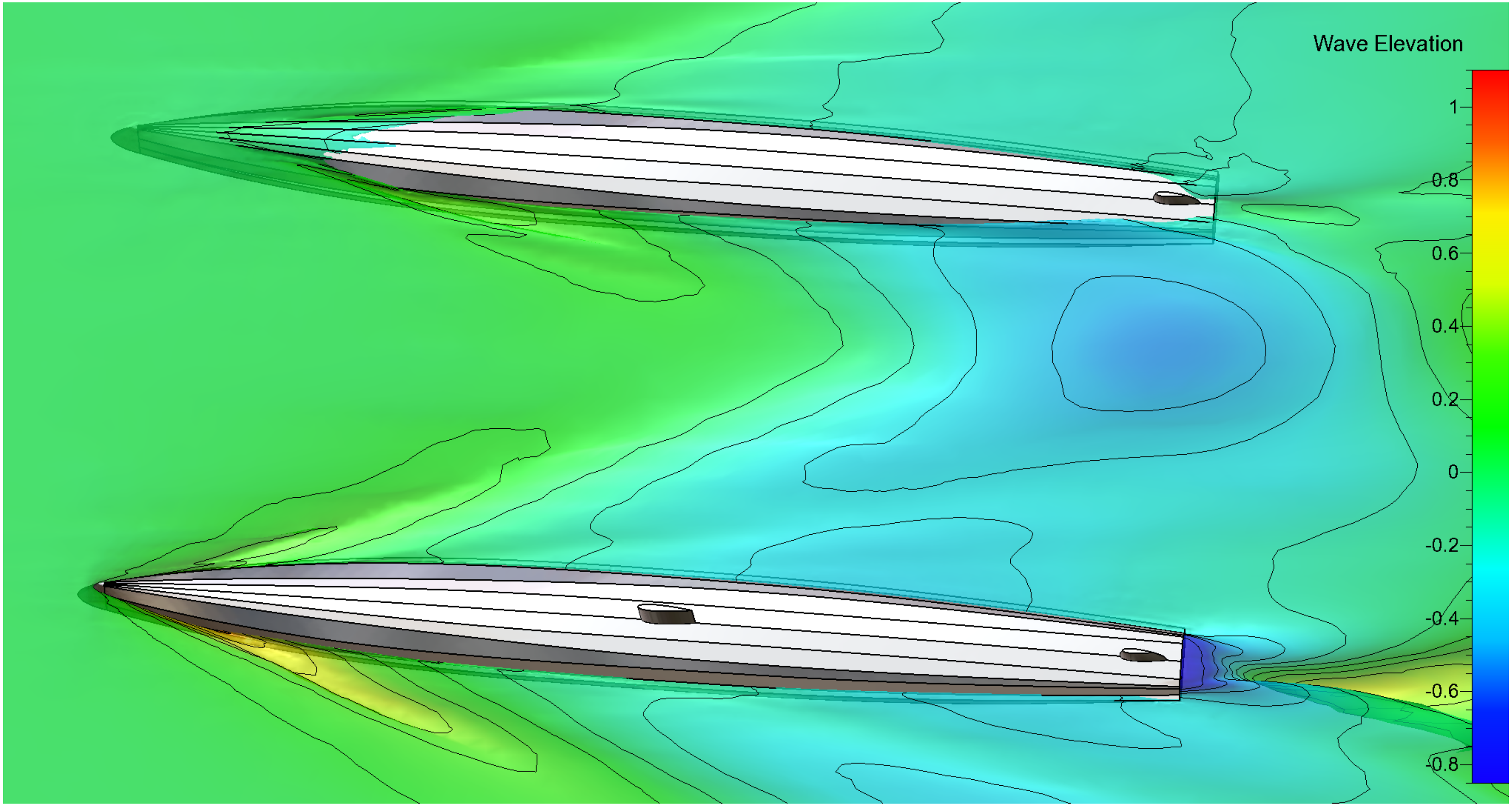


DCOne: Visual inspection 1



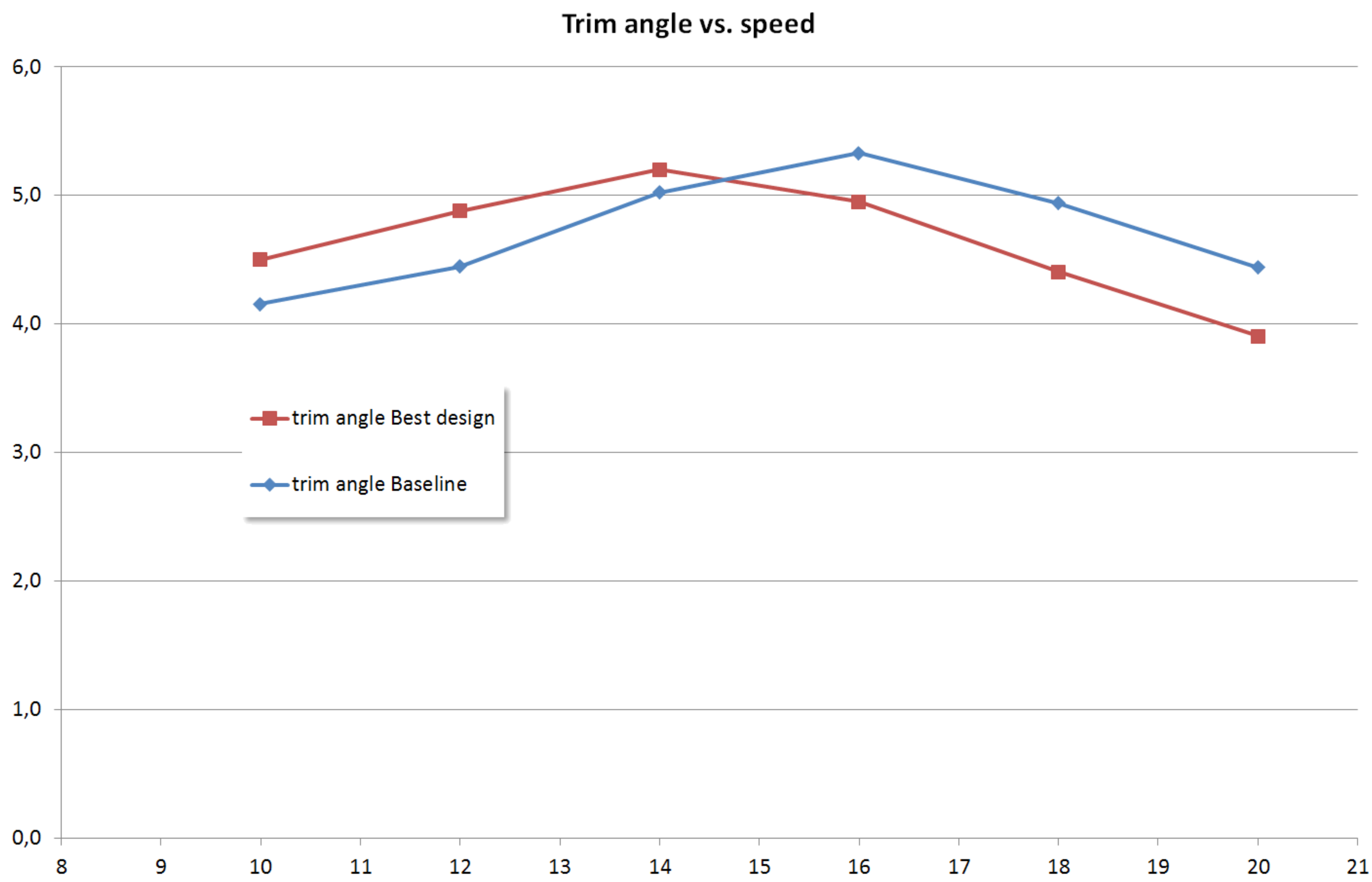
Pressure distribution: rectangular shape vs. elliptical appendage shapes

