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Numerical and Experimental Methods for the Identification of Interlaminar Properties in LSI Manufactured C/SiC Composite

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ABSTRACT

Ceramic Matrix Composites (CMC) combine good structural properties with resistance to high temperature, abrasion, erosion, and friction. Composites based on Silicon Carbide matrix reinforced by carbon fibers (C/SiC) are nowadays a solution for the development of hot structures and thermal protections in the aerospace field [1]. To extend the usage of C/SiC composites in structural applications, it is fundamental to expand the knowledge of failure modes of the composite and the ability to predict them. The task is not straightforward, since the material exhibits non-linear inelastic responses even in the low strain region, as widely studied in literature [2], while the investigation of the interlaminar damage and failure is relatively less studied. Actually, delamination can occur in CMC structural elements under different circumstances. Some of them are common to long fiber reinforced polymers, such as in failure near tapering or in curved regions, while others are characteristics of CMCs and originate from defects induced by the manufacturing process and from thermal residual stress arising in the subsequent cool down phase. This work aims to characterize the interlaminar properties of a C/SiC composite, hence an experimental campaign was performed by means of Double Cantilever Beam (DCB) tests. The evaluation of different methods to produce the pre-cracks is presented and the potential interaction between in-plane stresses and delamination is assessed using different thickness for the tested specimens. The tests showed that the crack propagation was characterized by deviation, inelastic phenomena and fiber breakage. By the application of Modified Beam Theory (MBT) to evaluate the interlaminar fracture toughness, an R-Curve effect was identified, which could be attributed to the development of damage in the reinforcing fibers of the plies adjacent to the interlaminar crack. The numerical modelling of the delamination is obtained through the implementation of a Cohesive Zone Model based on the tri-linear CZM proposed in literature [3], using an automatic identification algorithm for the model parameters. The identification procedure uses a regression model based on neural networks and an optimization through a genetic algorithm or a Monte Carlo like method to minimize the discrepancies between the experimental and the numerical response. The application of the method separately on each specimen allows to correlate the scattering of the experimental results with the parameters distribution. The work improves the understanding of the delamination phenomena in CMC produced via LSI technique, by defining a reliable numerical-experimental protocol to identify the interlaminar toughness and the parameters of a CZM model capable of predicting the forces required for delamination propagation.

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