





RSSSEN

FUELED UP

As methanol becomes the carrier of choice for many shipyards, Lürssen Yachts continues to push forward with the prototype stage of its fuel cell development project

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With the environment increasingly in the spotlight, the maritime transportation industry is fielding criticism about its emissions. Finding a solution for large cargo vessels and cruise ships is a significant challenge, but shipyards - including yacht builders - are looking at alternatives. Many are taking the hybrid route, with diesel engines for long-distance cruising and electric for silent, zero-emission running in port or in areas of environmental sensitivity. Battery-electric solutions are being used too, but mainly in small pleasure craft.

Hydrogen fuel cell technology provides other opportunities. At the 2019 Monaco Yacht Show, Netherlands-based Sinot Yacht Architecture & Design debuted the Aqua mega-yacht concept, which uses liquefied hydrogen in PEM fuel cells to create 4MW of power and give the 112m-long yacht (developed in partnership with Lateral Naval Architects) a cruising range of 3,750 nautical miles at an average speed of 10-12kts.

Although the Aqua's aspirational, luxury appeal is obvious, and its potential cruising range impressive, others are looking at fuel cell propulsion on a slightly more realistic level. This includes German shipyard Lürssen Yachts, which in April 2021 announced that it was building its first yacht using fuel cell technology. The shipyard has a history of firsts, claims CEO Peter Lürssen. His grandfather, Friedrich, is credited with building the world's first motorboat in 1886 and, as Peter is widely

Right: Freudenberg's type B-500kW fuel cell rack design



Supply and demand

Methanol has already been acknowledged as a future fuel solution for the marine industry. Pure hydrogen will work in situations where refueling is easy, such as short-distance ferry services, but for long-distance yachts and ships, a carrier such as methanol or ammonia is viewed as the way to go.

In August, Danish shipping firm Mærsk announced it was placing an order worth US\$1.4bn for eight new vessels that will run on what the company describes as 'carbon-neutral methanol'. The first of these will be ready in 2023 and will be capable of running on either e-methanol or low-sulfur diesel.

Availability of green methanol will be crucial, says Lürssen's Lennart Pundt, and further announcements by the shipping industry will increase demand and therefore make the fuel more widely available.

"The use of methanol is not limited to fuel cells. In merchant shipping, it is used in combustion engines, and that is going to push the demand for methanol in shipping and also for green methanol. We expect this will be a key driver in the availability of methanol and green methanol worldwide. It's a big step that the whole industry is taking."

"With fuel cell tech, we don't need a full engine room - more like a light technical space"

Lennart Pundt, head of technical project development, Lürssen Yachts



reported as saying, "My dream is to be the first to build a yacht without a combustion engine."

Fuel cell future

Lürssen has been looking at fuel cell technology since around 2005. According to head of technical project development Lennart Pundt, the company considers fuel cells to be integral to the future propulsion systems of not only trucks, buses and cars but also German submarines.

"Those modules in the past were the size of a desk and had 8kW of power," he says. "That was for silent military cruising for a submarine and not on the scale that would work on a commercial vessel or on a yacht. But we were already seeing a leap in the technology. Then we had our first joint research project with other shipyards and shipping companies in 2005."

A second project, called Pa-X-ell, was a joint venture funded by the German federal government to assess the feasibility of getting fuel cells on board passenger vessels or yachts.



Main: Lürssen Yachts has a history of building luxury vessels and, in April 2021, announced it was working on a hydrogen yacht
 Inset: Lürssen's fuel cell research could lead to changes in the traditional layout of a vessel engine room

The project began in 2009 and, to Pundt's knowledge, was the first of its kind for marine vessels on a commercial scale.

In 2017, Pa-X-ell 2 was initiated to take the technology further, to determine the feasibility of developing a fuel cell system capable of producing onboard electricity. That project has now reached an advanced stage and is in a position to install a prototype fuel cell in the shipyard to simulate the environment on board a vessel - with all the associated challenges.

"Do we have an interaction between the fuel that we use and the tank coatings and the steel structure?" Pundt asks. "Do we have corrosion? Does the coating work?"

