【欧州】【海事】

Maritime Issues - Environmental issues/Utilisation of fuel cells: Ammonia-based engines for maritime transport: A solution to achieve CO2 emission reductions?

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【概要：Summary】

Almost 90% of the EU's external freight trade is seaborne and in intra-EU transport, short sea shipping represents 40% in terms of ton-kilometres. However, the problem of air pollution and CO2 emissions originating from shipping is of increasing concern. While the new global sulphur limit of 0.5% is applied as of 1 January 2020, also the shipping industry's GHG emissions need to be addressed. The shipping industry is under increasing pressure to reduce its carbon footprint. In its initial strategy to reduce GHG emissions from ships, the International Maritime Organisation (IMO) has set a goal of reducing GHG emissions from ships by at least 50% by 2050 compared to 2008. With the general perspective of tightening the restrictions of ship emissions and the possible introduction of a regulation on GHG emission limits for the maritime transport, the shipping industry is intensifying its search for technologies and alternative fuels to reduce its GHG emissions. The shipping industry is seeking commercially viable zero emission fuels and propulsion systems for general utilisation by 2030. Trials with alternative fuel options such as LNG, methanol, biofuels (including bio-methanol), LPG (Liquid Propane Gas), DME (Dimethyl Ether) ammonia, nuclear and hydrogen (including bio-hydrogen) are taking place. Currently, there are favoured options under consideration also for medium to long-term utilisation, including biomass-derived fuels, hydrogen and synthetic non-carbon fuels, like ammonia. The utilisation of ammonia is considered being one of the pathways towards zero-carbon emitting vessels. Ammonia could be utilised as a direct fuel for internal combustion engines and also in fuel cells. This report will focus on the latest state of development for ammonia as alternative fuel in maritime transport. However, the fact that ammonia is very toxic to aquatic life with long lasting effects will have to be carefully considered when using it as alternative fuel in maritime transport.

【記事：Article】

1. Considerations regarding alternative fuels in maritime transport

In April 2018, the International Maritime Organization (IMO)'s Marine Environment Protection Committee (MEPC) 72nd session adopted the initial IMO strategy on reduction of GHG emissions from ships, RESOLUTION MEPC.304(72). It aims at reducing the total shipping sector's GHG emissions by "at least" 50% by 2050, from 2008 levels. In a first step, the IMO introduced a new mandatory fuel consumption data collection system (IMO DCS).

Also the EU and its Member States are committed to significantly lower the GHG emissions in order to meet the Paris Agreement's target. The EU supports the IMO's GHG emission reduction strategy at international level. However, it has also introduced its own regional monitoring, reporting and verification system for CO_2 emissions from maritime transport as a first step towards reducing GHG emissions from maritime transport. Under the EU Regulation (EU) 2015/757 on the monitoring, reporting and verification of CO_2 emissions (MRV), as of 2018, large ships of 5,000 gross tonnage and above, using EU ports were required to report their verified annual emissions and other relevant information. Furthermore, the EU had put some pressure on the IMO to agree on a system for global shipping, comparable to the EU Emissions Trading System (EU-ETS). If this cannot be achieved, the European Commission intends to include shipping into the EU-ETS, starting from 2023. In fact, the recent amendment to the EU Emissions Trading System (EU-ETS) Directive under Directive (EU) 2018/410 underlines the need to act also on shipping emissions. The Directive (EU) 2018/410 states that the Commission should regularly review the IMO's action and calls for action to address shipping emissions starting from 2023.

The maritime transport industry supports the IMO's decarbonisation plans and also the shipping industry needs to find ways to apply alternative fuels and propulsion systems, because energy efficiency improvements alone will not be sufficient. In the transition to zero-carbon fuels and new propulsion systems, different solutions have different benefits for different types of ships and it is important that solutions are not only viable from a commercial perspective. They also need to be technically feasible and safely operated. While in short-sea shipping, like ferries, electrification is a possibility and hybrid and electric ferries already exist in Norway, Denmark and Sweden, other alternatives are needed for deep-sea vessels.

Research, trials and even some applications of alternative fuel options such as LNG, methanol, biofuels (including bio-methanol), LPG (Liquid Propane Gas), DME (Dimethyl Ether) ammonia, nuclear and hydrogen (including bio-hydrogen) are taking place. The simplest solution identified so far for deep-sea vessels is a form of liquid fuel to replace heavy fuel oil.

