Velocity Prediction Program Development for Hydrofoil-Assisted Sailing Monohulls

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Motivation

- Sailing industry is using hydrofoils
- Pleasure yachts and high performance
- No much academic work so far

https://www.yachtingworld.com

https://www.americascup.com

https://infinitiyachts.com

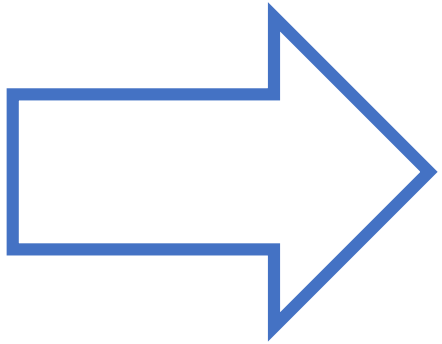
State of the art

- Hydrofoil-assisted sailing monohull – towing tank tests
  - Increase in drag
  - Increase in righting moment

- Velocity Prediction Programs
  - Balance of hydrodynamic and aerodynamic forces
  - Conventional vs Dynamic
  - Analytical
  - Empirical
  - Numeric

Objectives

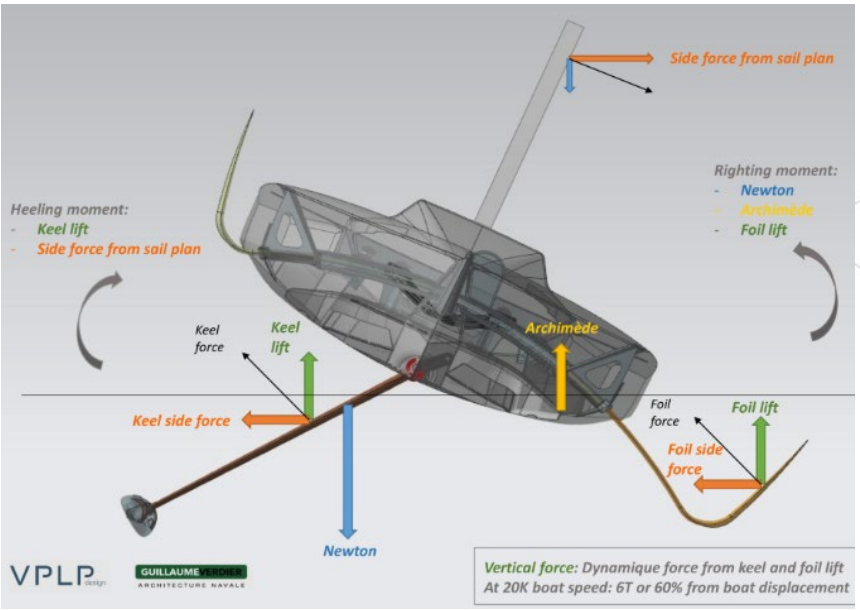
- Understand the consequences of hydrofoil
- Select aerodynamic and hydrodynamic models
- Developpe a preliminary design tool
- Suggest foils optimizations



Developpe a Velocity Prediction Program

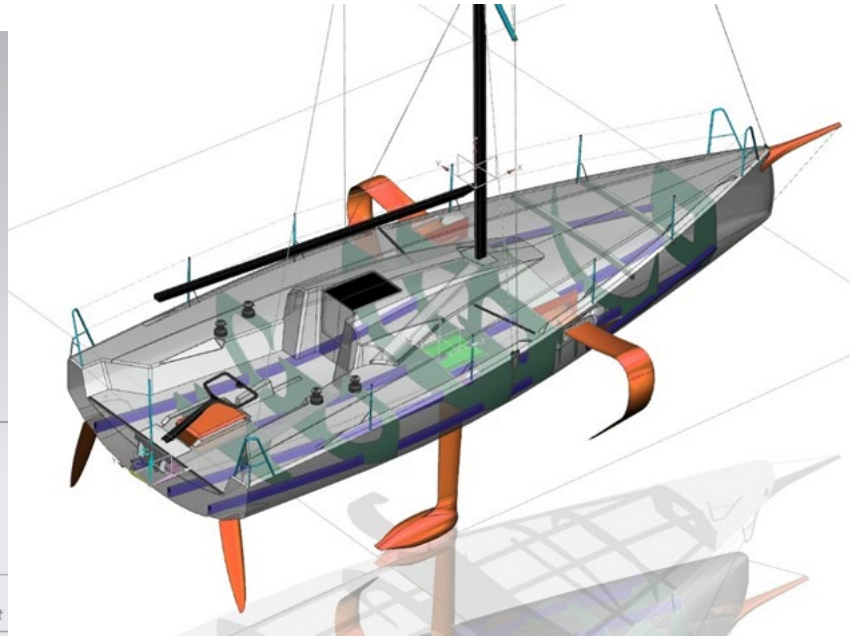
Hydrofoil classification

Dali Moustache (DM)



