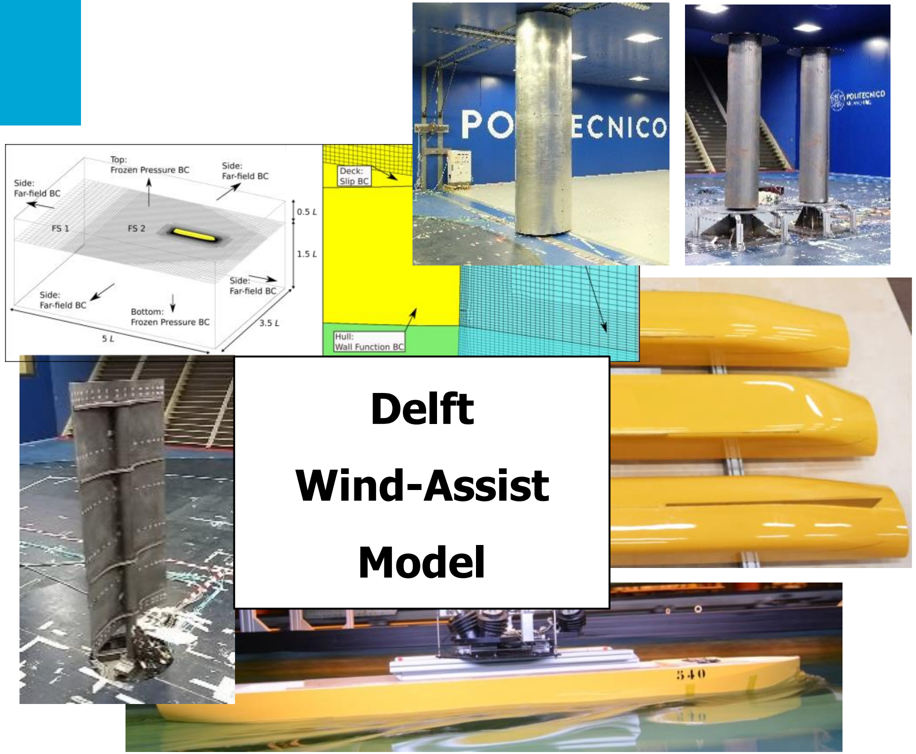
Delft Wind Assist Vessel Model

A Comprehensive Model for Wind Assisted Ships

Nico van der Kolk, MSc
PhD Researcher
n.j.vanderkolk@tudelft.nl

Giovanni Bordogna, MSc
PhD Researcher
g.bordogna@tudelft.nl

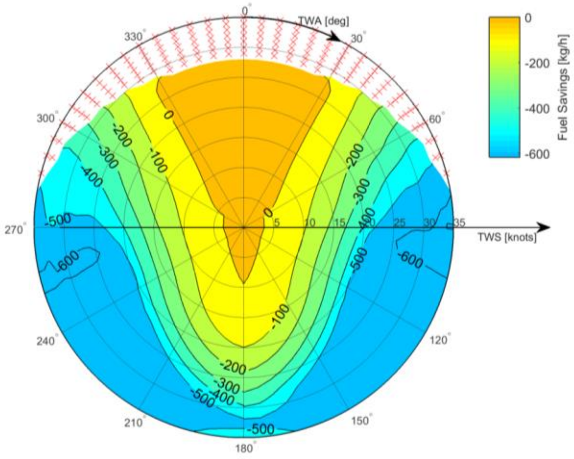
Delft Wind-Assist Research



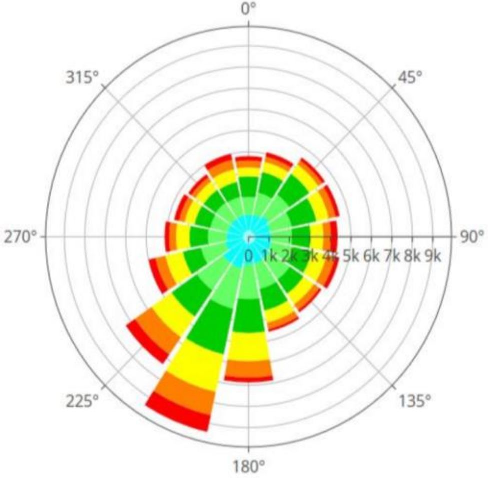
- Aero/Hydro modeling based on experiments and full scale RANS simulations
- Large database of hulls and appendages
- Aero/Hydro coupling with 4 degree-of-freedom solver
- Flettner rotors, Dynarigs, Wingsails, user-provided CL/CD curves

Assessing the Promise of Wind Assist

1. Vessel Model



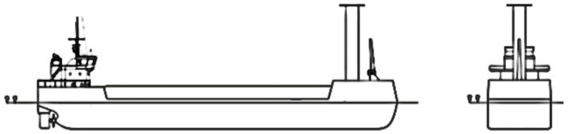
2. Route-specific Weather Conditions



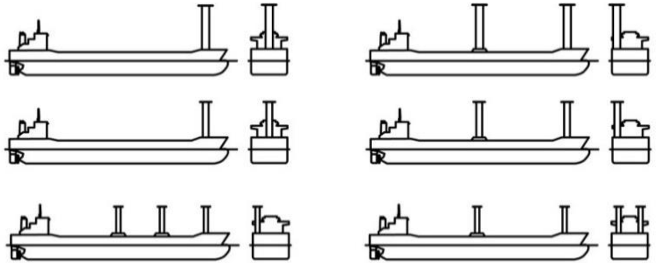
3. Economic / Environmental Evaluation

Lessons learned: Case Study[1]

