Advanced diagnostics development to investigate the NO_x formation processes in representative Hydrogen aircraft combustor

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Duration : 36 months
Employer : CNRS
Salary : 2135 € gross income per month
Location : Université Paris-Saclay, CNRS, CentraleSupélec, Laboratoire EM2C, 91190, Gif-sur-Yvette, France.

Context of the study

In line with the European Green Deal target of reaching carbon neutrality within the aviation industry by 2050, multiple incremental and breakthrough technologies are being researched related to novel aircraft design and propulsion systems. Regarding future propulsion systems, one avenue that is being considered for regional, short and medium-range aircraft types is the use of hydrogen as a fuel source. However, it will require a complete overhaul of aircraft design, refuelling infrastructures, certification processes or aeronautical regulations. As evaluated in the "Hydrogen-powered aviation" commissioned by CleanSky2 in May 2020, H2 propulsion could lead to a climate impact reduction potential between 50 and 75 % in terms of CO2 equivalent compared to the full climate impact of kerosene-powered aviation. Already widely used in the space sector as a fuel used with liquid oxygen, the design and development of hydrogen for civil aircraft remains in its infancy and represents a revolution in the aviation industry. Several critical obstacles must be identified and solved before any serious industrial development can occur. One main issue with H2-air combustion is the production of Nitrogen Oxides (NOx). These NOx are atmospheric pollutants implied notably in acid rains and ozone pollution.

A European consortium HESTIA (HydrogEn combuSTion In Aero engines) led by SAFRAN was granted a 48 months project to overcome those issues. Among others, the actual NOx emissions have to be adequately quantified and understood to assess free pollutants emission of future H2 aircraft combustors.

Within this project, the proposed PhD research aims at developing advanced diagnostics to analyse the NOx formation processes of partially premixed combustion regimes in turbulent H2/ flames at atmospheric pressures. This PhD research will be part of a research task focussing on stabilisation, flashback, ignition, auto-ignition, NOx emissions and heat transfers, including teams from France, Italy, UK and Canada.

Description of the PhD research plan

The research plan is composed of two complementary aspects : development of a measurement technique and applications of diagnostics in turbulent hydrogen-air flames.

Your first PhD task will be dedicated to the implementation planar laser induced fluorescence bench dedicate to the measurement of Nitric oxide molecule and the atomic oxygen key species in NOx formation.

During the last part of the PhD, a series of laser diagnostics will be used to further understand NOx formation in turbulent flames. Together with planar velocity fields and position of the flame front, the mixture fraction will be measured by a special Laser Induced Plasma Spectroscopy technique [1-2]. This local mixture fraction may be combined also with a volumetric measurement of the velocity [3].

[1] Zimmer, L., Okai, K., Kurosawa, Y. (2007) Combined Laser Induced Ignition and Plasma Spectroscopy: Fundamentals and Application to a Hydrogen-Air Combustor, Spectrochimica Acta Part B: Atomic Spectroscopy, 62 (12) 1484–1495

[2] Zimmer, L. (2019) Fundamentals and applications of Laser Induced Plasma Spectroscopy, Journal of the Combustion Society of Japan, 61(198):331-346

[3] Baudoin, R. et Zimmer, L., Système et procédé de détection optique d'objets dans un fluide, FR Patent 3045825, December 2015.

The EM2C laboratory and Université Paris Saclay

The EM2C Laboratory (CNRS/INSIS and Université Paris-Saclay/CentraleSupélec), through its high-level academic research in energy and combustion and its applied studies in partnership with the most prominent companies or research centers in the field of transport and energy, contribute significantly to the progress of knowledge on these critical issues, both for the climate and for the environment. To meet these challenges, the laboratory's research activities are organized around three axes entitled Combustion, Out-of-Equilibrium Plasmas, Transfer Physics, and a transversal action in Applied Mathematics.

You will be included in the Combustion axe and more precisely in the Aeronautical Propulsion group.

As PhD student, you will be registered in the SMEMAG (SCIENCES MÉCANIQUES et ÉNERGÉTIQUES, MATÉRIAUX et GÉOSCIENCES) Doctoral school.

Candidate profile:

You hold a Master of Research or graduated from an Engineer School in fluid mechanics, combustion or energetics. You have an appetence for experimentation and data processing. An experience in laser diagnostics would be appreciable.

How to postulate:

You should send a CV and a letter of motivation to the three researchers involved in the supervision of the work. A dedicated web site will be available for the official submissions of your application.