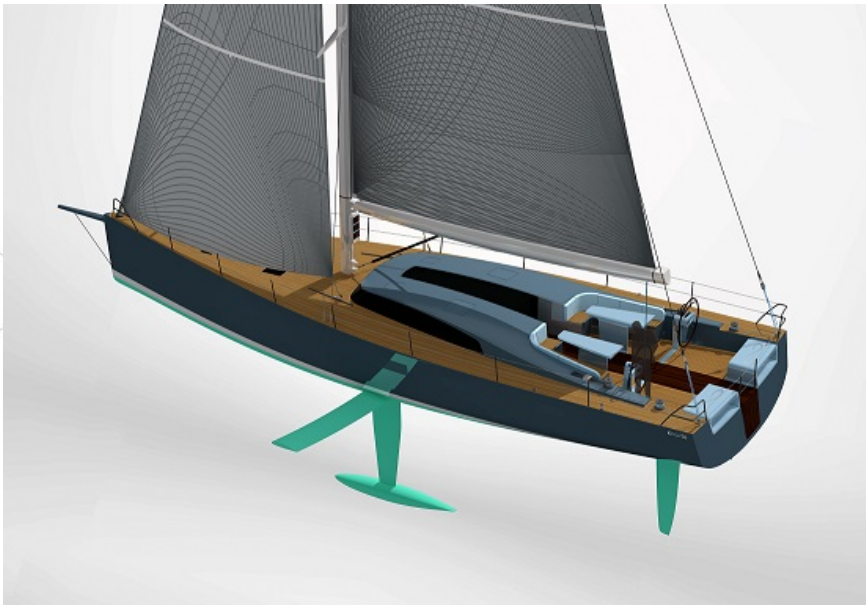
https://www.sailingscuttlebutt.com/

Chistera (FF)



http://www.beneteau.com/

Dynamic Stability System (DSS)



https://infinitiyachts.com

VPP - models selection

- Aerodynamic and Hydrodynamic models:
- Analytical
  - Simple and fast
- Polynomial regression from experimental data
  - Simple and reliable
- Numerical (CFD, FEM, FSI)
  - Complex and expensive
- Experimental
  - Complex and expensive

Aerodynamic and Hydrodynamic models

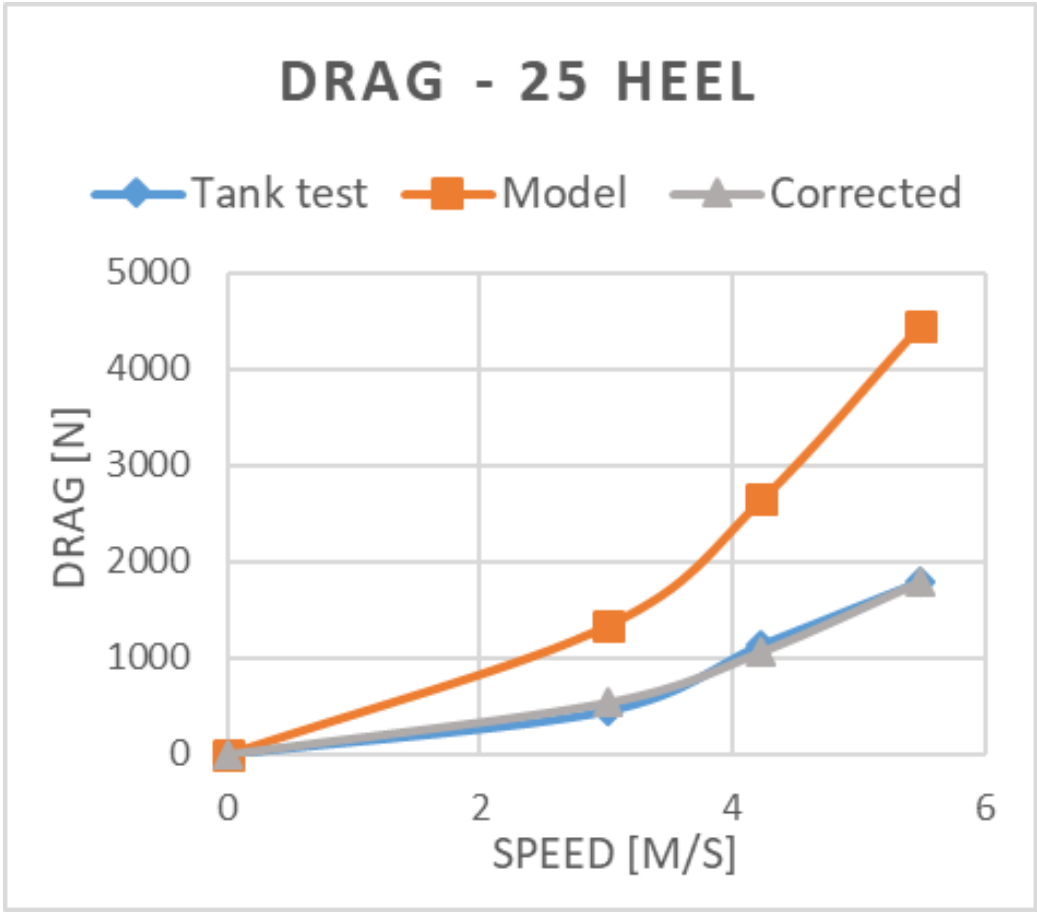
Offshore Racing Congress (ORC) – Aerodynamic