- DAMEN Combi-freighter on a Baltic sea route
  - 5000t – small bunkering requirement
  - Light winds in the Baltic region



- North Sea Case – in progress
  - 19500t vessel
  - Favorable wind conditions



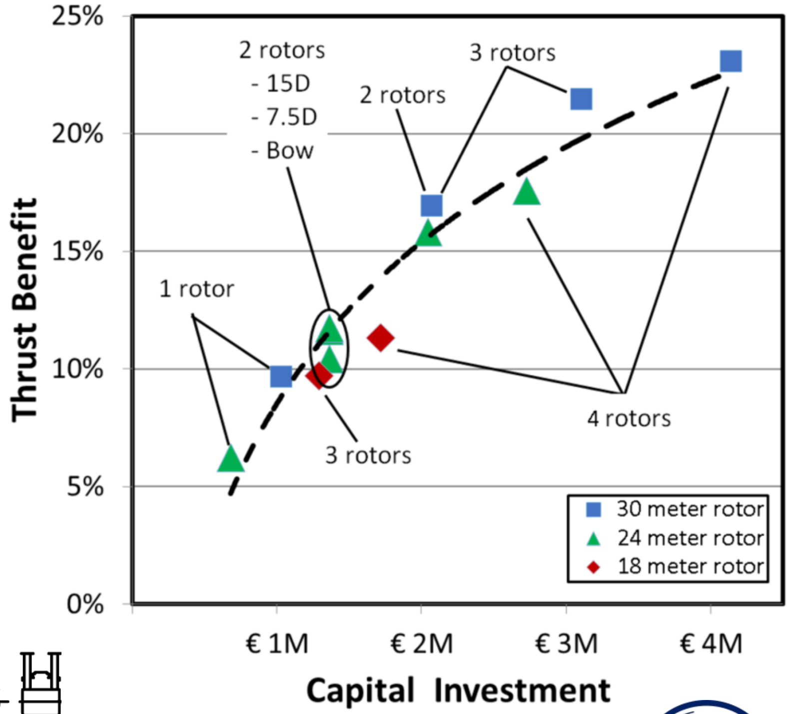
1. **Case study: Wind-assisted ship propulsion performance prediction, routing, and economic modelling**. / van der Kolk, Nico; Bordogna, Giovanni; Mason, J.C.; Desprairies, P.; Vrijdag, Arthur. International Conference Power & Propulsion Alternatives for Ships. The Royal Institution of Naval Architects, 2019.

Design Space Exploration

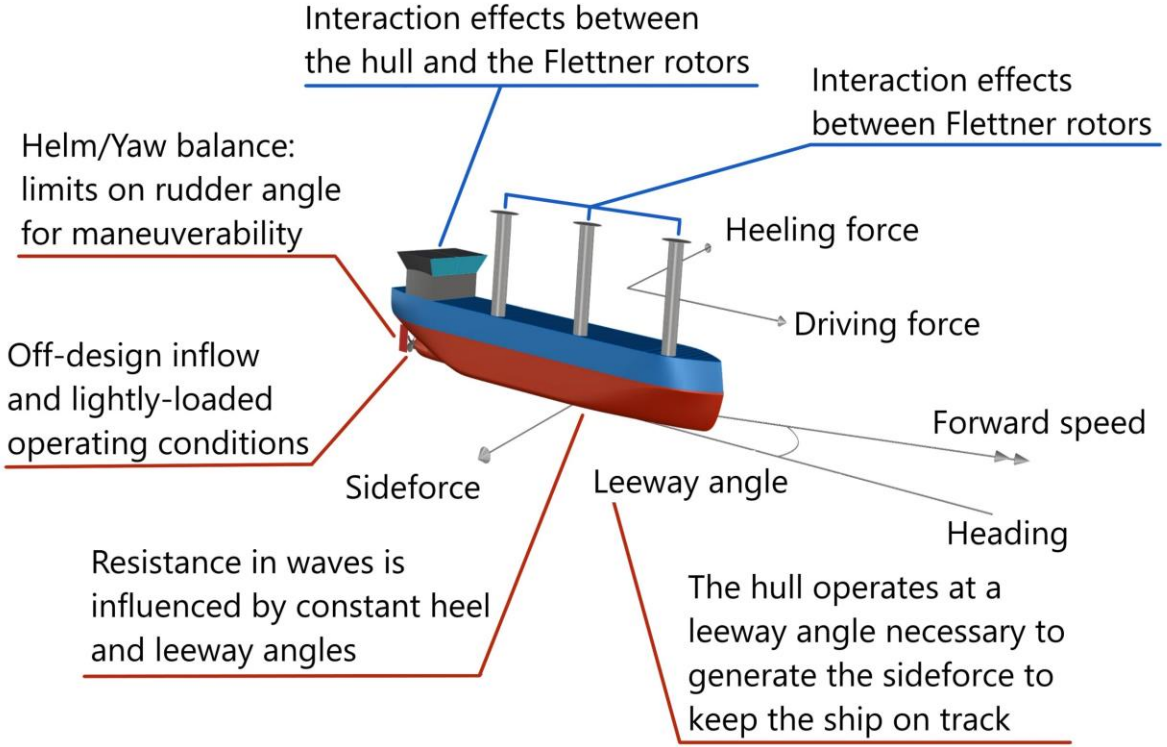
- Thrust benefit (TB):

