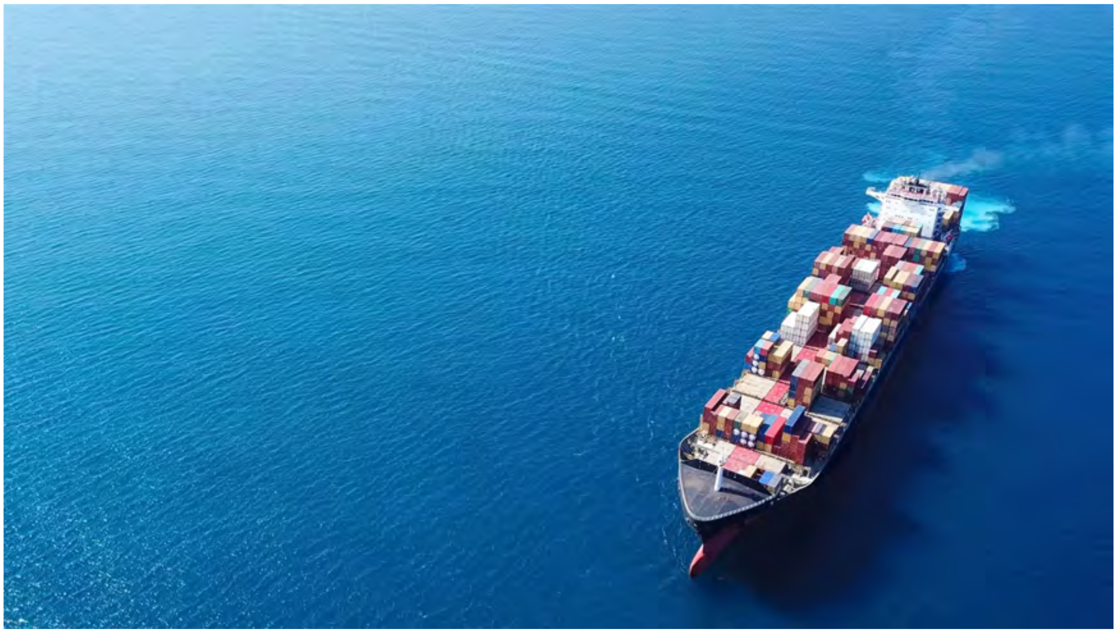
Ammonia as a Ship's Fuel



Introduction

The global shipping industry is at a crossroads, grappling with the urgent need to reduce carbon emissions by changing to greener fuel options. Ammonia has emerged as a promising candidate for fueling ships in this quest. Consortia, including designers, classification societies and shipyards have also unveiled designs for ammonia-fueled ships. Recent developments, such as the successful combustion tests conducted by MAN Energy Solutions (MAN ES) on the 4T50ME-X two-stroke test engine in Copenhagen, highlight the potential of ammonia as a marine fuel. This article examines the prospects of ammonia as a ship's fuel and its potential to transform the maritime sector by providing a carbon-free alternative. It explores the safety considerations and technical challenges of adopting ammonia as a marine fuel.

Ammonia: A Zero-Carbon Fuel with Promising Results

Ammonia is a globally traded commodity, being frequently loaded and unloaded between terminals and ships. However, for ammonia to become a commercially-viable long-term shipping fuel option, comprehensive supply-side infrastructure would need to be built, and stringent new safety regulations be developed and implemented.

Ammonia offers a range of advantages as a marine fuel, including its carbon-free nature and the absence of CO2 emissions during combustion. MAN ES envisions ammonia to become the leading alternative fuel by 2050, comprising approximately 27% of the fuel mix for large merchant marine ships. Meeting this demand would require millions of tons of ammonia production, both blue and green ammonia[1].

Characteristics of Ammonia

Ammonia, a compound of nitrogen and hydrogen (NH_3), is a colourless gas with a distinctive pungent odour at atmospheric pressure and ambient temperatures. However, when subjected to higher pressures, ammonia transforms into a liquid state, making it more convenient for transportation and storage. In terms of heating value, ammonia is comparable to methanol. Like many alternative fuels, ammonia exhibits a lower energy density than petroleum-based fuels, necessitating approximately 2.4 times more volume to generate the same energy content.

