Analytical and numerical modelling of thermo-mechanical behaviour of additively manufactured Continuous Carbon Fibre Reinforced Polylactide (CCFRP)

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Continuous carbon fibre reinforced polylactide (CCFRP) is a novel type of engineering material which is manufactured by a modified Fused Filament Deposition (FFD) method. In such manufacturing process the polylactide (PLA) filament and pre-impregnated continuous carbon fibre (CCF) are fed into an extruder, where the filament is melted, extruded through a nozzle and deposited in a precise pattern creating subsequent material layers. The application of easily processable PLA and pre-impregnated CCF of high strength results in generation of a composite material of improved interlayer adhesion and favourable mechanical properties. On the other hand, complicated system geometry combined with high thermal expansibility of the PLA matrix causes that the manufactured material is characterized by nonlinear and complex thermo-mechanical properties, which are thoroughly analyzed within this study.

The contribution starts with a brief description experimental tests when the CCFRP composite is subjected to thermal loading of wide range of temperatures and its deformation is measured using Bragg grating sensors. Then, a micro-mechanical finite element model of the CCFRP composite subjected to thermal loading is developed. The proposed model utilizes temperature-dependent stiffness and thermal expansion coefficient of PLA as well as the obtained from the numerical homogenization material properties of pre-impregnated CCF. Further, a simplified analytical micro-mechanical model of a single ply is created, used to determine its homogenized properties and to develop an equivalent single layer (ESL) model of the CCFRP composite. The results obtained from both models are compared against each other, and against the results of the experimental tests. Finally, general conclusions about the thermo-mechanical properties of CCFRP composites and their response to a wide range of thermal loadings are presented.

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