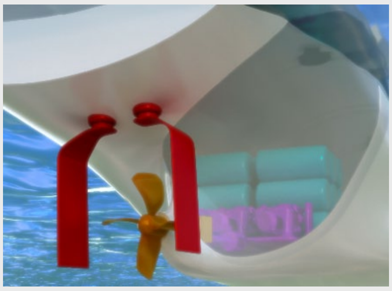
Wind Propulsion | Optimisation and Verification

How to ensure maximum performance and operability

Wind propulsion can result in substantial savings in fuel consumption and exhaust gas emissions. Demonstration projects have shown that savings of 5% to 15% are immediately achievable in average wind conditions without really changing operations and ship design.

However, present development projects indicate that by changing design and operations those savings can even be highly increased, getting close to 80% to 90% savings in favourable wind. This is a very interesting prospect for shipping. Wind propulsion can deliver savings that are out of range for other technologies. It can also reduce the operational cost that is inevitably involved with carbon free / neutral fuels.



'Substantial wind propulsion can benefit from a reconsideration of design and operational conventions'

How to make best use of these newly (re)introduced wind propulsion technologies? What is the best wind propulsion arrangement to use and do you need to change the hull, appendages and propulsion? And how do we make sure that the solutions indeed perform as promised and are fully operational and compliant, also in demanding conditions? Certainly for the higher savings these questions require answers which vary per ship type and operation.

Based on more than ten years of research and pilot projects, MARIN provides integrated services for optimisation and verification of ships with wind propulsion systems. These services are presented in the flow diagram below and include Concept, Design Optimisation, Design Verification and Operational Performance.

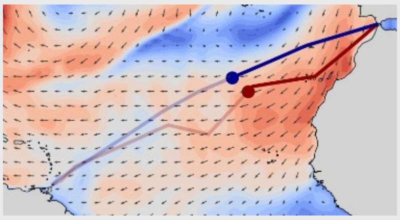
Concept →
- Feasibility check
- Exploration of wind propulsion types and arrangements
- See the 'Quick Feasibility and Concept Study' leaflet

Optimisation →
- Voyage simulation
- Aero optimisation
- Hydro and propulsion optimisation

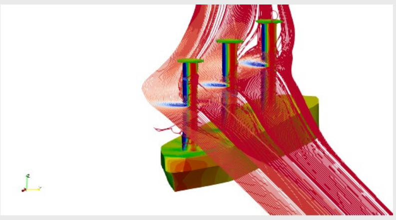
Verification →
- EEDI & EEXI
- Wind tunnel / CFD
- Captive model tests
- Seakeeping & manoeuvring model tests

Operational
- Crew handling
- Trials & monitoring

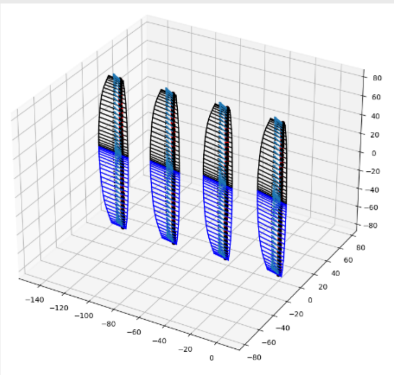
Facilities and tools:



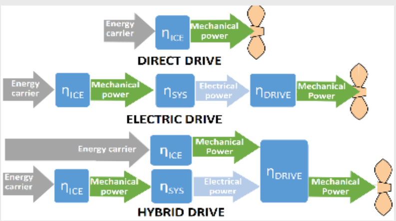
GULLIVER voyage simulations to predict performance and check additional benefit of routing to the wind



ReFRESCO CFD for flow over ship and in depth prediction of aerodynamic loads



Fast lifting line code to quickly explore design variations



SPEC comparison of different power and propulsion architectures

Design optimisation

Voyage simulations

Voyage simulations are indispensable when considering wind propulsion in the design stage. Simulations of actual voyages are conducted for a long time duration to get proper statistics of performance. They allow to assess:

- Benefits of sailing to better wind with route optimisation.
- Certainty to arrive in time, possibly with reduced conventional power.
- Impact of nautical constraints using ‘captain decision mimic’.
- More detailed environmental description (current, wind sea and swell, including added resistance).