Delft Systematic Yacht Hull Series (DSYHS) - Hydrodynamic

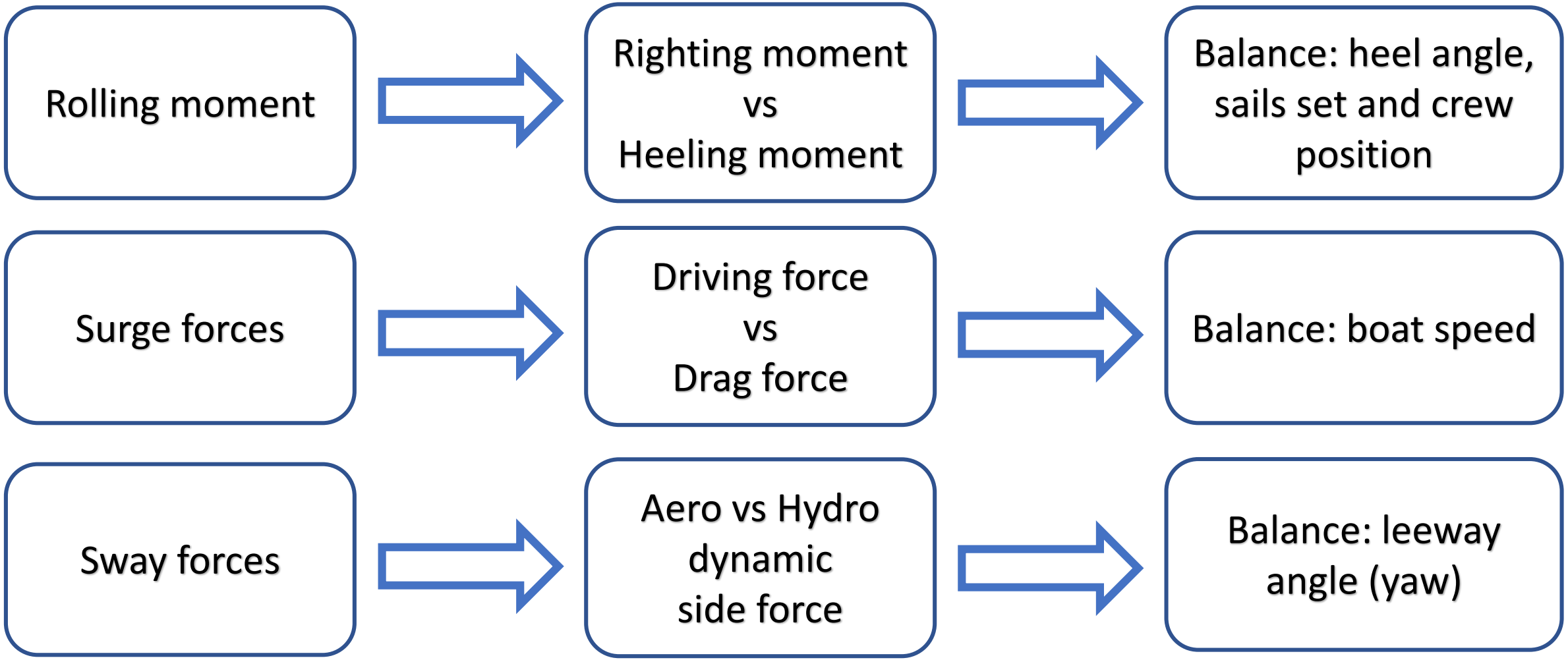
- Input: boat dimensions; sailing conditions
- Output: side force, its height and thrust/drag force
- **3 DOF**
- Validation with Masuyama, Y. et al. (2009) and DSYHS database

