Ph.D. Position: Potential of ammonia as fuel additive with ethanol fueled Spark-Ignition engine

Subject :

One way for the storage of the renewable energy excess is what is commonly named 'electro-fuels' (*e*-fuels), feasible if users develop adapted technical solutions to use them in energy converters and/or in transport systems. Ammonia can be considered as a mere hydrogen carrier (as recognized by IEA, 2018) due to some advantages over hydrogen as 1) its lower cost per unit of stored energy; its higher volumetric energy density; 2) easier and more widespread production, handling and distribution capacity, and better commercial viability; 4) its liquid phase by compression to 0.9 MPa at ambient temperature; 5) a well-established, reliable infrastructure already exists for both ammonia storage and distribution (including pipeline, rail, road, ship). By considering global efficiency, it will be better to consider NH_3 directly as a fuel combusted in gas turbines, industrial furnaces or internal combustion engines, most likely after partial or complete thermal cracking into nitrogen and hydrogen to balance out its high ignition temperature – a positive safety feature. The limited knowledge of the combustion process (ignition, flame stabilization, combustion propagation, pollutant emissions…) limits for the moment to generate power with high-efficiency and low emission impacts from small to utility-scale power units.
PRISME recently started (with a joint phd, half financed by CAPRYSSES, with Vrije Universiteit Brussel (BE)) to study in depth ammonia combustion process targeting a use in SI engines. Even if recent results clearly pointed out the possibility to run engine with pure NH3, a first step is required to heat up the system and to ignite up thanks to ignition promoter. Moreover, if the combustion of rich ammonia/air mixture avoid NO_x emission, it leads too high unburnt NH_3 levels. One solution to improve ammonia reactivity could be to mix it with another liquid e-fuel as e-ethanol (or Bioethanol). Due to its partial miscibility with NH_3, an emulsion will be performed and could be improved thanks to the device 'MICROSPHERE500' developed by Bellettre et al. (2017) at LTEN, Nantes.

The proposed project will focus on two aspects:
PRISME (Univ. Orléans) + LTEN (Univ. Nantes): Firstly to optimize emulsion process as a function of liquid fuel nature and proportion and to perform single cylinder experiments to evaluate the potential of NH3-Ethanol in comparison with NH3-H2 mixtures.
PRISME (Univ. Orléans) + ICARE (CNRS, Orléans) - Secondly to study the combustion properties of this new alternative fuel to provide a unique data base of laminar burning velocities for NH3/ethanol mixtures, measured both in PRISME and ICARE using different complementary experimental setups at temperatures and pressures never explored before. ICARE will provide isochoric laminar burning velocities using a newly developed experimental set-up and processing (OPTIPRIME), recently successfully applied for methane/air flame at high-pressure and temperature. PRISME will conduct measurements of laminar burning velocities under isobaric conditions. These new experimental results will serve as a database to develop and improve a detailed kinetic mechanism.

The expected impacts are compliant with long-term expectations: carbon-free energy and synergies with the transition to renewable energy sources. This project affords fundamental knowledge on the reactivity of a future energy carrier: ammonia. It features a unique combination of experiments for

characterizing the reactivity combined with kinetic modelling. The partners bring complementary expertise, skills, and facilities to achieve mutually linked tasks. The expertise of researchers involved in the present project concerns experimental chemical kinetics in laminar combustion, effective mixing of liquid fuels and combustion processes in engine.
The interactions between the teams are numerous and essential to progress on this important subject. This project will enable a very systematic analysis of the involved processes and will provide baseline data.

The long-term goal of this project is to provide the obtained knowledge gain with respect to ammonia/ethanol combustion for the scientific environment in the form of publications and scientific repositories. Aspired publications are intended to provide auspicious and innovative approaches that would have a multiplier effect on the research and development of novel alternative fuels.

Keywords : e-fuels, combustion, ammonia/ethanol, flame speed, SI engine

Conditions

Start : October 2020

Duration: 3 years

Location: Orléans with several short research stays @ LTEN, Nantes

Net Salary: 1420€ / month, opportunity for 1660€/month with extra missions (e.g: teaching)

Contact :

Thesis Director : Christine MOUNAÏM-ROUSSELLE (Univ. Orléans, PRISME), Fabien HALTER (CNRS, ICARE)

Advisors : Jérome BELLETTRE (Univ. Nantes, LTEN), Guillaume DAYMA (CNRS, ICARE), Pierre BREQUIGNY (Univ. Orleans, PRISME)

email : pierre.brequigny@univ-orleans.fr