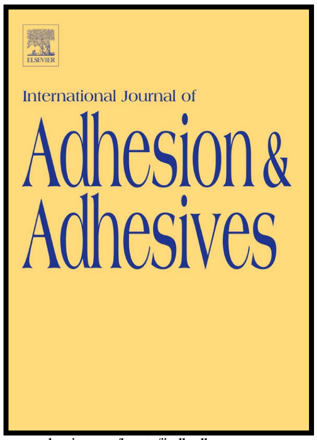

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Inter-laminar Delamination Analyses of Spar Wingskin Joints Made with Flat FRP Composite Laminates

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Abstract 3D Finite Element Analyses have been carried out for Spar Wingskin Joints made with laminated Graphite Fiber Reinforced Plastic composites subjected to uniformly distributed transverse load. The delamination has been pre-embedded at the most likely location, i.e. in resin layer between the top and next ply of the fiber reinforced plastic laminated wingskin and near the spar overlap end. Multi-Point Constraint finite elements have been made use of at the vicinity of the delamination fronts. This helps in simulating the growth of the embedded delamination at both ends. The inter-laminar peel and shear stresses responsible for causing delamination damage have been evaluated. Strain energy release rate components corresponding to the Mode I (opening), Mode II (sliding) and Mode III (tearing) of delamination are determined using the principle of Virtual Crack Closure Technique. These are seen to be different and non-self-similar at the two fronts of the embedded delamination. Mode I Strain energy release rate (G_I) primarily governs the process of delamination propagation.

Keywords: Delamination, Strain Energy Release Rate, Spar Wingskin Joint, Virtual Crack Closure Technique

1. Introduction

Adhesive bonded Spar Wingskin Joints (SWJs) used for integral wing design and manufacture is an efficient fabrication method which facilitates layup and co-cures in a single operation, the spar and lower wingskin using suitable bonding material. This process yields significant cost savings by doing away with the assembly tools and multiple curing in autoclave. Efficient sharing of the wing load has been the primary concern of the SWJs. Since analysis of SWJs subjected to transverse loadings is comparatively a much more complex process, suitable steps towards their analyses find significant importance for design and manufacturing of integrated modular wings.

The SWJs are generally subjected to out of plane transverse loadings. Further, the configuration is complicated in nature and the constituent parts (spar and wingskin) are made with Fiber Reinforced Plastic (FRP) composite (orthotropic) laminates. The delamination simulation process and its propagation require greater involvements of FE schemes. Thus, the analysis of the SWJs serves as an useful step and greater importance for the integrated modular wing design of aircraft and fuselage structures.

However, some experimental as well as numerical analyses have been carried out to predict the strength of the joint. Lackman et al. [1] developed a method for strengthening bonded structures such that the joints can withstand the combination of structural loads and fuel pressure which generates peeling forces at the end of the spar base flanges. They initially introduced the concept of using either metallic pins or stitching to reinforce with the conventional I-beams which was inefficient to bear up loads acting on the wings. Gillespie and Pipes [2] conducted experiments and Finite Element Analyses (FEAs) on integral composite joints with titanium and graphite/epoxy inserters in the SWJ. They proposed the load coupler concept which significantly increased the load transfer capability of the joint.

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