DCOne: Visual inspection 2



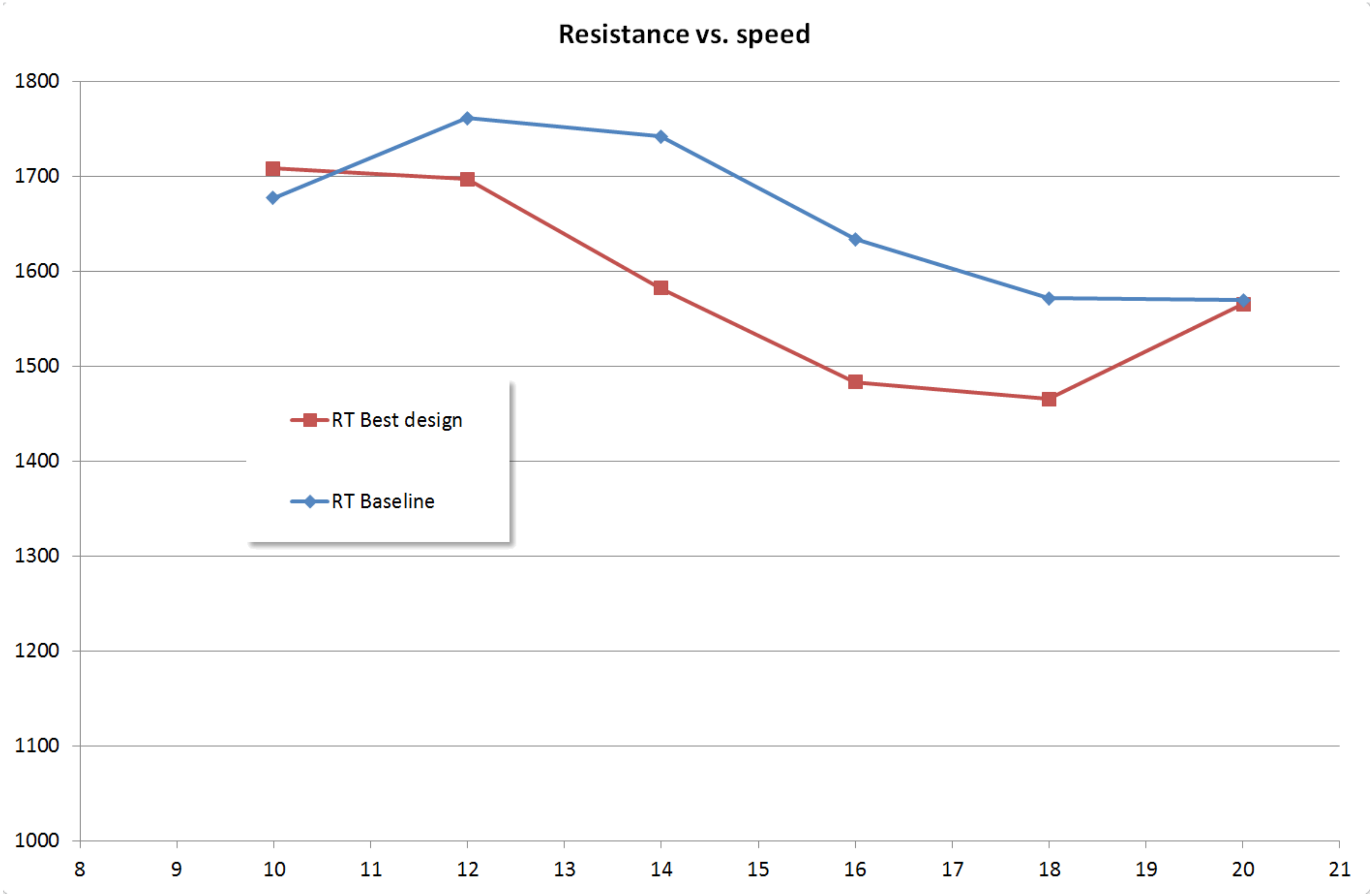
Wave elevation: Bottom view, no rudder ventilation

