【欧州】【海事】

Maritime issues -Utilisation of Hydrogen as fuel: The deployment of hydrogen fuel cell propulsion systems for vessels in Norway

Andrea Antolini　Former Researcher JTTRI

【概要：Summary】

Since the maritime transport sector was explicitly excluded from the UNFCCC's COP21 Paris Agreement of future CO2 emission reduction, the pressure on the International Maritime Organisation (IMO) increased to take measures to mitigating the CO2 emissions from international maritime transport. On 13 April 2018, the IMO's Marine Environment Protection Committee (MEPC) 72 adopted the initial strategy on GHG emission reduction for international shipping. The strategy is the first step in a three-step approach on reducing CO2 emissions in maritime transport by 50% by 2050, based on 2008 levels. In order to achieve this, the focus will have to shift to the development of low and zero emission propulsion systems and alternative cleaner fuel solutions in maritime transport. Considering the options in maritime transport, Liquefied Natural Gas (LNG), electricity, biodiesel, and methanol seem to be suitable alternatives to replace oil based fossil fuels.

However, the shipping industry will have to consider different solutions depending on the utilisation of a vessel in short-sea shipping or deep-sea shipping. While in short-sea shipping and ferry transport, electrification could be a viable solution, long distance ocean transport will need other carbon neutral biomass-derived fuels, hydrogen and synthetic non-carbon fuels, like ammonia as suitable alternative low to zero carbon emission fuels and propulsion systems.

However, the new generation of vessels that utilises hydrogen or other CO2 emission neutral fuels need to be developed in the next decade in order to be ready and available for deployment by 2030 in order to achieve the zero net carbon emissions target by 2050.

There are currently several projects underway using hydrogen-based fuel cells propulsion solutions for vessels. While the international codes and standards for hydrogen fuel cell powered ships are not in place yet, countries can test the technology in their territorial waters. In Europe, Norway is one of the pioneers in developing and testing hydrogen-fuelled vessels, and to some extend also Sweden, Denmark and Finland. In July 2019, the Norwegian ferry operator Norled announced it planned hydrogen car ferries in Norway. There is also a group of Norwegian companies, which intends to build a fuel cell powered cruise ship for operations in the World Heritage Fjords and along parts of the Norwegian coastal route by 2023. It would be the first liquid hydrogen fuel cell cruise ship. This propulsion change will enable the cruise ship to still enter the Norwegian World Heritage Fjords after 2026, when vessels powered by any form of hydrocarbon will be banned from the fjords.

At international level, the codes and standards for hydrogen fuel cell powered ships are not in place. This lack of amendments to international codes and

standards poses a barrier for the deployment of the hydrogen technology and potentially delays the development and utilisation of hydrogen fuel cells in maritime transport beyond a state's territorial waters.

【記事：Article】

1. The IMO's and the EU's efforts to reduce GHG emissions from maritime transport

According to the IMO, maritime shipping is responsible for 3.5 to 4% of CO2 emissions worldwide. In the past decades, the IMO and the shipping industry had been postponing measures to deal with the problem of GHG emissions in maritime transport. The IMO's initial strategy identifies levels of ambition for the international shipping sector for reducing GHG emissions from ships. It aims at reducing the total shipping sector's GHG emissions by "at least" 50% by 2050, from 2008 levels. The IMO's new mandatory data collection system for reporting the ships' fuel oil consumption and the adoption of the strategy to reduce GHG emissions from shipping are the first measures in a three-step approach. However, the IMO's initial strategy does not give a schedule for the set-up of legal restrictions on CO2 output. It is rather a framework for IMO member states to set levels of ambition to reduce GHG emissions.

Therefore, the EU introduced the Regulation (EU) 2015/757, on the monitoring, reporting and verification of CO2 emissions from maritime transport as of 2018. The European Commission also adopted a proposal for revising the EU's monitoring, reporting and verification system for CO2 emissions from maritime transport (COM (2019) 38/F1) to facilitating the harmonious implementation of the EU and IMO systems and to support the European Green Deal's target. With the European Commission and the European Parliament moving towards including maritime transport's CO2 emissions into the EU-ETS, the shipping industry will soon have to seriously consider its options for reducing the CO2 emissions by moving towards low- and zero-emission propulsion systems for its vessels.

