Experimental and Numerical Characterisation of Porosity in Secondary Bonded Laminated Composite Joints

Abstract

Composite materials are used to manufacture aircraft components and sub-assemblies using many methods like monolithic, co-cured, co-bonded and secondary bonding process. Secondary bonding differs from other manufacturing methods. In the secondary bonding method, an adhesive is used to bond the adherends (skin and rib assembly). This leads to complication in manufacturing as well as Non Destructive Inspection and Evaluation. A new manufacturing methodology was developed by simulating the real situation in the production unit of composite industry. This methodology was called “Diverse Cure System” (DCS) and was adopted in the manufacturing of porous laminates (monolithic) and in secondary bonded constructions. The monolithic laminates were fabricated with porosity using the DCS method and these laminates were tested non-destructively for porosity evaluation. The influence of porosity was studied by mechanical testing of different specimens for ILSS (Inter Laminar Shear Strength) were analysed. Porosity levels were determined using acid digestion method and compared with mechanical strength. The failed specimens were also analysed for porosity by micro graphical studies. The results of Non Destructive Evaluation (NDE) of laminates were compared and correlated with the numerical model.

Similar manufacturing process was adopted for secondary bonding of cured laminates. Three different categories of lap joint specimens were manufactured, that is pristine, medium and poor secondary bonded specimens. The secondary bonded lap joints were further evaluated by NDE and finally tested for failure strength in each category. All the three categories of lap shear joints were modeled and analysed numerically. The appropriate NDE method of inspection and quantification of different bonds was arrived at. All these results were correlated and the ideal NDE method was obtained. Further, this process has been extended to stiffened construction like 'T' joint, which is similar to the actual critical joints followed in aircraft structure. The pre-cured laminate and 'T' construction panel were bonded with adhesive by following the above manufacturing process. The secondary bonded 'T' joint specimens of three categories were initially evaluated by NDE and were compared with the numerical model for evaluation of joints. Abaqus® software was used for modeling pristine, medium and poor 'T' joints. On completion of NDE analysis, the 'T' joint specimens were tested for failure initiation and strength. The behaviour of porosity is well understood in bonded joints its qualification methodology developed using ultrasonic NDE. An attempt has been made to develop a segment of aircraft structure using secondary bonding technique. Two skins and internal sub-structure (miniscule box) were bonded using the secondary bonding method. The above NDE method / database was used for quantification of the miniscule box structure. The NDE results were similar and the quantification of the miniscule box assembly was comparable. This research work gives confidence towards applying this methodology in the actual aircraft applications.

Keywords: Composite laminate, porous laminate, secondary bonds, lap joints, porosity, Non Destructive Evaluation, ultrasonic, pulse echo inspection, 'T' joint / junction, box structure / assembly.