A new way of fuelling the marine industry

Niels de Vries from C-Job Naval Architects outlines why ammonia has a lot of potential as renewable fuel that will help ship operators eliminate harmful emissions

Reducing, and eventually eliminating, carbon dioxide and other greenhouse gas emissions is a key priority for the maritime industry. However, the main challenge for passenger ship operators is to do so as cost effectively as possible in order that they remain profitable and competitive.

Currently, many operators use conventional heavy fuel oil (HFO) to power their vessels because it's both cheap and widely available. But, HFO is a big pollutant and now that there are multiple rules and regulations limiting acceptable greenhouse gas emissions from ships, operators are now having to invest in exhaust gas treatment systems. Others are considering the relatively cleaner, yet more expensive, marine diesel oil (MDO), but will only switch if there is a mutual agreement that all vessel operators will do so. Another alternative is LNG, which is now being considered more widely in the maritime industry. Although the business case for using natural gas has a positive momentum, general availability remains a limiting factor.

So, how can operators achieve zero greenhouse gas emissions, while keeping costs sustainable and remaining competitive in the industry? What renewable fuel options would be suitable for them to use? Perhaps multiple renewable fuel solutions could be used to collectively fulfil the demand of the maritime industry? C-Job Naval Architects believes that another promising and viable option for a clean and renewable fuel may be right under our collective noses: ammonia.

Ammonia is a compound of two elements – hydrogen and nitrogen – which can be bonded together easily using the Haber-Bosch process. The method uses large-scale air separation methods to produce the required level of nitrogen atoms, while the hydrogen is produced by electrolysis of clean water. Thanks to the abundance of the sources for hydrogen and nitrogen, ammonia is a fully renewable fuel alternative that could be produced in great capacities with the overcapacity of wind and solar power.

In some cases, methanol could be a sustainable fuel alternative. Methanol, like ammonia, is also poisonous, but requires carbon dioxide to be separated from air to obtain a sustainable cycle. Carbon dioxide makes up 0.04% of the air, while nitrogen, which is required for ammonia, forms 78% of the air. Therefore, the production of methanol requires significantly more energy. Methanol can also be produced via biomass, but this requires substantial amounts of land, which will make both crops for fuel and crops for food more expensive. Biomass waste, which does not compete with food production, will not create sufficient methanol to supply the entire maritime industry.

> **"Ammonia is a fully renewable fuel alternative that could be produced in great capacities"**

Like pure hydrogen, ammonia is carbon free, but it offers a significantly higher volumetric energy density (LVH ammonia measures 12.7 gigajoules, whereas liquid hydrogen is 8.8 gigajoules). Ammonia can also be stored as a liquid below -33.4°C at atmospheric pressure (1 bar), or room temperature when at 10 bar. These conditions are far more acceptable and practical than with pure hydrogen, which is liquid at -253°C at 1 bar, or in compressed form at 350-700 bar. However, three times the volume of ammonia is required to provide the same energy as HFO, and the former is twice as heavy as the latter.

Another potential drawback is that ammonia is poisonous. However, industrial companies have been working with ammonia for more than a century, so this knowledge could be used to develop a safe and acceptable design for using it as a

C-Job Naval Architects has created an
initial concept design for an ammonia-powered ferry

marine fuel. Today, the fertiliser industry is the main consumer of ammonia, which is carried on ships in bulk loads of up to 60,000 tonnes. This existing infrastructure could be used to create bunker locations for ships' ammonia fuel in future.

Ammonia can be burned in an internal combustion engine, which requires a catalyst that partially breaks down the ammonia in hydrogen and nitrogen. The pure hydrogen will ignite and burn with ammonia, forming water, nitrogen and some nitrogen oxides (NOx). The combustion engine or gas turbine should be designed and operated to suppress these NOx emissions as much as possible. Furthermore, a DeNOx installation can be applied which consumes a small amount of ammonia.

One of the first ammonia combustion engines was used to power a car in 1935. Nowadays, numerous examples of ammonia, either as a dual or pure, fuel for transportation have been developed and executed safely. The transport and fertiliser industry's experience of handling and transporting ammonia should enable the next step to provide ammonia as a safe and renewable fuel for the maritime industry.

Alternatively, ammonia could be used in fuel cells. To use a fuel cell that runs on pure hydrogen – such as a proton exchange membrane fuel cell, or a solid oxygen fuel cell – one must first fully separate ammonia into nitrogen and hydrogen. The hydrogen is then used to generate electric power. However, new technologies show that a solid oxygen fuel cell running on ammonia could prevent the need for a cracker. Further studies will indicate which option is most suitable.

As ammonia is already produced and transported in large quantities, it's clear that the demand for ships fuelled by ammonia can be accommodated. Although the conventional ammonia production methods will eventually need to become sustainable, the available conventional ammonia production does enable a smooth transition away from HFO and other fossil fuels.

A full industry transition towards using ammonia as a fuel will take time, particularly as shipowners need a viable business case to ensure financial survival. However, increasing industry regulations and rising customer demand for shipowners to reduce their emissions will eventually motivate the industry to move to a sustainable future where ammonia is a viable renewable and sustainable fuel.

C-Job Naval Architects, which is the Netherlands' largest independent ship design and engineering company, is researching the concept of using ammonia as a renewable fuel for ships. The company has more than 100 in-house engineers operating worldwide and has created innovative designs for passenger ferries like TESO's Texelstroom. It offers a multidisciplinary approach for newbuild or converted/modified vessels. **C&F**