ANALYSIS AND OPTIMIZATION OF HYBRID POLYMER COMPOSITES IN UNIAXIAL TRACTION: ANALITYCAL AND COMPUTATIONAL STUDY

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ABSTRACT

Composite materials have met increasingly interest in industry specially in lightweight construction (for example, in automotive and aerospace applications) due to their special properties compared to the conventional structural materials [1,2]. However, they are characterized by having a brittle failure, i.e. typically they have no ductility, which possibly may limit their usage. A ductile failure of a composite material is desired, like in the metallic materials, which present yielding after the elastic region followed by an increasing of the strength. Hybridization is a key factor to introduce a designated pseudo-ductile behavior [3] in the fiber reinforced composite material. The hybridization here consists in the use of two different types of fibers (with different failure strains or strengths) embedded in a polymer matrix with the goal of improving overall composite properties and performance. The present work analyzes and optimizes this hybrid fiber reinforced composite based on failure analytical models. Ultimately one discovers the optimal mix of fiber materials which produces a ductile behavior in the composite material when it is subjected to a tensile load.

To predict the failure of the composite materials, two different analitycal models developed by Tavares et al. [4,5] are used in this work, which are coupled with optimization algorithms. The first model considers a bundle composed of two different fiber types, without matrix, named by hybrid tows. To account for the presence of the matrix, a second analytical model is used here, based on the multiple fragmentation of the fibers. Despite the simplicity of these failure models, they are very useful to work on a correct parameterization of the response curve of the hybrid composite subject to uniaxial traction. A parameterization of that response is strictly necessary for its control and consequent optimization to achieve the desired pseudo-ductile response. One proposes here four parameters which fully characterize the response. These parameters are included in optimization problems formulated here either using a multi-objective function or a weighted sum of objective functions. The final goal is discovering the optimal mix of the base constituents of the hybrid composite.

As regards the nature of problem design variables, two different types of optimizations are performed here using the aforementioned analytical failure models. Firstly, one formulates and solves a discrete optimization problem and then a continuous one. In the discrete problem the objective is to find, from a database of 20

pre-defined fibers available in the market, the optimal match of fibers for hybridization achieving outstanding pseudo-ductile behavior. In the continuous problem, the objective is discovering the properties of the fibers that could be considered ideal to produce the greatest pseudo-ductile behavior. These two types of optimizations are performed here using typically the Genetic Algorithm (GA) as the optimizer.

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