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Centre for Research-based Innovation

The Research Council of Norway

WIND PROPULSION ANALYSIS

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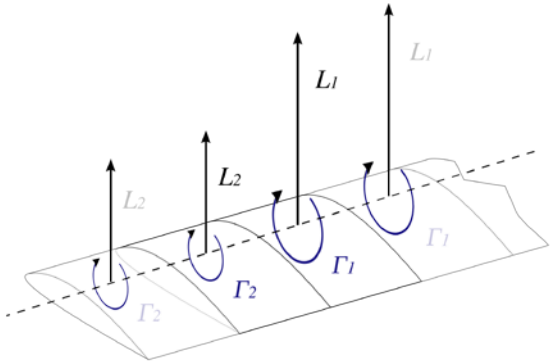
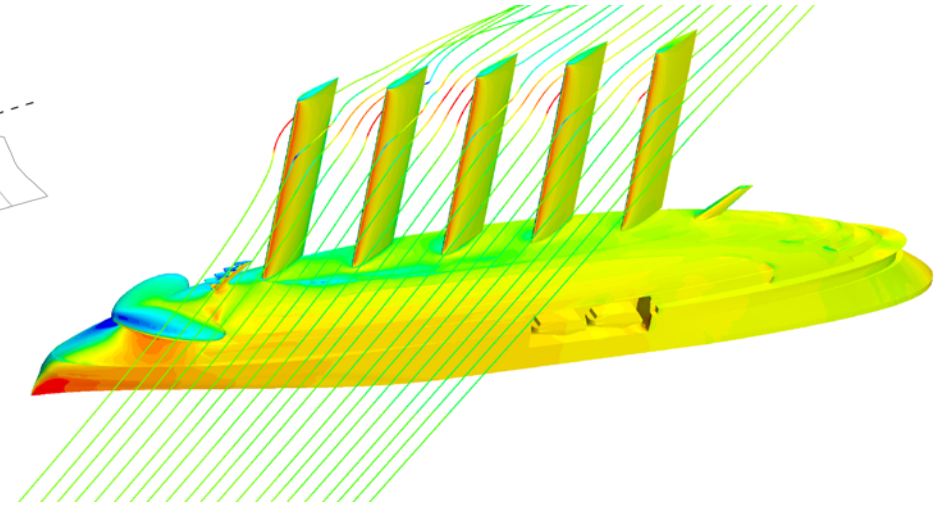
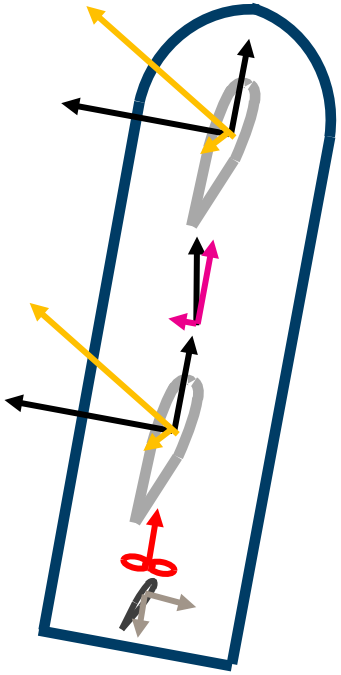
Numerical and model test methods for WASP assessment

