Research project

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Title: Development of a novel metering valve for future airliners fuelled with Hydrogen

Description:

Introduction

Using Hydrogen as fuel in turbofan engines of airliners in place of Kerosene-based fuels is regarded as one of the most effective solutions for achieving carbon-free aircraft in the near future, which is a target defined by the EU to reduce global warming caused by C02 emissions from the aviation sector.

The development of Hydrogen-fuelled aircraft must face issues related to the production and supply chain of green Hydrogen, the design of reliable fuel systems for Hydrogen aboard aircraft, and the combustion of Hydrogen in aircraft engines. This proposal is concerned with the study of fuel systems for Hydrogen, which best fits with the host supervisors' research expertise in hydraulics and pneumatics [1-3], keeping in mind that the other aspects are currently being studied extensively in industry and universities.

A fuel system for Hydrogen must include all the components needed to take the fuel (liquid Hydrogen) from the tank and deliver it, in the gaseous state, to the engine, thus comprising:cryogenic tanks (needed for fuel storage), cryogenic pumps (for fuel delivery), heat exchangers (for thermal management), metering valves (for fuel metering), along with intermediate tanks, injection nozzles, pipes, venting and safety systems. At the state of art, there are not final solutions for the architecture of a Hydrogen fuel system and for the design of the components, despite the efforts made by the main manufacturers, including Avio Aero. The main challenges are related to the fact that typical fuel systems, working with liquid Kerosene, must undergo a complete redesign to be adapted to Hydrogen. Metering valves are the most critical components to be re-designed; they have great importance in fuel systems, since they must provide high accuracy and fast response to adjust the fuel flow rate injected into the combustion chamber. In typical fuel systems for Kerosene-based fuels, two-stage servovalves are used, usually deflector jet and double nozzle flapper valves [4]; however, these architectures cannot work with low viscosity fuels, such as Hydrogen.

Brief description of the research to be carried out by the experienced researcher

Novel solutions for the Hydrogen metering valve will be investigated numerically and experimentally by the successful applicant to the "MSCA-post doc fellowship" call (henceforth, referred to as the experienced researcher), to cope with the above-mentioned issues related to the use of Hydrogen in airliners.

The research advancement expected to be obtained with this project is noteworthy, given that the design of metering valves for Hydrogen-powered airplanes is a new research field.

The host supervisors have already carried out a preliminary numerical analysis of a novel Hydrogen fuel system architecture, taking advantage of years of experience in the simulations of conventional fuel systems [5-10]. The good results already obtained have prompted the host supervisors to plan an experimental activity on a forthcoming test rig facility, whose construction is underway benefiting from the collaboration of Avio Aero (BA) and CCA (centro combustion ambiente, Gioia del Colle, BA). The test rig will be located at the facilities of CCA in Gioia del Colle,

BA). The experienced researcher will be hosted at the DMMM of the Polytechnic university of Bari under the supervision of Prof. Riccardo Amirante and prof. Paolo Tamburrano, providing all the tools needed to perform the numerical and experimental activity. The activities will allow the following objectives to be pursued:

- Achievement of a digital twin of the test rig, including the metering valve, starting from the existing preliminary model [9].
- Design of the metering valve, which will be constructed using the MSCA funding.

The activities employed to reach these objectives will be numerical and experimental. The numerical activity will make use of simulation tools like Simulink/Simscape and CFD software, and the experimental activity will be carried out on the test rig at the facilities of CCA under the supervision of CCA's and Avio Aero's engineers.

The duration of the MSCA fellowship will be two years with a secondment of 6 months carried out at the CCA premises.

Scientific and technological impact

Nowadays the consumption of Kerosene-based fuels in aircraft, which is directly connected with CO2 emissions, is mainly due to intra-continental flights, both short-range and medium-range, accounting for about two-thirds of the overall. For short-range and medium-range airliners, Hydrogen, to be stored in the liquid form and used as fuel in modified turbofan engines (assisted by Hydrogen fuel cells for electricity generation), is regarded as the most effective solution to decarbonize. This is due to the fact that green Hydrogen produced from renewable sources will eliminate CO2 emissions from flights, and recent studies show that even NOx emissions will be reduced substantially by employing lean-mixture technology without significantly affecting the engine efficiency.

The strict targets to significantly decarbonize the aviation sector by 2050 imply that, by that date, Hydrogen-fuelled airliners must be able to flight regularly in full safety. However, the technology needed for the storage, delivery, thermal management and metering of Hydrogen aboard airplanes is still immature because of several technical issues; therefore, advances must be made very quickly towards the solution of these issues.

One of the main difficulties is related to the design of the metering valve for Hydrogen. This proposal aims at providing solutions for the design of this component, in order to achieve real technological advances in two-years' time frame. The benefits that the global university and industrial research will have from the proposed activities, planned to achieve feasible objectives in two years, are substantial.

Economic impact

Many recent economic studies in the literature have identified Hydrogen as the most important resource for decarbonization and economic recovery after the COVID-19 pandemic. According to the Hydrogen Energy Center, "with increasing use of Hydrogen and technical advances, the costs of production, distribution and product manufacturing will become increasing affordable. By continuing to build partnerships between business, government, universities and non-profit organizations, Hydrogen will be the foundation of a sustainable energy economy".

The significant economic impact of using Hydrogen in aircraft has been confirmed by the largest commercial aircraft manufacturers. According to Airbus, "the cost of Hydrogen is likely to significantly fall over the next decade, largely due to the declining cost of renewable electricity and the scaling up of the Hydrogen economy. This is expected to make zero-emission flying increasingly economical." Recent studies confirm that liquid Hydrogen prices are expected to drop over the years because of the higher demand for liquid Hydrogen and associated production cost

improvements, whilst Sustainable Aviation Fuels (in particular syngas) will remain more expensive than liquid Hydrogen, which is regarded as the best solution for short and medium range carbon neutral airplanes.

A recent study, commissioned by "Clean Sky 2 and Fuel Cells & Hydrogen 2 Joint Undertakings on Hydrogen's potential for use in aviation", confirmed that "Hydrogen – as a primary energy source for propulsion– could feasibly power aircraft with entry into service by 2035 for short-range aircraft" also stating that "costing less than €18 extra per person on a short-range flight, and reducing climate impact by 50 to 90%, Hydrogen could play a central role in the future mix of aircraft and propulsion technologies".

According to Boeing, there would be a "significant increase in airline staff, e.g., pilots, cabin crew, and maintenance technicians. This increase will also impact other roles and services in allied industries, such as tourism, trade, and logistics, that rely on aviation services".

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Candidates should provide detailed CV.

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