Maneuvering and Seakeeping with wind propulsion

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Natural Propulsion Conference, Webb, 16-11-2021

Outline

- Criteria
- Predictions & results

Maneuvering & Seakeeping criteria

Maneuvering

- For maneuvering there are some quantitative criteria:
- IMO Resolution MSC 137(76)
  - Turning circle test
    - Advance
    - Tactical diameter
  - Zig-zag test
    - 10°/10°
      - Initial turning ability
      - First overshoot angle
      - Second overshoot angle
    - 20°/20°
      - First overshoot angle
  - Crash stop test

Turning ability

Initial turning, yaw checking and course keeping ability

Stopping ability

Maneuvering

Zig-zag test on LCF frigate of Dutch MoD (www.dutchdefencepress.com)

90 m OPV turning circle test (articles.maritimepropulsion.com)

- Required for any ship longer than 100m, or when carrying dangerous goods
- Formally in calm conditions (without wind)
- With wind propulsion, it's generally interpreted that wind is to be accounted for (important for safe operations)

Seakeeping

- Some binding requirements from IMO (e.g. on stability)
- However, nothing relating to behaviour in operational conditions

- Some projects/ships have their own criteria
- Anyway, the following is generally important for operations:

Added resistance

Course/track keeping

Motions

Comfort/sickness

Slamming

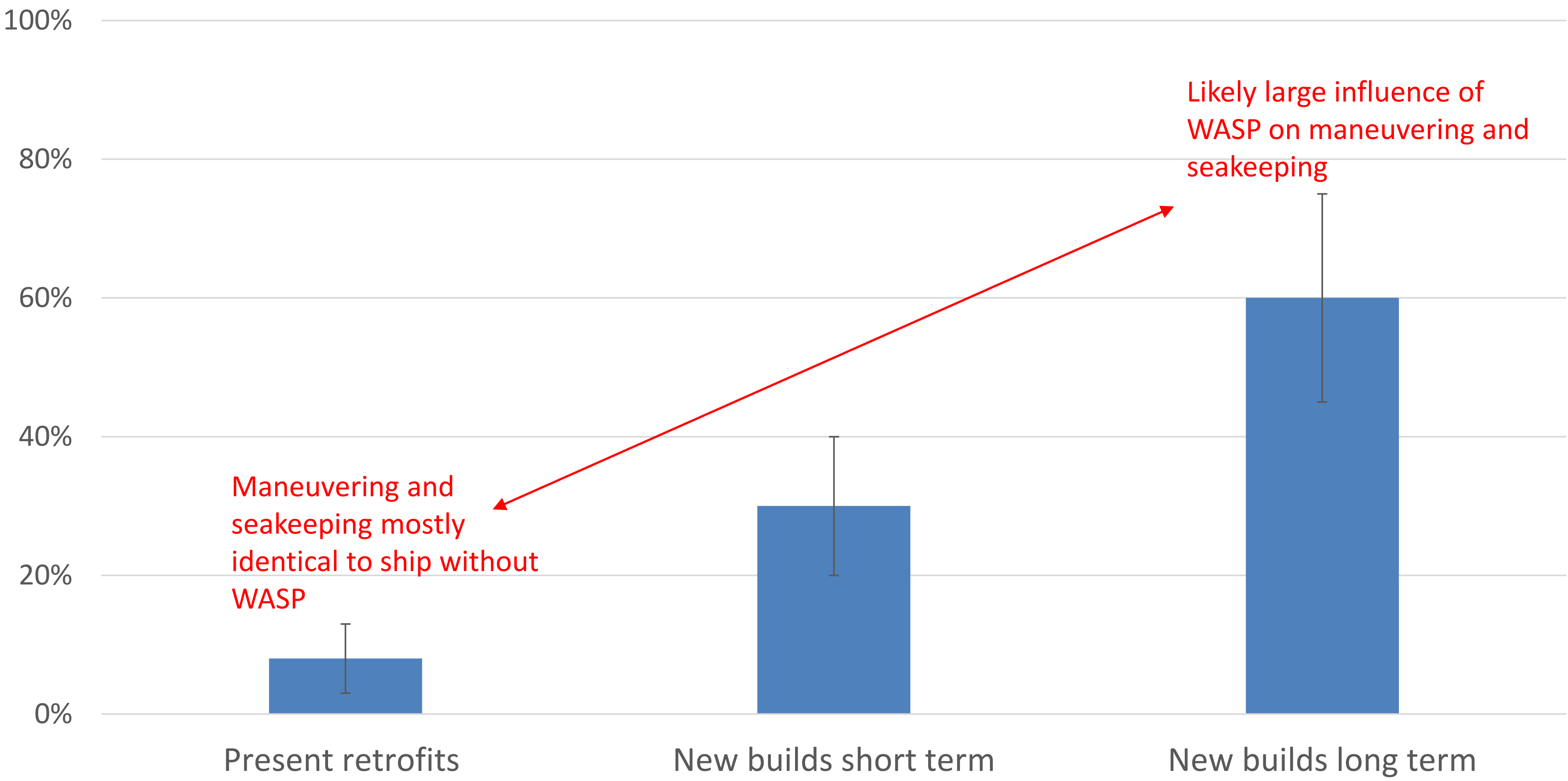
Propulsion

“Green” water on deck

(Structural) loads

Predictions (calculations & model tests) and results

Relevance


100%
80%
60%
40%
20%
0%
Likely large influence of WASP on maneuvering and seakeeping
Maneuvering and seakeeping mostly identical to ship without WASP
Present retrofits
New builds short term
New builds long term

How to model?