- CFD
- Lifting Line
- SteadySail
- Hybrid model test

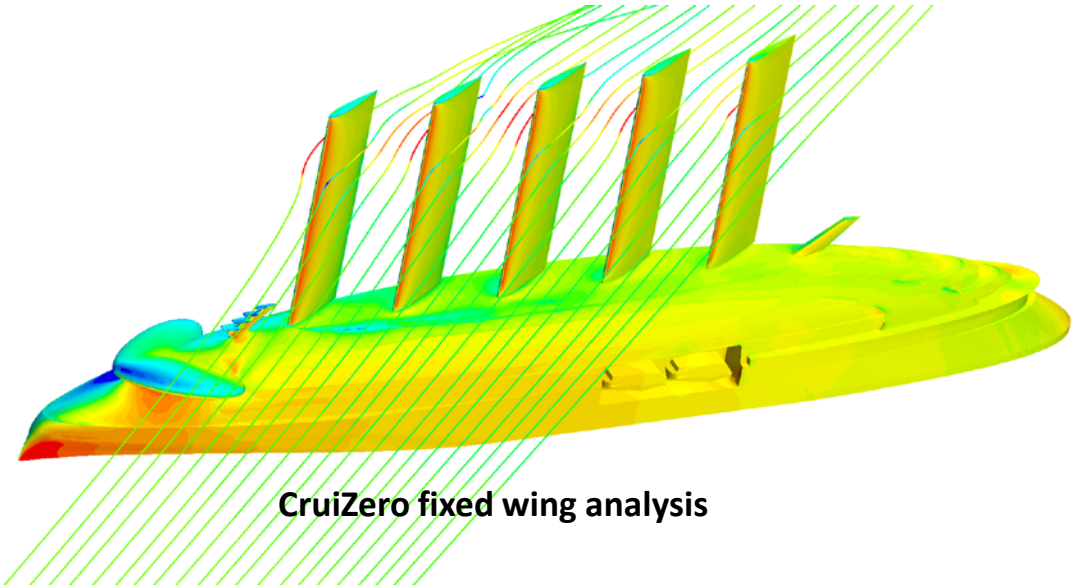






CFD

- CFD can be used to analyze interactions between multiple sails including the influence of the superstructure
- Combines the effect of ship velocity and atmospheric boundary layer profile
- Resource demanding, calculation time in the order of ~hour(s)



CruiZero fixed wing analysis

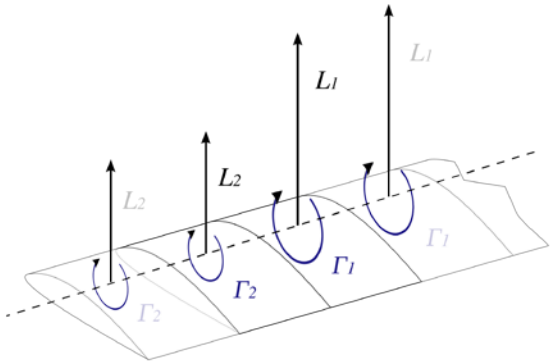
Benefits using CFD:

- Analyze and understand complex flow features
- Calculate 2D profile lift and drag data (input to lifting line solver)
- Can be used to validate/verify lifting line solver results

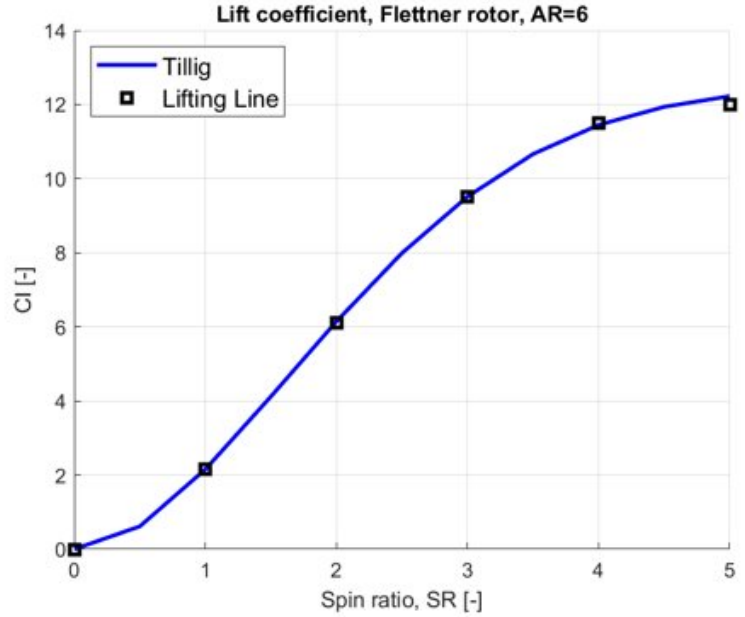
Limitations:

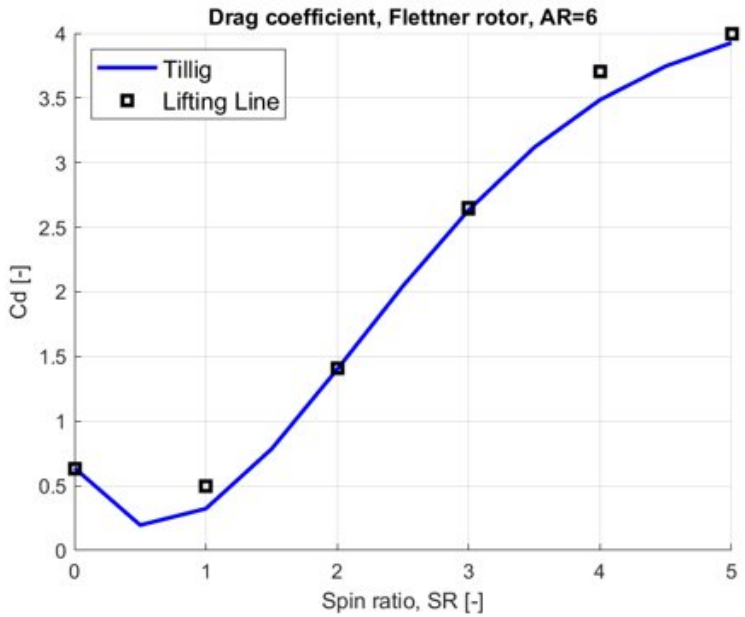
- Too demanding to be used in combination with performance analysis tools (SteadySail)
- Can only be used for a limited set of flow conditions
- Not suitable in early design studies

Lifting Line



- Based on classic aerodynamic theory (Prandtl 1918)
- Use 2D profile lift and drag data as input
- Can calculate interaction between multiple sails
- **Fixed wing** and **Flettner rotor** models implemented
- Very fast (~10 ms)





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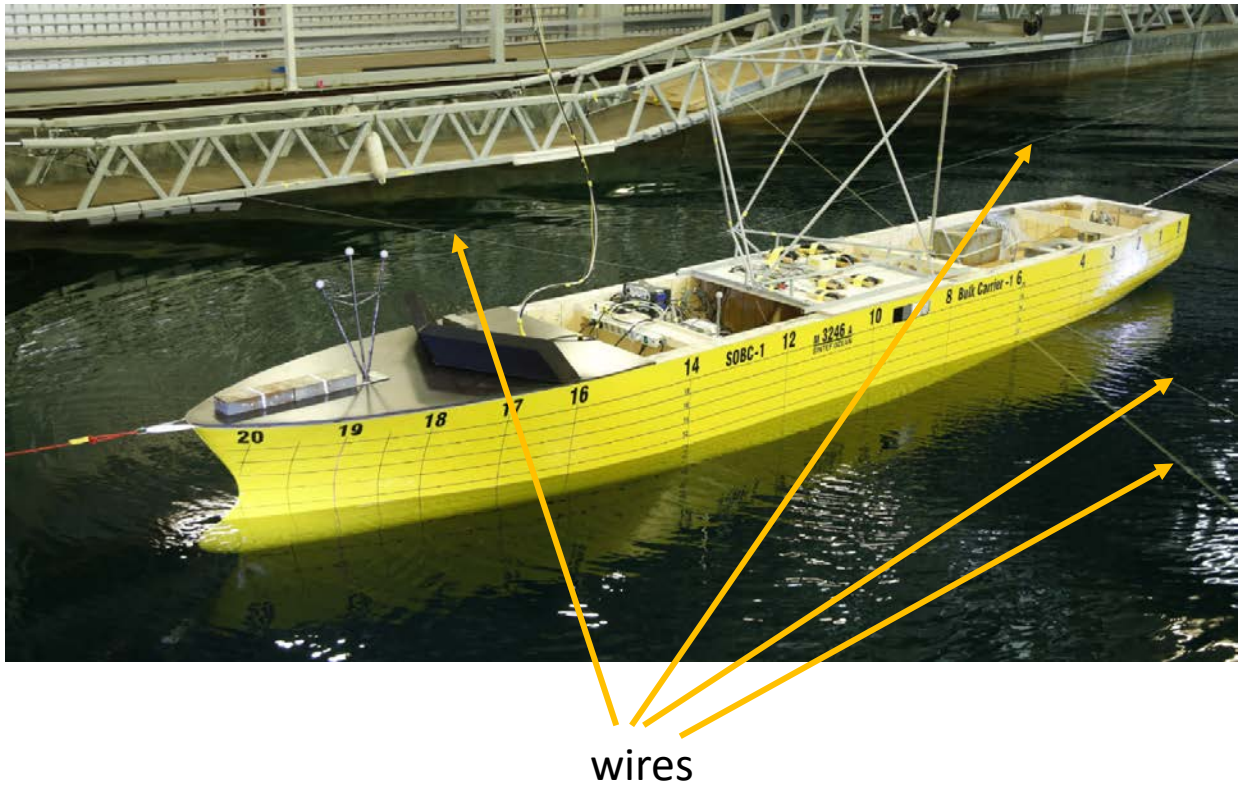
Hybrid model tests