2. Considering the concepts of low and zero emission propulsion and fuelling options

In order to achieve the CO2 emission reduction in maritime transport and to introduce low to zero emission vessels, the idea is to replace fossil fuels and conventional diesel generators with alternative fuels and new propulsion systems. The type of propulsion and alternative fuel selected will have a direct impact on the vessel's emissions, including GHG, NOx, and SOx. Currently, in the deep-sea maritime transport, which accounts for 80% of the global CO2 emissions from shipping, the majority of new vessels are still being planned and built to use fossil fuels. Accordingly, the focus has to shift towards the development of potentially low and zero carbon emission propulsion systems and fuels. Since vessels typically have a life span of about 25 years, vessels that use new low to zero carbon emission fuels like biofuels, hydrogen or other potentially CO2 emission neutral fuels would have to be already available by 2030 in order to achieve the IMO's 2050 target. LNG is considered being one of the alternatives to crude oil in maritime transport, but as long as the additional methane emissions of LNG processing and bunkering are not eliminated, it cannot be considered being a sustainable solution for maritime transport.

Instead, in short-sea shipping markets, the use of electricity and batteries for propulsion could lead to a paradigm shift for the operational setup in ferry transport. In particular, in Norway, Denmark and Sweden, the concept of electric powered ferries is being tested. In western Norway, a mid-sized car ferry MS Ampere, carrying 120 cars and 360 passengers, has been traversing operating since early 2015. Denmark and Sweden are cooperating on a plan to introduce electric passenger ferries and have already launched two battery ferries. Also Finland launched its first electric car ferry and dozens of hybrid ferries. Hydrogen-based fuel cells could play a greater role as ship propulsion systems,

especially if the hydrogen is produced using renewable energy sources.

3. Hydrogen fuel cells as ship propulsion systems

There exist a number of different hydrogen fuel cell propulsion systems in development or trial stage, according to a study commissioned by the European Maritime Safety Agency (EMSA) and produced by DNV GL. The study highlighted the wide range of 12 on going fuel cell projects involving shipping, including FellowSHIP, FCShip, METAPHU, Nemo H2, FELICITAS, SF-BREEZE, Pa-X-ell, US SSFC, MC-WAP, ZemShips, SchIBZ and RiverCell. Seven different fuel cell technologies are being evaluated, including the alkaline fuel cell (AFC), the proton exchange membrane fuel cell (PEMFC), high temperature PEMFC (HT-PEMFC), direct methanol fuel cell (DMFC), phosphoric acid fuel cell (PAFC), molten carbonate fuel cell (MCFC) and the solid oxide fuel cell (SOFC).

Some argue that the prospect of below € 20/MWh electricity prices for utility-scale solar electricity coming from North Africa and the Middle East, or €50/MWh from massive offshore wind farms, means the poor efficiency of green hydrogen would no longer be an issue. However, green hydrogen will have to compete with petrol, diesel, marine fuel oil, among others. In long-distance or deep-sea shipping, hydrogen-based fuel cells could become an alternative propulsion, as these systems can operate over longer distances without emitting GHG during operation. According to the environmental NGO T&E, the goals set for the utilisation of green hydrogen should be realistic and achievable and should focus on creating a secure market for green hydrogen or hydrogen derived efuels, with high sustainability standards so that industry can make the long-term investments. For shipping, stringent operational CO2 and zero-emission port standards could be used to require cargo and luxury cruise ships to run on green hydrogen or ammonia. Ports will play a major role in any successful hydrogen strategy as this is where hydrogen would likely come on shore.

In long distance transport like ocean transport, any kind of low to zero carbon emission liquid fuel could replace heavy fuel oil. Currently, carbon neutral biomass-derived fuels, hydrogen and synthetic non-carbon fuels, like ammonia are considered as solutions, although each of these three have challenges. Biomass-derived fuels are being tested as drop-in fuels on certain routes, but they are considered being only a transition solution. Hydrogen or synthetic non-carbon fuels seem to have the highest potential as a long-term solution for maritime transport. Since a vessel's life span is about 25 years, any new ship propulsion based on biofuels, ammonia, hydrogen, batteries or another will have to be ready for the next decade, as the shipping industry will soon need to prepare for the transition towards zero-carbon emission technologies to achieve the 2050 emission reduction target.

In September 2019, the Danish Minister for Foreign Affairs, and the CEOs from Maersk Container Industries and about 80 companies of the maritime, infrastructure, energy and finance sectors, including Shell, Citibank, Cargill, Kuehne + Nigel, Unilever and the Antwerp Port, among others, launched the so-called "Getting to Zero Coalition". The shipping industry considers zero emission fuel cells as a long-term solution to decarbonise shipping. There is an increasing interest from the merchant shipping fleet in the uptake of hydrogen fuel cell technology in the next five years. However, one challenge is that hydrogen fuel cells have never been used for ship propulsion for ocean going vessels and trials are only starting for short-sea shipping and ferries. The use of hydrogen-powered fuel cells for ship propulsion is still at an early design and trial phase, with applications in smaller passenger ships, ferries or recreational craft. Besides the construction of hydrogen fuel cell propelled vessels, this will also require specific vessels tailored to transporting and bunkering liquefied hydrogen as well as the construction of the necessary bunkering infrastructure.