- **Simulations** combining aerodynamic and hydrodynamic forces
  - Hydrodynamic model tests/calculations with forced motions
  - Aerodynamic wind tunnel tests/calculations with forced motions
  - Simulations to merge all modelling
- **Tests** combining hydro and aero
  - Applying motions in a wind tunnel
  - Applying pre determined aerodynamic forces in a hydrodynamic model test:
    - Fans
    - Winches

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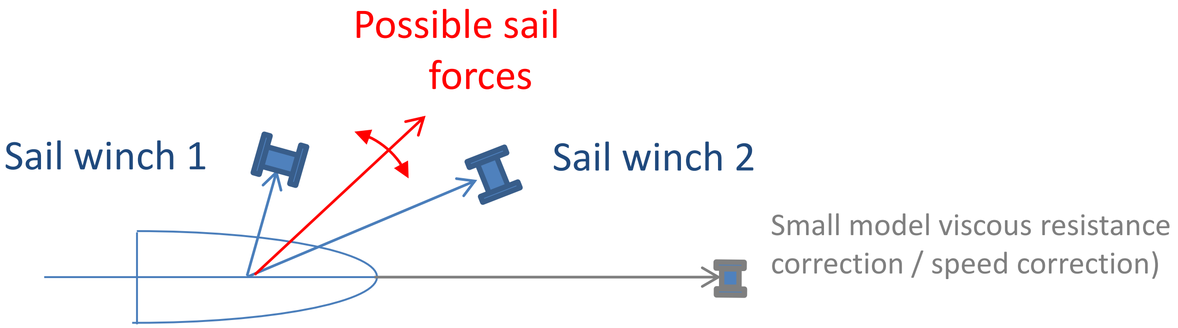

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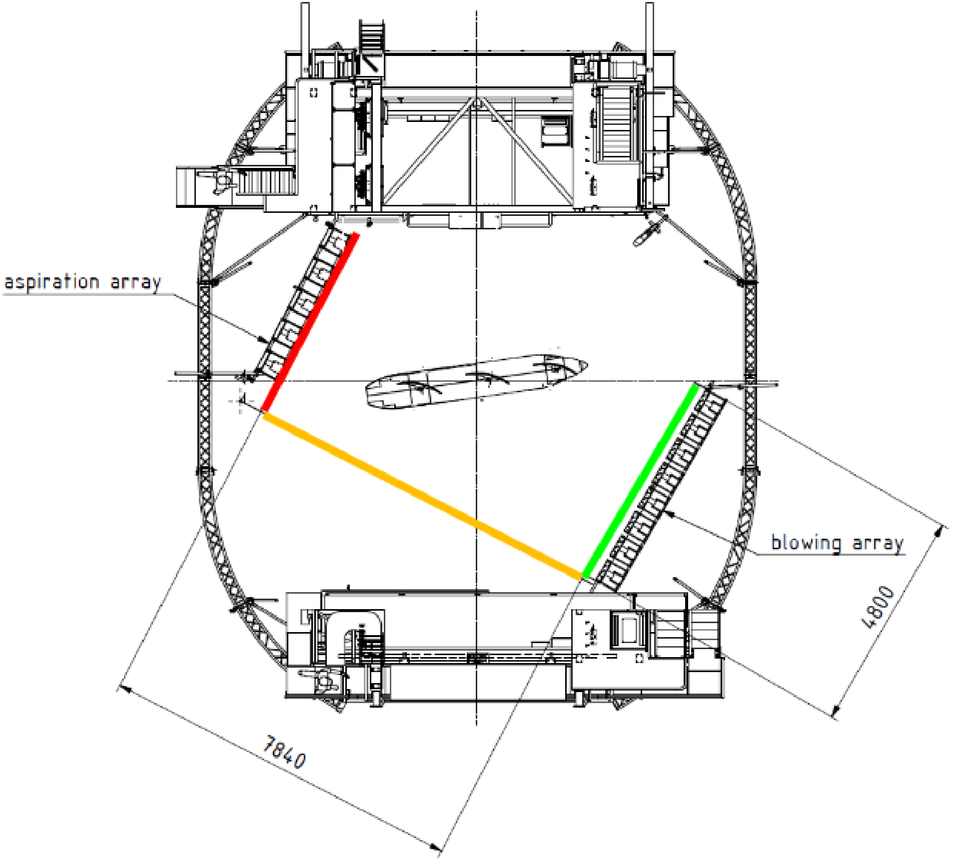
  - **Letting both hydro- and aerodynamics work by itself**

“WindLab” Project

- Aero- and hydrodynamics modelled at the same time in one test-setup
- Experimental research!
- Limitations in wind quality
- Ship speed changes effect not modelled correctly (yet)
- Calculations performed in parallel
- Some first indications of manoeuvring and seakeeping with WASP

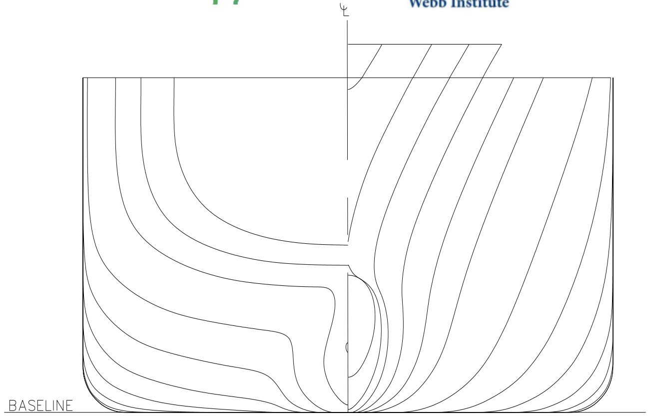
R. Eggers and A. S. Kisjes, “Seakeeping and Manoeuvring for Wind Assisted Ships,” London, United Kingdom, 2019-10.