- Free running, self-propulsion
- Calculated forces added by wires to the model
- Course control with autopilot connected to rudder
- Investigate various conditions:
  - Constant wind speed and direction
  - Turbulent wind (including gusts)
  - In waves
  - Manoeuvring zig-zags

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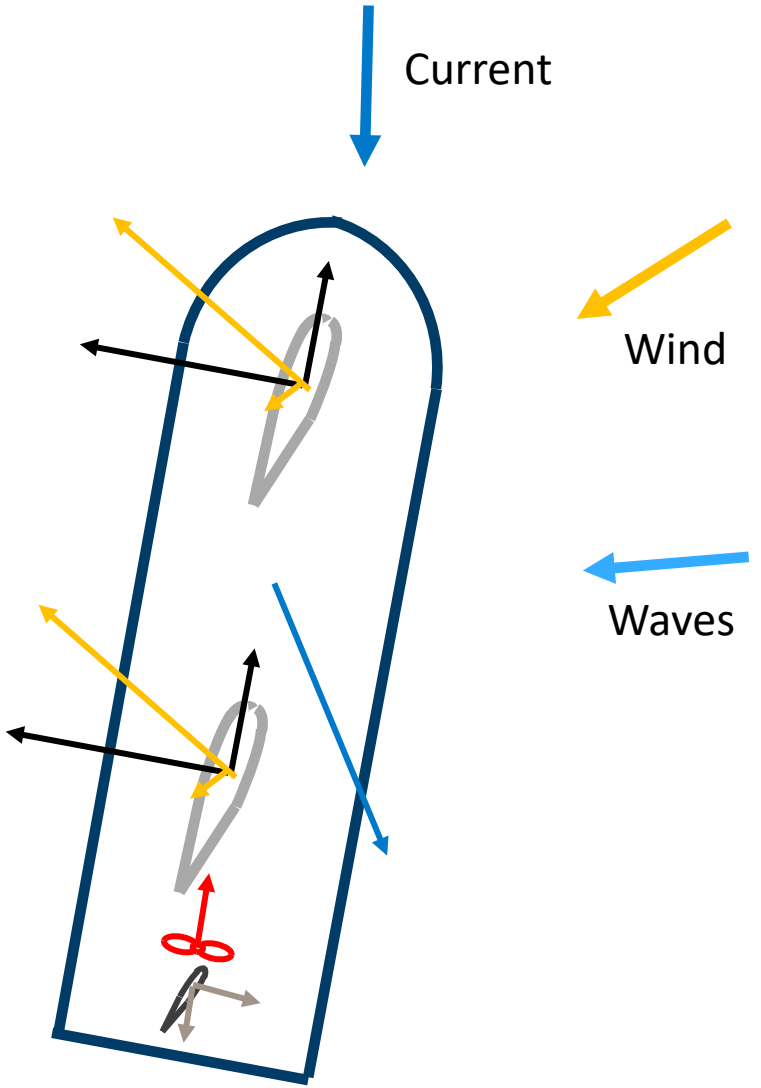
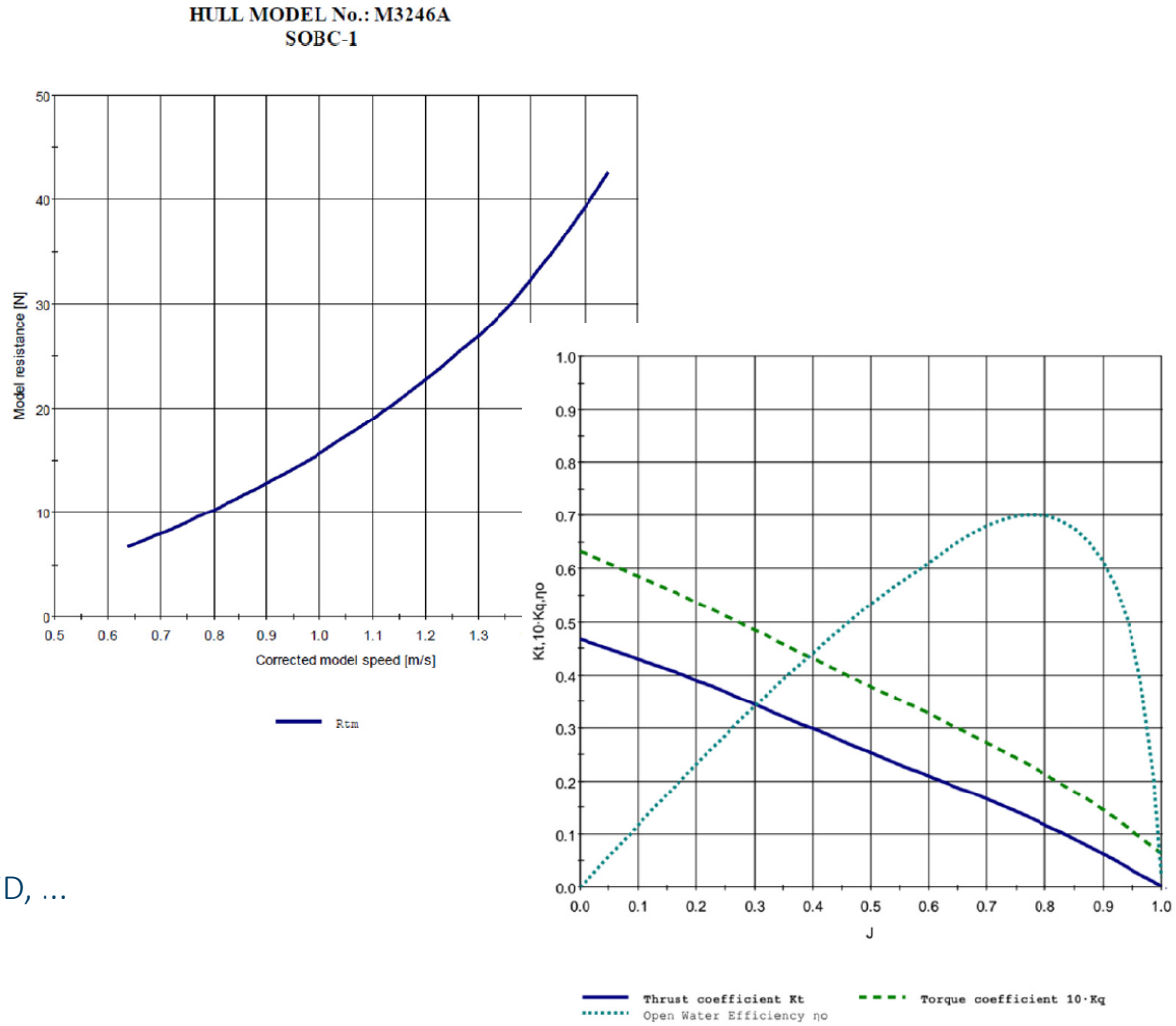
SteadySail Performance Prediction Program