$$TB = \frac{Aero\ thrust}{total\ Resistance}$$

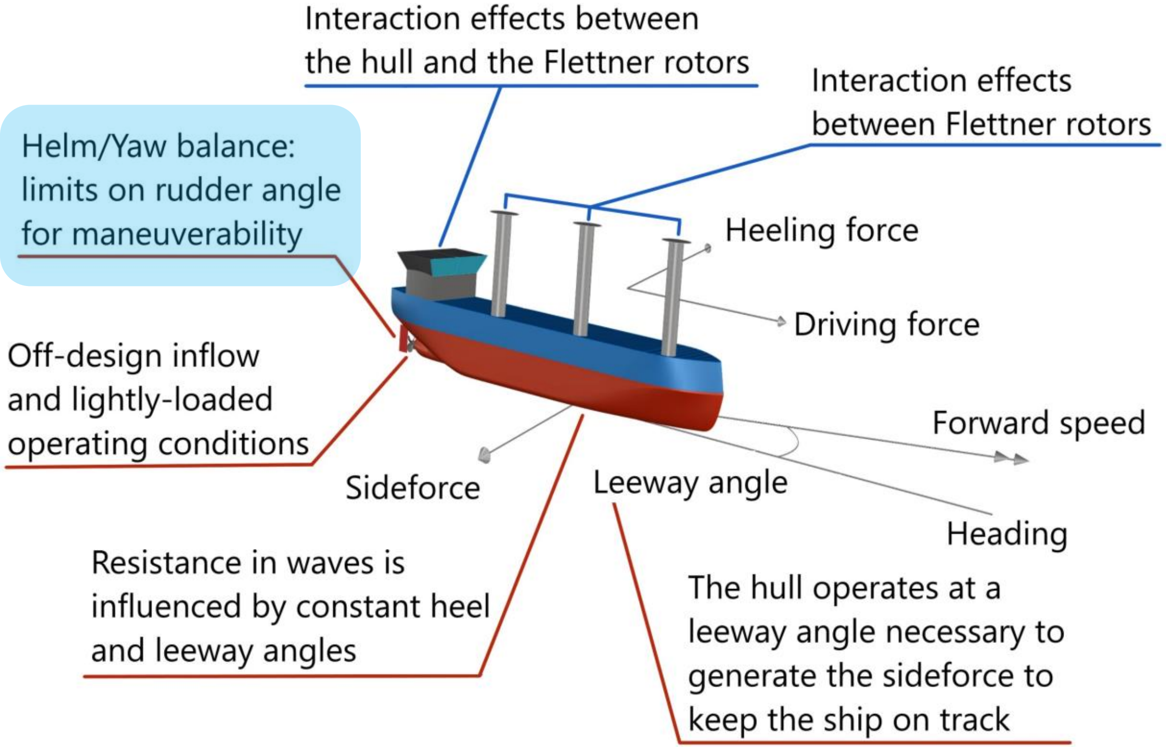
- Analysis with route-specific weather conditions



