New Research Shows Benefits of Ammonia as Marine Fuel

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Ammonia can be safely and effectively applied as a marine fuel to reduce harmful emissions in the maritime industry, according to new research by C-Job Naval Architects in the Netherlands.

The research uses a new concept design, an ammonia carrier fueled by its own cargo, to study the concept of using ammonia as a marine fuel and achieve a significant reduction in greenhouse gas emissions in shipping.

Niels de Vries, Lead Naval Architect at C-Job Naval Architects and research lead, says: "Reviewing all ammonia power generation options, the Solid Oxide Fuel Cell (SOFC) is clearly the most efficient. However, it does have practical challenges as the power density and load response capability are not on an acceptable level yet. Therefore, in the short term applying the internal combustion engine is the way to go."

Key research findings include:

- A stepwise implantation could accelerate the application of ammonia as a marine fuel with in the first stage ammonia with marine diesel in an (Compression Ignition) Internal Combustion Engine (ICE). The second stage is an ICE using ammonia hydrogen mixtures followed by the third and final stage an SOFC using ammonia.

- Reviewing all remaining options (ICE, Proton Exchange Membrane Fuel Cell (PEMFC), Alkaline Fuel Cell (AFC) and SOFC) the SOFC is clearly the most efficient with a system efficiency of 53.9 percent. However, the SOFC does have practical challenges as the power density and load response capability are not at an acceptable level yet. Furthermore, despite the higher efficiency of the SOFC the total cost of ownership is still higher than the ICE based on these guidelines and estimations. The (two-stroke, low speed) internal combustion engine is second in efficiency with a system efficiency of 49.4 percent and therefore more efficient than the PEMFC and the AFC with a system efficiency of 44.5 percent and 44.8 percent respectively. Furthermore, the ICE is less expensive, more robust and has acceptable power density and load response capability. In the future further development of fuel cell technology might change the outcome of this evaluation. Based on the comparison the ICE is currently selected as best option for this project.

- Comparing the ammonia ICE option with the conventional fossil fuelled ICE option the technical performance is similar on power density, load response, part load performance, coping with marine environment and system efficiency. However, the conventional option has significantly more harmful emissions (with NOx assumed to be similar). Studying the cost based on equal range the ammonia powered option is clearly more expensive, about 3.2 times the expenses of the conventional option. This follows from a basic cost scenario of 850 euro per ton ammonia and 500 euro per ton low sulfur 0.5 percent HFO. Looking into future scenarios the ammonia powered option can be in similar cost range as the conventional option. This is the case when using 400 euro per ton ammonia, based on low electricity cost, combined with either a 500 euro per ton HFO with 100 euro per ton CO2 taxation or 811 euro per ton HFO without CO2 taxation.

- To safely handle ammonia (and hydrogen) as a fuel, spaces containing fuel lines should be equipped with ammonia (and hydrogen) detection combined with ventilation. Furthermore, in case of leakages remote operated shut-off valves should be installed to isolate the leakage and limit its impact. In line with this mitigation, redundancy in the fuel supply line should be arranged to ensure sufficient fuel supply for continuous operation in case part of the fuel supply is shut-off. In addition, in case of a blackout the main remote operated isolation valves should be installed with a fail close so when there is a loss of power the valves close automatically. As ammonia exposure to humans and the environment should be limited as much as possible, fuel lines should be routed with a sufficient distance from the shell, for example B/5 from the side. Where possible, fuel lines should be located in separate unmanned spaces. Where impossible, for example in the engine room, double-walled piping with pressure transmitters should be applied.

- The ammonia fuel treatment room and similar to other fuel systems, the engine room, should be equipped with fire detection and a fire fighting system. Furthermore, to monitor the conditions of the fuel, pressure transmitters, temperature transmitters and flow detectors should be added. In addition, to cope with overpressure a pressure relieve system should be installed.

- The main ship design consequences of the mitigations are on the arrangement due to the required separate spaces for the redundant fuel supply lines covering fuel trunks and fuel treatment rooms. Furthermore, the ventilation of the spaces containing fuel supply lines also require space for the intake and exhaust of air. The requirement of routing with sufficient distance from the side also impacts the effective use of available space of the vessel. All these factors increase the cost, especially the redundancy requirement. Therefore, implementation of 2 x 50 percent system capacity instead of 2 x 100 percent is considered to be important to limit these additional costs. The system design indicating the consequences on the arrangement is available separately upon request or can be found in the appendix of the link below.

- As an ammonia carrier is used for the ammonia fuel system the main issue of ammonia fuel storage is not addressed as it was covered by existing regulations. Therefore, it is recommended to further investigate ammonia fuel storage so it can be applied on other ship types as well.

Ammonia has so far been a little-considered future fuel for shipping, but it's proponents say it's one that does not suffer from the “which comes first, the chicken or the egg” dilemma that has plagued the adoption of LNG as bunker fuel.

For LNG, the dilemma has been that shipowners have been reluctant to make the switch to LNG as bunker fuel in the absence of ports around the world able to supply it. Yet, the development of the required infrastructure is dependent on such demand. As ammonia is already produced and transported in large quantities around the world, bunker supplies could be readily accommodated, though of course it will have to be expanded once the first ammonia powered vessels are realized, says de Vries.

“Nowadays the main consumer of ammonia is the fertilizer industry,” he says. “This industry is supplied by ships which carry ammonia in bulk loads of up to 60,000 dwt. The industry's existing infrastructure could be used to realize bunker locations for ships in the future, and current production offers the possibility of a smooth transition. There are ports available already that could supply the first ships.”

C-Job has felt for a number of years that ammonia could be a viable and promising option for a clean and sustainable fuel. C-Job joined the Ammonia Energy Association last year to intensify collaboration with other industries to realize its ambition. Together with Proton Ventures and Enviu, C-Job established a consortium in 2017 to further investigate ammonia as marine fuel. With the completion of the theoretical research, the consortium project which will now move towards lab testing, pilot and evaluation.

The report is available here.