Test set-up



"MARIN Hybrid Transition Coaster"

Length between perpendiculars	L_{PP}	68.7	m
Breadth moulded on WL	B	14.0	m
Draught	T	4.4	m
Displacement mass in seawater	Δ	4146.0	t
Transverse metacentric height Dynarigs	GM	0.69	m
Transverse metacentric height Flettner rotors	GM	0.67	m
Block coefficient	C_B	0.76	-

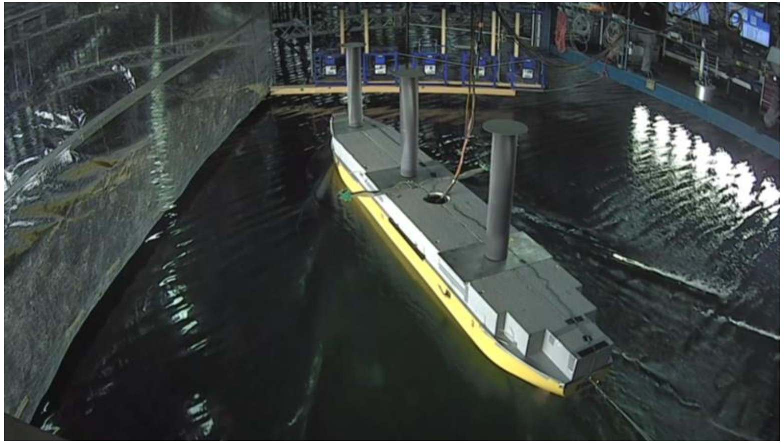


Dynarigs

Span (incl. yards)	s	29.9	m
Average chord	c	16.4	m
Combined projected area	A	1474.5	m^2
Overall air draught from WL	h_{air}	38.4	m

Flettner rotors

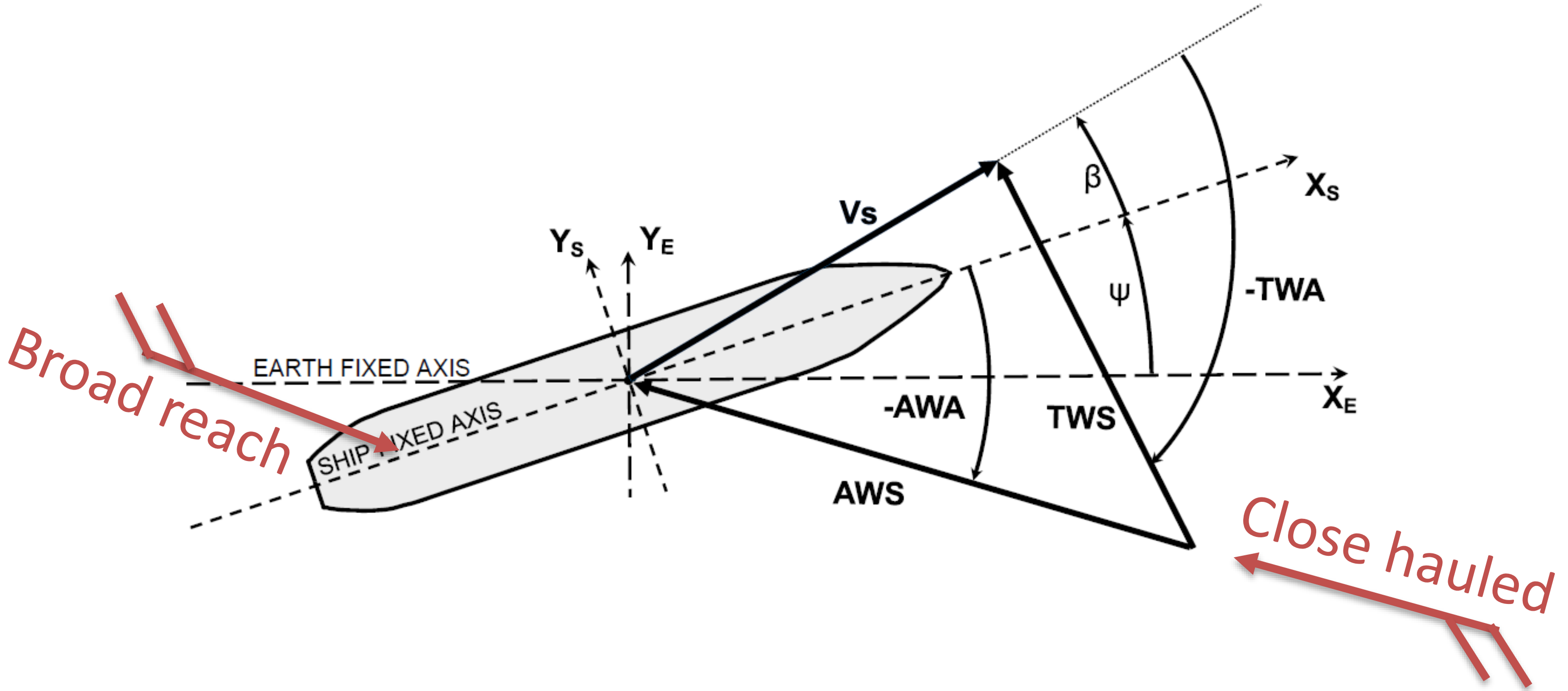
Height	**h**	**18.0**	**m**
Diameter cylinder (disk)	d	3.0 (6.0)	m
Combined projected area	A	162.0	m^2
Overall air draught from WL	h_{air}	25.56	m



