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Development of a multifunctional panel for aerospace use through SLM additive manufacturing

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Abstract

Lattice materials can overcome the need of light and stiff structures in the aerospace industry. The wing leading edge is one of the most critical parts for both on-board subsystem and structure features: it must withstand to the aerodynamic loads and bird-strike, integrating also the anti-ice system functions. Nowadays, this part is made by different components bonded together such as external skin, internal passageways, and feeding tubes. In the present work, a single-piece multifunctional panel made by additive manufacturing will be developed. Optimal design and manufacturing are discussed according to technological constraints, aeronautical performances and sustainability.

Keywords: DOE; Metamodeling; Pareto optimality; Virtual protyping; Response surface; Additive manufacturing.

1. Introduction

Thermal anti ice is one of the most widely used groups of anti-ice systems and have been extensively used for the anti-icing since the advent of turbomachines [1]. Those systems are installed in the leading edges of airplane to avoid the formation of ice during flight. From theoretical point of view, icing problem on aircraft or on wind turbine has been widely studied [2,3,4,5,6]. An example of P180 [7] aircraft scheme of this system is reported in Fig.1. Insufflating hot air behind the external panels (such as leading edges of wing helicopters blade) assure that the outer surfaces remain at a temperature over ice formation point [8]. Those systems fulfil a vital function: ice forming may cause an overweight on the wing or lock the control surfaces with potential catastrophic effects [9,10,11].
Other kind of anti-ices have emerged as powerful platforms: over the literature is frequent to find proposal of novel piezo electrical anti ice embedded in carbon fiber structures [12,13] or microwave heating sources [14].

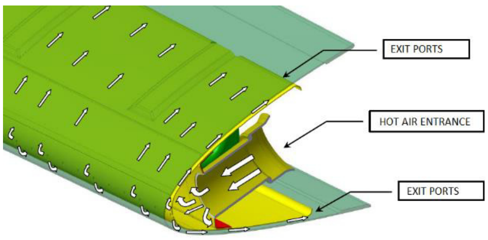

Fig. 1. Layout of P180 anti-ice system [7].

Recently, evidence of flying aircraft, such as the 787, suggests that more electrical airplanes will install more frequently combined power sources. By the way, one of the main obstacles of that type of system is the great current that have to be generated, which would require a revision of the generation system of electrical power. Electro thermal anti ice system is also associated with an increased risk of parasite current and lightning risks.

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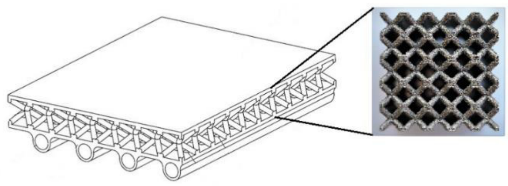

Fig. 2. Panel section with focus on trabecular core.

Despite of it, there is little published data on novel thermal anti ice: most of the papers published have not dealt with the integration of thermal anti ice system inside of the primary structures. The entire system is designed as multiple parts added to the primary structure with joining, bolts or rivets. This work traces the development of a novel system of anti-ice, directly integrated inside the primary structure. This new-patented system [15] uses a lattice core as a heat exchanger, as reported schematically in Fig.2.

Using this sandwich is possible to obtain a light and stiff structure with a great internal thermal exchange surface. Although this novel solution should be complicated to be constructed and tested with traditional technologies, it is easy to be manufactured in a *single-piece* with Additive Manufacturing technology. In fact, Selective Laser Melting (SLM) and Electron Beam Melting (EBM) can realize non-stochastic structures with controlled porosity.

Several papers describe the behaviour of such structures using different material and different cell types, among others [16,17]. The specific objective of this paper is to test different models of cells type and different skin thicknesses to understand which design variable affect mainly the mechanical behaviour.

Data for this study were collected using an aerodynamic 2D CFD tool, Xfoil [18], and a high-fidelity FEM structural code, Optistruct. DOE approach has been utilized introducing Hyper Study to speed up the analysis process. Due to practical constraint, this paper cannot provide a comprehensive view of all the aero-elastic behaviour but is intended to provide new insights for further development.

2. Material and Method

2.1. Model set-up

To establish whether of the design variable affects majorly the mechanical resistance of the sandwich panel, a Design of Experiment (DOE) has been designed. DOE method has been applied through FEM simulations on a NACA profile, using real loads from aerodynamic simulations. FEM model considers the outer skins modelled as shells and the lattice core made by beams. So that, DOE design variables considered in the present work are:

- Cell type: from simple body centered (BCC) to body centered plus vertical beams (BCCZ), as analyzed previously in [19], reported in Fig. 3.
- Cell length: considering thermo-fluid requirements two cell length had been imposed, of 5 and 7 mm each.
- Beam section radius.
- Shell thickness.

FEM geometry (cell type and length) was set-up through a MATLAB code designed for automatize the FEM pre-processing as described in Fig 4.

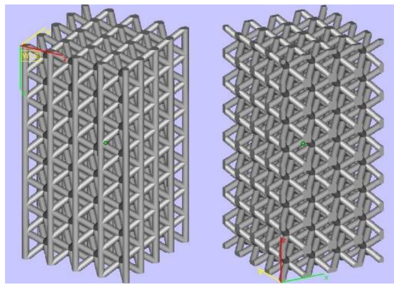

Fig. 3. Cells type made with SLS, on the left BCCZ on the right BCC.

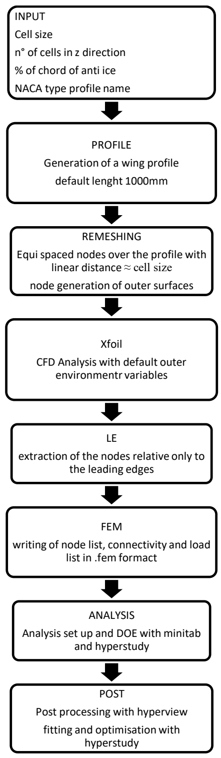

Fig. 4. Set up routine.