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Department	School of Engineering and the Built Environment
Supervisors	Dr Stathis Tingas, Dr Chris Guiver
Funding Status	Funded PhD Project (Worldwide)
Application Deadline	14/04/2022
Project Title	Decarbonising the maritime transport with ammonia

PROJECT DESCRIPTION

Thermal engines are inarguably the prevalent technology powering the maritime sector worldwide, predominantly with fossil fuels. Solid evidence suggests that such engines will maintain a large share of the market for decades to come. Yet, legislation and environmental concerns mandate the drastic reduction of greenhouse gases (GHG). To this aim, current relevant technology must be decarbonized and replaced by environmentally friendly and financially viable solutions. The introduction of alternative, carbon-free, fuels powering such thermal engines, seems to be the apparent solution in this direction.

Ammonia is considered by many as the most suitable candidate to replace fossil fuels in such thermal engines because: It is carbon-free (i.e., has no direct GHG effect); it can be synthesized from renewable sources; an established, reliable infrastructure already exists for both storage and distribution along with safe handling procedures; it allows efficient engine operation, and; it exhibits much higher energy density than gaseous/liquid hydrogen. In fact, a conventional thermal engine can operate on ammonia with only minor modifications.

The use of ammonia in thermal engines has a long history, with most efforts concentrating on spark ignition (SI) engines or gas turbines and only few on compression ignition (CI) engines, due to ammonia's low flame speed and high resistance to auto-ignition. Yet, the great benefits of CI against SI engines (i.e., fuel economy, power efficiency, durability and heavy-duty application) fueled with ammonia have largely remained unexplored.

In CI engines, ammonia has been mainly used in dual-fuel configurations with only few studies on pure ammonia operation. The implementation of ammonia in a single-fuel concept has been proven to be challenging due to the extremely high compression ratios required in order to overcome the high auto-ignition temperature. In dual-fuel operation, (where ammonia is used along with an additive which promotes the ignition of the mixture) ammonia has been mainly used with carbon-based fuels, such as diesel, which (in)directly produce carbonaceous emissions (e.g., CO_2), thus, cancelling or reducing the efforts for GHG reduction. Limited studies have also been reported with the addition of hydrogen, where a large quantity of hydrogen (at least 30% vol.) were reported to be necessary to maintain stable combustion, and NOx increased significantly.

An alternative approach to the dual-fuel strategy is to use a non-carbon based fuel, like ozone or hydrogen peroxide, which are both well-documented great ignition promoters. Such substabnces (which can be injected into the engine cylinder either as a pure substance or as emulsified fuels) have clear benefits against other carbon-based ignition promoters and hydrogen since: (i) they are both well-documented environmentally benign energy carrier, and, (ii) recent evidence suggests that they can decrease ammonia ignition delay time (IDT) drastically without increasing NOx substantially.

The objective of the current project will be to perform a multi-level computational comparative investigation on ammonia operation in CI conditions with hydrogen peroxide or ozone as ignition promoters and water/EGR for NOx reduction, thus, paving the way for the development of a novel, affordable and environmentally friendly technology for CI maritime engines, in alignment with UK's

plan for zero emissions by 2050. The decarbonisation technology proposed in the current project aspires to combine carbon-neutrality with the simplicity and the high efficiency of the thermal engine.

Academic qualifications
A first degree (at least a 2.1) ideally in Mechanical Engineering or a closely related discipline with a good fundamental knowledge of thermodynamics.

English language requirement
IELTS score must be at least 6.5 (with not less than 6.0 in each of the four components). Other, equivalent qualifications will be accepted. Full details of the University's policy are available online.

Essential attributes:

- Experience of fundamental engineering, particularly CFD and thermodynamics
- Competent in mathematical modelling.
- Knowledge of thermal engine layout
- Good written and oral communication skills
- Strong motivation, with evidence of independent research skills relevant to the project
- Good time management

Desirable attributes:
Experience in engine simulations using commercial software.
Knowledge of control theory.
Knowledge of marine engines' layout.
Experience in undertaking independent research.
A completed or near completion MSc in a relevant subject area.

Indicative Bibliography	1. Heywood, J. B. (2018). Internal combustion engine fundamentals. McGraw-Hill Education. 2. Dimitriou, P., & Javaid, R. (2020). A review of ammonia as a compression ignition engine fuel. International Journal of Hydrogen Energy, 45(11), 7098-7118. 3. Valera-Medina, A., Xiao, H., Owen-Jones, M., David, W. I., & Bowen, P. J. (2018). Ammonia for power. Progress in Energy and Combustion Science, 69, 63-102. 4. Review on the production and utilization of green ammonia as an alternate fuel in dual-fuel compression ignition engines. Energy Conversion and Management, 251, 114990. 5. Kurien, C., & Mittal, M. (2022). Review on the production and utilization of green ammonia as an alternate fuel in dual-fuel compression ignition engines. Energy Conversion and Management, 251, 114990. 6. MacFarlane, D. R., Cherepanov, P. V., Choi, J., Suryanto, B. H., Hodgetts, R. Y., Bakker, J. M., ... & Simonov, A. N. (2020). A roadmap to the ammonia economy. Joule, 4(6), 1186-1205.
Funding notes	This project may be funded by a scholarship of the School of Engineering and Built and Environment. Please see School-funded PhD scholarships - RESEARCH AND INNOVATION (napier.ac.uk) for information on the scholarships and how to apply for them.

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Enquiries	For informal enquiries about this PhD project, please contact Dr Stathis Tingas e.tingas@napier.ac.uk
Web page	https://www.napier.ac.uk/research-and-innovation/research-degrees/application-process

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