- Simulation of a vessel sailing on a steady course
- 3 DOF: surge, sway, yaw
- Considers effects from:
  - Wind
  - Waves
  - Ocean current
  - Vessel velocity and attitude
  - Propellers and rudders
  - Wind propulsion devices
- Calculation modes:
  - Propulsion point for given speed
  - Speed for given propulsion point
- Standalone tool for power predictions
- Integrated in ShipX and Gymir route simulator



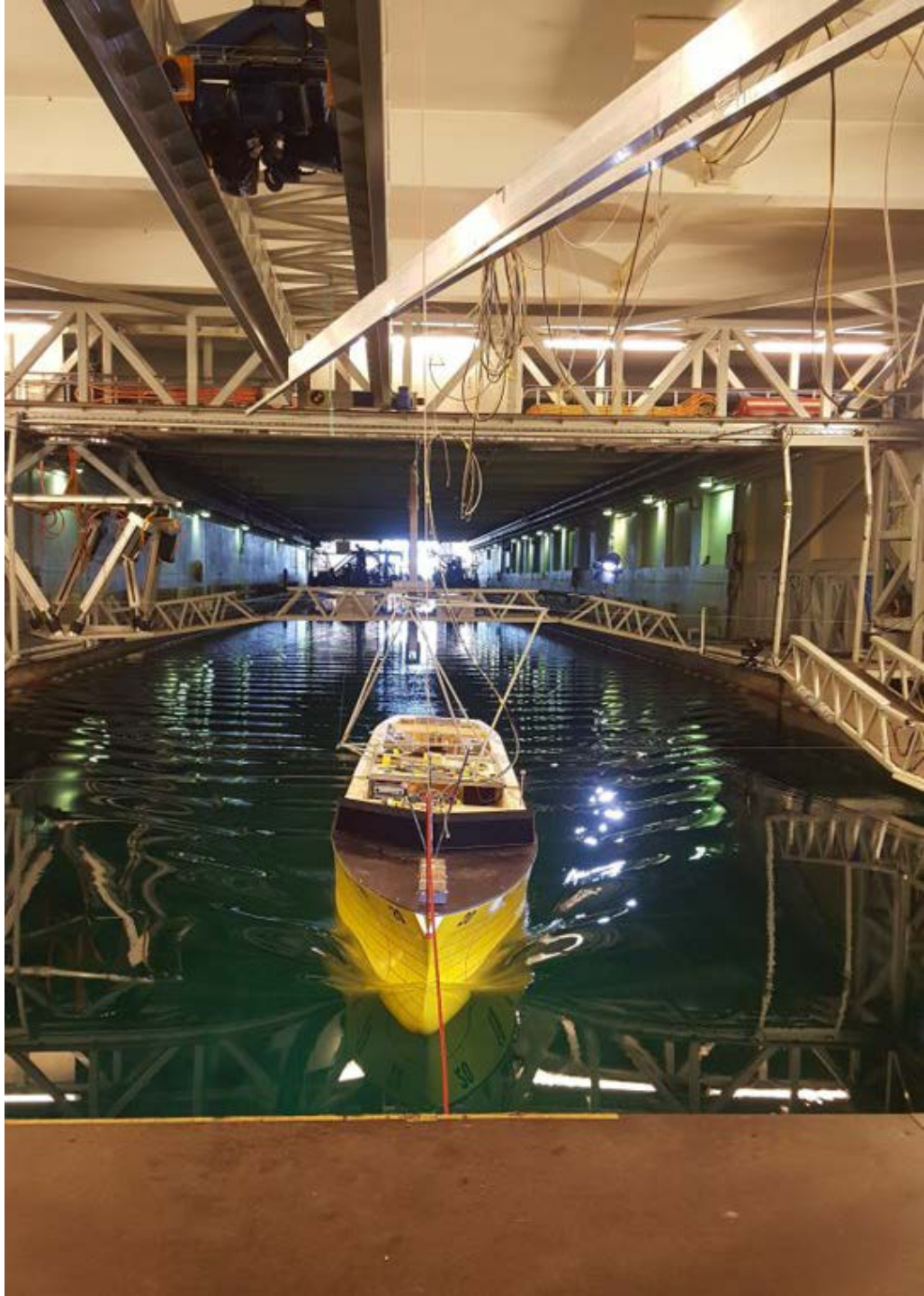
SteadySail input

- Manoeuvring model input
  - HullVisc (strip theory)
  - Model tests or CFD
- Propulsion input
  - Type
  - Geometry
  - Open water curves
  - Propulsive coefficients
- Wave drift coefficients
  - VERES, MULDIF, WAMIT, model tests, etc
- Superstructure aerodynamic coefficients
  - Blendermann library, custom input from wind tunnel, CFD, ...



StedySail validation

- Hybrid model test cases for validation
  - SOBC (SINTEF Ocean Bulk Carrier)
  - Constand wind speed and direction
  - True wind speed: 10, 15 and 20 m/s
  - True wind direction: 30, 50, 70, 90, 110, 130, 150 degrees
  - Constant propeller power: 3078 kW
  - Constant Flettner rotor RPM: 180 RPM
  - No waves
  - No wind loads on hull