It will also require the amendment of the legislative framework, including the IMO's International Code of Safety for Ships using Gases or other Low-Flash-Point Fuels (IGF Code), which will have to be reviewed in order to cover fuel cells or hydrogen as fuel.

4. Recent hydrogen-fuelled vessel projects

In Europe, Norway is one of the pioneers in developing and testing hydrogen-fuelled vessels there are several projects underway using hydrogen-based fuel cells. With the backing of the government, in 2017, the Norwegian Public Roads Administration (NPRA) established a project with the ultimate goal of building and operating a hydrogen-electric ferry on the Hjelmeland - Nesvik route on the southwest coast. A second project, called HYBRIDShip (Hydrogen and Battery Technology for Innovative Drives in Ships), was initiated by Fiskerstrand Holding AS in 2016 and aims at converting an existing diesel-powered ferry to hydrogen propulsion. Furthermore, MAN Cryo, ship-owner Fjord1 and designer Multi Maritime in Norway announced the development of a marine fuel-gas system for liquefied hydrogen, designed for vessels, such as ferries for short routes. Another Norwegian government-funded project aims at developing a hydrogen propulsion system for large maritime vessels. Furthermore, the company Moss Maritime, in cooperation with Equinor, Wilhelmsen and DNV GL, have developed a design for a liquefied hydrogen (LH2) bunker vessel to permit transport and bunkering of liquefied hydrogen to merchant ships and to open sea transport. Also the cruise operator Royal Caribbean has already announced plans to use hydrogen fuel cell technology as a means of additional power on their new LNG-powered Icon-class vessels, which will be delivered in 2022 and 2024. However, despite the number of hydrogen-related projects, the shipping industry remains divided on the question of suitability of hydrogen fuel cell propulsion.

5. Norwegian companies work on hydrogen fuel cell propulsion for cruise ships

Meanwhile, Viking Cruises is working on the construction of the world's first cruise ship fuelled by liquid hydrogen. Different fuel cell types are available, but liquid hydrogen has not been used as marine fuel so far. One of the technical challenges is to maintain the liquid hydrogen fuel at minus 253 degrees C° to keep it from evaporating. Furthermore, hydrogen is also a very explosive gas, and protection against gas leaks is an important part of the safety requirements. The ship will probably be registered in the Norwegian International Ship Register, and the cruise line is already in discussion with the Norwegian Maritime Authority. According to the project manager Serge Fossati, the ship will be around 230 meters long and will accommodate more than 900 passengers and a crew of 500. The cruise ship will be based on the design of the cruise line's other ocean-going ships, such as the Viking Sun. According to the Norwegian Maritime Authority Director General of Shipping and Navigation, Olav Akselsen, a distribution network may be established, which will enable others as well to use hydrogen as fuel and it could contribute to a zero-emission shipping industry.

At present, liquid hydrogen is not produced on a large scale in Europe, but Fossati stated that Viking Cruises is in dialogue with Statoil in order to find a solution based on a Norwegian refinery.

In July 2019, the Norwegian ferry operator Norled announced it planned hydrogen car ferries in Norway. The plan is to use liquid hydrogen fuel for the first ferry and compressed hydrogen for the second. The benefit of using liquid H2 for hydrogen car ferries is that this fuel has more energy than the compressed version. According to Norled project manager Ivan Ostvik, the reason the first ferry is using liquid hydrogen and the second is not, is that tender requirements pushed the company to the liquid solution. The supply chain for liquid hydrogen fuel is not yet developed in Norway and therefore, the second of the two hydrogen car ferries is likely to

use compressed hydrogen (H2) in Norway. Norled is working with partners to develop the supply chains and infrastructure needed for these projects. This supply chain and infrastructure will be based on utilizing green hydrogen produced from renewable energy sources.

Meanwhile, a group of Norwegian companies is working to build a fuel cell powered cruise ship for Havila Kystruten for operation on the Norwegian mailboat route from Bergen to Kirkenes from 2021. The ships have been designed by the Norwegian Havyard Group, and owned by the Norwegian company Havila, which operates sightseeing cruise in the Norwegian fjord waterscape. Initially, the shipyard had planned LNG based propulsion systems, but Havyard intends to equip the vessels with several fuel cell system modules connected in parallel, with a total power of 3.2 MW. This will allow for zero-emission operations in the World Heritage Fjords and along parts of the Norwegian coastal route. The propulsion change is necessary for entering the Norwegian World Heritage Fjords after 2026, as vessels powered by any form of hydrocarbon that produces CO2, exhaust and other emissions will be banned from the fjords from 2026 onwards. This is one of the reasons, why Norway is fostering clean marine technology for large ships. With electricity not being an option on longer sea routes, green hydrogen produced from renewables is seen as an adequate alternative fuel to lower or end emissions in the shipping sector.

