AEROSPACE ENGINEERING

Ateneo/DIMEAS - Sustainability in Aviation: Methodologies for Direct Hydrogen Combustion in Aircraft Engines

Funded By	Dipartimento DIMEAS Politecnico di TORINO [P.iva/CF:00518460019]

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Context of the research activity	Direct hydrogen burning in modified gas turbine aero engines is an appealing but challenging approach for aviation sustainability. This research aims to enhance predictive models for performance and emissions by developing a comprehensive framework. The approach integrates multi-fidelity and multi-disciplinary methods, machine learning techniques, and the results of experimental analyses.

Objectives	The effect of aviation emissions on human-induced climate change has become a major concern in the last decades. Aircraft should be less polluting, less noisy, and more fuel efficient. The expected reduction of CO2 emission and NOx are very challenging. Current incremental technological improvements appear unable to achieve these targets and different breakthrough technologies have been proposed. Direct hydrogen combustion in modified aircraft engines is one of them (e.g. see Airbus ZEROe Concepts). The use of hydrogen as an aircraft fuel has tremendous environmental benefits over current systems with the elimination of carbon monoxide (CO), carbon dioxide (CO2), sulfur oxides (SOx), unburnt hydrocarbons (UHC), and smoke. Nevertheless, high temperatures and high flame speeds introduce new issues wrt hydrocarbon fuels. Burning hydrogen in diffusion mode produces large quantities of NOx due to the high flame temperatures. Since H2 has a larger flammability range wrt hydrocarbon fuels, lower equivalence ratios can be chosen with a possible reduction of NOx emission. Thus, the development of lean premixed hydrogen combustors for gas turbine aero engines can reduce not only greenhouse gases emissions but also nitrogen oxides. Unfortunately, lean premixed flames have been susceptible to experiencing problems with stability, caused by different mechanisms. For instance, the flashback takes place when the turbulent flame speed exceeds the average upstream velocity (high average velocities determine high pressure drops thus reducing engine performance). Different approaches are then under development.

	In the frame of an on-going research activity in the Aerospace Propulsion Research Group, the goals of the present PhD program are to develop methodologies for predicting performance and emissions. To reduce the computational effort, multifidelity approaches can be applied: a great number of system outputs can be easily obtained from low-order models and augmented with few high-fidelity data. The resulting model is capable of high accuracy at a reduced computational cost. Examples of these techniques commonly used in aerospace engineering are kriging, co-kriging, radial basis function models, moving least-squares, and artificial neural networks (ANN). In addition, experimental data may be embedded in the multi-fidelity approach under development and/or be used to train surrogate models. Thus, experimental campaigns are potentially foreseen during the three-year research activity. Tasks will include: • SOA – literature survey (pervious/existing programs, H2 direct combustion, H2/air reaction mechanisms, experimental data, multifidelity approaches…..) • Methods development and validation • Applications • Experimental test campaign • Dissemination

Skills and competencies for the development of the activity	Aerospace propulsion – Combustion – Combustion instability– Heat tranfer-Modelling skills – Programming skills – CFD experience -Machine learning background – Experimental skills/experience