POLITECNICO DI MILANO

PhD in INGEGNERIA AEROSPAZIALE / AEROSPACE ENGINEERING - 39th cycle

PNRR 117 Research Field: ICE DENSITY MODELLING FOR IN-FLIGHT ICE ACCRETION SIMULATIONS

Monthly net income of PhDscholarship (max 36 months)
€ 1400.0 In case of a change of the welfare rates during the three-year period, the amount could be modified.

Context of the research activity	
Motivation and objectives of the research in this field	In EASA's 2019 annual report, in-flight icing was identified as a priority 1 issue for large aeroplanes with the aggregated European Risk Classification Scheme (ERCS) score being amongst the highest safety issues. In-flight icing can occur when an air vehicle flies through clouds of supercooled droplets, namely, drops of liquid water with a temperature below the freezing point. This is an unstable state for water, and when such drops impinge onto aircraft surfaces, they generally freeze, leading to ice accretion. Aircraft icing can reduce visibility, damage due to ice shedding, blockage of probes and static vents, reduced flight performance, adverse aerodynamic effects, engine power loss, etc. Climate change is already increasing the number and intensity of thunderstorms and pushing them upward into cruising altitudes. Urban Air Mobility vehicles, operating at low altitudes and in liquid ice and snow conditions, are expected to be strongly affected by icing and snow conditions. Certification costs are very high due to the complexity and innovative nature of UAM vehicles and the large variability of the operating conditions. The present research aims at developing ice density models from high-fidelity morphogenetic ice accretion simulations over three-dimensional swept wings. Density models will be implemented in existing Messinger/Meyer Finite Volume codes at CIRA and at Politecnico di Milano.

Methods and techniques that will be developed and used to carry out the research	The research leverages the theoretical, numerical, and experimental background developed during previous H2020 projects (UTOPIAE, NITROS, ICE-GENESIS) and the current MSCA Double-Doctoral network TRACES, coordinated by Politecnico di Milano. Research goal: design, development and validation of an ice density model to study accretion around complex geometries of aeronautical interest, to simplify and drastically speed up the numerical analysis of the conditions that determine the transition to the solid phase of water droplets suspended in cumulonimbuses and/or rain during low-altitude flight. This study is extremely important for the certification of regional aircraft and for the entire civil and commercial sector which are subject to scrupulous controls precisely to prevent breakdowns and air disasters due to icing. A mathematical model will be developed, to predict the variation of ice density in typical conditions at low altitudes: 'glaze' but also 'mixed'. The model will reproduce measurements from databases available in the literature and from recent EU-funded projects (EXTICE, HAIC, GENESIS, etc.) in which CIRA and Politecnico di Milano participated. First step: development of a numerical method based on 'morphogenetics' to calculate the deposition and sedimentation of water droplets on low-temperature surfaces. In addition to mimicking the typically randomised accretion process, the solver will allow a DoE (Design of Experiment) numerical analysis campaign based on geometric parameters and air-water thermo-fluid-dynamic conditions typical of the droplet clouds encountered by the aircraft during take-off, hold and landing. The result is the density distribution of ice on the geometry (swept wings, air intakes, flight sensors, etc.). Following the realisation of the database with morphogenetic simulations, the formulation of a density model suitable for finite-volume (FV), finite-difference (FD) or finite-element(FE) "macroscale" methods including, for example, Messinger, "shallow-water" and "double- or triple-layers" will be carried out.

	The activity will be divided into: - Study, definition and development of a "morphogenetic"-based calculation method (1st year). - DoE with variation of geometrical parameters and air-water fluid dynamic conditions and results in terms of density distribution of the ice formed (2nd year, with secondment for experiments at TU Braunschweig and comparison with numerical simulations). - Density model for conventional methods such as FV, FD, FE (Messinger, Shallow-water, PDEs, 3rd year, with internship at CIRA (6 months) and implementation in in-house software at CIRA and Politecnico di Milano)
Educational objectives	The PhD candidate will receive inter-disciplinary, international and intersectoral training. Formal training in fundamental aspects of icing and possible applications will be delivered at Politecnico di Milano. Training on numerical schemes will be delivered at CIRA and at Politecnico di Milano. Training on icing wind tunnel testing will be delivered at CIRA and at TU Braunschweig. The training programme involves ‘training on-the-job’ via project-oriented research, complemented by training programmes in science and transferable skills. .
Job opportunities	The project ambition is to train a PhD researcher in the inter-disciplinary, inter-national and inter-sectoral skills that will enable a successful career in: • the academic sector, where the doctoral fellow could continue their fundamental research on in-flight icing, numerical and experimental fluids dynamics, and uncertainty quantification. • the industrial sector, as a researcher/technic in partner companies or as an entrepreneur, • certification authorities, contributing technical knowledge with policymakers about the available technical options for virtual certification in icing conditions.
Composition of the research group	1 Full Professors 0 Associated Professors 3 Assistant Professors 11 PhD Students

Name of the research directors	Prof. Alberto Guardone

Contacts
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Additional support - Financial aid per PhD student per year (gross amount)	
Housing - Foreign Students	--
Housing - Out-of-town residents (more than 80Km out of Milano)	--

Scholarship Increase for a period abroad	
Amount monthly	700.0 €
By number of months	6

National Operational Program for Research and Innovation	
Company where the candidate will attend the stage (name and brief description)	CIRA
By number of months at the company	6
Institution or company where the candidate will spend the period abroad (name and brief description)	TU Braunschweig (DE)
By number of months abroad	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information
The PhD candidate will receive a desk, possibly through a hot-desking procedure, and a personal computer, if needed. Apart from the compulsory ones, the PhD candidate will have the opportunity to follow additional courses and receive economic support to attend summer schools and participate in conferences. There will be the possibility of paid teaching assistantship.