Hybrid hydrogen combustion coupled with an electrolyser

Institut de Mécanique des Fluides, UMR5502, CNRS
31400 Toulouse France

Within the framework of the "Green Hydrogen Key Challenge" funded by the Occitanie Region, **IMFT and the company Bulane** propose a thesis grant on the **experimental analysis of hybridized combustion by adding hydrogen directly from an electrolyser**.

Context:

The objective of this project is the **progressive decarbonisation of heat production** by hybridising a fossil fuel with hydrogen produced locally from green electricity. By substituting a fossil fuel (in this case natural gas) with renewable or low-carbon energy (electricity), it is possible to reduce greenhouse gas emissions by coupling an electrolyser with existing equipment. The electrolyser supplies hydrogen to the burner, whose natural gas consumption can be reduced while maintaining service, i.e. heat production.

The target applications are domestic heating and low power industrial burners (<100kW) but the coupling strategies developed will be adaptable to higher power devices. The main benefit of this strategy is that it avoids the heavy investment and time delays required to set up a hydrogen distribution network.

Objectives:

In this project we propose to develop a solution for the hybridization of combustion with locally produced hydrogen through an electrolyser. Three issues requiring fundamental and applied research have been identified:

1. Combustion: The aim is to determine the maximum amount of hydrogen that can be substituted while guaranteeing the safety and durability of the equipment.
2. Coupling: Connecting the electrolyser to a burner or heater requires validation of the coupling and data exchange strategy between the devices.
3. Electrolysis: The need to develop and test specific electrolyser technologies for this type of application will be evaluated.

The final objective of the project is to propose operating ranges for hybrid combustion in one or two practical cases (domestic boiler and/or burner), to detail a hybridisation strategy and to propose an optimised electrolyser technology for this application.

Work Program:

Preliminary studies by Bulane and IMFT have shown that for hydrogen levels in natural gas of up to 50% by volume, burner modifications are not necessarily required to maintain safe combustion. Figure 1 shows the influence of the hybridisation level in the case of a domestic boiler burner. It can be seen, however, that despite constant power and equivalence ratio, the temperature of the burner walls increases. Thus, in order to ensure safe operation and avoid premature ageing, it seems necessary to change the operating point.

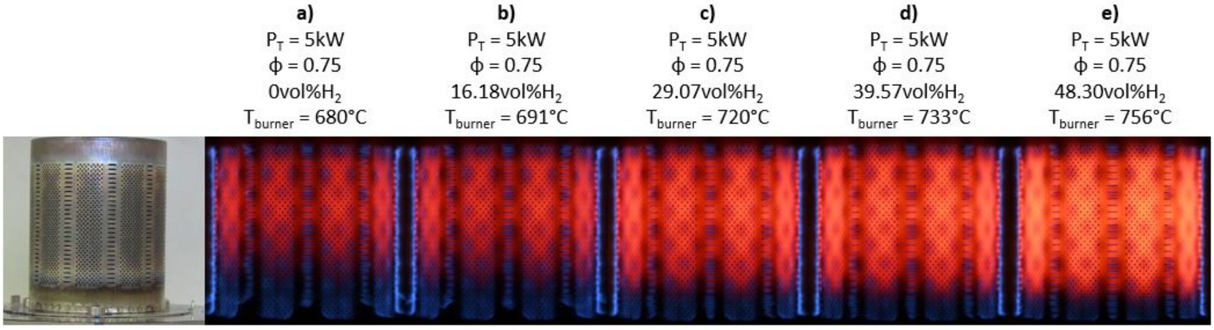

Figure 1: Influence hydrogen volume fraction in the fuel, at constant equivalence ratio $\phi = 0.75$, for a typical domestic heater burner.

This experimental work will be pursued at the component level (the burner) but also at the scale of the system, i.e. the heating device (boiler, torch, etc.) coupled with the production device (electrolyser). The study is divided into three main parts:

1. **Combustion**. Based on the experience acquired during the preliminary study, the hybridisation of a commercial device (boiler or torch) will be carried out and its response to hybridisation will be determined. Particular attention will be paid to the following points, which are essential for good combustion: flame shape, flashback, wall temperature, production of pollutants (NOx and CO). This work will be completed by a detailed study of the burner outside the boiler in order to study the flame stabilisation mechanisms.
2. **Coupling**. Most boilers and industrial burners can be modulated in power, which implies a coupling between combustion and electrolysis. The simplest way to do this is to use a fluid coupling with a buffer tank. The electrolyser provides a nominal pressure in the tank and the boiler draws off as needed by activating a valve. The need for a more complex dialogue between the electronics of the two machines will be discussed, while favouring the simplicity, robustness and safety of the coupling.
3. **Electrolysis**. The current technology developed by Bulane produces a stoichiometric H_2/O_2 mixture. Although it can be beneficial from a combustion point of view to take advantage of the production of oxygen, the interest of proposing a separate supply of gases will be evaluated. This parameter can have a significant impact on flue-gas temperature and pollutant levels so the value of having an additional control parameter, i.e. the oxygen fraction, will be assessed.

Finally, throughout this study, the objective of reducing greenhouse gas emissions will be kept in mind. The gains will be quantified and the technical choices will be constrained by this parameter at the level of the overall system.

Required skills:

The candidate should have a research Master's degree or an engineering degree with skills in fluid mechanics, combustion and heat transfer. An advanced level of scientific and technical English and good written and oral communication skills are required. A sensibility to the challenges of energy transition and a particular interest in experimental research activities will be appreciated.

Supervision team:

Laurent Selle CR CNRS - HDR, laurent.selle@imft.fr
Thierry Schuller Professeur, Université Toulouse III, thierry.schuller@imft.fr