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Multidisciplinary analysis of a novel anti-icing system for a fixed wing UAV

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# Summary

Aerospace has always been a challenging branch of engineering. Since the first flight of the Wright brothers' the request to have better flying machine has pushed engineers and scientist to more challenging goals.

The need to reduce weight, improve the safety and increase the reliability of aircraft is the same of one century ago. Aeronautics has always been one of the pioneer fields for the introduction of novelty: starting from light alloys going through avionics and finishing with the carbon fibres lot of the invention of common use have been developed for aerospace industry.

Among the most advanced branches within aerospace engineering it is undoubtedly possible to identify the ones relating to structures and to on-board systems. Both of these branches have had a massive development over the past 30 years. This innovation was driven by precise market demands, mainly for liners in the civil and fighters for the military. This development has led to high performance systems with high operating costs and a high degree of complexity. A notable example is carbon fibres with integrated piezoelectric or the more electric philosophy. These innovations, now fully developed and mature, rarely find application in low-cost and low-performance aircraft.

In contrast to the earlier developments, the explosion of the UAV (Unmanned Aerial Vehicle) market forced the entire aerospace industry to rethink past development choices. If until the end of the 1980s the tendency towards more complex and expensive aircraft seemed unquestionable today, many customers require simple, reliable, dependable and inexpensive machines for multipurpose uses.

Mission profiles such as border surveillance, remote sensing, aerial work and military operations have increasingly seen the introduction of UAVs. Today these machines are entrusted with dangerous, dull or risky tasks where the loss of a crew is not acceptable. If only 10 years ago the UAVs were of exclusive military prerogative it is now certain that in the next 20 years they will be increasingly used also in the civil market.

The current need faced by aerospace companies is to make these machines able to operate with an equal safety level of liners or fighters, although with a considerably lower complexity, dictated by their low take-off weight and their reduced power installed.

It is therefore necessary to redesign many systems putting an effort to system integration in order to save weight and reduce the powers involved. Introducing new multidisciplinary design methodologies and exploiting new production technologies can bridge this gap.

This is evident for the anti-ice system. In modern liners it is realized by introducing a conductive mesh inside the composite panel. By contrast, this solution is almost impossible to be applied to light UAV that often have low-power electrical systems, as DC 28V current.

In this thesis this problem is dealt starting from scratch. Exploiting a new design philosophy known as design for additive, anti-icing system has been completely redesigned obtaining advantages both on global weights and on the thermal powers needed. This approach has permitted to go beyond the mere topological optimization and to fully exploit the potential of additive manufacturing.

Lattice structures, impossible to be realized using traditional manufacturing, allowed the integration of the system into the structure, obtaining a resilient and multifunctional structure. Taking advantage of AM (Additive Manufacturing), a sandwich with trabecular cores has been realized, able to fulfill structural purposes and to allow heat exchange. The global efficiency permits to install this system also in piston engine aircraft, thanks to its increased efficiency.

Moreover, the use of additive technologies is not affected by initial investments for the realization of templates and molds; this fact enables to introduce this plant even in very small UAV series.

To achieve this innovation, however, it is prior necessary to lay the foundations of this research topic.

This thesis provides new insight, starting from structural analysis campaigns, prosecuting with experimental and numerical evaluation of heat exchange and defining new computational tools for the prediction of ice formation on leading edges. This work casts lights on this innovation and presents itself as the first step in this pioneering project for the development of an integrated and multifunctional aeronautical system.