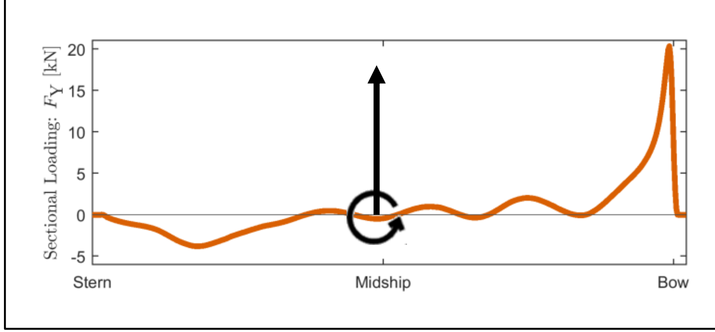
Delft Wind Assist Model



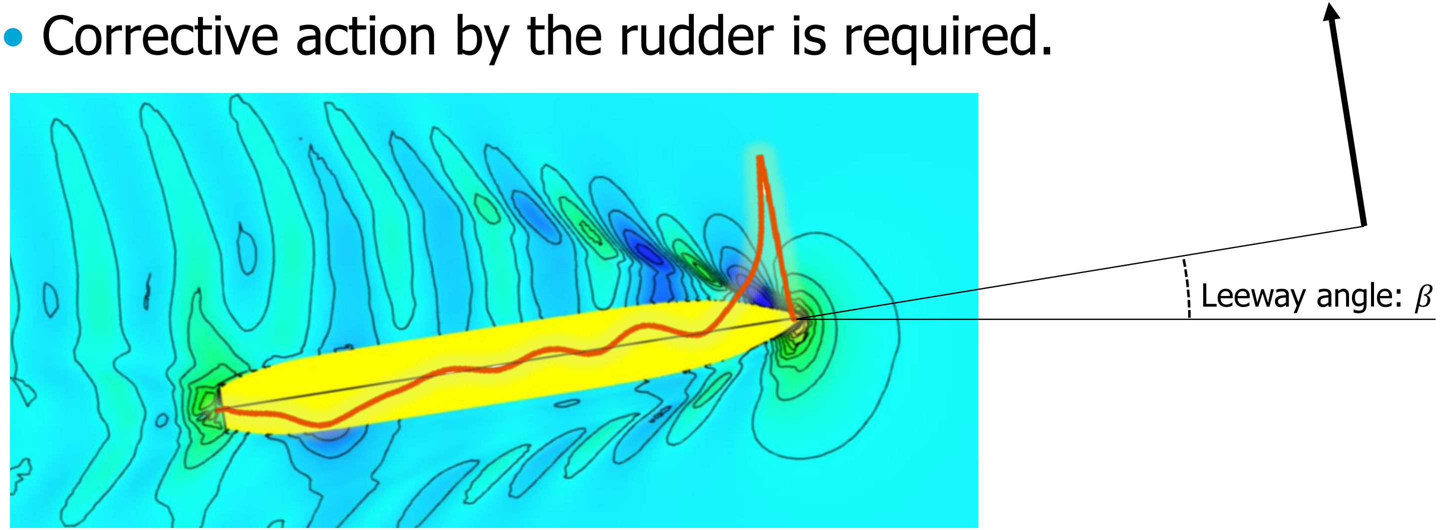
Delft Wind Assist Model



Helm Balance



- The hydrodynamic centroid is far ahead of the vessel (unappended hull).
- Corrective action by the rudder is required.

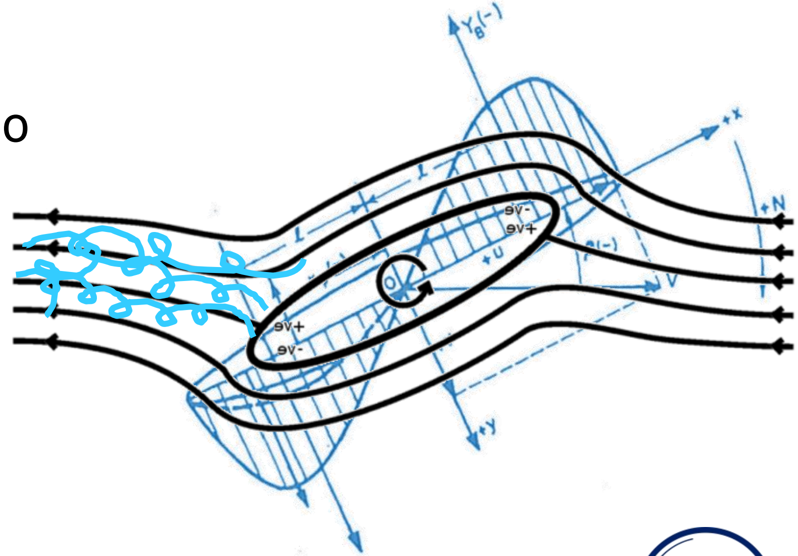