Riva: Numerical Results 1



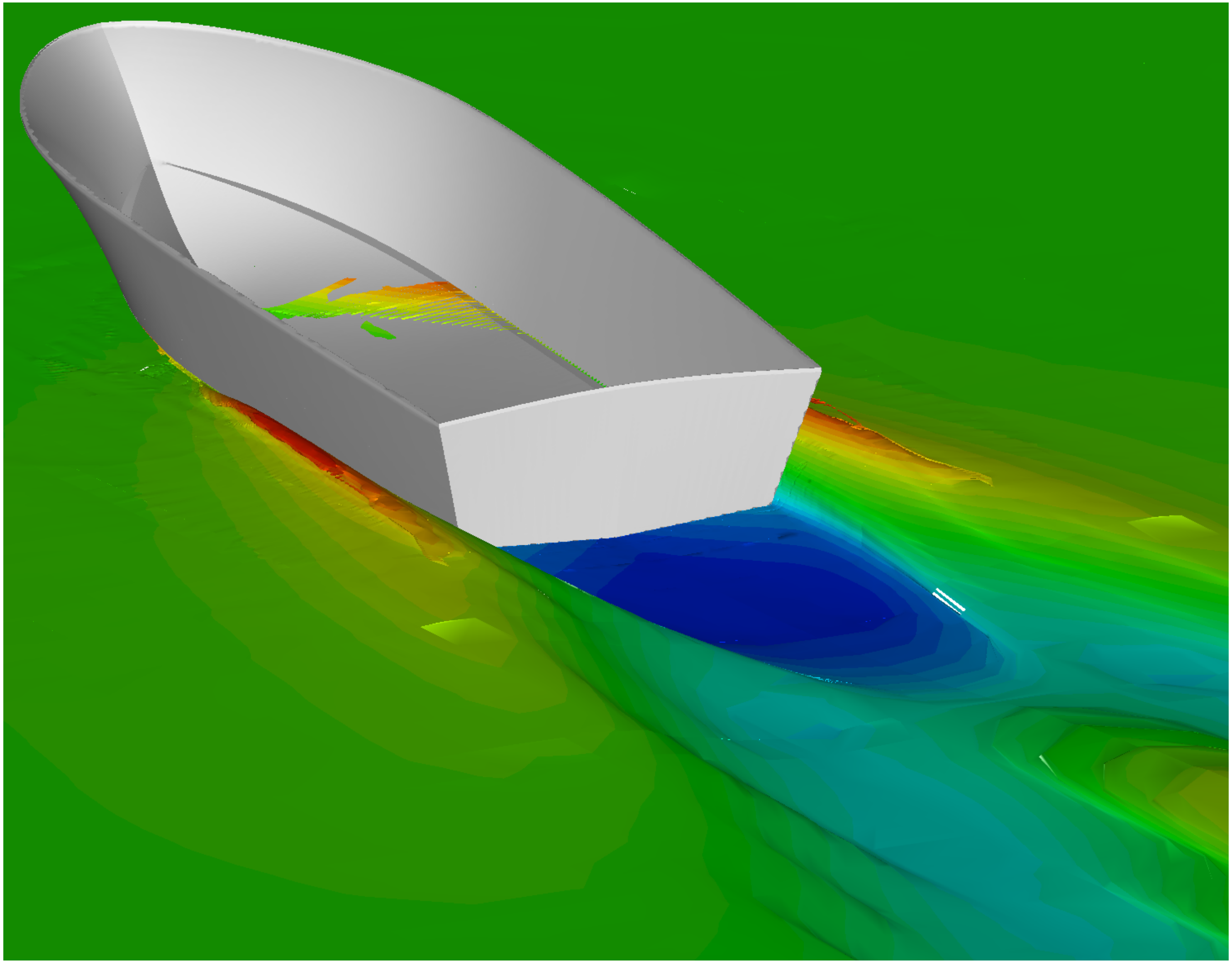
Typical result of a one point optimization

