ALTERNATIVE FUEL FOR MARITIME INDUSTRY

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1-ABSTRACT: *Maritime shipping is an important component of the global market, yet the burden it places on the biosphere is growing rapidly. Approximately one-quarter of all emissions from the international transportation sector are attributed to maritime shipping. The shipping industry, which emits almost one billion tons of CO2 annually, is under great pressure to decarbonize in the next decades. As the use of fossil fuels becomes increasingly constricted, there is a growing demand for alternative fuels at sea. Several initiatives have proved the use of compressed hydrogen as a roadway transportation fuel. Green hydrogen has the potential to significantly reduce carbon footprints in the shipping industry. The utility of hydrogen as a fuel for seagoing ships is studied in this paper. Because hydrogen has a low volumetric energy density under typical settings, efficient storage of this fuel is critical. The fundamental processes of hydrogen utilization are described, as well as hydrogen synthesis from fossil and renewable sources. The discussion will center on whether and how hydrogen could be used to replace fossil fuels in long-distance sea cruises. This research also offers a conceptual overview of various hydrogen storage mechanisms. The main challenges and roadblocks to developing hydrogen storage for the maritime industry are investigated.*

KEYWORDS: **Hydrogen Economy, Fuel Cell, Green Hydrogen, Blue Hydrogen, Gray Hydrogen, Electrolysis, Inexhaustible Energy, In exhaustible Energy, Hydrogen Storage, Energy Carrier, Decarbonization**

INTRODUCTION

Background The maritime industry faces significant challenges. Stringent environmental regulations, uncertainties regarding the impact of globalization, geopolitical impacts, and digitalization and cyber risks are multiplying the already complex operational scenario. At the same time, shipping stakeholders are trying to identify and deploy the most appropriate decarbonization strategies by examining propulsion efficiency and fuel options. However, the most significant threat to the planet is global warming, caused primarily by anthropogenic emissions. The shipping industry is responsible for approximately 3% of the world's carbon-dioxide (CO2) emissions caused by human activities; A more sustainable future requires urgent action. In April 2018, the IMO agreed to align its regulations with the goals of the UN's Paris Agreement and reduce GHG emissions from shipping. IMO's initial GHG-reduction strategy (Resolution MEPC. 304(72), which includes the ambition to reduce annual emissions by at least 50% by or around 2050 (compared to 2008), providing a large and signals the beginning of international change. fuel. This strategy has been revised during MEPC 80 in 2023, significantly increasing the level of ambition to reach net-zero GHG emissions by or around 2050. With the average commercial ship's lifespan exceeding 20 years, owner uncertainty about whether to invest has put a halt to many new-building decisions. Pressure is building to begin the transition as quickly as possible and regulatory developments in the EU indicate that the industry may need to respond quickly. Hydrogen fuel is a new renewable feedstock for producing other types of fuels and chemicals, and it can be used directly as a fuel or as a clean-energy source. Currently, design Builders, owners and operators consider hydrogen (H2) as an environmentally friendly alternative source of energy to traditional fossil fuel use. This study provides information on the properties, production, suitability and sustainability of hydrogen use as marine fuel. Fuel all stake holders and regulators. In addition, it provides a comprehensive analysis of the existing regulatory framework, techno-economic assessment and a series of detailed risk-based case studies highlighting the commercial and safety implications of the use of hydrogen as marine fuel

Scope and Objectives:

The scope and objectives of this study examine the technical issues, regulatory framework and state of play for the application of hydrogen as a fuel. They address the possibility of using hydrogen as a fuel in shipping, which was part of the EMSA tender EMSA/OP/43/2020 for 'Study on alternative fuels/electricity for shipping' and which was supported by ABS, CE Delft and Arcsilea. Proposal of 27 January 2021. The scope specifically addresses the tasks of the EMSA tender:

- Providing a state of the game on the use of alternative fuels/electricity in the shipping sector. (See Section 2 of this report for findings under this work.)safety and environmental standards/regulations/guidelineson production, transportation and distribution, bunker