Ammonia is toxic to humans, and exposure must be limited to permissible limits to ensure the safety of personnel onboard the vessel. Ammonia can irritate the eyes, lungs, and skin even at low concentrations. However, it poses an immediate life-threatening hazard at high concentrations or through direct contact. Symptoms of ammonia exposure include difficulty in breathing, chest pain, bronchospasms, and, in severe cases, pulmonary edema, where fluid accumulates in the lungs and can lead to respiratory failure. Contact with concentrated anhydrous ammonia on the skin can cause severe chemical burns. At the same time, exposure to the eyes can result in pain, excessive tearing, corneal injury, and damage to the iris and cornea, potentially leading to glaucoma and cataracts. Acute exposure to liquid anhydrous ammonia can cause redness, swelling, skin ulcers, and frostbite. Given these risks, and given that ammonia fuel technology is still relatively new, it will be important to ensure that there is good cooperation across the industry, and that lessons are learned and shared quickly as the technology develops.

Addressing Technical Challenges and Ensuring Safety

While ammonia holds significant potential as a marine fuel, it also poses technical challenges that must be addressed. These include its toxicity, corrosive nature, and lower energy density than conventional fuels. Nonetheless, ongoing research and development endeavours are focused on finding innovative solutions. Design improvements like double-wall barriers and ammonia catch systems are being explored to mitigate safety concerns and prevent ammonia leaks. The industry is also committed to strict adherence to safety protocols and the implementation of robust hardware designs to enable the use of ammonia as a fuel across various types of vessels.

Ammonia-fuelled ships require different or additional concepts in ship designs, particularly in several key systems. These include the ammonia fuel containment system, the associated ammonia bunker station, and transfer piping. A fuel supply system and provisions for handling boiloff gas, reliquefaction, gas valve units/trains, nitrogen generating plants, vent piping systems, and masts are necessary. Additional equipment may be required to manage tank temperatures and pressure depending on the type of ammonia tank used. Other considerations for ammonia-fuelled ships encompass deluge systems, personal protective equipment, independent ventilation for ammonia spaces, emergency extraction ventilation, and closed fuel systems.

Ammonia can be used for marine propulsion either in internal combustion engines or in a fuel cell. Majority of projects looking at ammonia as a maritime fuel have focused on conventional internal combustion engines. In this option, ammonia is burnt in an internal combustion engine with either compression ignition and a pilot fuel or spark ignition. In the case of fuel cells[2], ammonia can be used directly as a fuel source or divided into hydrogen and nitrogen in which case hydrogen becomes the principal fuel used.

Ammonia when used in internal combustion engines, possesses specific characteristics that affect its combustion process. It has a high auto-ignition temperature, a high heat of vaporization, and a narrow flammability range. As a result, when employed in two-stroke diesel cycle engines, ammonia typically necessitates pilot fuel injection to initiate ignition. High-pressure injection systems are required to minimize the release of unburned ammonia, which is toxic.

Further, when ammonia is combusted in compression ignition engines, it produces significant amounts of nitrogen oxides (NO_x) due to the elevated temperatures and pressures involved. Nitrous oxide (N_2O), a potent greenhouse gas with a global warming potential approximately 298 times greater than CO_2 over 100 years, is among the byproducts. Therefore, in the research and development of ammonia-fueled engines, it is crucial to develop appropriate combustion technologies and assess exhaust emissions to ensure compliance with regulatory limits for NO_x. Furthermore, investigations are necessary to address potential issues with N_2O emissions and control the levels of unburned ammonia to meet acceptable standards.

Current research and development efforts in the realm of fuel cells are rapidly gaining momentum, promising notable advancements in the efficiency and cost-effectiveness of ammonia-based fuel cell technologies in the foreseeable future. One notable development is the recent in principle approval of the ammonia fuel cell project led by ShipFC.