Riva: Numerical Results 2



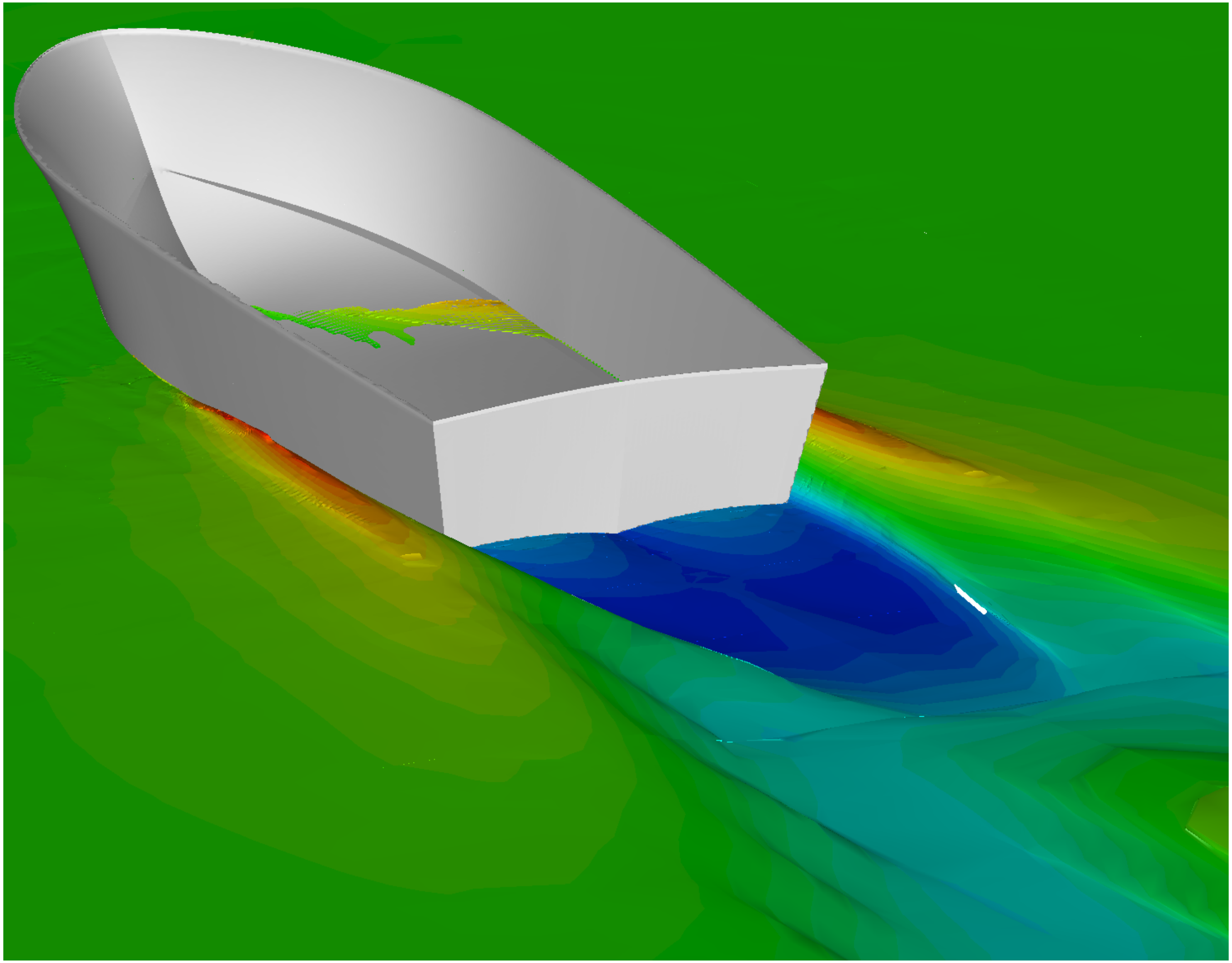
Resistance: 7% reduction at design speed

Riva: Visual inspection 1



Base line at design speed (18kts)

Riva: Visual inspection 2



Best Design at design speed (18 kts)

Conclusions

- Key success factors
  - Selection of design objectives
  - Fully parametric models
  - Automation of CFD simulations
  - Flexible optimization strategies
- Simulation Driven Design is a versatile tool to solve complex yacht design problems from overall design aspects to specific details

Thank you!

Questions?

For further information visit my Website:

www.dreamcatcherone.de