The Munk Moment

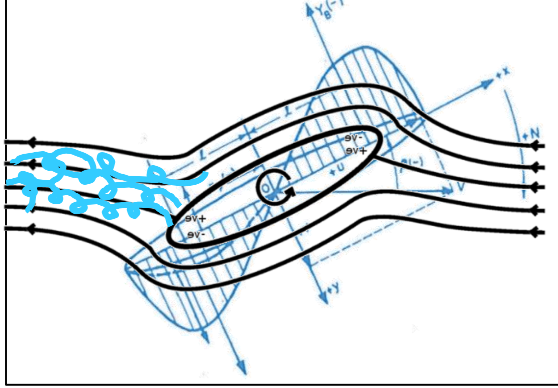
- Linear, destabilizing reaction for body in oblique flow

- Results in a couple, a pure moment
  - In principle (potential flow) there is no sway force

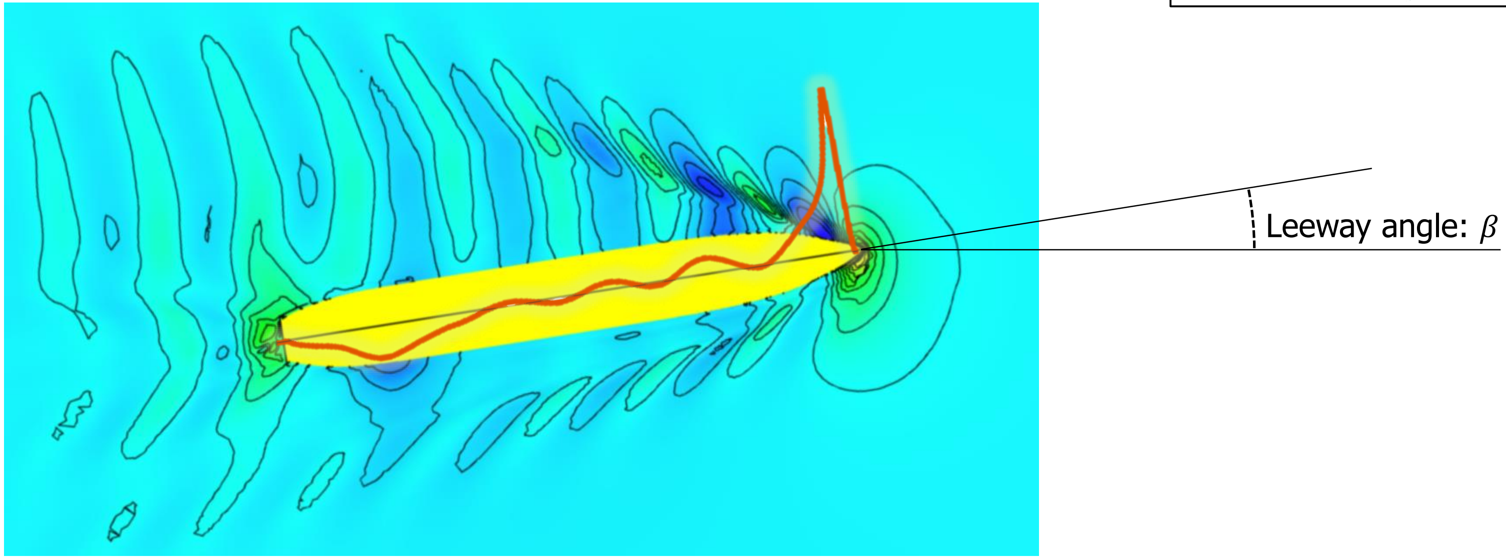
- Some flow separation along aftbody reduces the underpressure



