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DAMAGE SEQUENCE OF IMPACT EVENTS ON 3D-PRINTED COMPOSITE LAMINATES WITH QUASI-STATIC INDENTATION TEST

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ABSTRACT

Additive manufacturing techniques are nowadays common in many industrial sectors due to their versatility, fast product development and reduced cost. Although at a different level of use, quick and easy manufacturing of lightweight composite parts, facilitates the introduction of additive manufacturing in aerospace and automobile industries. However, this type of components are susceptible of receiving impacts during their service-life. While this can be one of the most compromising events for the integrity of the structure, there has been little research conducted on the response of 3D-printed composites against impact. In fact, the analysis of the damage mechanisms and sequence taking place in 3D-printed composite laminate during a low-velocity impact event is a key factor for a wider use of this type of materials. As for any other type of laminate, this knowledge will lead to more accurate numerical modelling, improving designs and reducing material weight and costs.

In this investigation, the impact damage in 3D-printed continuous carbon fibre reinforced polymer (C-CFRP) with thermoplastic matrix (PA6) is studied by means of quasi-static indentation (QSI) tests. The additive manufacturing technology used in this case was Fused Filament Fabrication (FFF). Markforged® carbon fibre printing filaments were used to manufacture 80 × 80 mm specimens with 24 layers and a ply thickness of 0.125 mm. Two different stacking sequences, one quasi-isotropic and another with dispersed orientations, were analysed to consider differences in the fibre orientation of the laminate. Coupons were tested under different displacement levels of the indenter, analysing the different phases of the impact.

From the tests, load-displacement curves were obtained and analysed. Different stages of material response were identified. These stages are determined by the occurrence of different damage mechanisms in the material. In this way, it has been possible to identify the delamination threshold load or the load level at which most delaminations in the material take place changing the stiffness of the laminate. Similarly, it has been also determined the load level at which extensive fibre breakage occurs. The damage extension in the specimens was inspected with X-ray Computed Tomography (CT) technique and optical microscopy. The indentation depth after the impact was also characterized. A comparison between the two laminate types considered has been stablished.

The results of this study allowed us to understand the damage sequence in C-CFRP manufactured with FFF 3D-printing technology under out-of-plane loadings, giving a wider comprehension of the mechanical behaviour of these materials.