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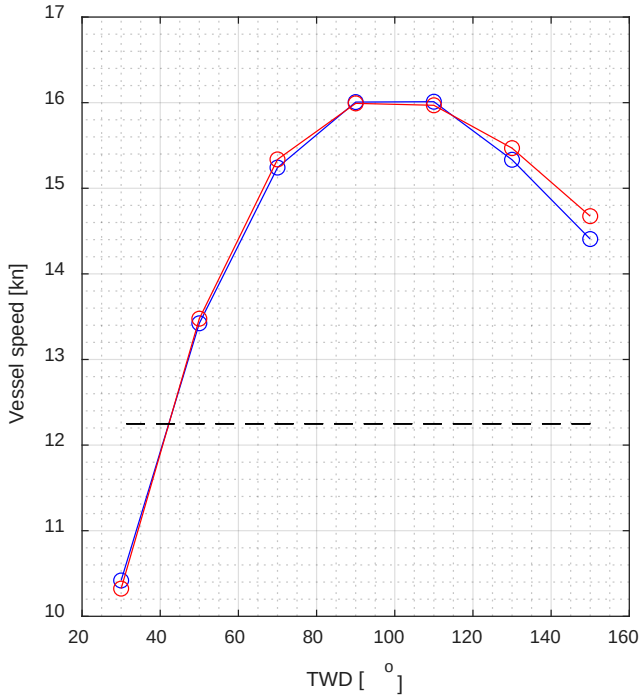
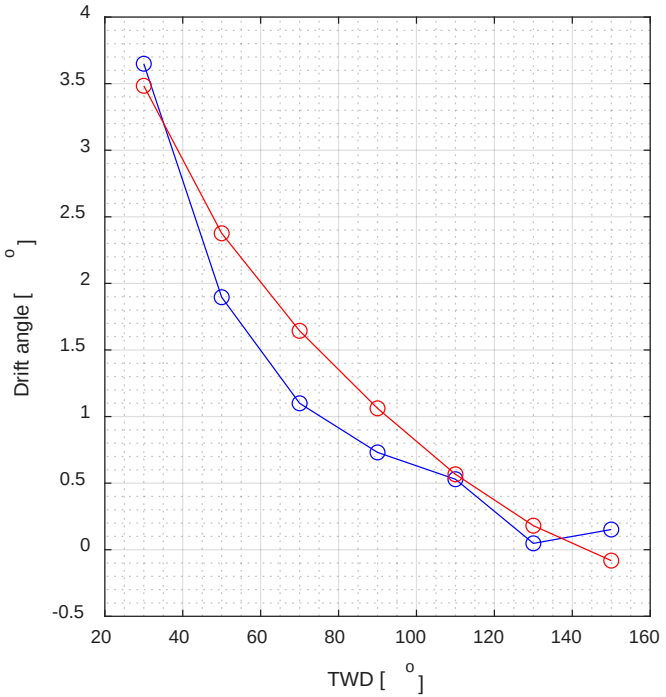
StedySail validation results

