AN INTERVAL-BASED APPROACH FOR THE COMPUTATION OF UNCERTAINTY IN THE MICROMECHANICAL PROPERTIES OF UNIDIRECTIONAL COMPOSITE MATERIALS

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The accuracy of the computed micromechanical properties of unidirectional (UD) composite plies depends on the efficiency of the adopted analytical relations and the uncertainty of the input properties of the fibers and matrix. The uncertainty in the elastic properties of the UD ply reflects to the computation of the stresses and strains while the uncertainty in the strengths to the predicted damage. Thus, there is an accumulative influence on the efficiency of the micromechanics-based numerical design of UD composite materials.

In this work, we present an interval-based approach for the computation of the uncertainties in the micromechanical properties (elastic properties and strengths) of UD composite plies. The micromechanical properties of the UD lamina have been derived using the simplified micromechanics equations proposed by Chamis [1], while the levels of uncertainty are arbitrarily assigned to be the input parameter plus or minus a percentage of it. Our aim is to compute the “tightest” lower and upper bounds for the range of the micromechanical properties. This problem is equivalent to finding the global minimum and maximum values. To this end, we propose an interval branch-and-bound algorithm for computing verified enclosures on the exact range of the micromechanical properties, when the input parameters vary over the uncertainty intervals. The required inclusions are obtained via the use of interval arithmetic which constitutes a valuable tool for estimating and controlling the uncertainties automatically. Our implementation was done in C++ on a Linux platform using the C-XSC-2.5 library [2] for interval computations, while the bounds are computed with the prescribed accuracy 10^{-15}.

The proposed methodology has been applied to the AS4/3501-6 carbon-epoxy UD composite. The input data for the fibers and the matrix have been taken from [3]. Since the Chamis model [1] is deterministic, for assessing the uncertainty of the model, we have repeatedly running the model using different levels of uncertainty from ±0% to ±5% for the uncertain inputs. The corresponding distributions as well as summary statistics for each elastic property are reported. Having already computed the ranges of the strengths of the UD ply, we have used interval arithmetic operations to derive in closed-form the damage prediction uncertainty for the Hashin-type failure criteria [4]. Using the closed-form uncertainties of intervals and sets of stresses obtain by finite element analysis for a quasi-isotropic AS4/3501-6 composite laminate, we have quantified the uncertainty of damage prediction for each damage mode.

References

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