The Munk Moment

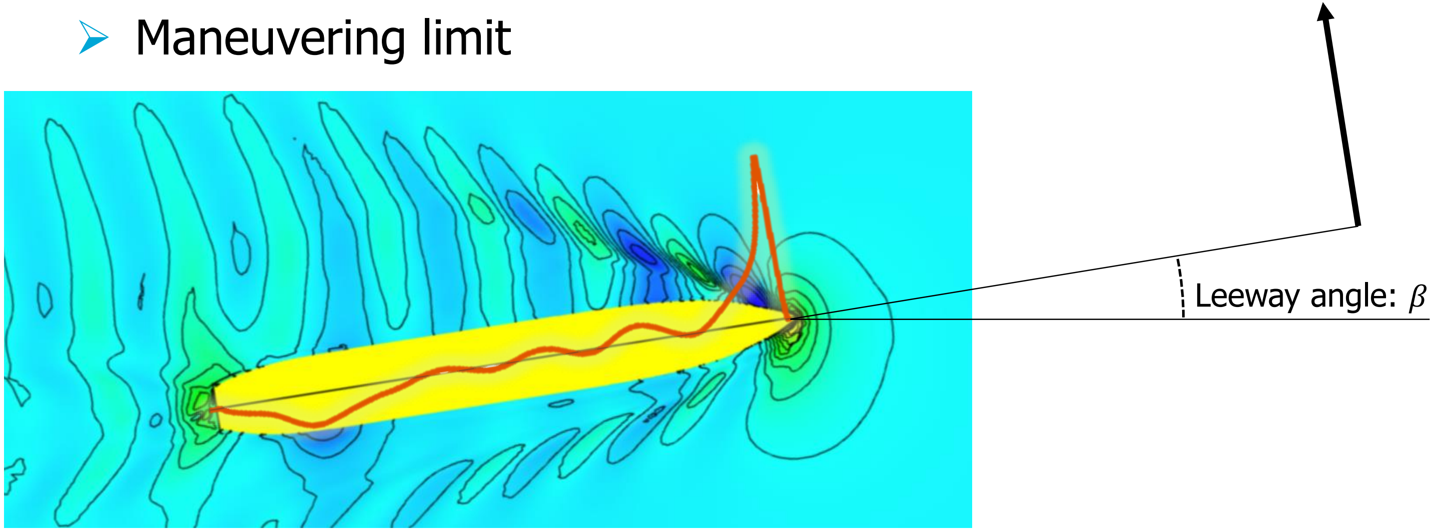


- Destabilizing reaction for body in oblique flow

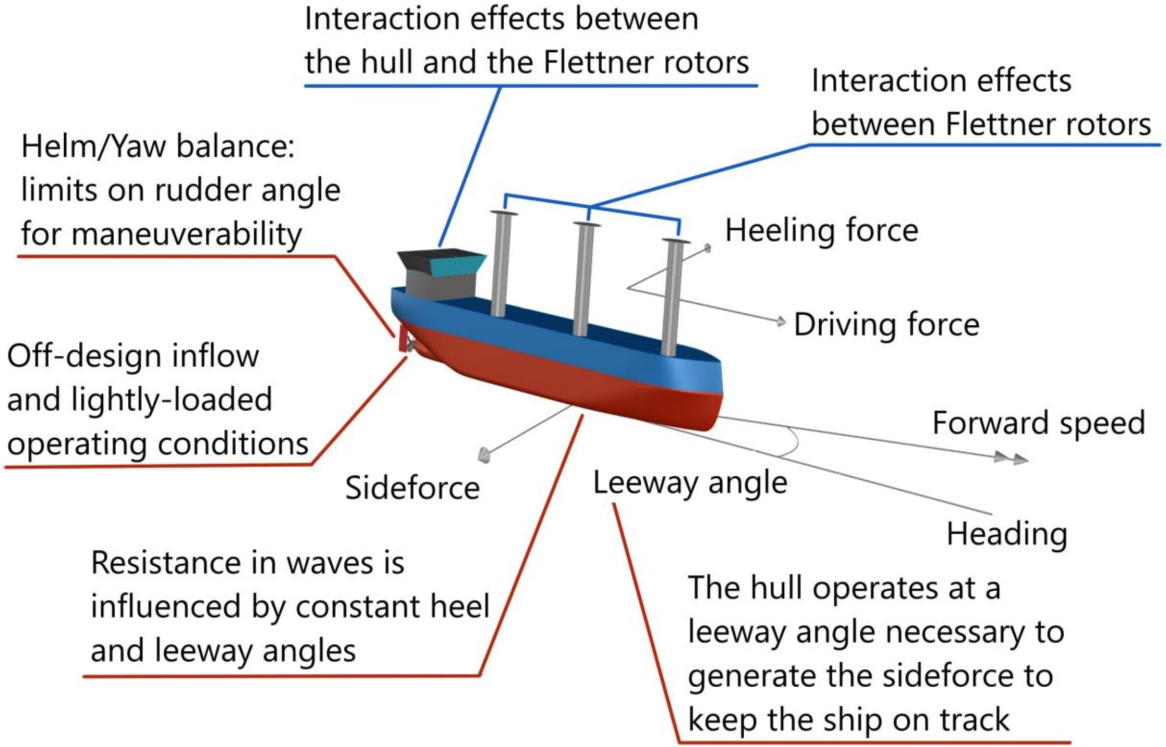


Helm Balance

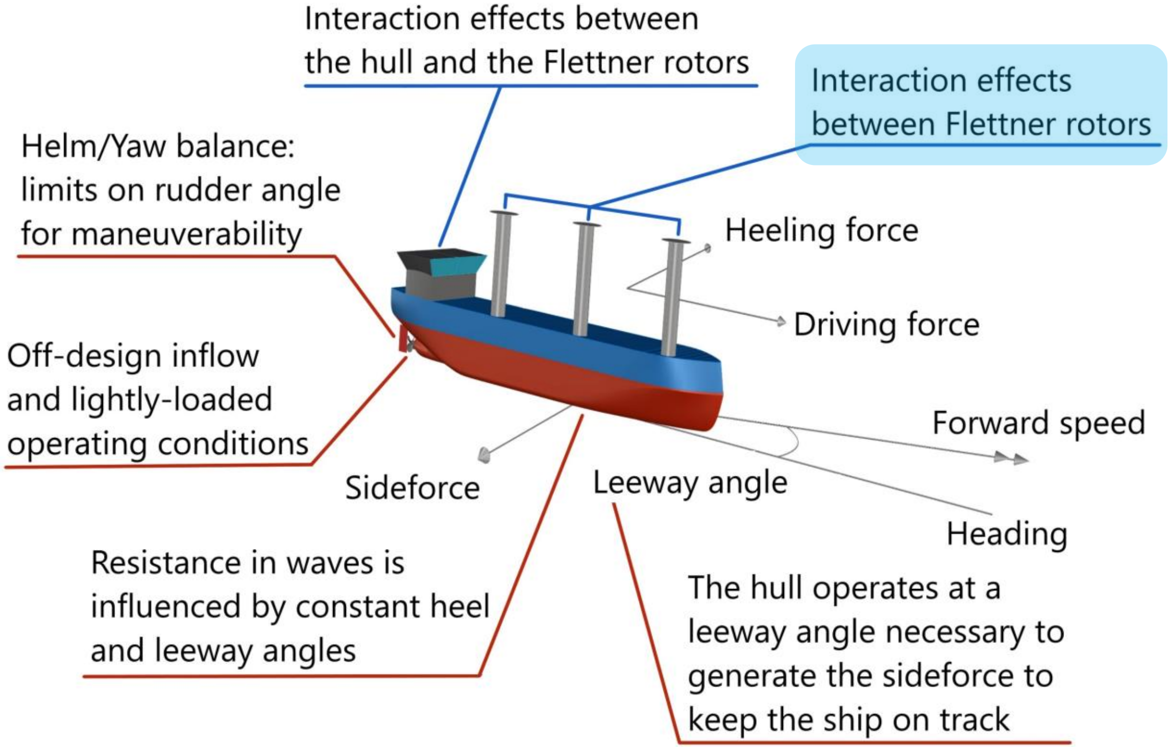
- Corrective action by the rudder is required.
  - Resistance penalty
  - Maneuvering limit