ShipFC is a 6-year project funded by the EU’s Research and Innovation programme Horizon 2020 under its Fuel Cells and Hydrogen Joint Undertaking (FCH JU). The project envisions to deliver the world’s first high-power fuel-cell to be powered by green ammonia.

Regulations

The IGF Code applies to ships covered by Part G of the International Convention for the Safety of Life at Sea, 1974 (SOLAS) Chapter II-1. It provides prescriptive requirements for the burning of natural gas. It allows for using other low flashpoint fuels as marine fuels as long as they meet the goals and functional requirements of the IGF Code and maintain an equivalent level of safety.

The IGF Code does not include specific prescriptive requirements for low flashpoint fuels such as ammonia. However, it offers a mechanism to approve alternative technical design arrangements for using low flashpoint fuels, pending acceptance by the Flag state. The process for approval of alternative technical design arrangements is outlined in Section 2.3 of the IGF Code. In the short term, discussions with the Flag Administration will be necessary to address the use of ammonia.

Certain Classification Societies provide "Alternative Fuel Ready" notations, including the "Ammonia Fuel Ready" notation, for vessels operating on conventional fuels but possessing design features suitable for future conversion to a specific gas or low flashpoint fuel burning concept. These design features are assessed to ensure their compatibility with the intended alternative fuel use.

Bunkering

Ammonia as a bulk commodity is frequently loaded/unloaded in the marine industry from terminals to ships and ships to terminals. The operation is similar to bunkering – the difference is that ammonia is transferred to a dedicated storage tank instead of a fuel tank. Liqiud ammonia, as a new bunker fuel, will require the establishment of provisions and guidelines for successful bunkering operations. It is anticipated that the previous experience from the fertilizer and chemical industry, as well as the recent development from LPG/LNG bunkering will help to establish the process.

The Global Centre for Maritime Decarbonisation (GCMD) along with its partners and consultants have completed a study aimed at creating guidelines for safe ammonia bunkering in Singapore. More than 400 potential risks were analysed, and the study proposed four technically-feasible operational concepts for ammonia bunkering: breakbulk and bunkering at anchorage, as well as shore-to-ship transfer and cross-dock transfer at two land-based sites.

The study found that the identified risks are manageable with appropriate mitigation measures. The level of individual fatality and injury risk was found to be influenced by factors such as ammonia flow rate, number of transfer operations, duration per transfer, and the length of piping and transfer arms. The study's findings will pave the way for GCMD to make further inroads, develop pilot , and the UK Club will continue to monitor developments to support its Members.

Conclusion

The bar is being raised when it comes to the requirements for shipping to decarbonise. See, for example, the UK's Club's roadmap for decarbonisation and the Club's article summarising the outcome of the 80th session of the IMO's Marine Environmental Protection Committee (MEPC), which established indicative checkpoints to reach net-zero GHG emissions from international shipping.

As a fuel that contains no carbon, ammonia holds significant potential as a sustainable fuel for ships, presenting a promising avenue for decarbonising the maritime industry. Advancements in technology and continuous research are tackling the technical obstacles related to using ammonia as marine fuel. However, the safe implementation of ammonia as a fuel requires a comprehensive evaluation of various aspects, including bunkering, storage, consumption, and the potential risks of leakage or system failure.

To ensure a successful transition to ammonia as a marine fuel, a prudent and safety-first approach is essential. This approach should prioritize crew training and the development of robust infrastructure to handle ammonia effectively. By taking these precautions, the maritime sector can confidently embrace ammonia as a widely adopted and environmentally friendly fuel option, supporting global efforts to combat climate change. The UK Club is committed to supporting its Members in their transition to alternative fuels and technologies, whether that be ammonia or one of the other new fuels - please see the UK Club's article outlining the various transitional fuels and tomorrow's zero emission options available. The UK Club is also committed to ensuring that its loss prevention, underwriting and claims handling services continue to evolve to reflect the emerging needs and requirements of these technologies. Further details are set out in the Club's Sustainability Report and on the Sustainability pages of the Club's website.