 Numerical Simulation Strategies of Single Lap Joints

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\textbf{ABSTRACT}

Single Lap Joints between steel and composite adherends, bonded with an epoxy resin, are numerically examined. The purpose of this work is to verify the reliability of different numerical strategies in simulating the delamination of the interfaces. Theoretical fundamentals of each method are taken into account. The main geometrical parameter is the overlap length. Numerical results are compared to experimental tests; benchmarks of the simulation quality are the elastic stiffness of the joint and its failure load.

\textbf{KEY WORDS}: single lap test; cohesive zone model; bonded joint; ADINA; Marc

\textbf{INTRODUCTION}

Composite patches are being increasingly used to repair metallic corroded or cracked components or even to reinforce structures which are subjected to loading conditions heavier than those of design. Compared to traditional repairs, the use of composite patches allows to save weight and costs, especially considering the restrictions in carrying out hot works. Moreover, aeronautical industry has been making extensive use of adhesive bonding for seventy years with excellent results and the strength and durability of bonded joints have been demonstrated over the years; nevertheless the extension of this technology to other fields is still a challenging task.

Bonded joints are a potential substitute of conventional technologies such as riveted and welded joints or mechanical fasteners. The use of bonded joints preserve the structural integrity, avoiding stress concentrations that would arise at reduced contact areas when rivets, bolts or point welds are used. In particular, when fiber reinforced composite are used, traditional fasteners usually result in the cutting of fibers and in the introduction of stress concentrations; on the contrary, bonding allows to preserve the continuity of the structure. However a lack of suitable material models and failure criteria has resulted in a tendency to overdesign adhesive bonding and to include mechanical fasteners as a safety precaution.

Main challenges to bonding deal with surface preparation, adhesive selection, technician skills and confidence in analyses; this work addresses the latter challenge by investigating numerical strategies to predict the adhesive behavior.

The purpose is to provide useful informations about the selection of material parameters, the calculation of strain and stress field in the adhesive and the evaluation of the failure load of the joint.

The test case is a single lap joint, a solution widely used for several applications and which is considered representative of the behavior of most adhesive bonded joints. In fact single lap tests do not aim to characterize the constitutive parameters of the materials but they are useful to provide the general behavior of the joint and to compare different adhesives; in particular this type of test is useful to investigate the ultimate strength of the joint and its failure mode.

Shear stress along the bond line is not uniform because of stress concentrations at the overlap ends; moreover the arm existing between the pull loads produces peel tension in the joint and at the interfaces; therefore samples are loaded in a mixed mode I-II.

Many authors developed closed-form solutions for bonded lap joints when the adherends are loaded in tension. The first analytical model to provide the stress distribution in a bonded joint was developed by Volkersen (1938). He considered that the adhesive only deforms in shear, while the adherends only in tension; the bending effect due to the eccentric load path is not considered. The adhesive is modeled as a set of elastic springs which counteract the axial relative displacements between the adherends.

Goland and Reissner (1944) considered the peel stresses for the first time. They studied a bonded joint in which the adhesive was compared to couples of independent springs which could withstand both axial relative displacement and bending deflection; adherends were considered as beams and their bending were taken into account to predict the peel stress in the adhesive.

Later, Volkersen’s model was extended by Hart-Smith (1973) who considered elasto-plastic adhesives and by Tsai, Oplinger and Morton (1998) who introduced the shear deformation of the adherends. However the theories just exposed are valid only for adherends of the same material and of identical length and thickness.

On the contrary, literature on bonded joint between dissimilar adherends is very limited. Meanwhile the use of dissimilar adherends is an interesting task, since the stress concentrations at the ends of the overlap could be reduced acting on the Young’s modulus or the ratio of adherends’ thickness. The most complete work on non balanced single lap joints was carried out by Cheng et al. (1991) and by Zhao et al.