Project specific constraints are always implemented in order to make sure that changed routes are realistic. MARIN can conduct voyage simulations based on forecast, rather than hindcast as available from many research centres.

Aerodynamic optimisation

A large number of options are generally available for positioning and dimensioning of wind propulsion units. Maximising the size or number of units, savings won’t increase linearly with the total area put on board. Devices will start to (negatively) affect each other due to aerodynamic interaction effects. Changing the deck and superstructure arrangement may also be beneficial to ensure compliance with IMO SOLAS requirements on bridge visibility; if moving the deck house forward is feasible then that may enable a lower building height with better aerodynamics.

MARIN can help you to establish the most effective arrangement and dimensioning of wind propulsion units using an efficient combination of Computational Fluid Dynamics and simplified ‘lifting line’ simulations [1]. You can compare the savings against different levels of costs sourced from suppliers and shipyards, to find the most favourable configuration for your objectives.

Hydrodynamic and propulsion optimisation

As savings increase beyond about 15% (yearly overall average), the hydrodynamics and propulsion will also become important, because of:

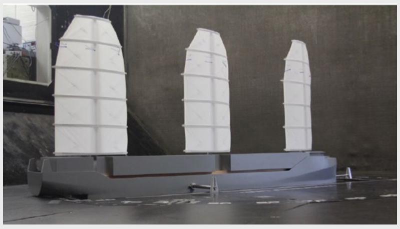
- Speed variation, side force and yawing moment resulting in increased hull and rudder drag.
- Large heel exceeding reference/owner thresholds.
- Propulsion and power generation inefficient or incapable to run at low loads.

Depending on ship type each of these aspects can limit the savings.

This can be remedied extending the hydrodynamic optimisation process with the following options:

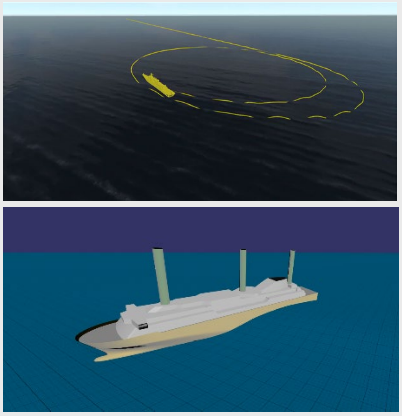
- Changed hull lines.
- Changing or adding appendages.
- Changing control of wind propulsion units.
- Dedicated propeller design for wider load variation.
- Alternative Power, Propulsion and Energy architectures using SPEC.

Facilities and tools



Subcontracted wind tunnel tests to verify aerodynamic performance

Captive basin tests for hydrodynamic loads with heel, leeway and rudder in the Deep Water Basin



Simulations in aNySIM to predict manoeuvring and seakeeping performances

Free running basin tests in the Seakeeping and Manoeuvring Basin for verification

Design verification

Once a design has converged, the performance of it can be verified using more detailed calculations or experiments. This may be especially relevant for innovative designs requiring validation, or to ensure compliance to rules & regulations or contracts.

EEDI & EEXI

The IMO has recently renewed its guideline to quantify wind propulsion for the purpose of EEDI & EEXI, MEPC.1/Circ.896, also using input from the MARIN led WiSP Joint Industry Project. MARIN can do the performance modelling for a compliant EEDI or EEXI, using either wind tunnel tests or CFD.

Steady aerodynamics – wind tunnel

MARIN can subcontract wind tunnel tests to a suitable facility. Whereas CFD and lifting line are very suitable for design work, they still exhibit inherent assumptions. Depending on the device type (a wind tunnel is not suitable for all devices), wind tunnel experiments can increase the confidence in predictions prepared earlier.