Hydrofoil model

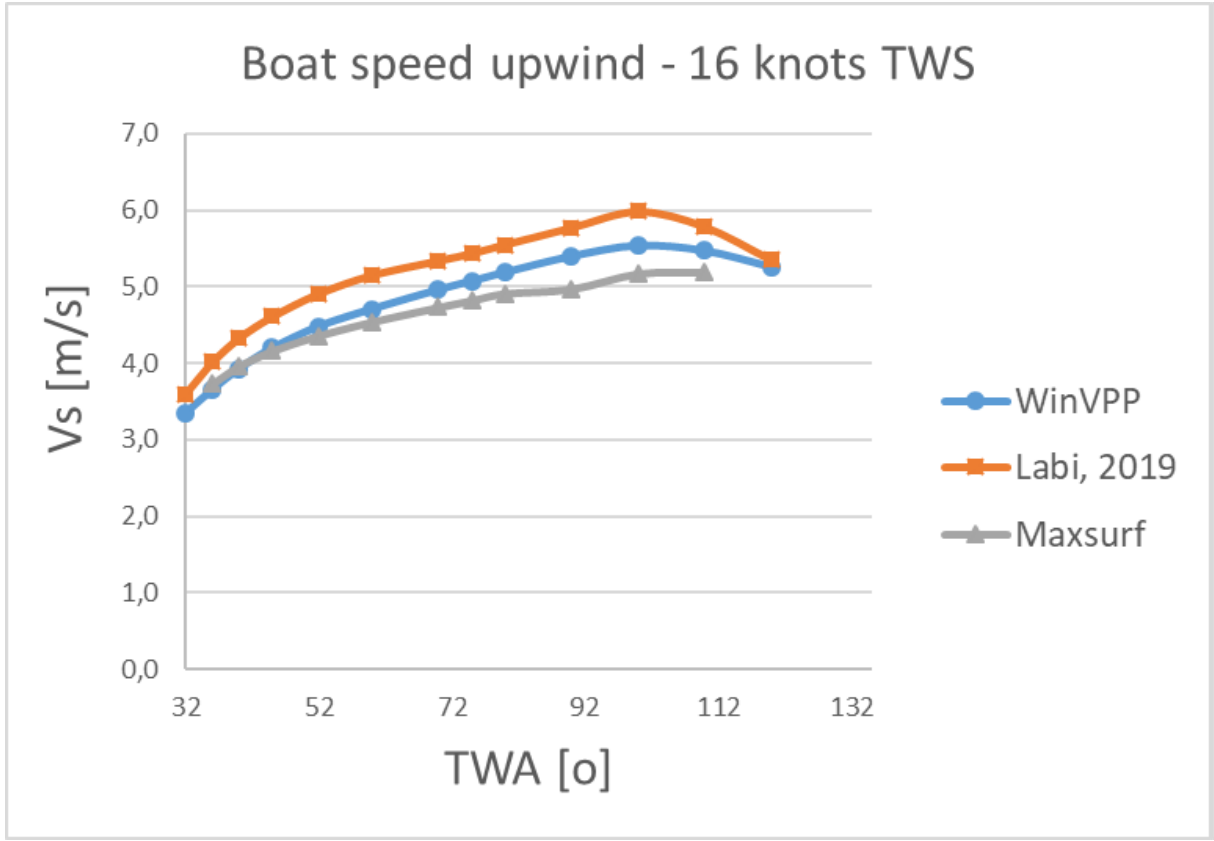
- Classic wing theory
- To consider free-surface proximity, **Glauert bi-plane theory** is used
- Other effects: tip vortex, bow wave, ventilation, foil and hull interaction
- Towing tank tests to find an **efficiency coefficient** (correction factor)

