INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Thesis Title: Experimental and Computational Analysis of Interface Fracture using Extrinsic and Intrinsic Cohesive Zone Modelling

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SHORT ABSTRACT

In recent years, material interfaces have become part of numerous engineering and structural applications. Interface failure comprising both cohesive and adhesive failure is one of the shortcomings of bonded structures during service loading conditions. Therefore, predicting interface failures is essential for ensuring the reliability, safety, and cost-effectiveness of systems and processes across various industries. The cohesive zone model (CZM) is a widely used computational technique for analyzing the interface fracture phenomenon within computational fracture mechanics studies. The main objective of the present thesis is to expand the applicability of the CZM for a wide range of material interfaces, ranging from adhesively bonded joints to laminated composites. Additionally, the experimental crack growth studies of isotropic and orthotropic material interfaces augment the proposed numerical methodology within the finite element framework.

The CZM is classified into two types based on the shape of the traction-separation law (T-S-L): the extrinsic and the intrinsic. While there are many studies on the applications of the intrinsic CZM owing to its simplicity in implementation, the associated stress singularity characterized by the stress intensity factor (SIF) of a crack is not nullified. Until now, there has been no practical application of the extrinsic CZM, which nullifies the SIF for predicting the interface crack propagation. Therefore, one of the primary objectives of the present work is to investigate the influence of the primary parameter – characteristic length of the extrinsic cohesive zone towards nullifying the SIF and predicting load vs. displacement response due to crack propagation. The SIF at the crack tip is obtained using the interaction integral technique, including crack face traction. The computed results agree with the analytical/semi-analytical results for constant and linear T-S-L. The influence of the order of different extrinsic cohesive laws on the crack tip SIF is also analyzed and contrasted with one another. To extend the applicability of the extrinsic CZM with SIF nullification criteria, experimental interface crack growth studies on adhesively bonded joints are carried out under pure mode I and mode II loading conditions. For pure mode II loading, the intrinsic CZM is also used to predict the experimentally observed load vs. displacement response, and its performance is contrasted with the extrinsic CZM results.

Though CZMs are popular, few deterministic approaches exist to estimate the cohesive strength and fracture energy for predicting interface failure due to crack propagation. In most cases, direct and indirect approaches are used to evaluate the CZM parameters, which involve customized experimental setups and numerical procedures. The latter include regression analysis, trial and error, etc., to determine the parameters, which are computationally intensive and time-consuming. In the present thesis work, the cohesive strength is estimated using the cross-tension and short-beam shear (SBS) tests for mode I and mode II, respectively. Subsequently, the mode I and mode II cohesive energy are determined from double-cantilever beam (DCB) and end-notch flexure (ENF) tests. The experimentally determined cohesive parameters are used in the FE analyses for predicting the mechanical responses for hydroxyl functionalized multi-walled carbon nanotubes (MWCNTs) reinforced, laminated carbon fiber reinforced plastics (CFRP) under pure mode I, mode II, and mixed-mode loading. The computed mechanical responses are in good agreement with the experimental findings for different kinds of loading, demonstrating the effectiveness of the proposed approach. Finally, the fracture surfaces of composites are investigated under field emission scanning electron microscopy (FESEM) to understand the mechanics of the interface fracture.