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Safety and Certification of Discontinuous Fiber Composite Structures

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ABSTRACT

Recently, discontinuous fiber composites (DFCs) are widely used in various engineering applications, thanks to their unique mechanical properties and manufacturability compared to their continuous fiber counterparts. For the broad application of DFCs in aerospace industry, however, we need to have a thorough understanding of the complex behavior of DFCs, particularly their fracturing mechanisms. Previous studies have hinted that the failure behavior of the DFCs are highly dependent on their chip morphology, the presence of defects at the microscale, and the structural geometry at the macroscale. However, systematic studies on their effects are incomplete, and their unique failure mechanisms compared to continuous fiber composites are as yet elusive. In this study, we investigate experimentally and numerically the size effect of DFCs. We test geometrically similar single-edge notched specimens with a constant thickness, but in three different unidirectional prepreg chip sizes (25×4, 50×8 and 75×12 mm). To control the sizes of the platelets which are not available in the commercial market, we develop an in-house manufacturing process, such that each platelet's dimensions are precisely controlled. We test five different sizes of single-edge notched specimens, geometrically scaled with a constant thickness. The scaling ratio is chosen to cover the wide range of the specimen sizes which deviate from the traditional single-edge notched specimen size. We apply a uniaxial tension load and record the fracturing behavior of the DFCs. As a result, we observe notch insensitivity meaning that the crack initiated away from the notch, when the structure size is small. However, after a certain threshold, the larger size coupons always show a significant notch sensitivity. To analyze such unconventional fracturing behavior, we employ Bazant's size effect law. Experimental results are well fitted with the law, clearly showing the transition behavior of the DFC from the notch insensitive to sensitive. The transition of fracturing behavior implies that design criteria for use with DFCs should shift from strength-based to energy-based approaches. To obtain the fracture energy, we develop a finite element model based on the stochastic laminate analogy. The findings in this study enhance our understanding of the damage behavior of DFCs, which can potentially contribute to establishing guidelines for the optimal and safe design of DFC-based aerospace components.