Currently, there are three options considered viable, including biomass-derived fuels, hydrogen and synthetic non-carbon fuels, like ammonia. In December 2017, the maritime classification society Lloyd's Register and the commercial advisory service University Maritime Advisory Services (UMAS) published a study entitled "Zero-emission Vessels 2030. How do we get there?" They aimed at identifying what needs to be in place to make zero emission vessels (ZEVs) a competitive solution. The study concluded that from a financial perspective, for the time being, biofuel consistently outperforms other zero-emission alternatives. Hydrogen and ammonia were described as being "the middle ground", as they involve higher capital costs in terms of storage – particularly when used with fuel cells.

None of the ZEVs are estimated to be more competitive like ICEs of conventional shipping before 2030. However, hydrogen and other non-carbon fuels like ammonia seem to have the highest potential as a long-term solution.

2. Ammonia for utilisation in combustion engines and fuel cells for maritime transport

The potential of ammonia (NH_3) as a fuel was demonstrated as early as 1822, when ammonia was used to fuel a gas locomotive. Research of the ammonia combustion process has been going on since the 1930s. However, during the last decade research on ammonia has again gained interest as a solution in the light of the search for alternative fuels in maritime transport. Ammonia gives a clean combustion without generating CO_2 or SOX. It is easily liquefied by compression and is non-explosive, unlike hydrogen, which cannot easily be transported and stored. The widespread use of ammonia in industrial processes as an agricultural fertilizer and immediate power generation makes it a commercially attractive product. An established and reliable infrastructure already exists for storage and distribution of ammonia.

When generated by renewable energy sources, ammonia has no carbon footprint and emits almost no CO2, SOx or particulate matter when burned in engines. Although ammonia is a GHG in the sense that it absorbs infrared radiation, ammonia is short-lived and broken down too easily to ever be a problem like CO2 or methane. In fact, the large difference for CO2 is the long time period is takes to remove CO2 from the atmosphere, which is 20–200 years for 65% to 80% of CO2. The rest of CO2 is removed in even slower processes that take up to several hundreds of thousands of years. Also methane has a comparatively longer lifetime than ammonic of about 12 years, and methane is roughly 30 times more potent as a GHG than CO2.

Instead, ammonia has a lifetime in the atmosphere of only one week. Since ammonia is so short lived in the atmosphere and reactive, it has an effective global warming potential of zero, despite absorbing the right frequencies of infrared radiation to otherwise be a GHG. For global warming discussion, ammonia has a net cooling effect since the increased formation of particulates in clouds and haze. Furthermore, ammonia is expected to find favour as a fuel in the maritime industry as it does not need cooling, unlike LNG or liquid hydrogen. It also has a higher energy density than liquid hydrogen, making it simpler to store in the quantities needed to deep-sea ships.

In October 2019, a team of the Department of Management, Technology and Economics at the Swiss Technical University at ETH Zurich investigated possibilities towards emission-free shipping based on shipping activities in the North and Baltic Seas as well as the infrastructure, costs of new fuels and storage options. Christian Oldendorff, entrepreneur and co-owner of German shipping company Reederei Nord, commissioned the team to undertake the study on new fuels. According to the study's lead author Petrissa Eckle, the team investigated routes in the North and Baltic Seas. According to the study results, zero-emission propulsion systems in the form of electric motors, fuel cells or combustion engines powered by ammonia have the greatest potential in the near future.

The most suitable source of energy depends on the type of ship and length of the route. In the North and Baltic Seas, ships with electric propulsion systems are already being used for short distances. For long distances, the report considers ammonia to be a suitable option. However, due to its toxicity, its use as a fuel is not currently permitted. As for hydrogen, there is still a lack of capacity for liquefying and transporting; testing will soon begin on the first cargo vessels.

In June 2019, the Netherlands-based C-Job Naval Architects published the findings of a study, which determined that ammonia is "safe and effective" as a marine fuel. According to the study's author, C-Job Naval Architects' Niels de Vries, it also has the potential to be at similar price ranges as conventional oil-based bunker fuel. In order to accelerate the adoption of ammonia as fuel in maritime transport, it can be used with marine diesel as a dual fuel solution in internal combustion engines. According to de Vries, for reliability reasons, ships can stick to diesel as a pilot fuel, and if ammonia cannot be supplied as a fuel, diesel can be used instead. Rules, regulations and procedures need to be further developed and adapted, while the toxicity of ammonia should be handled properly. In fact, ammonia is very toxic to aquatic life with long lasting effects and this will have to be carefully considered when using it as alternative fuel in maritime transport. Therefore, a lot of regulatory and safety related steps have to be taken before ammonia as a marine fuel can actually be widely used.

3. The projects for utilising ammonia as a marine fuel

3.1. MAN marine internal combustion engine

Ammonia and hydrogen are currently the most discussed potential alternative fuels that the shipping industry could switch to in medium and long-term. However, commercially viable vessel designs have yet to emerge. The introduction of ammonia as a marine fuel will require the active engagement of technology companies, such as engine manufacturers. MAN Energy Solutions has become already active in research and development of a marine two-stroke internal combustion engine running on ammonia, with diesel as pilot fuel.