Test program

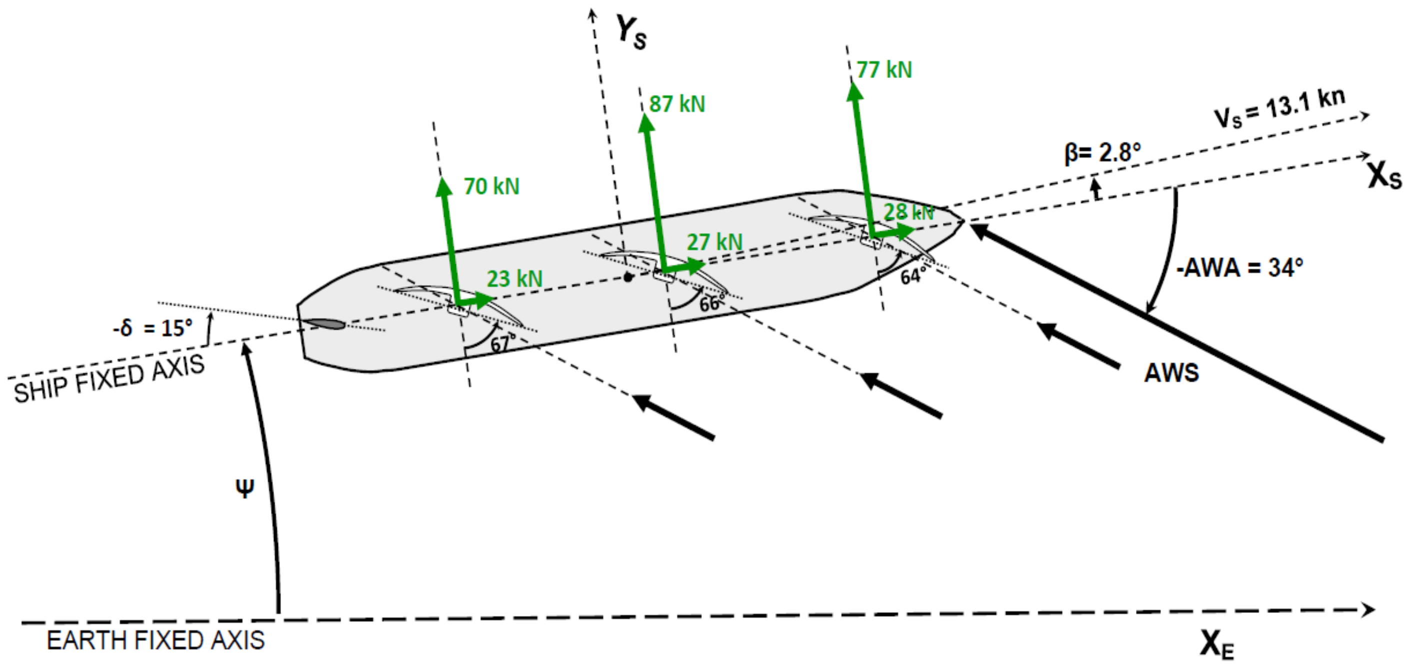
- Tests with Dynarigs in close hauled (bow quartering) wind conditions:
  - Speed runs and roll decay tests
  - Zig-zag tests
  - Seakeeping tests in regular and irregular bow quartering waves
- Tests with Flettner rotors in broad reach (stern quartering) wind conditions:
  - Speed runs and roll decay tests
  - Zig-zag and crash-stop tests
  - Seakeeping tests in regular and irregular stern quartering waves

Definitions (& wind conditions)



Sailing

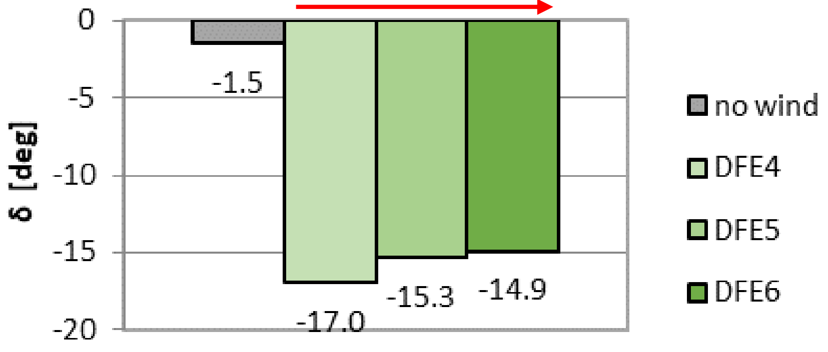
Equilibrium condition Dynarigs



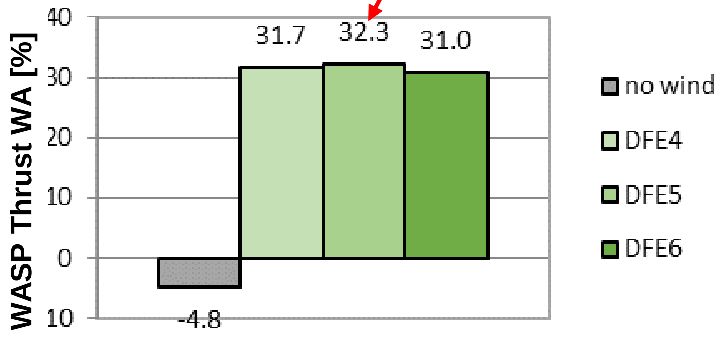
Sailing equilibrium

- Large rudder angles!

