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OPTIMIZATION OF UNIDIRECTIONAL HYBRID POLYMER COMPOSITES USING A SPRING ELEMENT MODEL

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Abstract: Composite materials have met increasingly interest in industry specially in lightweight construction due to their special properties compared to the conventional structural materials. However, they are characterized by having a brittle failure, i.e. typically they have no ductility, which may limit their widespread usage. To overcome this shortcoming, the fibre hybridization method is used to introduce a designated pseudo-ductile behaviour in the fibre reinforced composite material. The present work analyzes and optimizes this hybrid composite material under tensile load based on a Spring Element Model (SEM) proposed in Tavares et al. (2017). In a previous study (Conde et al., 2018), an optimization problem was already formulated in order to find an optimal fibre hybridization using two different analytical models. Despite the employed methodology proved to be effective back then, a new optimization problem formulation is also proposed in this work. This new optimization problem formulation uses the plastic deformation energy per unit of volume as objective function and a new constraint that relates the elastic modulus and the failure strength of a fibre in the frame of continuous optimization. In Conde et al. (2018) analytical models were used and therefore important mechanisms involved in the longitudinal failure of unidirectional composites were not taken into account leading to unrealistic results. The main relevance of the present work has to do with the use of a numerical model of the microstructure which takes into account more failure mechanisms. These new model features enrich the optimization problem such that optimal and more realistic fibre hybridizations are sought. The SEM works here with the definition of a Representative Volume Element (RVE) where a package of two types of fibres embedded in a polymer matrix can be found randomly or periodically distributed. Besides the spatial locations of the scattered fibres regardless their type, it also merits our attention here the possible formation of clusters of fibres of one type or another. In fact, the fibre-type distribution or lay-out impacts the overall composite response and motivates here pursuing a lay-out (topology) optimization problem. A measure of the degree of fibre dispersion in space is proposed here and one uses it to study the sensitivity of the pseudo-ductility behaviour to fibre dispersion or clustering. Ultimately one discovers an optimal mix of fibre materials, as well as, an optimal fibre spatial arrangement for such hybridization which produces a relevant pseudo-ductile behaviour in the composite under uniaxial traction.