ANALYSIS OFADHESIVELY BONDED JOINTS IN AIRCRAFT STRUCTURE

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Abstract :

This thesis focuses on experience with adhesively bonded joints in aircraft structures. Adhesively bonded joints are used in the assembling of structural parts, especially of those which are made from dissimilar materials. These joints consists of adhesive layer and adherends with different mechanical and thermal properties. Some imperfections like holes, thermal residue stresses occurring in the bolted, welded, riveted and soldering joints don't take place in these joints. So the main advantages of bonded joints are lightness, sealing, corrosion resistance, heat and sound isolation, damping and quickly mounting facility which is proved. This thesis introduces an attempt to study the debond analysis of adhesively bonded joints. Single lap joints having failure at the interface of adherent and adhesive are modeled in MSc Nastran software. The coordination of the experimental and numerical techniques makes it possible to find an efficient tool for studying the debond performance of adhesively bonded joints.

I. INTRODUCTION

1.1 Adhesive bonded joints

Adhesive bonding technology has expanded greatly in recent years as more and more advanced composite materials are being utilized. Adhesive bonding is material joining process in which the adhesive, placed between the adherend surfaces solidifies to produce adhesive bond. Adhesive bonding is good choice for joining similar or dissimilar materials. The use of adhesive bonding as a joining method in aircraft construction is the accepted method of attaining high structure efficiency and improved fatigue life. The adhesive bonding gives the light, stiff and economical structure free of blemishes caused by conventional assembly methods. It is observed from the various experiments and analysis that adhesive joints prove to be more efficient for lightly loaded structure, whereas mechanically fastened joints are more efficient for heavily loaded structure. Bonded joints have the major advantages of having less source of stress concentration, efficient load transfer in large area of bonding, superior fatigue resistance and high strength to weight ratio compared to discrete joints.

Adhesive being viscous, flow over the surface of soild and because of their intimate contact, interact with its molecular forces. Then, as a result of adhesive curing process, they become strong solid which while retaining intimate contact with the surfaces hold them together. These adhesives are not strong as metal adherends, and hence, the adhesive interlayer will always tend to be the weakest link in bonded structures. Care is therefore to be taken to ensure that service stresses are well within its capabilities. This is normally achieved by providing a relatively large area in bonding. The failure in adhesively bonded joints can occur due to any of the following reasons: cohesive failure within adhesive, adhesive failure which occurs at interface of adhesive and adherend and failure of adherend which also includes delamination in composite structure or due to their combinations. The other type of failure is cyclic debonding in which progressive separations of adherends occur by failure under cyclic loading.

1.2 Failure modes

In adhesively bonded joints under in-plane loading, there exists typically three failure modes. They are,

- Adherent or substrate failure: a substrate failure occurs when the adherent fails before the adhesive. In metals, this occurs when the adherent yields.
- Cohesive failure: a cohesive failure is characterized by failure of the adhesive itself.
- Adhesive failure: an adhesive failure is characterized by failure of the joints at the adhesive or adherent interface. This is typically caused by inadequate surface preparation either chemically and/or mechanically.

1.3 Advantages of adhesive bonded joints

- Uniform stress distribution
- Possibility to join large surfaces
- Possibility to join very large thin adherents
- Gas-proof and liquid-tight
- No contact corrosion
- Good damping properties
- High dynamic strength
- Dissimilar materials, such as metals, plastics, wood, and ceramics can join.

