Delft Wind Assist Vessel Model

A Comprehensive Model for Wind Assisted Ships

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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

- 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

Design Space Exploration

- Thrust benefit ($TB$):
  $$TB = \frac{\text{Aero thrust}}{\text{total Resistance}}$$

- Analysis with route-specific weather conditions
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Challenge the future
Delft Wind Assist Model

Interaction effects between
the hull and the Flettner rotors

Helm/Yaw balance:
limits on rudder angle for maneuverability

Off-design inflow
and lightly-loaded operating conditions

Sideforce

Resistance in waves is influenced by constant heel and leeway angles

Interaction effects between Flettner rotors

Heeling force

Driving force

Forward speed

Leeway angle

Heading

The hull operates at a leeway angle necessary to generate the sideforce to keep the ship on track
Helm Balance

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

Leeway angle: $\beta$
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

Leeway angle: $\beta$
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The Flettner rotor velocity ratio

- Velocity ratio = Rotor tangential velocity / Freestream velocity
- For a given FR type, lift and drag depends only on the velocity ratio

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

Best for upwind sailing

Best for downwind sailing

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
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