ASD Lab

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PhD Studentship: Design and optimisation methodology for hydrogen-powered regional aircraft development and environmental impact assessment.

Reference: ASD0002

Closing Date: 23/03/2022

Department: Bioengineering and Aerospace Engineering Department

Start Date: 01/04/2022

Eligibility: Anyone eligible to work in Spain

Duration of award: 3 years (extendable to 4 years)

Supervisors: Dr Andrea Cini, Dr Marco Raiola

Applications are invited for a fully funded PhD studentship within the Aeroelastic and Structural Design lab (ASD Lab) and the Experimental Aerodynamics and Propulsion lab (EAP Lab) at the University Carlos III of Madrid

Project Description

This PhD project aims at investigating the feasibility and operation viability of hydrogen-fuelled propulsion concepts applied to regional airliners by adopting a holistic multidisciplinary design and optimisation approach. The developed methodology will focus on assessing the benefits of these new green technologies in terms of environmental impact, and noise footprint, while including operability aspects such as costs, certification, and reliability. The growing attention to global warming and air transport environmental impact resulted in the setting of ICAO ambitious targets to achieve climate neutral aviation by in 2050. This objective fulfilment requires disruptive technology implementations, as incremental improvements on aircraft efficiency fall short of meeting the deadline. The aerospace community foresees energy sources, such as hydrogen, as net zero environmental impact alternatives to kerosene for regional aircraft.

The PhD will be mainly focus on developing the design and optimisation methodologies for sizing, airframe integration and performance assessment of H2-fuelled powertrains of regional aircraft. Airframe multidisciplinary optimisation and efficient integration are required to offset the weight penalty caused by the powertrain technology immaturity. Several possible powertrain architectures will be identified as promising such as H2-fuelled turboprop and turbofan, turbo generator for twin-engine and Distributed Electric Propulsion (DEP) and parallel and serial H2 hybrid/fully electric powertrains. The ASD Lab digital platform, developed to optimise battery-powered hybrid/electric aircraft, will be integrated with new design modules to analyses and assess all those powertrain configurations. Methods to efficiently and safely storing, supplying and converting hydrogen on short range aircraft will be implemented defining thermal, airframe, power and aerodynamic constraints. Fuel cells sizing and optimisation procedure as function of the required power will be implemented too. Jet engine and turbo generator internal combustion chamber sizing modules will be modified to evaluate the H2 combustion process and the derived flow thermodynamic variables. Thermal Management System (TMS) modelling will be enhanced developing a dedicated thermal control for the hydrogen storage tanks and fuel cells. Insulation materials for cryogenic fuel tanks combined with active systems for heat regulation and recovery and multifunctional structures with thermal management properties will be investigated. The electric powertrain sizing and optimisation module will be modified to include an estimation of the aerodynamic interaction between the propulsion system and the airframe, enabling the implementation of non-conventional propulsion architecture such as DEP and ducted fan. DEP surrogate models tuned on experimental and high-fidelity CFD prediction will be developed within the optimisation platform.

An efficient powertrain/airframe integration is required to offset the weight and performance penalties caused by the technology lack of maturity. All the aircraft conceptual design and optimisation modules will be adapted to allow the H2-fuelled powertrain integration and the airliner performance and operational capability assessment. Structural weight will be computed by means of GFEM-based airframe sizing procedures owing to the lack of experience-based weight estimation correlation formulas for H2-fuelled airliner. Reduced Order Models (ROMs) will be generated from the FE sizing and implemented on the optimisation for fast and computational cost-effective weight estimations.

A tool, able to predict the acoustic footprint has to be integrated within the optimisation. Different models for propeller noise and aerodynamics with different degrees of fidelity will be identified and implemented. While simplest model can be based on semiempirical correlations, more refined implementations can rely on physically grounded low-fidelity models for the aerodynamics (e.g. Blade-Element Momentum Theory, Blade Vortex Theory) and aeroacoustics analogies (e.g. Ffowcs Williams-Hawkings Analogy) and derived models (e.g. Hanson’s method) for the noise. Blade-wake and wake-airframe interaction problems will be accounted in the modelling. The models will be then validated against high fidelity data, either proceeding form simulations or experiments where available. To this purpose high-fidelity propeller URANS/LES simulations in commercial CFD solvers which will serve as a baseline for the assessment of the developed models will be developed.

The optimisation platform will also allow airliner mission performance evaluation and operational capabilities review. Airworthiness requirements will drive the powertrain configuration sizing and selection in terms of engine inoperative conditions, fire protection and reliability. Operation capability prediction methods and strategies will be implemented to evaluate aircraft turnaround time, 24h flight capabilities, and the impact of ground handling on airport infrastructures and procedure. A conceptual design cost model will be developed as well to assess the economic viability of H2 powered short-range airliner. The environmental benefits of the novel H2 powered airliners will be quantified by Life Cycle Assessment (LCA) method, assessing the potential environmental impact of a product system during its entire life cycle.

Entry Requirements:

Applicants should hold or expect to obtain a first-class or upper second-class honours degree, at master level or equivalent, in aerospace engineering or a relevant discipline, such as mechanical, thermal or electrical engineering. Students with a background in airframe design, aeroacoustics and powertrain development are particularly encouraged to apply. Candidates should be self-motivated and capable of working under pressure to meet deadlines. They should also have good communication skills, inclination to research and proactive behaviour. Previous experience in finite element modelling and CFD (Abaqus, Nastran, Ansys, OptiStruct, Fluent, OpenFOAM) optimisation (Open MDAO) and programming skills (Matlab, Python, C++) would be advantageous.

Funding:

Successful applicants will receive an average bursary of €18.000 p.a. and tuition fees for three/four years, subject to satisfactory research progress.

For further information please contact:

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Applicants are recommended to contact Dr Andrea Cini of Dr Marco Raiola to start the official application