The cruise vessel would be retrofitted with the largest fuel cell ever placed on a major ship. The 3.2MW fuel cell will enable the vessel to sail zero-emission for long distances. Batteries are planned to store additional energy to make the system fully emissions-free. The goal is to finish the retrofitting and have this vessel sailing Norway's fjords by 2023. The project team is working with tank supplier Linde and Sweden's PowerCell in seeking Approval in Principal for the hydrogen system.

The introduction of the Norwegian law to reduce any kind of emissions in the Fjords will foster the further development of hydrogen based fuel cell propulsion systems for ships. The Norwegian projects are valuable steps towards a wider introduction of FCH propulsion. Starting with operation of these ships on fixed routes in territorial waters will simplify the legal, administrative and logistic requirements and allows stakeholders to begin expanding the infrastructure while collecting valuable experience in operating FCH powered ships.

References

Bergman, Jamey: High-capacity hydrogen fuel cell project moves towards trials. In: https://www.rivieramm.com/news-content-hub/news-content-hub/high-capacity-hydrogen-fuel-cell-project-moves-towards-trials-56740, 07 Nov 2019, retrieved 26 February 2020

Berti, Adele: Could fuel cells soon be used in ship propulsion? In: https://ship.nridigital.com/ship_mar19/could_fuel_cells_soon_be_used_in_ship_propulsion, March 2019, retrieved 27 November 2019

Butler, Jeff: Revolutionary fuel cell powered cruise ship for Norway fjords. In: https://plugboats.com/revolutionary-fuel-cell-powered-cruise-ship-norway/, February 4, 2020, retrieved 25 February 2020

DNV-GL: MARITIME. STUDY ON THE USE OF FUEL CELLS IN SHIPPING (commissioned by EMSA). http://www.emsa.europa.eu/emsa-homepage/2-news-a-press-centre/news/2921-emsa-study-on-the-use-of-fuel-cells-in-shipping.html, retrieved 28 November 2019

Freist, Roland: Norwegian cruisers to set sail with fuel cells. In: https://www.hannovermesse.de/en/news/news-articles/norwegian-cruisers-to-set-sail-with-fuel-cells, 15 Jan. 2020, retrieved 25 February 2020

FuelCellWorks: Norway: Norled's hydrogen ferry begins to take shape. In: https://fuelcellsworks.com/news/norway-norleds-hydrogen-ferry-begins-to-take-shape/, 15.4.2019, retrieved 27 November 2019

Hydrogen fuel cell-powered marine vessels. In: https://www.accessscience.com/content/hydrogen-fuel-cell-powered-marine-vessels/BR0801191, August 2019, retrieved 26 February 2020

Hydrogen Powered Ships Sail Closer To Market. In: https://www.cruiseindustrynews.com/cruise-news/21853-hydrogen-powered-ships-sail-closer-to-market.html, November 04, 2019, retrieved 26 February 2020

Moore, Alicia: Norway's first hydrogen car ferries continue development. In: https://www.hydrogenfuelnews.com/norways-first-hydrogen-car-ferries-continue-development/8537889/, July 17, 2019, retrieved 25 February 2020

New design revealed to enable the creation of liquefied hydrogen bunker vessels. In: https://safety4sea.com/new-design-revealed-to-enable-the-creation-of-liquefied-hydrogen-bunker-vessels/, 29/01/19

PowerCell signs development contract for 3.2MW maritime fuel cell system with Havyard Group. In: https://www.greencarcongress.com/2019/11/20191105-powercell1.html, 5.11.2019, retrieved 26 February 2020

Radowitz, Bernd: World's first liquid hydrogen fuel cell cruise ship planned for Norway's fjords. In: https://www.rechargenews.com/transition/world-s-first-liquid-hydrogen-fuel-cell-cruise-ship-planned-for-norway-s-fjords/2-1-749070, retrieved 25 February 2020

Todts, William: Moving hydrogen from hype to hope. In: https://www.transportenvironment.org/newsroom/blog/moving-hydrogen-hype-hope, 5.2.2020, retrieved 25 February 2020

Williams, Bret: Norwegian company partnership to launch liquid hydrogen fuel cell cruise ship. In: https://www.hydrogenfuelnews.com/norwegian-company-partnership-to-launch-liquid-hydrogen-fuel-cell-cruise-ship/8539330/, February 13, 2020

World's First Hydrogen-Powered Cruise Ship Scheduled. In: https://www.maritime-executive.com/article/worlds-first-hydrogen-powered-cruise-ship-scheduled, 10-03-2017, retrieved 25 February 2020