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Microstructural X-ray analysis and in-situ testing of calendered hybrid CFRPs produced by automatic fibre placement

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Abstract

Lightweight high-performance carbon fibre-reinforced composites (CFRP) promised a 50% reduction in aircraft weight, thus significantly reducing CO2 emissions, but provided, up to date, only around 20% weight savings. Closing this gap requires the development of novel hybrid laminate (i.e. using two different types of carbon fibres) based on state-of-the-art manufacturing methods, such as automated fibre-placement (AFP). In this work, we propose a micromechanical study of thin-ply carbon fibre hybrid composites in view of their potential benefit for opening the design space of CFRP laminates. The use of calendering for the manufacturing of prepregs with tow-level hybridisation is a novel process developed by North Thin Ply Technology (NTPT) [1]. It consists in feeding two different thin ply prepregs through heated calendering rolls, which will flatten and spread the fibre tows, leading to the dispersion of individual fibres. Tow-level hybridisation allows achieving a higher dispersion of the two fibres, which has been associated with positive synergistic hybrid effects leading to improved mechanical

properties [2]. The first goal is to assess the more complex microstructural features arising from AFP-produced hybrid CFRPs resulting from two different hybridisation methods: (i) at the ply level using thin plies and (ii) at the intra-tow level using a novel fibre calendering process. Lab-scale X-ray microscopy (XRM) at a sub-micron voxel size using a Zeiss Versa 615 is used for the microstructural analysis and provides a rich database of microstructures (constituents, defects, porosities, misalignments, etc.) for these novel manufacturing methods, which will serve as basis for the generation of accurate representative volume elements (RVEs) for finite element analyses. The second objective is to perform in-situ double notched tensile tests (DENT) within the XRM to map the damage and failure sequence of the laminates and to relate it to the microstructural features resulting from the manufacturing. The damage and failure sequence is carefully analysed. Digital volume correlation is used to extract the local displacement fields, which will serve as validation for the development of micromechanical models based for the constituents including the impact of the processing. [1] Argyropoulos, A. PhD Thesis EPFL (2023), [2] Swolfs, Y. et al. Comp. Part A 67 (2014)

Keywords:

XRM microCT hybrid CFRP in-situ testing AFP