Decrease angle of attack

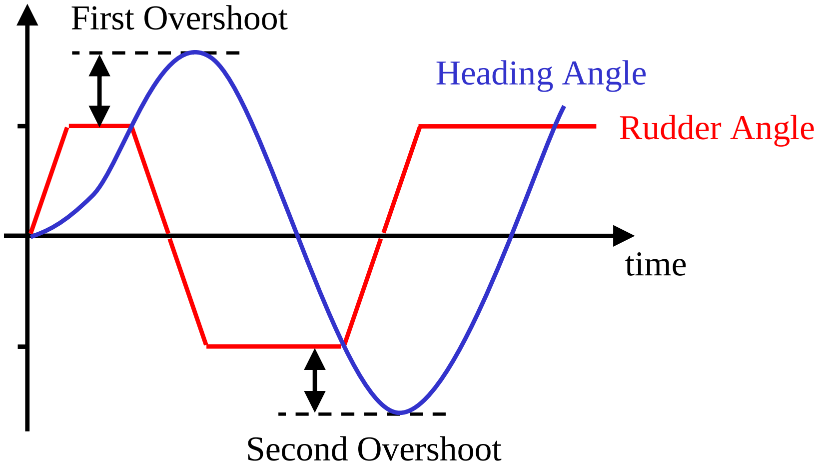


Best performance

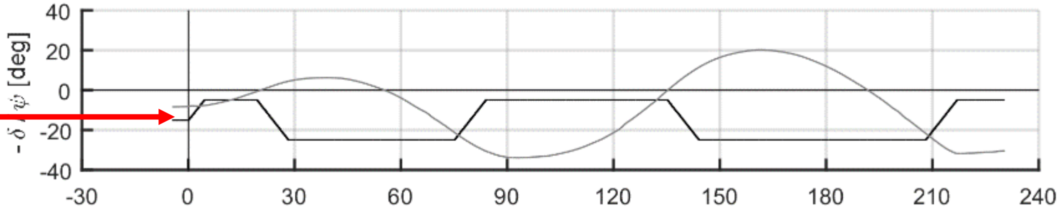


$$WA = \left(\frac{F_{X,sail,tot}}{F_{X,sail,tot} + T} \right) \cdot 100\%$$

Zig-zag tests Dynarig

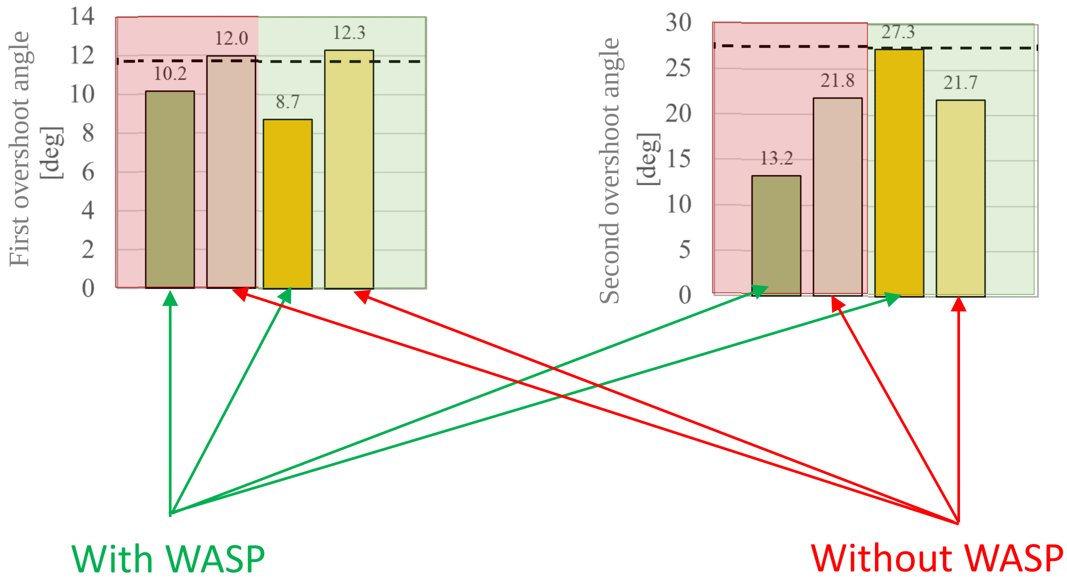


Started with non-zero rudder and leeway/yaw angle



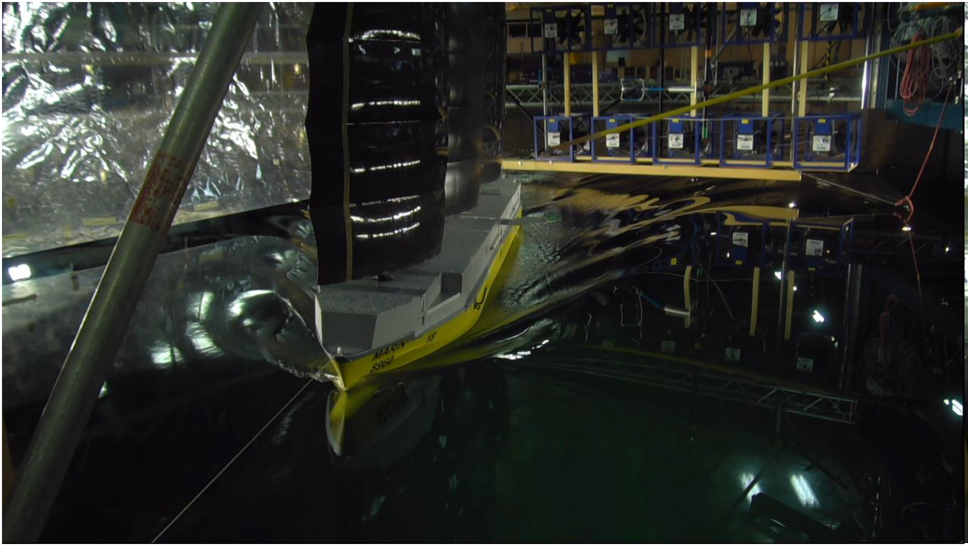
Zig-zag calculations Dynarig

- WASP significantly affects first and second overshoot
- *Generally* it seems to improve for Dynarigs upwind