Delft Wind Assist Model



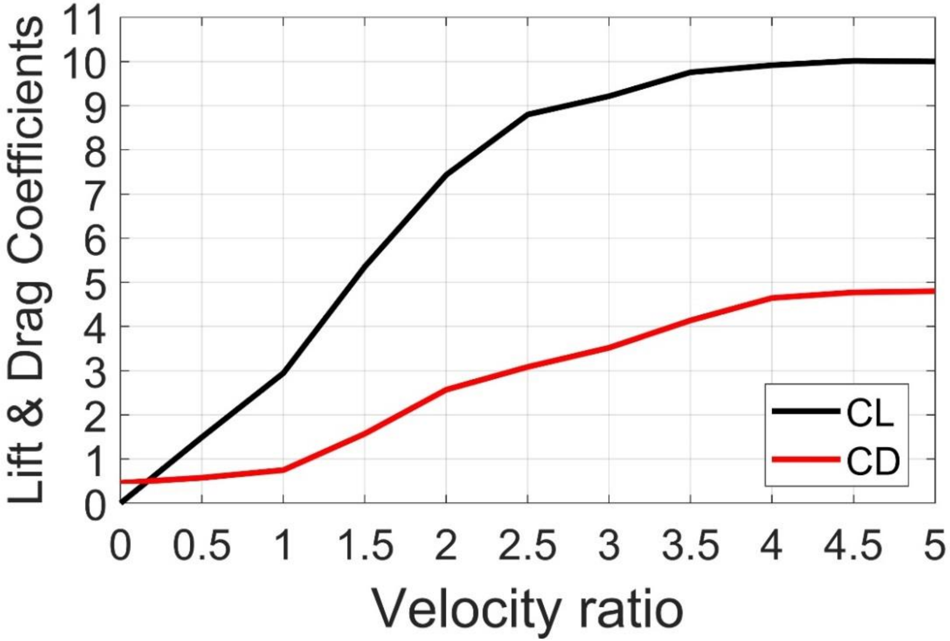
Delft Wind Assist Model



The Flettner rotor velocity ratio

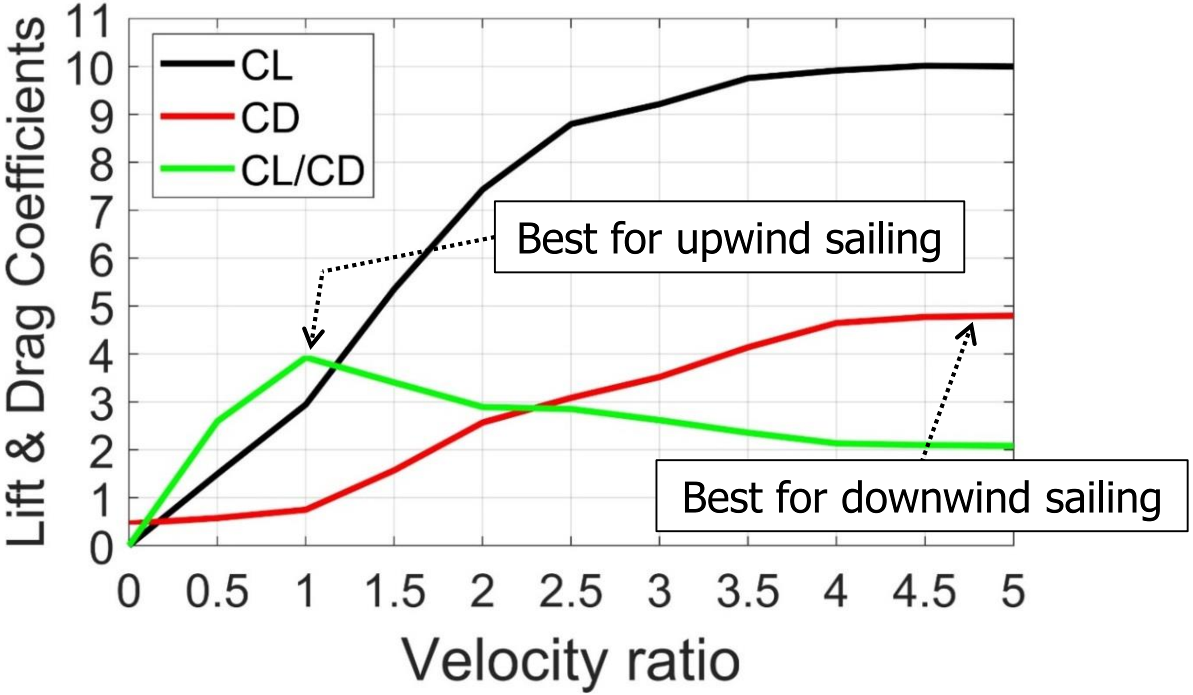
- Velocity ratio=Rotor tangential velocity / Freestream velocity

- For a given FR type, lift and drag depends <u>only</u> on the velocity ratio



Bordogna et al. (2019), J Wind Eng Ind Aerodyn, 188, pp 19-29

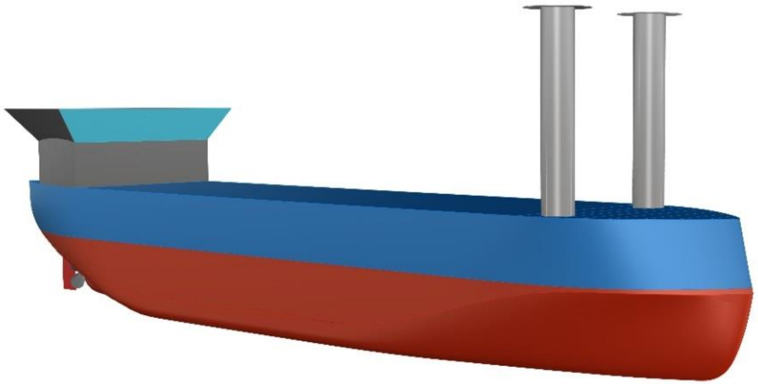
Optimal velocity ratio (theoretically)



