Delamination and debonding failure of composite T-joint

Background
During composite structure design and certification process, the building block approach (BBA) is usually used. The benefits from the interaction between experiments and analysis strongly rely on the predictive ability and accuracy of analyze methods. The increase in computational capabilities and advance in failure simulation methods has made it feasible to analyze the fracture mode and loading capacity of engineering structures. This project aims to improve the knowledge of the debonding and delamination failure mechanisms, and to develop accurate methods to predict the mechanical response of composite T-joints. In the last three years, several subtopics has been investigated, which are present as follows.

1. Pull-off failure of co-cured T-joints
Cohesive elements are inserted between every two bulk elements to predict the random crack initiation in the filler at the root of the composite joint. The composite joint is simulated under pull-off load, and the numerical result is in good agreement with experimental one.

2. Multi-scale simulation of Z-pinned composites
A meso-scale FEM for analyzing the Z-pin failure during mixed mode delamination was developed, which is able to predict the Z-pin bridging response in UD and cross-ply laminates. An enhanced frictional zone with significant plastic deformation was located near the delamination surface.

3. Higher order beam theory
A novel higher-order sandwich beam theory has been developed to analyze the beam consists of a single layer of adhesive and two adhered laminates. This theory is based on a special form of a cubic expansion for the in-plane displacement components through the thickness

Based on the present theory, a new method has been developed to measure the adhesive shear stiffness and strength

4. Constitutive law of ductile adhesive layer
The failure mechanism of adhesive material (particle toughened epoxy) under tension/shear load was investigated with in situ SEM. The local constitutive response of ductile layer was obtained on the base of J-integral. The dependence of adhesive loading capacity on tension-shear displacement path was discussed.

Summary
New numerical model and experiment method have been developed by the author to explore the fracture behavior of composite materials at meso/micro scale. Base on the improved knowledge of fracture properties, corresponding analysis methods have been present to analyze practical composite structures, i.e. T-joint in this topic.

The present work does not only contributed to the analysis of composite structure. Some potential applications include the failure of rivet joints, new method for biaxial test of polymer materials.

Publications
Hao Cui, Yulong Li, Sofonis Koussios, Adriaan Beukers,(2013) "Mixed mode cohesive law for Z-pinned composite analyses", accepted by Computational Materials Science.
Hao Cui , Yulong Li, S. Koussios, A. Beukers , (2010) “ Parametric evaluation on the curved part of composite T-joints base on numerical simulation”, ICAS 2010