Micromechanical failure in fiber-reinforced composites

Micromechanical failure mechanisms occurring in unidirectional fiber-reinforced composites are studied by means of the finite element method as well as experimental testing. This study highlights the effect of micro-scale features such as fiber/matrix interfacial debonding, matrix cracking and microvoids on the microscopic and macroscopic mechanical response of composite materials. To this end, first a numerical study is carried out to explore ways to stabilize interfacial crack growth under dominant Mode-I fracture using the cohesive zone model. Consequently, this study suggests a method to determine the normal interfacial properties. Afterward, two different numerical approaches (I) the regular fiber distribution approach and (II) the random fiber distribution strategy are established to evaluate the effect of the microscale features on the overall stress-strain response of unidirectional composites. In the first approach, the J2 plasticity model is implemented to model the elasto-plastic behavior of the matrix while in the second strategy the modified Drucker-Prager plasticity model is utilized to account for brittle-like and pressure dependent behavior of an epoxy matrix. In addition, the failure locus of the composite lamina under different loading conditions is obtained by means of computational micromechanics and compared with the predictions of Puck’s model. The results are in very good agreement with the predictions of Puck’s model under different interfiber failure modes. In order to validate the numerical microstructural approach accurately, an experimental test was carried out to be compared with the numerical results. It was found that the micromechanical model could accurately predict the crack initiation emanating from microvoids as well as crack propagation along the interfaces. The results of this thesis show that the strength of composite is significantly reduced by weak interfacial properties and the presence of voids. The size and shape of microvoids can also microscopically lead to different crack paths. Finally, the present numerical strategy seems to be a promising tool to predict the macroscopic and microscopic mechanical response of composites.