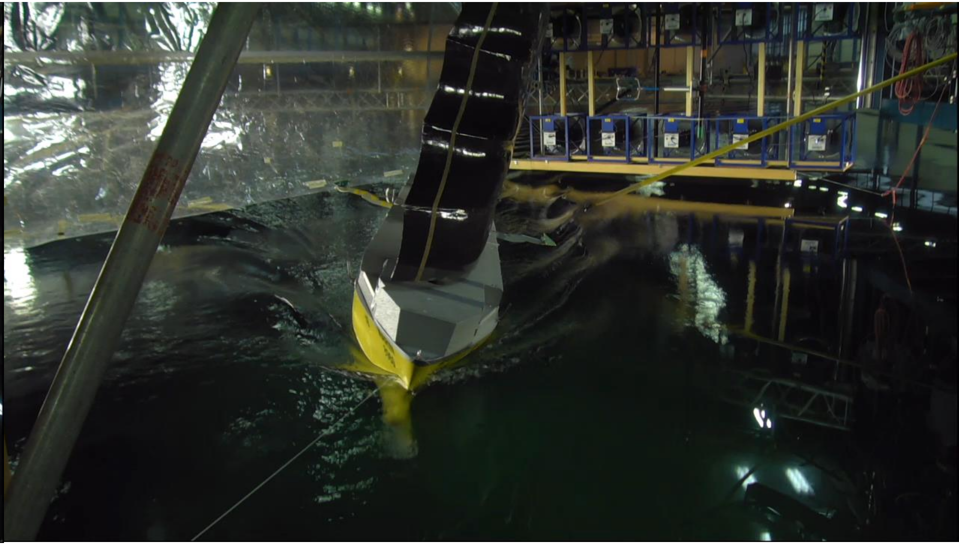


Roll decay tests Dynarig

Without wind

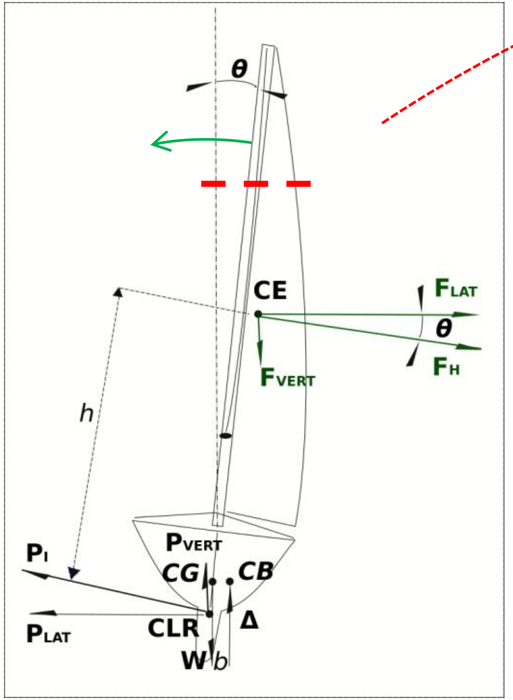


With wind

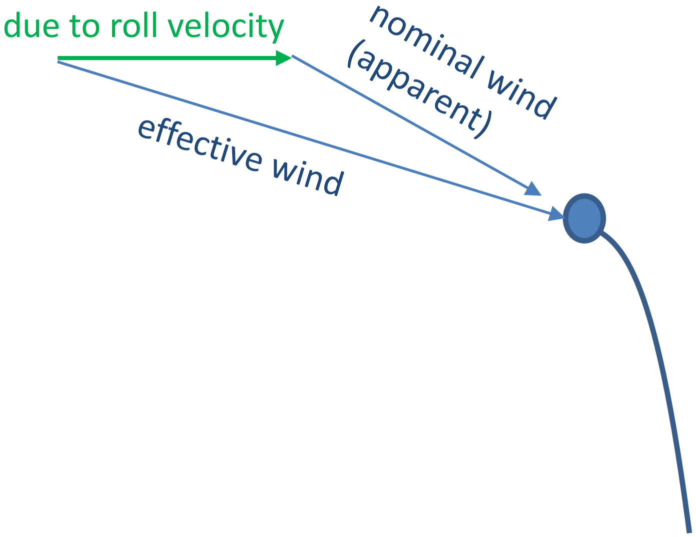


Roll damping with sails – what happens?

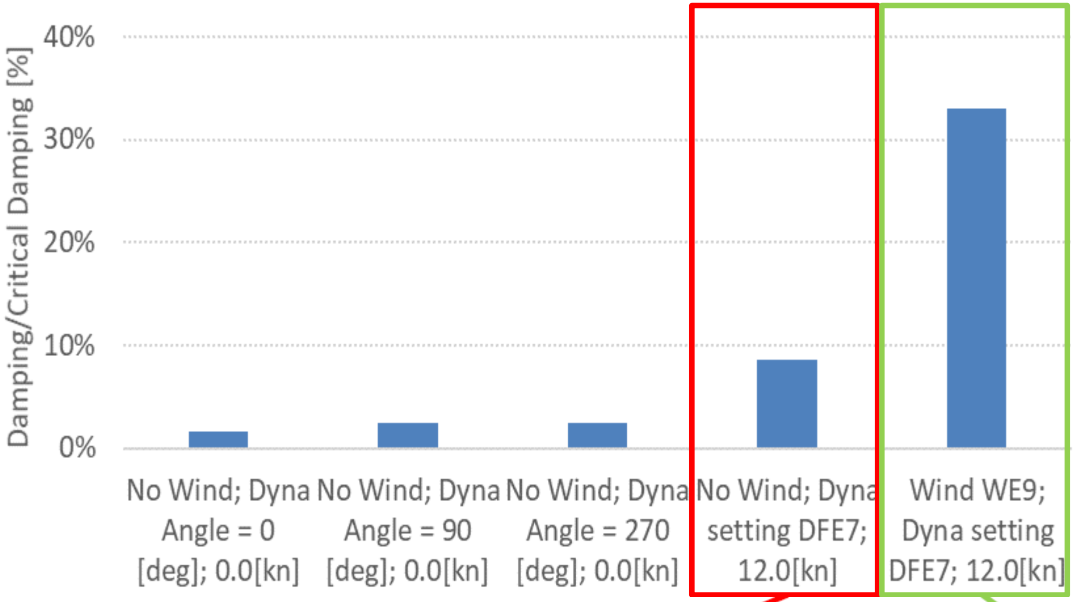
- Rolling to windward introduces a larger angle of attack on the sails
- Rolling to leeward introduces a lower (negative) angle of attack on the sails
- Both provide roll damping



