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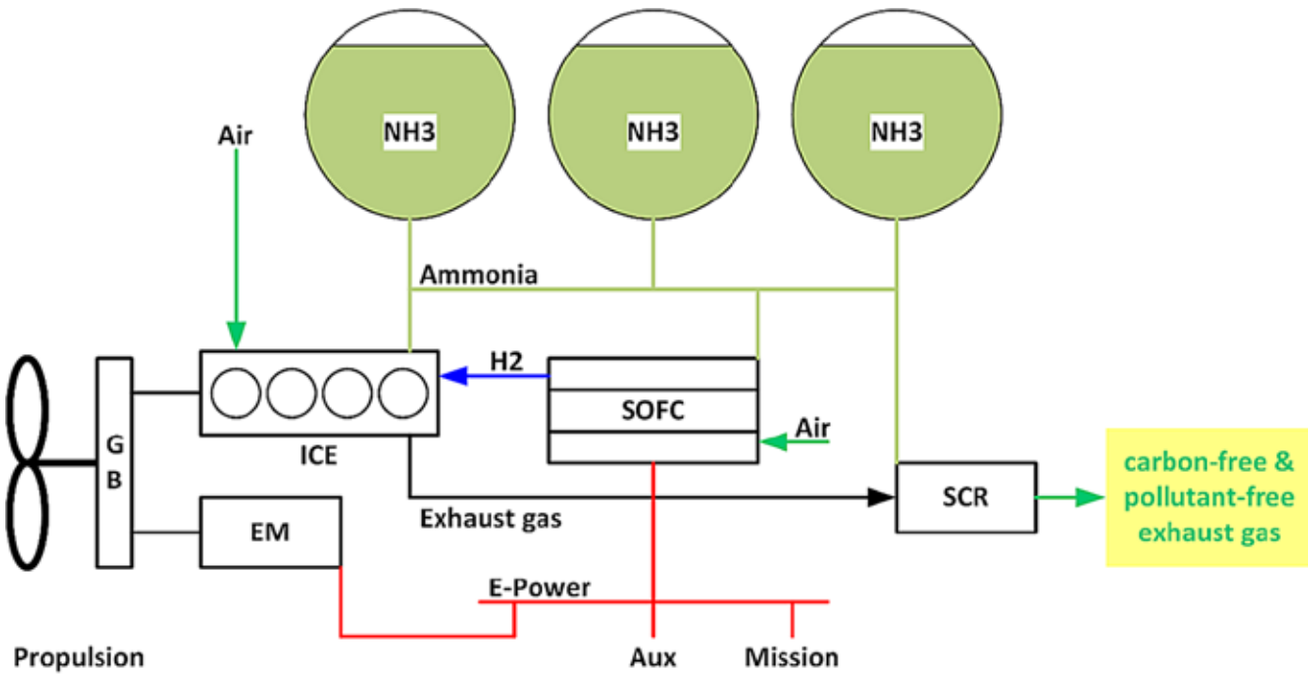
AMMONIADRIVE: A SOLUTION FOR ZERO-EMISSION SHIPPING?!

The hybrid internal combustion engine-solid oxide fuel cell AmmoniaDrive concept is a single-fuel, high-efficiency, high-tech ship power/propulsion plant solution that will produce no pollutant emissions. It also strikes the right balance between different, relevant ship design considerations. Too good to be true?



AmmoniaDrive preliminary system lay-out.

As discussed in the previous articles, ammonia (NH_3) is one of the more promising alternative fuels for maritime applications to meet the IMO 2050 goals. Its unique selling point is that the well-to-wake, or rather renewable-energy-source-to-wake, energy chain is carbon-free, if NH_3 is produced from renewable power. Since nitrogen can be quite easily extracted in large volumes from air, renewable ammonia synthesis is expected to be cheaper than for example methanol synthesis. Furthermore, the energy density and required storage conditions of ammonia are significantly better than that of pure hydrogen; making ammonia an ideal hydrogen and energy carrier for ships in particular.

The main disadvantage of ammonia is its toxicity to humans and animals, which may be one of the primary reasons why people do not tend to think of ammonia as a feasible fuel. Nevertheless, ammonia is already shipped in bulk today as it is used in for instance fertiliser and is a widely applied refrigerant. On board of ships the toxicity of ammonia may be less of an issue than it is in other transport applications, since ships represent a controlled environment that can only be accessed by trained professionals.

Therefore, several recent publications [1-3] that include a future outlook for the energy transition in the maritime industry select ammonia as one of the fuels that will be applied on board of ships in the near to distant future (10+ years or so). This message has recently received the attention of mainstream media as well [4] with MAN ES proposing a dual-fuelled ammonia ICE solution [5] that should be ready for application on board in approximately four years.

Thus, there are a number of clear indications that ammonia will be embraced as a marine fuel. However, a number of research questions need to be answered for the successful implementation of ammonia as a marine fuel. Questions such as, in which power plant configuration shall ammonia be used? Shall it be used as the only fuel on-board, or are other fuels needed as well? What will be a typical energy conversion efficiency when ammonia is used? And can that efficiency be improved? The latter question will in the coming decades be as relevant as it has been in the previous 200 years or so. If not more relevant.

AmmoniaDrive

The results of the Dutch GasDrive research [6-9] suggest that a hybrid power generation system of internal combustion engine (ICE) and solid oxide fuel cell (SOFC), in which the ICE runs on the anode-off gas of the SOFC and additional fuel, can raise the total power generation efficiency with multiple per cent points: five to eight per cent compared to ICE-only power plants. The efficiency improvement depends on the power split between the ICE and SOFC and the applied (heat) integration. The lower efficiency improvements (still five per cent) correspond to a high P_{ICE}-to-P_{SOFC} ratio. Such configurations, with relatively large engines and small SOFCs (in terms of power), are however deemed most realistic as ship power plants as they perform much better in terms of space and weight requirements, capital expenditure (CAPEX) and transient capabilities. However, the GasDrive project applies natural gas (NG) as a marine fuel. Ammonia as a fuel for a hybrid ICE-SOFC power generation system is much more interesting. Ammonia combustion in an ICE requires a "promoter fuel" to be used, because of the low flame propagation speed and combustion rate of ammonia. Hydrogen is an ideal promoter fuel and is carried within NH_3. In an ammonia-driven SOFC, hydrogen is released in the anode-off gas as a consequence of internal reforming and an inherently lower-than-one-hundred-per-cent fuel utilisation factor.

The preliminary system lay-out of the innovative AmmoniaDrive concept, which truly exploits ammonia as both hydrogen and energy carrier, is shown in the picture. Note that a selective catalytic reduction (SCR) is fitted as well to eliminate the only ICE harmful emissions: NO_X or NH_3.

> The AmmoniaDrive concept exploits ammonia as both hydrogen and energy carrier

AmmoniaDrive research & call for project partners

AmmoniaDrive is a novel and exciting idea with an enormous potential for research and development. A number of already formulated, both fundamental and applied, research questions have been omitted here, but the reader is invited to come up with his/her own questions based on this article.

The AmmoniaDrive concept answers the call for carbon-free and pollutant-free shipping. The idea originates from TU Delft and was recently awarded a MIIP (*Maritieme Innovatie Impuls Project*) subsidy for further development of the idea in a research project proposal. Project partners are needed to further define the actual research goals and for (financial) support. TU Delft, TNO, MKC and C-Job wish to cooperate with any partner that wants to contribute to AmmoniaDrive research. For any queries regarding AmmoniaDrive and/or to request further on-site elaboration, please contact the author of this article.

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