- To provide a detailed description of existing ing and onboard storage, handling and alternative use. Fuel/electricity for shipping, as well as those currently under development. (See Section 3 of this report for findings under this task.)
- To provide safety assessment of fueled/powered cargo and passenger vessels engaged in small sea (coastal) or high seas trade. In total, four security assessments are offered. If a ship can accommodate cargo and passengers (for example, a Ro-Pax ship), without prejudice to conducting the two remaining assessments for the cargo ship, only one safety assessment is required (small sea For). The simultaneous transportation and use of fuel (or energy carrier) must be considered. (See Section 4 of this report for findings within this work). Radar sensors

Use of hydrogen in the shipping sector

This section provides an overview of the status of using hydrogen as a fuel in the shipping sector. It is divided into the following sections

- An overview of the properties of hydrogen, including details of the production path, maturity level and further development. Which includes an overview of current and future supply in the EU and around the world and in relation to other regions.
- Suitability details include storage and production, onboard fuel supply, internal combustion engines, machinery space and fuel cells.
- Costing and development of hydrogen systems for marine applications, including technical- at total cost of ownership (TCO) for many vessel categories. Includes economic analysis.

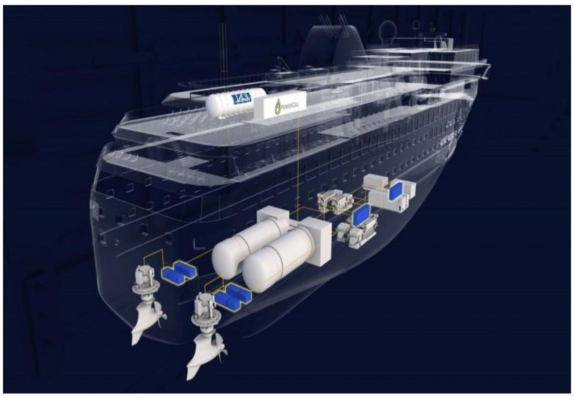

Fig No 1: hydrogen in the shipping sector

Hydrogen Properties and Production Technologies:

Hydrogen is a widely used, commercially available chemical. It is a building block for many chemical and pharmaceutical products, notably ammonia used as a fertilizer in food crops. Global production of hydrogen in 2021 was approximately 94 million tones (MT), of which only 0.04 (35,000 tones) was 'green' hydrogen produced from electrolysis (IEA, 2022). Broadly speaking, hydrogen was used in refineries, fertilizer production, and other industrial sectors. For comparison, annual consumption of conventional residual and 285 metric tons per year, or the equivalent of about 95 metric tons/year of hydrogen based on its low heating value (see Table 1). This section of the study examines the properties of hydrogen its production pathways, the maturity level of production technologies and ongoing pilot projects The findings of this section are presented.

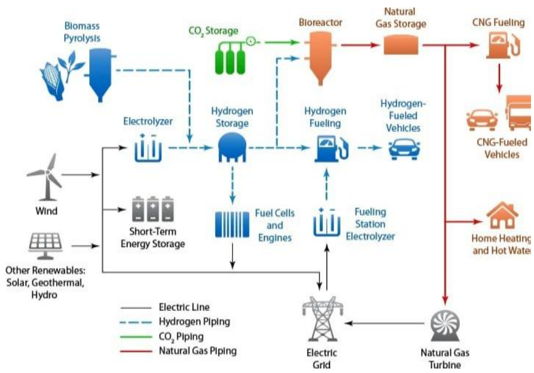

Fig No 2: Properties and Production Technologies

Production Paths:

Currently, hydrogen is mostly produced by Steam Methane Reforming (SMR) or Autothermal Reforming (ATR) of natural gas (Yousef Biser, 2017). In 2021, 62 hydrogen was produced from natural gas, 19 from coal, 0.7 from oil, 0.04 from electricity (water electrolysis) and 18 as a by-product of naphtha reforming in refineries (IEA, 2022). Hydrogen made from fossil sources is called 'grey' hydrogen. When CO2 emissions from the process of converting natural gas are captured and stored, it is commonly called 'blue' hydrogen. Only 0.7% of global hydrogen production in 2021 was blue hydrogen (IEA, 2022)