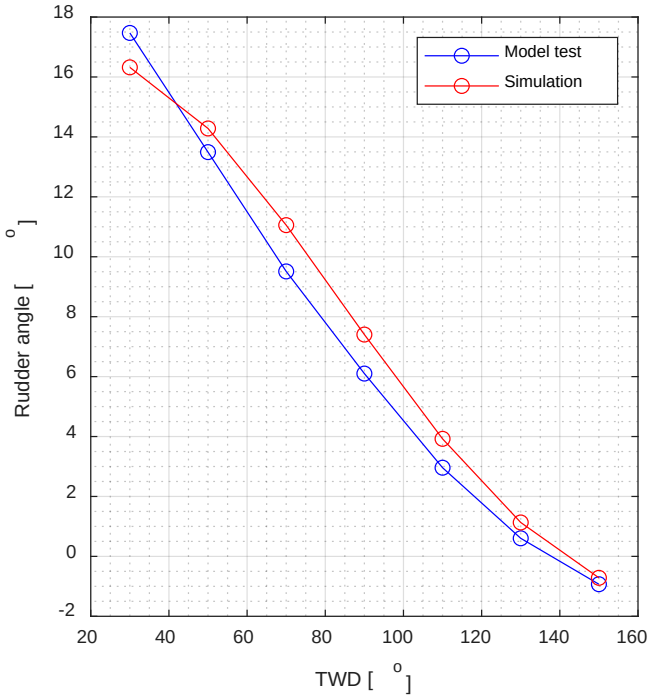
Vessel speed



Drift angle



Rudder angle



Simulated at 15m/s wind speed

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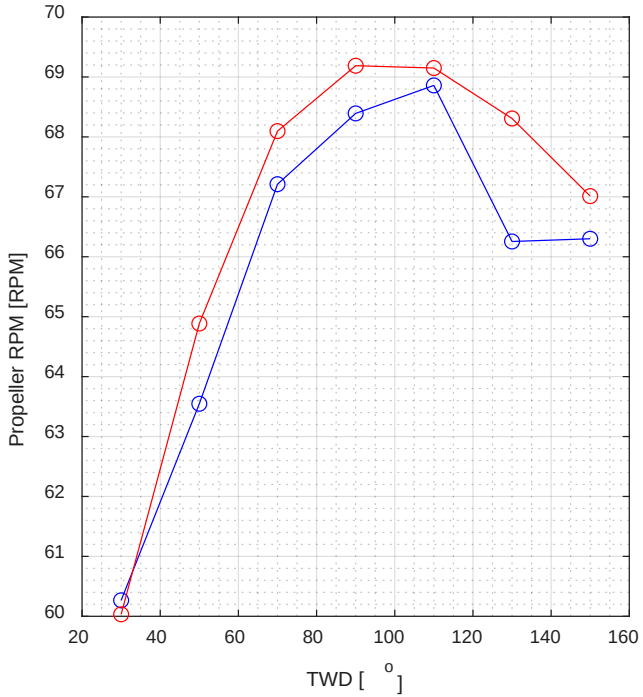
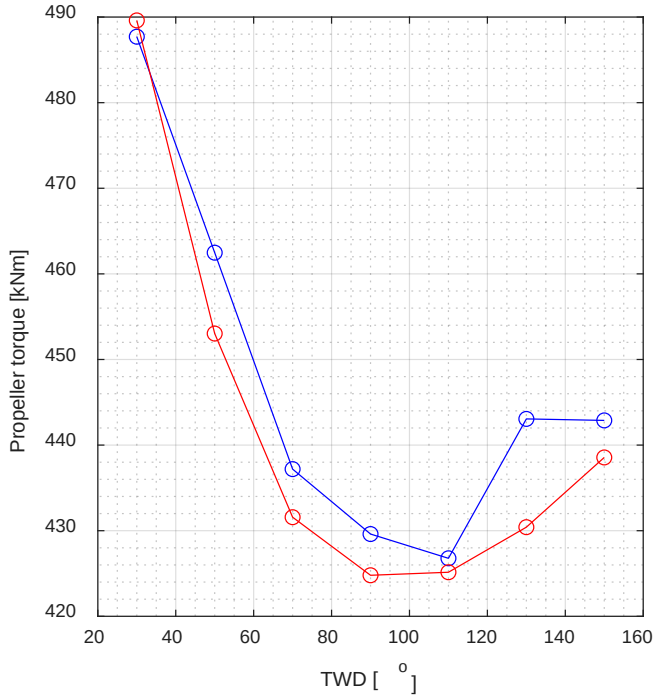
StedySail validation results

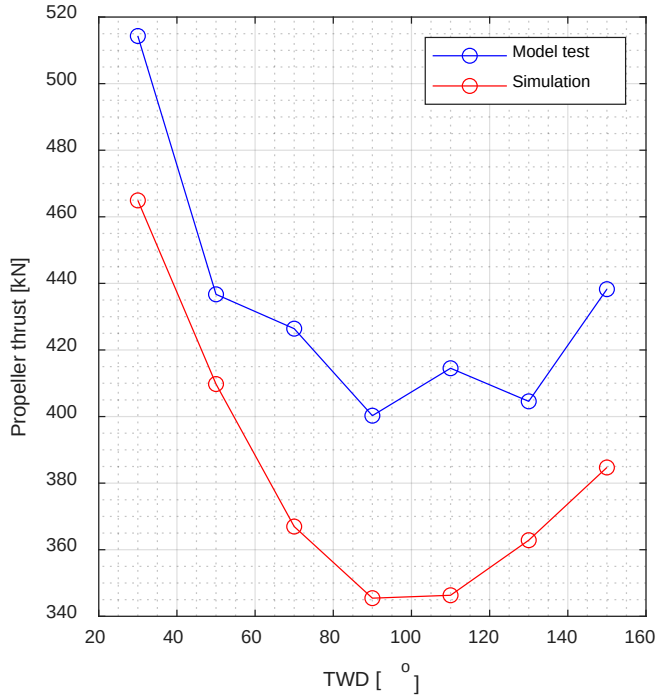
Propeller RPM



Propeller torque



Propeller thrust



Simulated at 15m/s wind speed

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Summary and conclusions

- We are able to analyze wind propelled vessels both numerically and in model tests
  - BUT: Only at steady state in the simulations
- A fast Lifting Line aerodynamic solver has been implemented
  - Needs further developments for unsteady simulations
  - Models for **fixed wing** and **Flettner rotor**
  - Should be easy to implement a **suction wing** model
- Able to perform accurate model tests using hybrid testing methods

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