On 15 January 2020, MISC Berhad, Samsung Heavy Industries (SHI), Lloyd's Register and MAN Energy Solutions announced they would cooperate in developing an ammonia-fuelled tanker in a joint development project (JDP) to support shipping's drive towards a decarbonised future. The companies stated that "ammonia is just one of the pathways towards zero-carbon emitting vessels" and that the shipping industry would "need to explore multiple decarbonisation pathways". The intention is to make deep-sea Zero-Emission Vessels (ZEVs) a reality within this decade.

The President & Group CEO MISC Berhad Yee Yang Chien commented that the global maritime industry needed to be more collaborative in defining its future together, rather than being confrontational and fragmented in the industry's efforts. Joon Ou Nam, President & CEO of Samsung Heavy Industries, stated that new zero-carbon fuel technologies, such as ammonia fuel, are to be brought on the table, in order to take action proactively on maritime GHG emissions in accordance with the IMO's ambitious road map.

Lloyd's Register's Marine & Offshore Director Nick Brown added that the IMO's 2050 GHG ambitions require substantial and collaborative input from all maritime stakeholders. Senior Vice President, Head of Two Stroke Business at MAN Bjarne Foldager Jensen stated that MAN looks forward to adding ammonia to the list of emission-friendly fuels.

3.2. ABS, MAN and SDARI to develop ammonia-fuelled feeder container vessel

ABS will advise on compliance and safety considerations as MAN Energy Solutions (MAN) and the Shanghai Merchant Ship Design & Research Institute (SDARI) develop a low-emission feeder container vessel. In May 2019, the companies signed the joint development project (JDP), which aims to produce designs for an ammonia-fuelled Chittagongmax container carrier of 2700 TEU capacity. SDARI will develop the ship design and engineering, which will utilize MAN's dual fuel technology. ABS will assess safety-related issues and contribute to the development of rules and standards in relation to ammonia as a fuel. The second phase of the JDP will move to engagement with owners to develop designs tailored to their specific operational requirements.

According to MAN Energy Solutions, ammonia could become a potential future energy-carrier of renewable primary-energy sources such as wind, hydro or solar.

3.3. Ammonia for fuel cell utilisation: The ShipFC project

Ammonia is considered being an abundant energy source, which can also easily be generated from renewable resources, making it one of the fuels that will likely meet part of shipping's future energy demand. Fuel cell research could involve also ammonia instead of hydrogen for fuel cells.

The ShipFC consortium of 14 European companies and institutions, co-ordinated by the Norwegian cluster organisation NCE Maritime CleanTech has been awarded $10 million from the European Union to install the world's first ammonia-powered fuel cell on an offshore vessel for its ShipFC project. The ammonia fuel cell system will be installed on the Viking Ene*rgy* in late 2023. The EU supports this initiative under the Horizon 2020 research and innovation programme, under its Fuel Cells and Hydrogen Joint Undertaking (FCH JU). The ShipFC consortium focuses on the retrofit of the offshore vessel Viking Energy, owned and operated by Eidesvik and on contract to energy major Equinor, with a large 2MW ammonia fuel cell. It is anticipated that the vessel will be able to operate solely on the clean fuel for up to 3,000 hours a year. The key goals of the programme are to demonstrate and ensure that long-range zero-emission with high power on larger ships is possible and that a large fuel cell can deliver total electric power to shipboard systems safely and effectively. This is the first time an ammonia-powered fuel cell will be installed on a vessel.

The fuel cell will be tested on land in a parallel project and the shipside ammonia system will be supplied by Wärtsilä. Norwegian crop nutrition company Yara has been contracted to supply the green ammonia, which will be produced by electrolysis and delivered to Viking Energy in containerised form to enable easy and safe refuelling.

The project represents the latest stage in the long running collaboration between Equinor, Eidesvik and Wärtsilä. Viking Energy was the first LNG powered ocean-going vessel in 2003, and Eidesvik and Wärtsilä also collaborated on the 2009-built Viking Lady, another LNG-fuelled vessel, which also featured fuel cells and marine batteries.

Another part of the ShipFC project will perform studies on three other vessel types, namely offshore construction vessels and two cargo vessel types, to demonstrate the ability to transfer this technology to other segments of the shipping industry. The ShipFC project complements the portfolio of maritime projects supported by FCH2 JU: MARANDA and FLAGSHIPS, which use hydrogen as a fuel and Proton Exchange Membrane Fuel Cells.

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