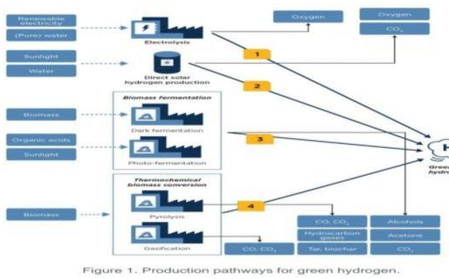

Fig No 3: production pathways for green hydrogen

Availability:

To produce enough green hydrogen to power maritime shipping, both its production capacity – and renewable electricity – will have to undergo a tremendous increase. The current global capacity of wind and solar parks is relatively low; This is even more true for global electrolyze capacity4 It should also be taken into account that the demand for renewable electricity and green hydrogen is expected to grow in almost all economic sectors (see subsection 2.3.3), so the associated production capacity will need to be increased to levels far beyond those required for the marine sector. Is. HOWTO MAKEE IT MORE EFFICIENT DURING ROLLING

Onboard Fuel Supply:

The purpose of a fuel supply system (FSS) or fuel gas supply system (FGSS) is to deliver fuel at the correct temperature and pressure to its consumer, fuel cell or internal combustion engine. The use of low-flashpoint fuels and gases makes fuel supply and consumer systems more complex and creates greater dependencies between major systems than conventional fuel systems.

The major elements of onboard hydrogen installation are the fuel-storage tank, the fuel supply system and the safety-valve system, commonly known as a gas valve unit (GVU) or gas valve train (GVT). For liquid fuels this is called the fuel valve train (FVT). The fuel supply system needs to be integrated with the tank systems - see Figure 7 and Figure

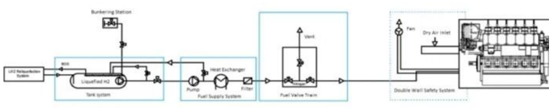

Figure 7. Schematic onboard hydrogen installation of the FSS for a 2-stroke Diesel-cycle hydrogen engine

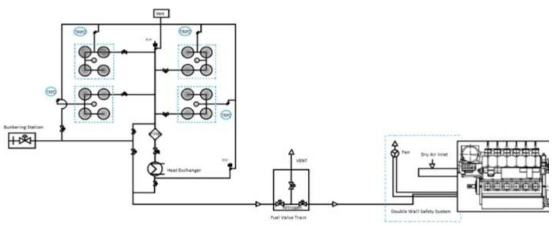

Fig No 4: Schematic onboard hydrogen installation of the FSS for a 2-stroke Diesel-cycle hydrogen engine.

8 below for the diesel cycle engine system and Otto cycle engine system. Figure 8 depicts a fuel supply system for a small ship installation that is not equipped with a bottle emptier, i.e., the tanks are not completely emptied before refilling For hydrogen, the FGSS needs to be designed very differently depending on whether it is stored in liquid or gas form. In a liquid-storage system, hydrogen will be pressurized into a cryogenic and liquid state; After this the temperature will be controlled. Both pressure and temperature will need to be controlled according to consumer needs.

Benefits of hydrogen in shipping

1. Zero emissions at the point of use: Hydrogen fuel cells emit only water vapor, eliminating CO_2 and harmful particle emissions.

2. Higher energy density: Hydrogen provides more energy per kilogram than diesel, allowing longer trips with less weight.

3. Compatibility with renewable energy: Hydrogen can be produced using renewable energy sources, which will reduce the shipping industry's dependence on fossil fuels.

4. Low Noise: Fuel cells produce less noise than internal combustion engines, benefiting marine ecosystems sensitive to noise pollution. Expected Benefits

Current Progress and Case Studies

1. Hydrogen-powered ferries and small ships: Several hydrogen-powered ferries have been launched in areas such as Norway, Japan, and California. These ships serve as pilot projects to test the feasibility of hydrogen in marine applications.

2. Partnerships and regulations: Companies and governments are collaborating to build hydrogen infrastructure at strategic ports. For example, the EU's Green Deal includes hydrogen as a key component for future transportation, with incentives for clean energy adoption.

