Department	School of Engineering and the Built Environment
Supervisors	Dr Stathis Tingas, Dr Fadi Kahwash, Professor Alex Taylor (Imperial College London)
Project Title	A zero-carbon hydrogen fuelled compression ignition engine for heavy-duty transport applications

PROJECT DESCRIPTION

A 3-year fully funded position is available to contribute substantially to the development of a new zero-carbon hydrogen fuelled thermal engine technology for heavy duty transport applications. The PhD studentship is funded by the Mechanical Engineering and Mathematics Subject Group in the School of Computing, Engineering and the Built Environment at Edinburgh Napier University.

Heavy-duty applications (e.g., long haul trucks, container/tanker/bulk carrier ships etc) are notoriously challenging to decarbonize. Electrification through batteries is far from a technologically mature solution and there are many challenges to be tackled. This explains why all the UK, EU and elsewhere have adopted a technology-neutral approach to allow the different technologies to develop and compete against each other.

Hydrogen can be produced from a wide variety of available feed stocks and energy resources, many of which are renewable and/or have (ultra)-low carbon impact. The clear benefits and the versatility of hydrogen have led several of the world's advanced economies to develop strategies for the development of local (national) hydrogen economies; see for instance Refs. [1-2] for the UK, Ref. [3] for Australia and Ref. [4] for the EU.

With hydrogen as a fuel, there are two main options for use for propulsion purposes. On one hand, fuel cells that use hydrogen are attractive because of their efficiency and their emissions (only water). On the other hand, they are currently compromised due to cost and durability concerns. The second option is to use hydrogen in an internal combustion engine (ICE) [5-6]. Many industry stakeholders recently announced R&D initiatives that aim to explore the use of hydrogen as a main fuel in ICEs; see for instance MAN Energy Solutions [7-8], Cummins [9], the Hydrogen Engine Alliance [10], BMW Group [11], DAF [12].

The current project concerns the development of a zero-carbon compression ignition (CI) hydrogen-fueled thermal engine technology that aims to decarbonise heavy duty applications through retrofitting. The novel technology makes use of modern low temperature combustion strategies and will potentially have negligibly low NOx emissions along with a unique operational flexibility and high efficiency, all features that no hydrogen-based technology has managed to achieve yet, especially for heavy duty applications.

In this project multidimensional engine simulations will be utilised, which will allow for: (i) The realistic determination of the engine performance, i.e., power, torque, thermal/fuel efficiency as well as NOx emissions, under low, medium and high load conditions and a range of engine speeds. (ii) The identification of the associated limitations and challenges, particularly related to engine knock, pre-ignition, in-cylinder pressure rise and backfire, in terms of the mixture composition, the thermodynamic conditions and the injection strategy.

The investigation will focus on variables relevant to the engine performance (IMEP, thermal / combustion / volumetric efficiency), combustion phasing (heat release rate, ignition delay time, mass fraction burned, CAD50, combustion duration), maximum temperature and pressure, specific fuel/energy consumption, NOx emissions and unburned H2, abnormal combustion (ringing intensity,

pressure rise rate). The validated simulation methodology will be sufficient for industrial utilization when
designing new H2 engines with a range of fuel injection strategies.

The PhD student will be supported through periodic meetings with the supervisory team (from both Edinburgh Napier University and Imperial College London), and trained on technical relevant skills such as writing research articles for publication and presenting at international conferences. Given the relevance of this project in the industrial context, the successful candidate is also expected to interact with the industry.

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

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 research analysis skills, particularly in CFD and thermodynamics.
- Competent in using CFD software (e.g., ANSYS, Converge, STAR-CCM etc)
- Knowledge of thermal engine layout and operation, thermodynamic cycles
- 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 (non-)commercial software.
Knowledge of low combustion technologies.
Experience in undertaking independent research.
A completed or near completion MSc in a relevant subject area.

Indicative Bibliography

[1] Secretary of State for Business, Energy & Industrial Strategy, UK hydrogen strategy, August 2021, CP 475

[2] Department for Business, Energy & Industrial Strategy, Hydrogen Strategy update to the market: July 2022

[3] COAG Energy Council, Australia's National Hydrogen Strategy, 2019

[4] EU Commission. (2020). Communication from the Commission to the European Parliament, the European Council, the Council, the European economic and social committee and the Committee of the regions. A hydrogen strategy for a climate-neutral Europe. Brussels, 8/7/2020.

[5] S. Verhelst, (2014). Recent progress in the use of hydrogen as a fuel for internal combustion engines. international journal of hydrogen energy, 39(2), 1071-1085.

	[6] P. Dimitriou, T. Tsujimura, (2017). A review of hydrogen as a compression ignition engine fuel. International Journal of Hydrogen Energy, 42(38), 24470-24486. [7] MAN Energy Solutions, H2 – key player in the Maritime Energy Transition, accessed 23 September 2022, https://www.man-es.com/marine/strategic-expertise/future-fuels/hydrogen [8] MAN Energy Solutions, Four Stroke Engines, accessed 23 September 2022, https://www.man.eu/engines/en/products/marine/man-dual-fuel-marine-engine.html [9] Cummins, accessed 23 September 2022, https://www.cummins.com/news/releases/2022/09/20/cummins-fuels-hydrogen-commitment-iaa [10] Allianz Wasserstoffmotor, accessed 23 September 2022, https://allianz-wasserstoffmotor.de/home.html [11] BMW Group, accessed 19 October 2022, https://www.press.bmwgroup.com/global/article/detail/T0403940EN/hycet-research-project:-consortium-promotes-sustainable-transport-logistics-using-hydrogen-trucks?language=en [12] DAF, accessed 19 October 2022, https://www.daf.com/en/about-daf/sustainability/alternative-fuels-and-drivelines/hydrogen
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