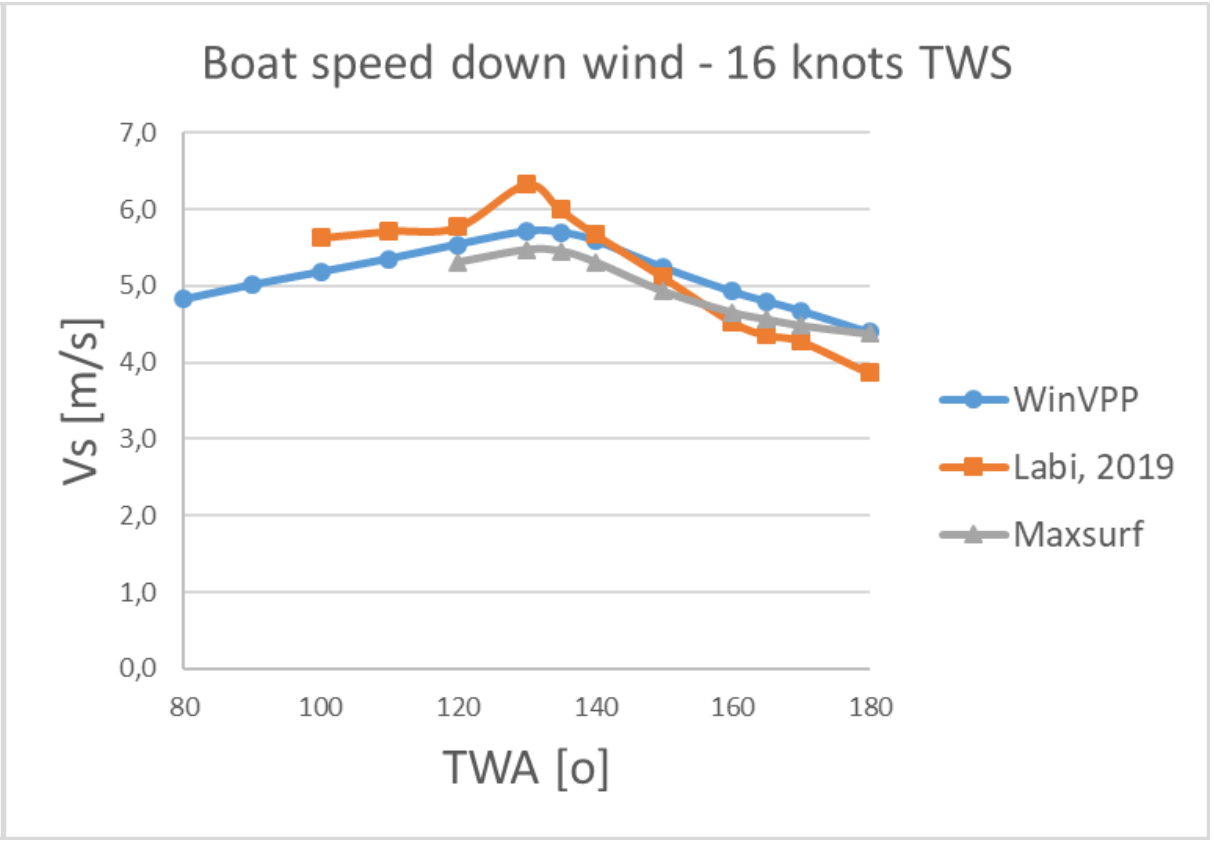


VPP forces balance

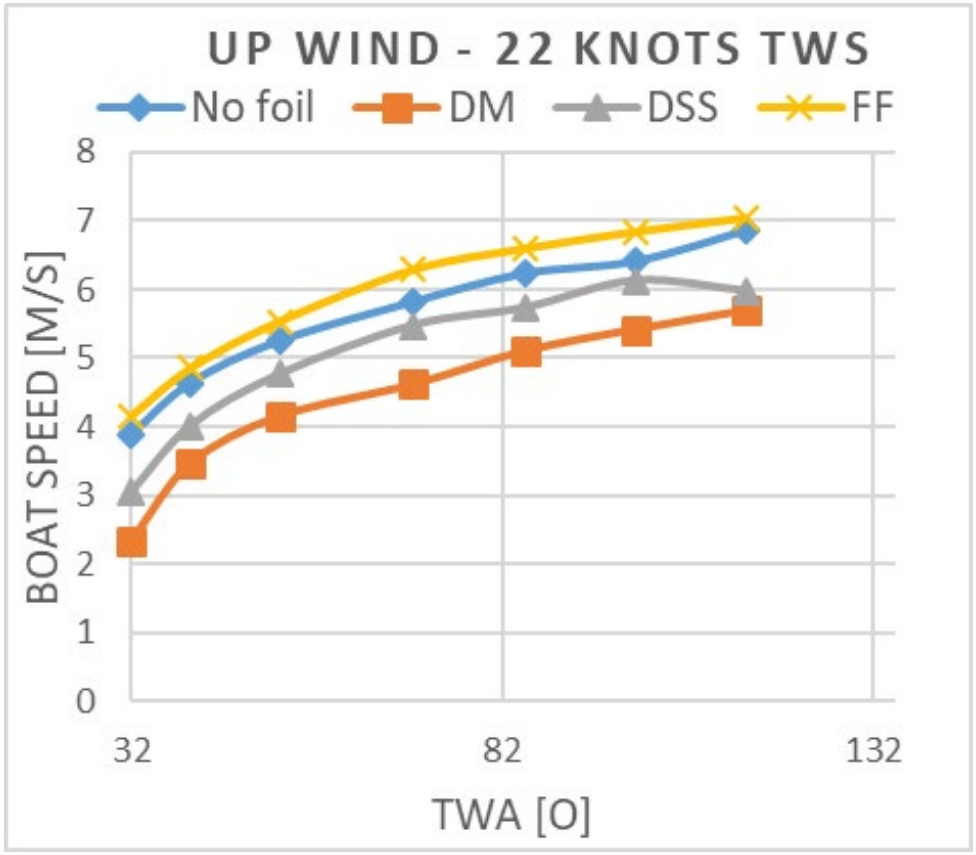


VPP validation

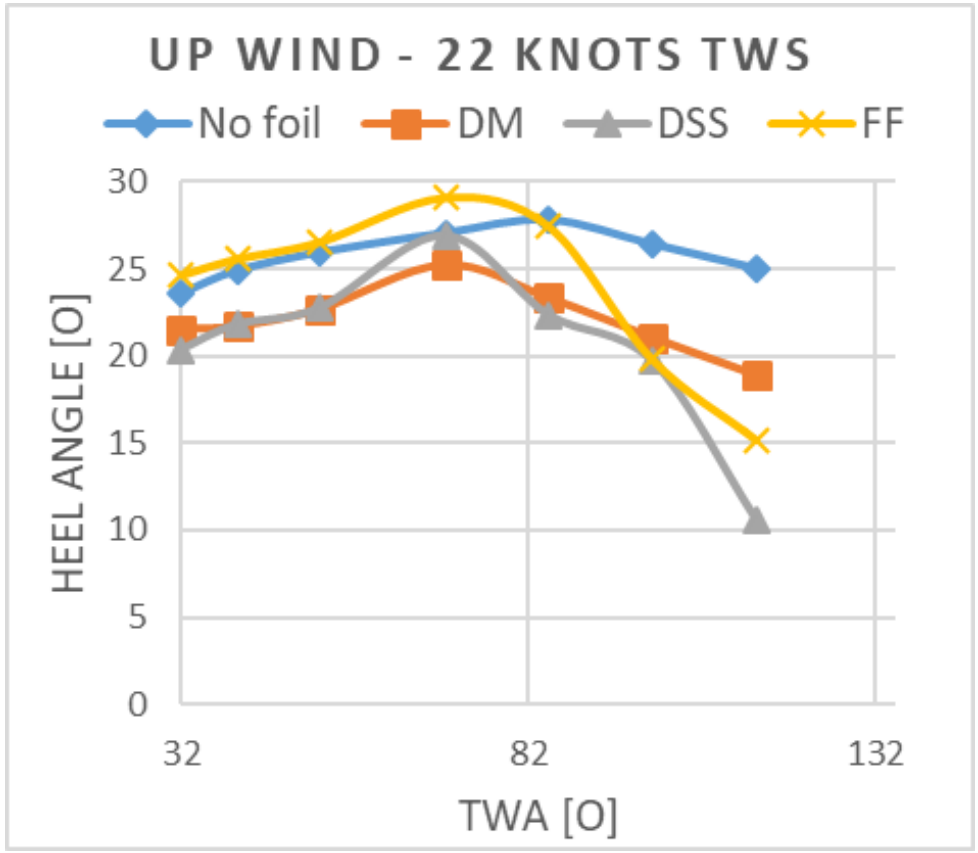




Results

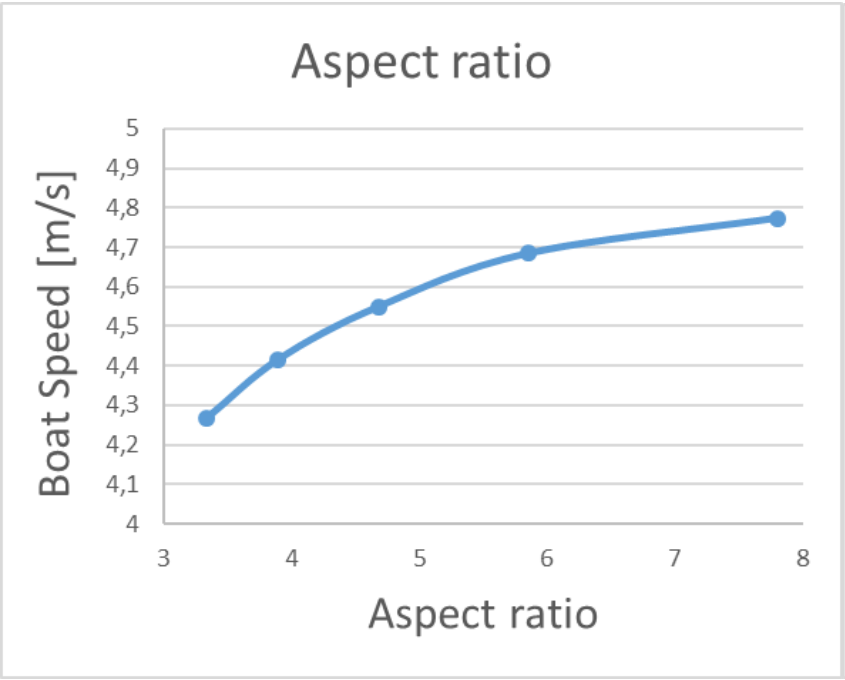


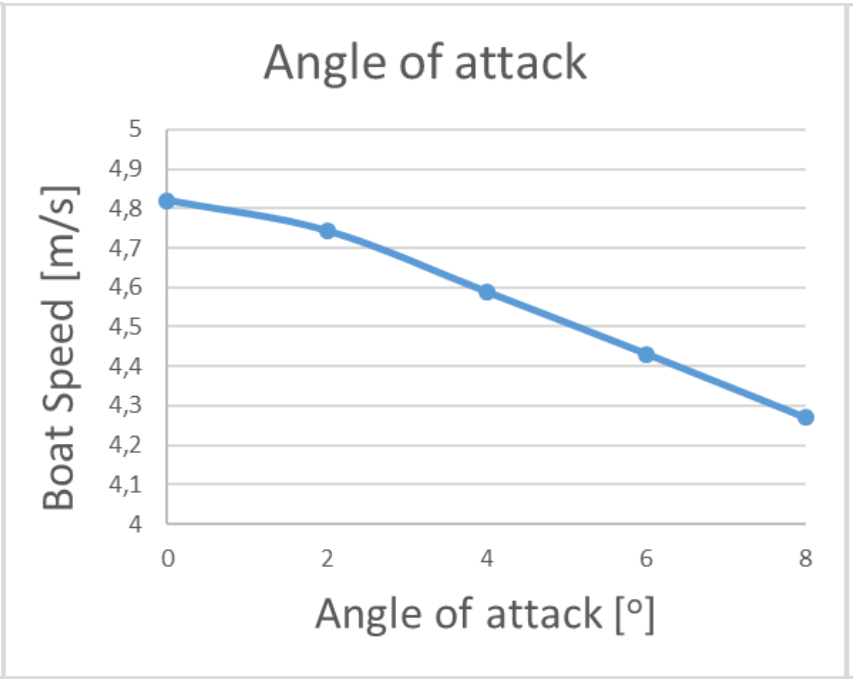
No better speed

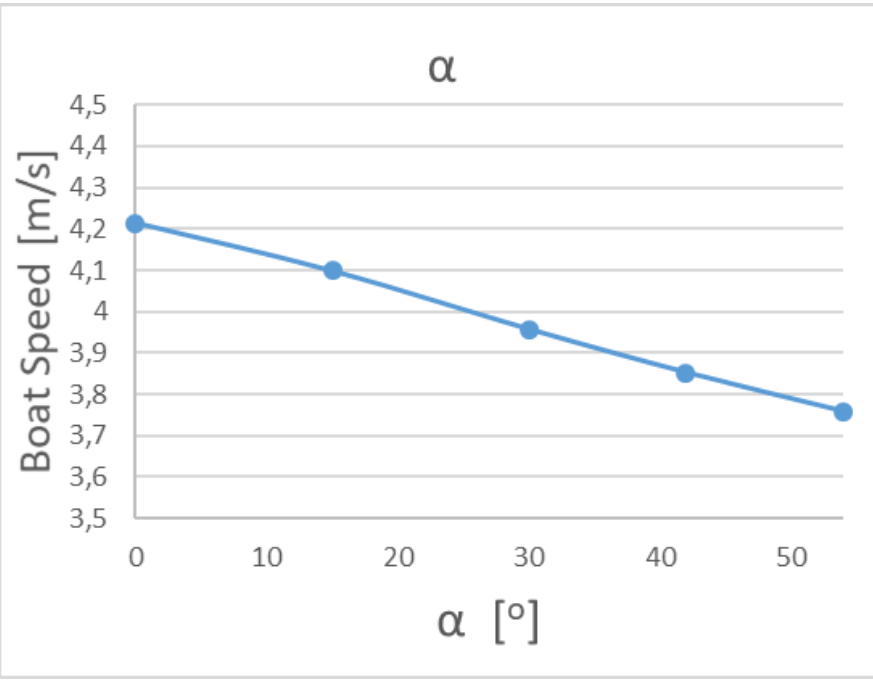


Around 5 degrees less heel

