# Optimization of Unidirectional Hybrid Polymer Composites using a Spring Element Model

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**Abstract** Composite materials have met increasing interest in the industry, especially in lightweight construction due to their unique properties compared to the more conventional structural materials [1,2]. However, they are characterised by having a brittle failure, i.e. typically they have no ductility, which, and due to safety considerations, may limit their use. To overcome this shortcoming, the fibre hybridisation method is used to induce pseudo-ductile behaviour in the fibre reinforced composite material [3]. The present work analyses and optimizes this hybrid composite material under tensile load based on a Spring Element Model (SEM) proposed in [4].

In a previous study [5], an optimization problem was already formulated to find an optimal fibre hybridisation using two different analytical models. Although the employed methodology proved to be effective, a new and more effective optimization problem formulation is proposed in this work. This new optimization problem formulation uses the plastic deformation energy per unit of volume as the objective function and a new constraint that relates the elastic modulus and the fibre failure strength in a continuous optimization framework. In [5] analytical models were used, and therefore essential 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 is the use of a numerical model of the microstructure that takes into account the possibility of more failure mechanisms. These new model features enrich the optimization problem such that optimal and more realistic fibre hybridisations 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 randomly or periodically distributed. Besides the spatial locations of the scattered fibres regardless of their type, it also merits our attention the possible formation of fibre clusters. In fact, the fibre-type distribution or layout impacts the overall composite response and motivates here pursuing a layout (topology) optimization problem. A measure of the degree of fibre dispersion in space is proposed and one uses it to study the sensitivity of the pseudo-ductility behaviour to fibre dispersion and clustering.

Ultimately one identifies an optimal mix of fibre materials, as well as, an optimized fibre spatial arrangement for such hybridisation which produces a consistent pseudo-ductile behaviour in the composite under uniaxial traction.

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## References

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