HYDROFOIL RESEARCH

MARIN JIP starts later this year

Hydrofoil craft have been used since the 1950s for passenger and military applications. Until the 1970s, significant research and progress was made on these craft, but ultimately, the higher costs and possible operational risks outweighed the advantages. More recently, racing yachts (such as the America's Cup boats) have brought hydrofoils back to the media spotlight, inspiring naval architects.

While most challenges remain, technology advancements over the past decades (in the fields of materials used and computation) can help to optimise hydrofoils and make them a feasible solution for a wider range of applications.

The total weight to lift is the most important factor to consider, given the consequences for the design and the performance of the hydrofoils. The use of modern composite materials makes it possible to build lighter craft. Very much like an airplane, the lift-induced drag (proportional to the weight squared) is a major component of the total drag, particularly at lower speed. Thus, the reduced weight results in lower total drag and makes a low-speed economic operation mode feasible. Furthermore, composite materials allow for hydro-elastic tailoring of hydrofoils, opening up new design options. The use of modern computers results in improved real-time control algorithms for stable and safe "flying". Furthermore, as early as from the design stage, advanced Computational Fluid Dynamics (CFD) packages are available to assist in the design of more optimised hydrofoils and hulls, contributing to lower overall resistance.

Society demands new efficient forms of transportation for goods and people on the path towards zero-emission shipping. While fast ships are not particularly energy efficient, they are expected to play a significant role in this energy transition: Passenger transport still needs to be availabe within a reasonable time frame, as well as the transport of time-sensitive goods. Despite their relatively niche position inside the large frame of the shipping sector transformation, fast transportation of passengers and goods is relevant enough to justify the investment in the development of efficient fast vessels, where hydrofoils can play a fundamental role.

Behaviour in waves

Independently of the aforementioned advancements, a number of challenges still need to be addressed to make fleets of foiling vessels a reality. Current and proposed research projects at the Maritime Research Institute Netherlands (MARIN), together with several partners in the maritime industry, aim to tackle these challenges.

No matter how advantageous a foiling craft is for passenger transport, it will only be successful if it's attractive to passengers and safety is guaranteed. The most relevant research topics for hydrofoil operability are: the foil dynamics in waves, control systems and cavitation and ventilation effects.

In terms of behaviour in waves, the onboard accelerations are in most cases lower on a foiling craft than on a conventional planing boat. However, this does not mean that the motions are irrelevant.

Photo: Model tests of a foiling boat at MARIN's facilities.

To the contrary, a good understanding of the forces generated by the hydrofoils in waves is the first step to developing good ride control systems. These are key for comfort and safety, but also for performance: frequent actuation on control systems results in increased average resistance in waves. While surface-piercing hydrofoils can be inherently stable, actively controlled fully submerged hydrofoils typically show better performance, at the cost of higher complexity. The development of robust control systems, adaptive to variable circumstances (be it different sea states or loss of lift on one foil), can therefore have a major impact on the performance.

Working the air

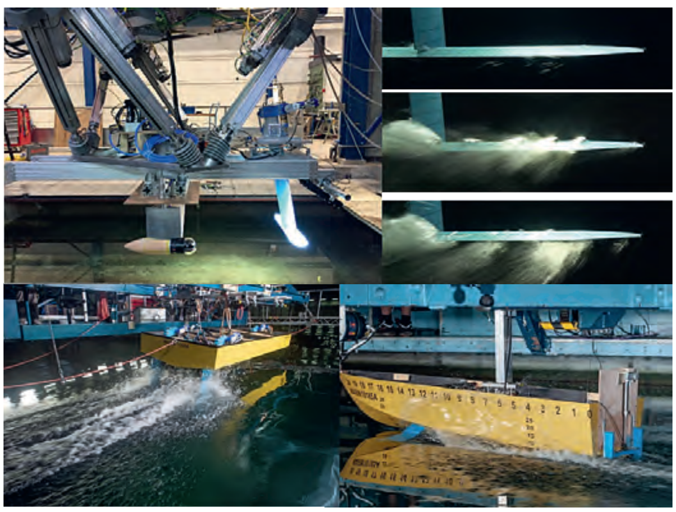
Cavitation and ventilation are hydrodynamic phenomena that can cause lift reduction and jeopardise the boat's dynamic stability. Cavitation is the generation of water vapour bubbles when the pressure drops low enough on the foil surface, and can also cause vibrations and erosion.

Ventilation happens when atmospheric air entrains the free surface and is drawn to the low pressure areas on the hydrofoil. This can lead to an extremely fast development of an air cavity, resulting in a sudden loss of lift of about thirty per cent, which can have severe consequences for the craft's stability.

There are many factors that affect ventilation inception (amongst which the presence of a cavitation bubble) and it has a somewhat stochastic nature. This represents a challenge for control systems, that will need to deal with ventilation in a reactive rather than a predictive manner.

JIP about to start

In the past, extensive research was performed on hydrofoils in steady state conditions, but all the aforementioned phenomena are unsteady. In general, the foil dynamics are often not considered in the design stage. Thus, the development of design tools (capable of including foil dynamics) has been considered the main objective of a Joint Industry Project (JIP), led by MARIN and set to start in Q4.



Model test setups for full foiling craft (bottom) and isolated foils (top).

A relevant take-off

In terms of foiling craft economy, particularly for shorter trips, the take-off phase is particularly relevant. At low speed, before the hull comes out of the water, the power a foiling boat needs is higher compared to a conventional planing boat, given the additional drag of the foils. The "reward" for this comes from the "flying" section of the trip.

The power demand for take-off can be minimised by optimising the hydrofoil shape depending on the expected trip length and take-off versus operational speed.

An alternative approach is to investigate propulsion systems that can provide a time-limited "boost" just to get the foil borne, returning to normal power afterwards. This approach could allow for lighter propulsion systems, but its requirements are still being investigated.

> Design tools will be developed to look into foil dynamics during the design stage

Hydro-elastic effects

Together with light weight, composite materials allow for (anisotropic) flexibility, which can be modulated by the fabrication process. This opens the possibility of hydro-elastic tailoring, where, for instance, a hydrofoil could deform to reduce the angle of attack when overloaded, thus minimising active control surfaces.

However, the interaction between the hydrodynamic forces and the elasticity can also lead to instabilities and ultimately unexpected material failure. The analysis of the dynamic behaviour of coupled hydro-structural aspects is therefore a research necessity in order to take full advantage of composite material properties.

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