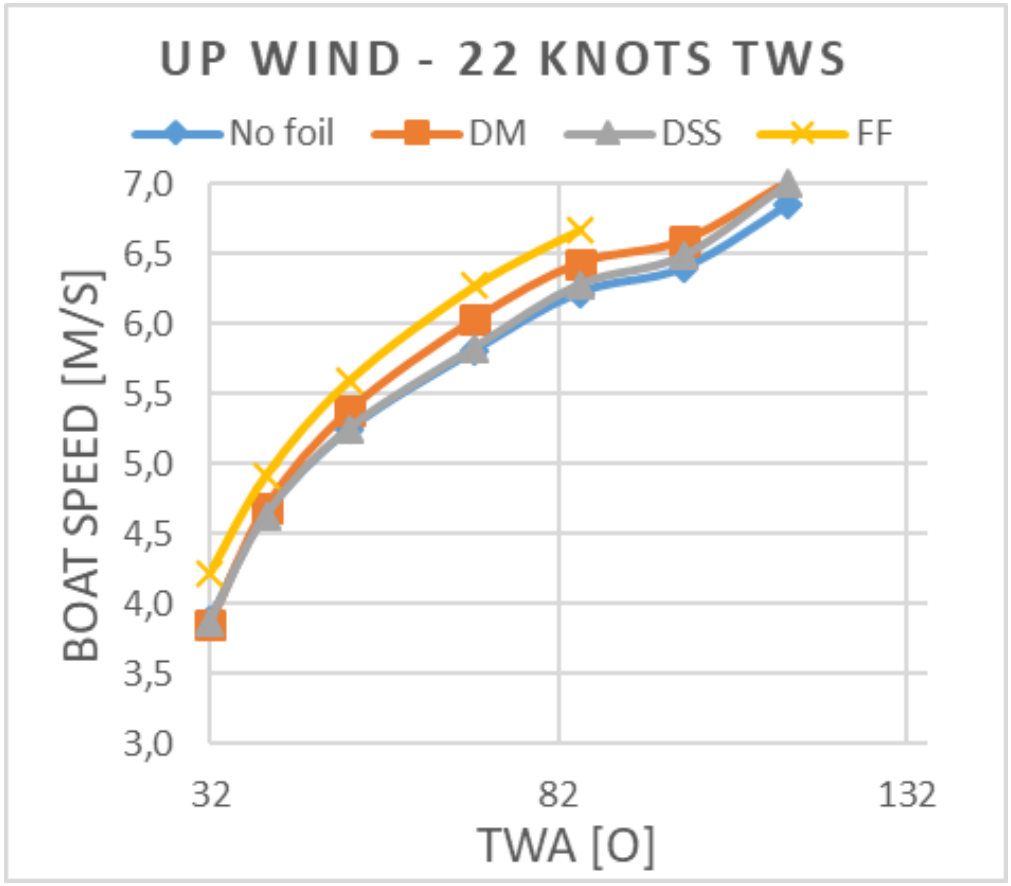
Optimization



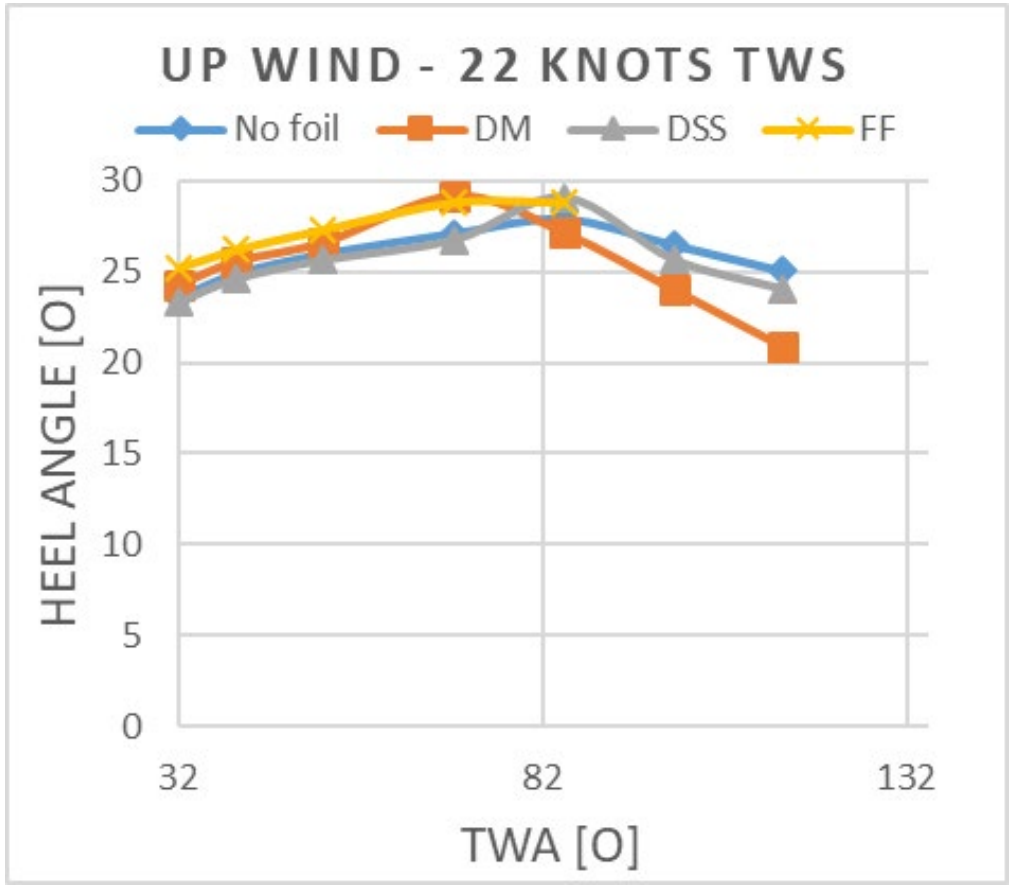




Optimization - results



Increase of speed



No better heel angle

Conclusion

- Preliminary design tool was successfully developed
- Tool allowed the understanding of possible optimizations
- Compromise between increase in boat speed and comfort
- Important understanding of the impacts of the side force
- DSYHS and ORC methods present limitations for foiling boats

Future work

- To developpe a tool with more degrees of freedom
- To apply more sophisticated methods – CFD, FEM and FSI
- To study the foils gain in sea keeping
- To study different physical effects:
  - Bow wave and foil interaction
  - Ventilation
  - Hull and foil interaction

Summary

- DSYHS and ORC methods are good model for preliminary design, but limited for foiling vessels
- Drag is not the only foil drawback, side force may be compromising
- More sophisticated models should be developed for better understanding of such crafts