Steady hydrodynamics – basin tests

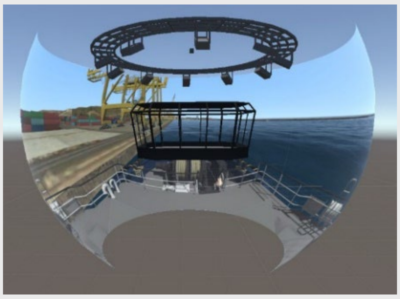
To validate the hydrodynamic performance of the hull and innovative appendages, captive basin tests can be conducted under (fixed) leeway, heel and rudder angle, including (partial) propeller thrust. This allows to verify the lift-to-drag performance and to assess yaw balance.

The impact of aerodynamics and hydrodynamics is established in (repeat) voyage simulations or deterministic Power Performance Predictions. *See our leaflet on Quick Feasibility and Concept Study for a description of a PPP.*

Manoeuvring & seakeeping

Substantial wind propulsion can affect manoeuvring and seakeeping [2]. Performance can either improve or worsen. In an early stage this can be predicted using simulations with aNySIM and afterwards verified through basin tests. In the basin tests dynamic aerodynamic loads are applied on the scale model using either multiple wind fans or winches, dynamically controlled based on the instantaneous attitude and motions (i.e. including the effects of heel, leeway, roll and yaw velocity). The experiments allow verifying compliance to statutory requirements such as manoeuvring standards and owner operability criteria, for instance on structural loads, course keeping ability or accelerations in waves. After a model test campaign, more conditions can be simulated using a validated numerical model in aNySIM.

Facilities and tools



New Full Mission Bridge

On-board trials & monitoring, including LiDAR wind scan and force measurements

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Check also our website for other and more recent publications.

Operational performance

Crew handling

Whereas some wind propulsion systems, particularly for modest assistance, hardly require attention for new crew handling procedures, other more substantial or new systems may need attention to:

- Develop operational procedures to operate the wind propulsion system, including for high wind and aerodynamic interactions.
- Operate the wind propulsion in combination with other propulsion systems on board.
- Define support systems.
- Develop training requirements for the wind propulsion (support) system.

These matters can be investigated on MARIN's desktop and Full Mission Bridge simulators. An upgrade allows to heel the Full Mission Bridge Simulator.

Trials & monitoring

The real impact of wind propulsion can be validated using dedicated trials or long term monitoring. In addition to general speed and power performance measurements, the direct thrust provided by the wind propulsion system can be measured. Directly measuring the thrust force allows to omit correcting for many external disturbances when only measuring shaft torque or fuel consumption. Another critical aspect is the effective wind at the time of trials or monitoring. MARIN can measure the undisturbed wind profile with LiDAR. This high fidelity technique can map the incoming wind in a large volume and it avoids the uncertainty with ship based anemometers that are often biased due to disturbance of the ship itself.

Track record & research

Since 2011 MARIN has been actively engaged in research to support the (re-) implementation of wind propulsion in commercial shipping with various EU projects, Joint Industry Projects, IMO MEPC contributions and direct services to clients. At present MARIN is involved in the following (public) initiatives:

- WiSP2 Joint Industry Project (with BlueRoute performance prediction).
- ITTC Committee on Performance of Wind Powered and Wind Assisted Ships.
- Optiwise EU Research project to rethink ship design and operations.

References

[1] M. Garenaux and J. J. A. Schot; "Flettner rotors performance and interaction effects on the MARIN Hybrid Transition Coaster", RINA Wind Propulsion Conference, London, 2021.

[2] R. Eggers and A. S. Kisjes; "Seakeeping and Manoeuvring for Wind Assisted Ships", RINA Wind Propulsion Conference, London, 2019.