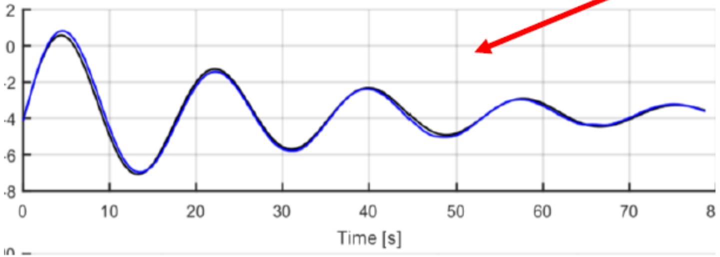
top view on cross section



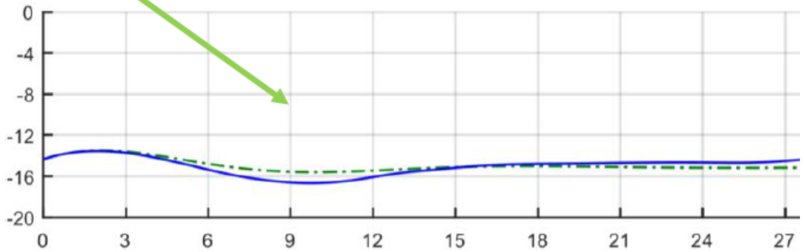
Roll damping Dynarigs



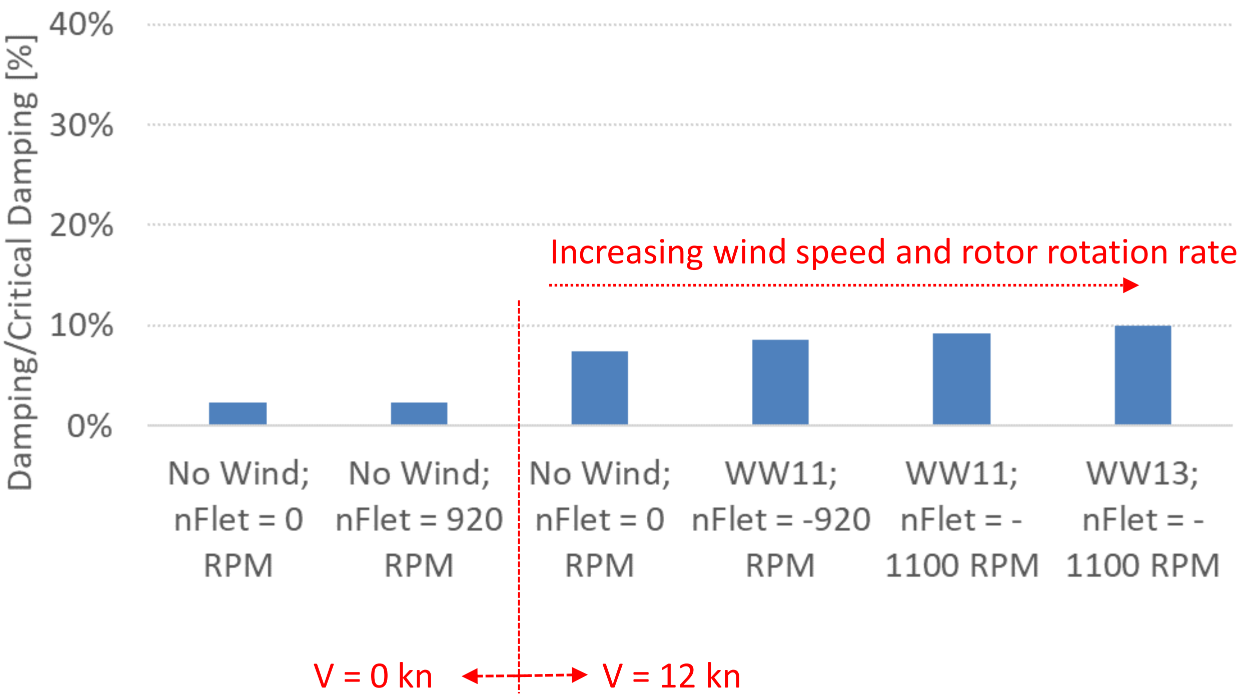
Without wind



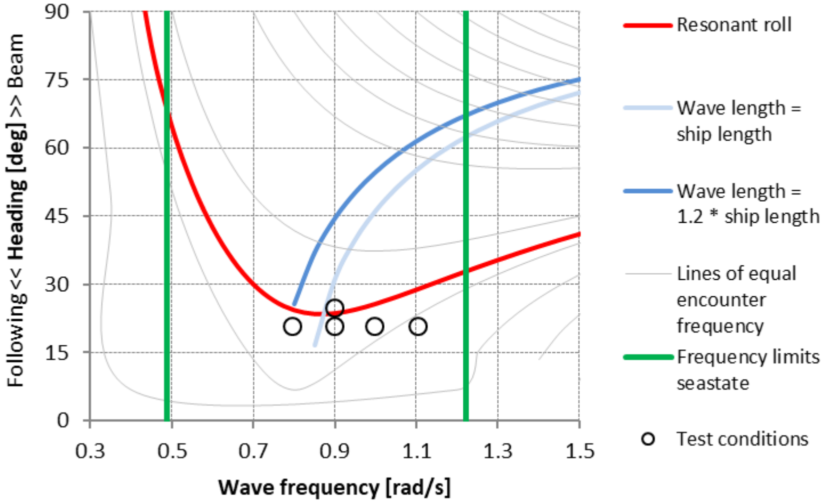
With wind

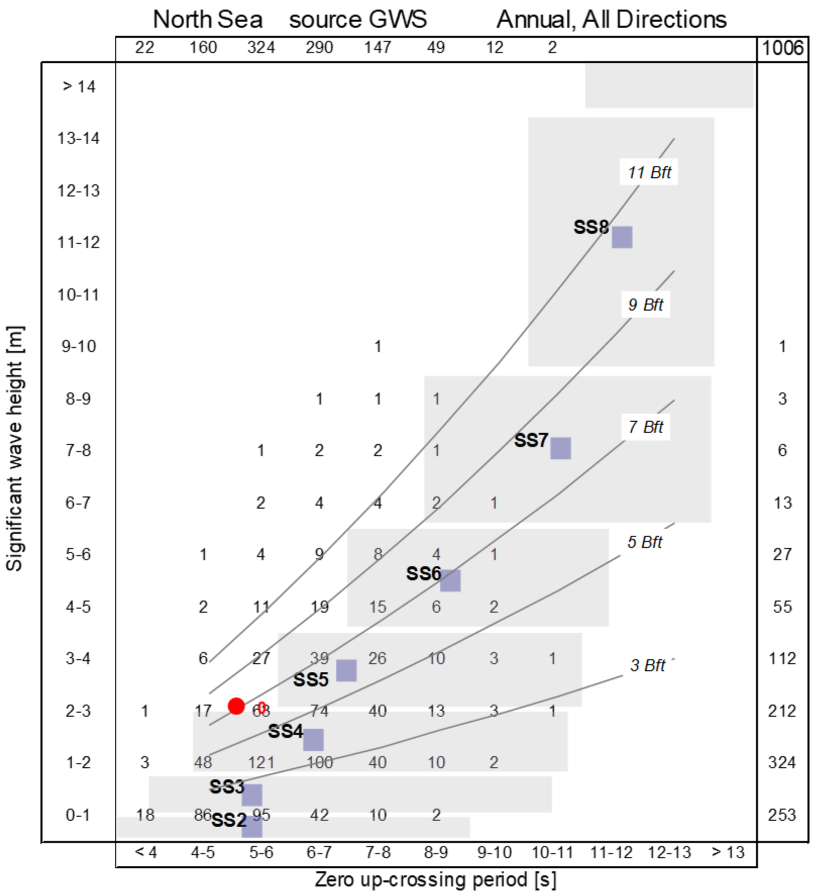


Roll damping Flettner rotors



Seakeeping tests Flettner rotors

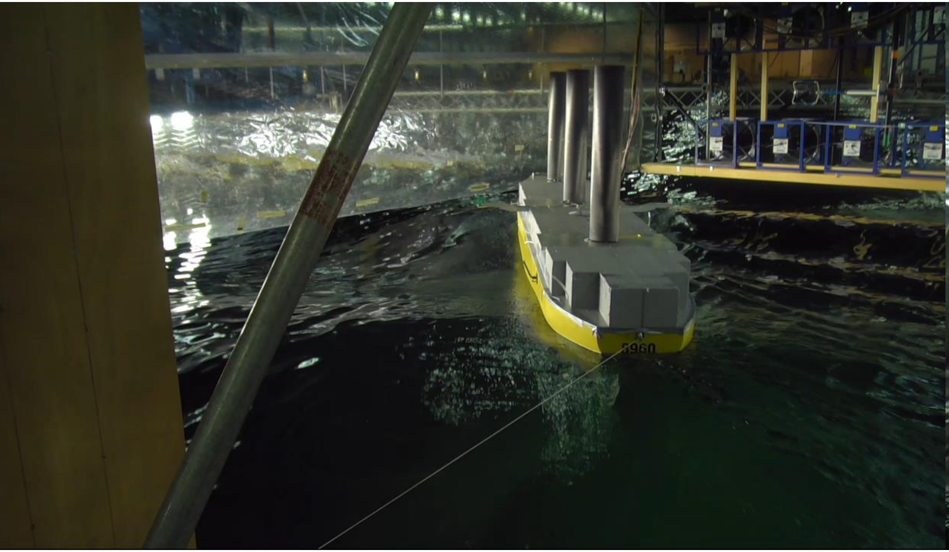




Seakeeping tests Flettner rotors

wind support Webb Institute MARIN

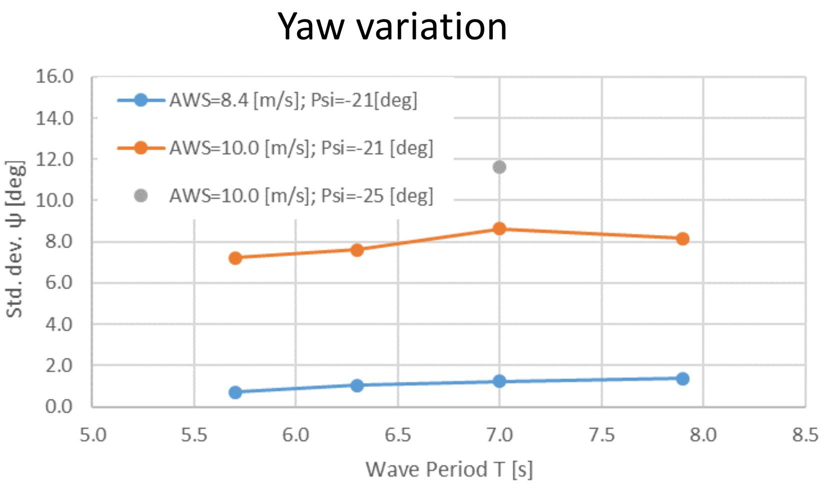
Low wind

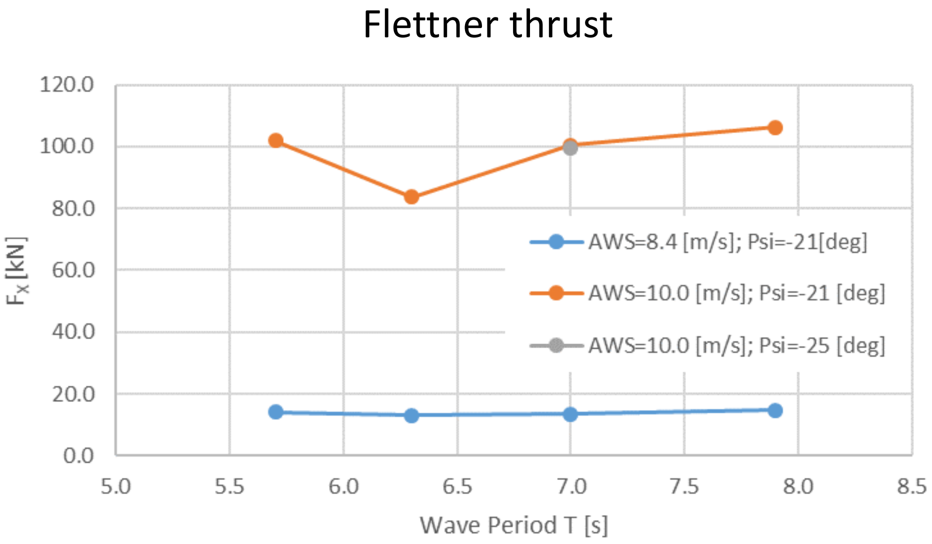


High wind

Seakeeping tests Flettner rotors

- Wind propulsion can substantially reduce the course keeping ability in *demanding* stern quartering wind and waves





What else?

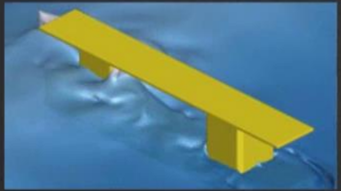
- Stopping tests
- Green water on deck may damage sails
- Dynamic (& fatigue) loads in rigs
- Propeller/rudder ventilation due to heel (twin propeller vessels)
- Which heel is acceptable (crew, cargo, …) ?
- ….

Summary

- Maneuvering & seakeeping can be influenced by substantial wind propulsion
- Prediction methods and specific impact of WASP on maneuvering and seakeeping still in development

THANK YOU - ANY QUESTIONS ?

MARIN



BETTER SHIPS, BLUE OCEANS

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