The simulation aims to answer these questions. However, there is one even more

critical challenge to be addressed, relating to external air quality issues that could damage the fuel cell membranes.

"If you have an inland laboratory space, you don't have an exhaust plume from a merchant vessel passing by, one that does not have the cleanest exhaust - with diesel particulates, sulfur emissions and NO_x emissions," says Pundt. "We have to simulate a vessel being in port, where the exhaust fumes of other vessels can come into the really clean environment on the inside of a filter. What kind of filter technology is required to deal with the air intakes? And once we have commissioned this on board our vessels, we need to be sure that you can go remote. It's more complicated than we thought, and it's

definitely more complicated than a land-based fuel cell company would have to deal with."

Power source

Then there is the question of which fuel to use. Pure hydrogen requires storage, either pressurized at 700 bar or in liquid hydrogen form at -250°C. It is easy to develop a fuel cell and membrane to work with this pure hydrogen, says Pundt, but onboard storage would be an issue.

"You can't build structural tanks and you cannot put it in the double bottom as you would diesel fuel, so you have to bring it onto upper deck levels, which is a more valuable space where we have storage areas, galleys, laundries and so on. So it consumes much more valuable space than diesel tanks."

Instead, Lürssen has chosen to not store hydrogen directly but to go with a hydrogen carrier, of which there were two choices: ammonia or methanol.

"Within the Pa-X-ell project we have seen that on board long-range vessels, methanol

"My dream is to be the first to build a yacht without a combustion engine"

Peter Lürssen, CEO, Lürssen Yachts



seems to be the most promising fuel to enable vessels for remote operations," Pundt says.

Pundt explains that initially the best option is to produce hydrogen from offshore wind power or other renewable sources. CO₂ can then be captured from the air and combined with the hydrogen to create green methanol, which is much easier to handle and store in structural double-bottom tanks on the vessel. The methanol is converted back to hydrogen in order to act as the fuel.

"We have a reformer in front of the fuel cell, which produces hydrogen from the methanol and then hydrogen goes into the fuel cell with the CO₂ returned to the air," he says.

Lürssen is now undertaking tests using artificial mixing of by-products to assess the lifetime of the membranes themselves.

"What we are looking at is a lifetime of more than five years for a membrane, but this is not the development cycle," Pundt says. "We cannot wait for a laboratory site to have them running for five years before we say, 'Okay, now it's good.' In the laboratory phase, you have to add more by-products than you would expect, speed up the aging and see what happens, how easy it is to replace and so on."

While all of that is ongoing, Lürssen and its fuel cell partner, Freudenberg Fuel Cell e-Power Systems (FFCPS), are ready for the next phase: prototype testing on-site. That required a customer to commit to having the prototype fitted into a vessel, which is the commission announced in April 2021. What Pundt refers to as the 'alpha prototype' has already been built, but now will be adapted for the vessel. As with



Top: Sinot Yacht Architecture & Design's hydrogen mega-yacht concept, the Aqua

Above: Freudenberg's heavy-duty fuel cell stack technology

most superyachts, construction can take several years, so there's time to refine the fuel cell itself. The lower tanks are already being built within the hull of the new yacht. Pundt explains that the modular fuel cell can be carried under one arm and installed in a rack - far easier than installing a traditional diesel engine.

Future possibilities

The potential of fuel cells is obvious, but there remain technological hurdles to overcome. The cells take time to initiate and, Pundt believes, yacht owners will not want to wait in a bay for two hours while the cells are readied so the yacht can continue its voyage. It is therefore likely that yachts will have batteries to provide some form of electric propulsion. As with many other forms of hybrid transport, once the fuel cells are up and running, the batteries can provide additional power if required.

With testing well underway, the role of fuel cells in the yachting industry looks set to further evolve, particularly in the area of safety. Pundt believes that it will be possible to have fuel cells placed in different compartments on a vessel, enabling power or propulsion to continue even when another fuel cell has been damaged or fails.

"With fuel cell technology, we don't need a full engine room. It's more like a light technical space that you can put it in. You can distribute it and you can develop new arrangement concepts that are different and much quieter. The possibilities are to really advance what we can do. We'll get totally new frontiers and new designs - it's very promising." +