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Editorial of special issue of "International shipbuilding Progress" on Maritime Hydrogen

As we write this editorial, the coronavirus has been declared a pandemic by the World Health Organization, and it is spreading at dramatic speed in parts of the world.

It would be difficult not to relate the current situation to the climate emergency that we are also facing in this same moment. While the time scales are different, the basics of the phenomenon are similar: experts are repeating that it is a major threat, and that once it has started, it will be difficult, if not impossible, to stop it before it dramatically impacts our lives. As current effects are small and the costs of acting are high, most world leaders are stalling, waiting for others to make the move. However, studies have shown that the costs of acting now is far less than the costs required for climate adaption in the long run.

The shipping industry makes no exception. Developments are not unseen, but slow, and mostly incremental. While there has been some efforts in reducing speed and moving towards cleaner fuels (mostly liquefied natural gas), these changes are still only applied in few cases, and will not be sufficient to shift the tide. Doing so would require the use of more innovative, disruptive solutions.

Hydrogen is commonly referred to as a future renewable energy carrier as well as chemical building block for a sustainable society. Although produced primary from fossil sources today, its potential lies in its generation using water and renewable electricity. It can be used to fuel conventional propulsion systems based on internal combustion engines, but most importantly newer technologies like fuel cells. This ensures continuity with the past and the potential to enable synergic effects with new, more efficient ways of converting energy on board ships. From a maritime perspective, and besides the superior fuel cell performance in terms of higher efficiencies and zero hazardous and greenhouse emissions, fuel cells are expected to enhance the holistic ship performance with low noise emissions, graceful performance degradation, reduced maintenance and the absence of a zero point of failure.

While hydrogen can hardly be described as the unchallenged solution for the future of shipping, there are definitely signs of rising interest, both from the scientific community, and from the industry. Notable projects include:

– Maranda: Installation of a hydrogen-fuel cell propulsion system on a research vessel in Finland;
– HySeas III: Development of a sea-going vehicle and passenger ferry at the Orkney Isles;

– FLAGSHIPS: Demonstration project with a river push-boat in Lyon and a passenger and car ferry in Stavanger;
– ELEKTRA: Development of an electric canal tugboat in Germany;
– ISHY: Development of a maritime fuel cell system and bunkering infrastructure, development of a hydrogen-powered inspection craft, crew transfer vessel and inland ship.
– H2SHIPS: Hydrogen-powered port vessel in Amsterdam and hydrogen bunker barge in Oostende;
– ZEFF: Development of a zero emission fast ferry;
– SeaShuttle: Development of a hydrogen-fuelled short-sea container ship.

These developments certainly justify a special issue of the International Shipbuilding Progress journal on hydrogen in shipping, with the aim of collecting the latest developments of the major researchers involved in this field. The issue comprises contributions ranging from a life cycle assessment to an outlook of the developments in the next decades.

The potential of hydrogen to reduce the life cycle emissions of ships is shown in a contribution by Mestemaker et al. They compare a hydrogen driven dredger to state-of-the-art configurations fuelled with liquefied natural gas in their contribution '*Designing the zero emission vessels of the future: technologic, economic and environmental aspects*'. Moreover, the authors point out the need for policies to stimulate a level playing field for the maritime energy transition.

The application of hydrogen in a maritime environment still faces a number of challenges. These include, for example, save storage of hydrogen with an acceptable volumetric density, as well as issues related to bunkering, handling and use on board. There are currently no prescriptive classification rules for the use of hydrogen as a marine fuel. Therefore, all hydrogen-fuelled ships need to be classified using the alternative design process in the International Code of Safety for Ship Using Gases or Other Low-flashpoint Fuels (IGF Code) in practice. This requires a detailed design of the hydrogen systems on board.

Hydrogen may be stored as a compressed gas, cryogenic liquid, in metal hydrides or even chemically bonded in the form of hydrocarbons, alcohols, ethers and ammonia. Taccani et al. describe a pressurised hydrogen storage system for application on ships in their study '*Hydrogen storage analysis for small fuel cell powered ferries*'. Moreover, the bunkering process from shore is simulated to predict the time required for fuelling.

The use of hydrogen as a marine fuel enables the use of fuel cells on board ships to generate power with high efficiencies and no hazardous emissions. Since fuel cell systems have few moving parts, they produce little noise and vibrations and are less prone to mechanical degradation. Moreover, single point failures are less likely to occur due to their modular nature. However, the power class of today's fuel cell technology is typically still limited and capital cost is relatively high. In addition, the technology still has to demonstrate its resilience to the harsh marine conditions with acceptable life span.

The automotive industry traditionally opted for the low temperature proton membrane electrolyte membrane fuel cell technology, among others for its high power density and fast load transient capabilities. For ships, other fuel cell technologies may be considered as well, as the operational requirement are distinctively different. This is especially the case if the hydrogen is chemically bonded in a molecule. The study of Diesveld and de Maeyer, ‘Maritime fuel cell applications: a tool for conceptual decision making’, describes the development of a tool to compare different fuel cell technologies for specific applications.

An important question remains when hydrogen-fuelled vessel become an accepted, economical solution in shipping. Important drivers are the greenhouse gas intensity, emission costing, fuel cost, capital cost and the availability of a bunkering infrastructure. The contribution from Köhler, titled ‘*Zero carbon propulsion in shipping – scenarios for the development of hydrogen and wind technologies with the MATISSE-SHIP model*’ describes a model that can be used to forecast the adoption of different fuels.

Given the very relevant full-scale Maritime Hydrogen passenger ferry initiatives in Norway, a Special Issue on Maritime Hydrogen would not be complete without a Norwegian research contribution. Aarskog et al. show how the energy system can be scaled for specific operational requirements in their paper titled ‘*Energy and cost analysis of a Hydrogen driven High Speed Passenger Ferry*’.

The collection of articles in this special issue point at the large potential of hydrogen and hydrogen-based fuels to reduce greenhouse gas and hazardous air pollutants in shipping. This is partly due to the low carbon intensity of hydrogen from renewable sources and partly because it enables the adoption of advanced energy conversion technologies. The issue also points out a number of important challenges for wide adoption in the maritime sector, such as the storage and bunkering of hydrogen, the need for prescriptive classification rules and stimulating policies for low emission shipping.

Although definitely not a silver bullet solution to the maritime energy transition, hydrogen can definitely provide an interesting solution for specific ship types. We envision that many of the challenges can and will be addressed in the next decade, as renewable hydrogen becomes increasingly available at a more competitive price level and hydrogen storage and fuel cell technology matures. As responsible Editor for this Special Issue, Klaas Visser thanks our guest-editors, Francesco Baldi and Lindert van Biert, for their excellent job in creating this Special Issue. With their dedication and inspiration they have navigated science and society further on course towards emission free sustainable shipping, as an indispensable link in global logistics, transport and security.

Delft, 15 April 2020

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