3. Dual-fuel engines: Some projects are exploring engines that can switch between hydrogen and other fuels, making the transition to hydrogen more flexible while reducing emissions. Flooding or structural stress is detected in real time, preventing catastrophic damage and ensuring the safety of the crew and the ship.

Challenges and Considerations

1. Storage and transportation: Hydrogen has a lower energy density by volume than conventional fuels, requiring larger storage tanks or advanced cryogenic storage systems, which add weight and space challenges on ships.
2. Cost: Hydrogen production, especially green hydrogen, is currently more expensive than conventional fuels, although costs are expected

to decline with advances in production technologies.

3. Infrastructure: Few ports currently have hydrogen refueling infrastructure, which limits the range and adoption of hydrogen-powered ships.
4. Safety: Hydrogen is highly flammable, requiring special handling and storage measures to ensure safety on board ships and in ports or replacement of damaged ship equipment and parts.

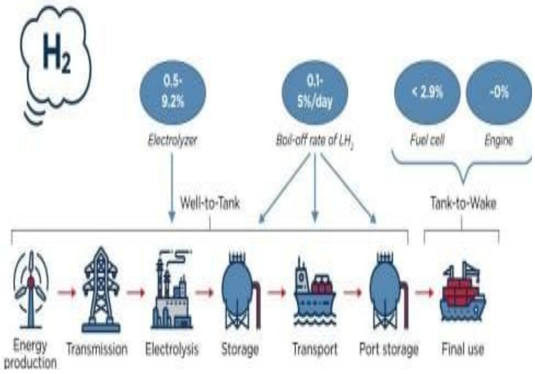

Fig No 5: Challenges and Considerations

CONCLUSION

Aligning with global efforts to reduce greenhouse gas emissions, hydrogen fuel represents a promising solution to decarbonizing the shipping industry. Its advantages include zero carbon emissions, abundant availability, and the ability to support energy independence when used in fuel cells. However, challenges such as high production costs, storage and transportation complexities and the need for extensive infrastructure development must be addressed.

Advances in green hydrogen production technologies, increased investment in hydrogen-powered ships, and international collaboration on regulatory frameworks are essential to unlock its full potential. With these efforts, hydrogen fuel can become a viable and sustainable energy source for the marine sector, driving the transition toward a cleaner, greener future.

water level, pressure, strain gauges, ultrasonic, radar, flow and temperature sensors – throughout the cofferdam, it is possible to continuously monitor critical parameters and detect overload conditions in real time.

This system increases the safety of both the ship and its crew by warning of potential hazards, such as water ingress, excessive pressure, or structural stress, before they turn into catastrophic failures. Additionally, the system supports efficient resource management by reducing unnecessary maintenance and downtime, improving decision making with reliable data, and optimizing vessel performance.

Furthermore, the advanced technology employed, including dynamic calibration, real-time data processing and integration with existing ship systems, ensures that the sensors adapt to different operating conditions, such as rolling or environmental changes, without generating false alarms. This adaptive approach, combined with redundancy in sensor placement, increases the reliability and accuracy of overload detection.

Ultimately, sensor systems to detect overloads in ship cofferdams provide long-term benefits, including improved safety, lower operating costs and increased structural longevity. The continued use and refinement of such systems will contribute to safer, more efficient maritime operations, ensuring that ships operate within safe parameters and are prepared for any unexpected risks

REFERENCE

1. *"Handbook for Hydrogen-Fueled Ships"* by DNV - This comprehensive guide provides detailed information into hydrogen storage, fuel systems and operational considerations for hydrogen-powered ships. It also includes safety and regulatory guidelines tailored for marine applications.

2. "Challenges in using hydrogen for marine applications" (Energy ^~^ Environmental Science, Royal Society of Chemistry) - This review article covers key processes such as hydrogen production, storage methods and challenges of implementing hydrogen systems. Does.

3. In maritime contexts. It provides insight into infrastructure needs and security measures Research by DNV GL and other academic papers - Studies such as DNV GL focus on hydrogen storage technologies (compressed, liquid and metal hydrides), their integration into ships and their impact on ship design and operation.

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