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Abstract

Spar Wingskin Joint (SWJ) comprises of a thin spar which overlaps and is co-cured to a thick wingskin by suitable adhesive materials. These joints are mostly used in integral modular fabrication of aircraft and fuselage wing structures usually made with curved laminated Fibre Reinforced Polymeric (FRP) composite panels. This paper deals with the analyses of initiation of adhesion failure and its propagation in SWJs subjected to transverse loadings using Finite Element Analyses (FEA) and fracture mechanics approach. Normal and shear stress distributions at different interfacial locations between the adherends and the adhesive have been evaluated. Tsai-Wu coupled stress failure criteria have been used to identify the location of onset of adhesion failure. The critical location for onset of adhesion failure has been found to be at the toe-end of the spar wingskin overlap region. Pre-embedded adhesion failure has been simulated at this location and Strain Energy Release Rate (SERR) components corresponding to Mode I, Mode II and Mode III of adhesion failure have been determined using the principle of Virtual Crack Closure Technique (VCCT). Rate of propagation of adhesion failure has been evaluated by sequential release of Multi-Point Constraint (MPC) and contact finite elements provided at the pre-embedded failure front. It has been observed that Mode I component of SERR primarily governs the process of adhesion failure propagation. The appropriate spar overlap length on the wingskin has been determined in order to prevent adhesion failure. Further, an attempt has been made to improve the structural integrity of the SWJ by reducing the stress concentration at the ends of spar and wingskin overlap. This has been achieved by obtaining a favourable stress distribution over the entire joint structure by using Functionally Graded Materials (FGM) in the spar and wingskin adherend instead of FRP composite panels. Exponential gradation indices have been used for material grading of the spar and wingskin adherends. It has been seen that peel and shear stresses and values of SERR components as well as total SERR reduce significantly by use of FGMs with suitable exponential material grading index.

Keywords: Adhesion Failure, Finite Element Analysis, Functionally Graded Materials, Multi Point Constraints Spar Wingskin Joint

1. Introduction

Studies on adhesively bonded joints reported so far have been broadly focusing on in-plane loaded joints like single lap, lap shear, double lap and butt joint, etc. In contrast, adhesive bonded SWJ is considered to be an out of plane loading type joint which are usually used for joining flat or curved panels in aerospace, automotive and chemical engineering industries. For integral design and manufacture of the wings for the fuselage of an aircraft, SWJ facilitates layup of the