ABSTRACT

Carbon fibre reinforced plastic (CFRP) composites are widely used in the aerospace industry for enhanced thermomechanical properties. This research work presents effective investigations for characterization of interlaminar, intralaminar and translaminar fracture in aerospace grade unidirectional laminated composites (Hexply 914/34%/UD 160/AS4-12K). The laminated composites panels are fabricated using autoclave curing process in order to achieve optimum laminate properties. Thin layer of release films have been inserted between the central plies of laminates to introduce a starter delamination in the specimens. Mode-I intralaminar and translaminar fracture toughness tests have been performed on compact tension (CT) specimens of CFRP laminated composites. The interlaminar fracture tests have been performed on non-precraked (NPC) and pre-cracked (PC) specimens in order to account for the amount of energy required to initiate crack propagation from the natural crack front and sharp crack tip, respectively. Mode-I, Mode-II and Mixed-Mode (Mode-I+II) interlaminar fracture tests have been performed on Double Cantilever Beam (DCB), End-Notched Flexure (ENF) and Mixed-Mode bending (MMB) specimens, respectively. The Mode-I and Mode-II frature tests have been performed on both NPC and PC specimens in order to estimate the influence of crack tip nature on fracture behaviour. Mixed-Mode fracture tests are performed on NPC specimens for the estimation of energy required to initiate crack growth from the natural crack tip.

The experimental Mode-I fatigue tests have been carried out on NPC and PC specimens. To determine the fibre bridging effect, DCB specimens have been tested under cyclic loading with constant stress ratio and displacement followed by increased loading displacement. A significant shift in Paris law resistance curves represents the influence of fibre bridging in the specimen. The Mode-II fatigue tests have been carried out using a 3-point bending fixture PC specimens. During their service life, composite structures are exposed to adverse environmental conditions. The Mode I & Mode II fracture tests are carried out on aerospace grade composite (AS4/914) specimens at -55^0C, which is similar to the cruise condition of an aircraft. A significant reduction in interlaminar fracture toughness has been observed due to the fragile nature of the matrix under a cold environment. The modified traction separation law for Mode-I tests has been evaluated

from the superposition of traditional bilinear law and derived fibre bridging law. The scanning electron microscopy (SEM) technique has been utilized for the examination of fractured surfaces in order to understand the fracture morphologies, failure source and probable cause of failure. The experimentally obtained fracture properties have been further introduced to numerical formulation for crack initiation and propogation modelling under different and environmental conditions. The service life of delaminated or damaged structures may be prolonged through effective damage control instead of immediate replacement of the structure. This research work presents, an investigation of Mode-I fracture control in unidirectional laminated composites using a smart material approach. The P1 type macro fibre composites (MFC) actuators are selected for current research because of their higher free strain, high mechanical flexibility and good blocking force. Mode-I fracture tests have been performed using surface bonded MFC actuators under the application of electric voltages. The MFC actuators have significant control over Mode-I fracture energy of CFRP laminated composites under the application of electric voltages.

A NURBS-based Extended Isogeometric Analysis (XIGA) approach has been adopted for fracture analysis in orthotropic media with varying angle of orthotropy. The numerical simulations of the intralaminar and translaminar fracture using XIGA approach shows a good agreement with experimental results. Numerical simulations of interlaminar fracture have been carried out using a combined framework of fracture mechanics encompassing extended isogeometric analysis (XIGA) and CZM approach of damage mechanics. The XIGA-CZM based approach efficiently models interlaminar fracture in laminated composites under Mode-I, Mode-II and Mixed-Mode loading conditions. This combined XIGA-CZM approach has been utilized for fatigue crack propagation modeling in DCB and ENF specimens. This XIGA-CZM based numerical approach has been further enhanced and enriched with thermally influenced fracture toughness properties. Results obtained from the present approach shows a good agreement with experimentally obtained results. The modified pin force model (MPFM) has been adopted for the evaluation of actuation forces in surface bonded MFC actuators. The XIGA-CZM based approach in combination with MPFM has been further utilized fracture modelling under electromechanical loading conditions and shows a good agreement with experimentally obtained results.