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CO2 FOOTPRINT MINIMIZATION FOR AFP BIO-COMPOSITES THIN STRUCTURES

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Abstract

The development of the aeronautical industry has brought about certain demands like the reduction of fuel consumption and, consequently, the weight of used structures. Therefore, topology analysis of aircraft components has played an important role in meeting these demands. Another factor widely studied in this context is the type of materials used in the manufacture of such components, hence, by presenting lower densities, composites have gained ground in this industry sector.

Besides, an increasingly sought-after characteristic is the sustainability associated with the entire life cycle of any system or part, from its design, through the production phase, to its end of life. The assessment of such sustainability is often carried out by analysing the life cycle's CO² footprint, which tends to decrease when the raw materials used are less processed. Materials of natural origin, also known as "bio-materials", have therefore been the target of study, being the basis of the concept of eco-design.

The accelerated development of 3D printing technologies has allowed the evolution of structural design methods. Additive manufacturing emerged in the 1980s and has since been expanding in the aerospace field. One of its great advantages is that it can be combined with the use of bio-composites, such as flax or hemp.

The topology optimisation of any given structure brings great benefits in terms of the mitigation of the CO² impact of a given part, as it translates into a reduction of its mass and fuel consumption. However, the combination of this method with the optimisation of the fibre path, in the 3D printing process, and the CO² footprint of the part's life cycle simultaneously can bring even more evident benefits.

In this paper modifications to existing methods are proposed. In MATLAB, strategies are developed to study the topology and fibre orientation of potentially 3D printed thin structures. Topology optimisation is performed by applying the compliance minimization method to a finite element model for orthotropic materials. Such method is drawn up from the 88-line code published by Andreassen et al.[1]. Furthermore, materials of natural origin are studied. Several resin and fibre couples which can be currently used in 3D printing are taken into consideration to evaluate parts' mass and CO² impact of its production and use phases. To do so, a technique for calculating the CO² footprint proposed by Duriez et al. [2] when studying metallic materials is adapted to suit the case under study. Density and gaussian

filtering are also used to achieve continuous fibre paths, reach mesh independence and eliminate checker-board patterns, ensuring manufacturability of the results.

Since the obtained results show a high dependency on the initial conditions and on the material couple, a parallel optimisation method is applied to find the global optimised solution starting from a set of different initial conditions.

The code can solve different load cases. For the specific case of a half MBB beam, modelled with a 10x30 finite elements domain and a target volume fraction of 0.3, the algorithm returns the result shown in Figure 1. In general, the optimised fibre orientation follows the direction of the material zones and a couple of cellulose resin with bamboo fibre is consistently concluded be one of the most sustainable choices.

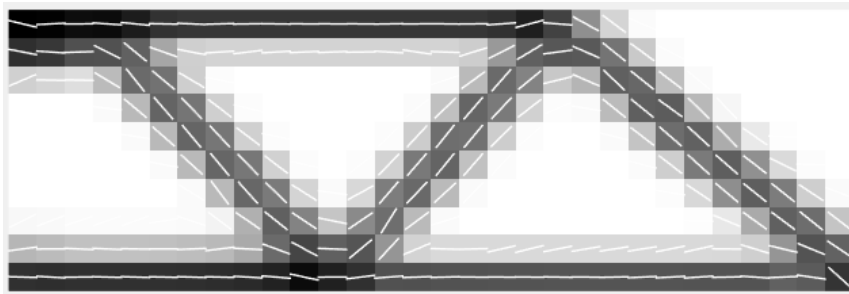


Figure 1– Density distribution and fibre orientation for the half MBB beam load case (volfrac = 0.3)

Keywords: Eco-design, Bio-composites, Topology Optimisation, Fibre Path, 3D Printing.

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