Upwind sailing

Downwind sailing

Optimal real-life velocity ratio

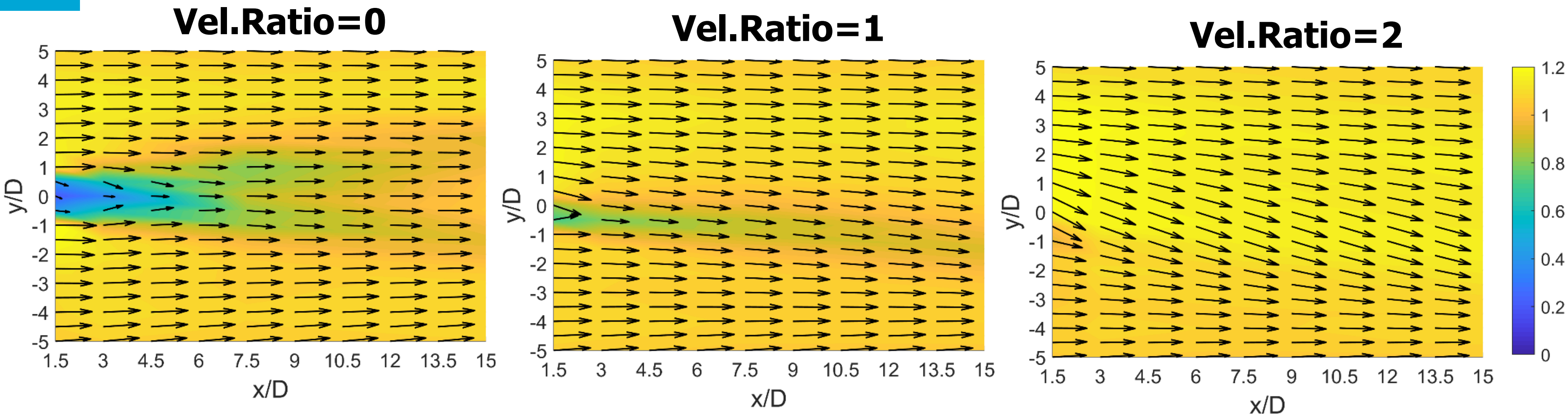


Case Study

- Two 4x24 Flettner rotors
- FR distance=5 diameters
- Interaction effects between the two rotors are taken into account

Optimal real-life velocity ratio

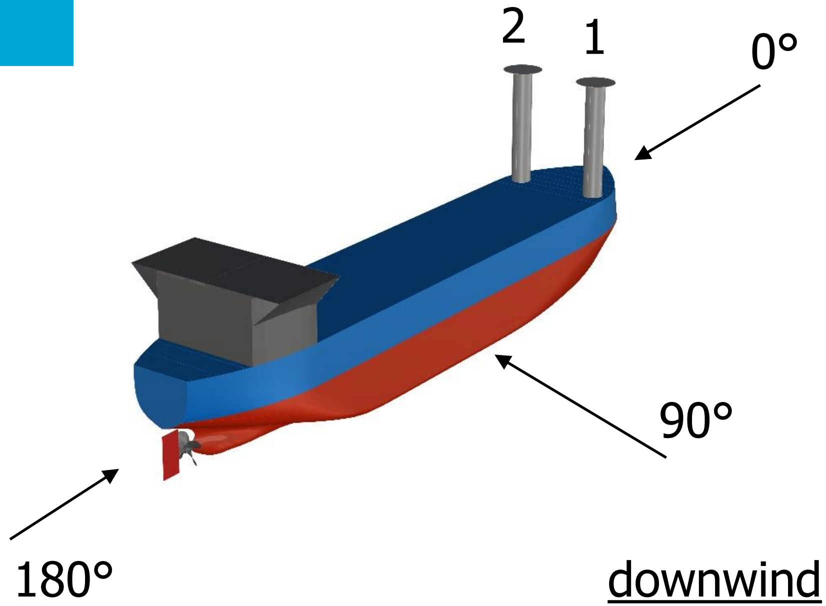
Effect of the velocity ratio on the flow



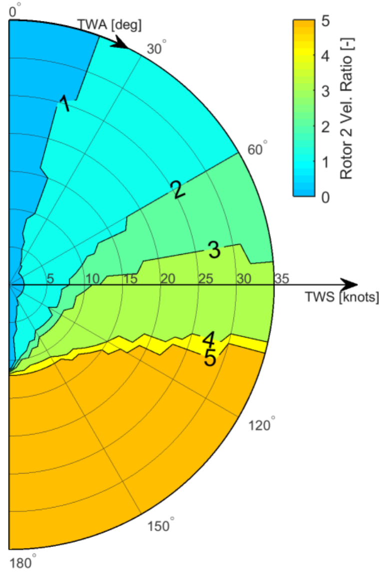
- Lower the velocity ratio, larger the flow speed reduction
- Larger the velocity ratio, larger the flow deflection

Optimal real-life velocity ratio

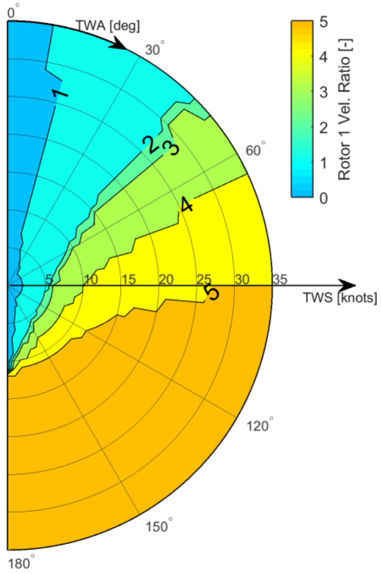
upwind



downwind



Vel.Ratio
Fletter rotor 2



Vel.Ratio
Fletter rotor 1

Conclusions on interaction effects

- Interaction effects influence operation of Flettner rotors to achieve optimal ship performance
- Interaction generally detrimental but adjusting the velocity ratio mitigate this effect
- As for sailing yachts, a proper "trimming" of Flettner rotor is essential

Delft Wind-Assist model

Future next steps

- Model currently used to predict fuel savings of various ship designs
- Ongoing collaboration with Tyndall Centre and UCL on North Sea case study
- Work on the Delft Wind-Assist model will be continued in the form of a consultancy business

Thank you