II. METHODOLOGY

2.1. Modelling of adhesively bonded joints

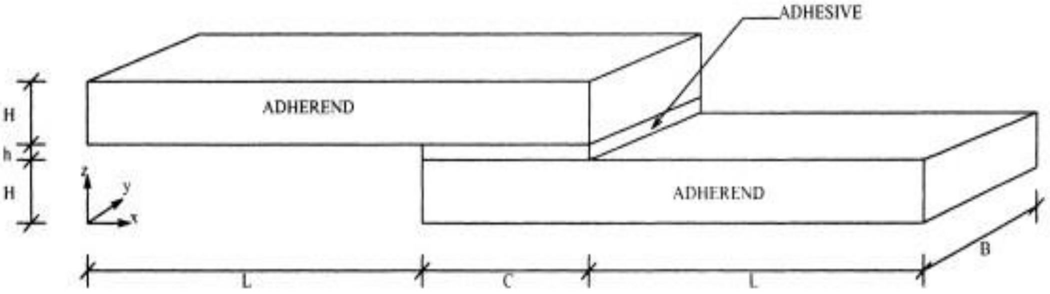

Fig.2.1 Dimensional representation of adhesively bonded joints

- Breadth of adherend(B) = 60mm
- Height of adherend(H)=20mmm
- Height of adhesive(h)=5mm
- Length of adherend unbonded region(L)=100mm
- Adherend – Aluminium,Graphite
- Adhesive – Redux 319

An adhesively bonded lap joint between aluminium-aluminium, aluminium-graphite and graphite-graphite is considered. Adherents are bonded using Redux 319 adhesive.

Since the adhesive free ends are subjected to high stress concentrations these critical regions will be refined until the reasonable results are obtained. Multipoint constraints will be used on the nodes to apply the stress. These act as rigid link between the nodes on the adherent and to the node of application of stress. This helps in the uniform application of stress on the adherent.

In the finite element method the structure is divided into small regions which has the same properties and with finite size. The elements are connected by nodes. The finite element type is also important in modeling the structure and to achieve a reasonably accurate solution. Since the problem requires a two-dimensional analysis, four noded iso-parametric quadratic quadrilateral plane elements were used to model adhesive layer and aluminium adherents.

The single lap joint will be modeled using finite element mesh. The stress state is relatively constant is relatively constant in the width direction. Therefore the problem will be considered as analysis of asymmetric joints, such as the single lap joint it is important to take geometric non-linearity (changing geometry under loading) into account. Commercial MSC Nastran software is used to solve the problem. Microsoft Excel is used to plot results.

2.2. Material properties

Numerical analysis is carried out using iso-parametric 2-dimensional Quad-4 elements. The adhesive is assumed to be elastic-perfectly plastic. Table 2.2 shows the material used in the various components of the adhesively bonded joints.The shear modulus of graphite/epoxy of 4146MPa is considered and analysis is done usimg orthotropic Quad-4 elements.

Materials	E_1 (MPa)	E_2(MPa)	ν (MPa)	σ_{yp}(MPa)
Adherent(aluminium)	71020	71020	0.3	324
Redux 319 (araldite)	2189	2189	0.33	43.2
Graphite/epoxy	130930	11720	0.0188	-

Aluminium 1060 alloy - 1060 aluminium alloy is aluminium-based alloy in the “commercially pure” wrought family. It is very similar to 1050 aluminium alloy,with difference coming down to 0.1% aluminium by weight. However,while both 1050 and 1060 are covered by the same ISO standard,they are covered by different ASTM standards.

Redux 319 – It is a high performance modified epoxy film adhesive curing at 350ºF.It is available in both supported and unsupported versions at areal weights between 0.03 and 0.08psf.The supported versions contain a woven nyon carrier for glueline thickness control and improved handle ablity.Redux 319 is a hot melt film which is free of solvents and consequently it has low volatile composition in it.

III. RESULT AND DISCUSSION

The stress analysis is carried onadhesively bonded joints with different adherents. The adherents of aluminium-aluminium, aluminium-graphite/epoxy and graphite/epoxy- graphite/epoxy are considered. The peel stress and the shear stress variations along mid bond line of adhesive lap length are drawn. The peel stress variation and shear stress variations. The peel stress distribution along the mid bond line is nearly symmetric due to the way of imposing boundary conditions on the two ends. Whereas, the shear stress distribution along the mid bond line has the value going near to zero, and on the right end has large value because of load transfer.

Peel stress distribution along mid bond line:

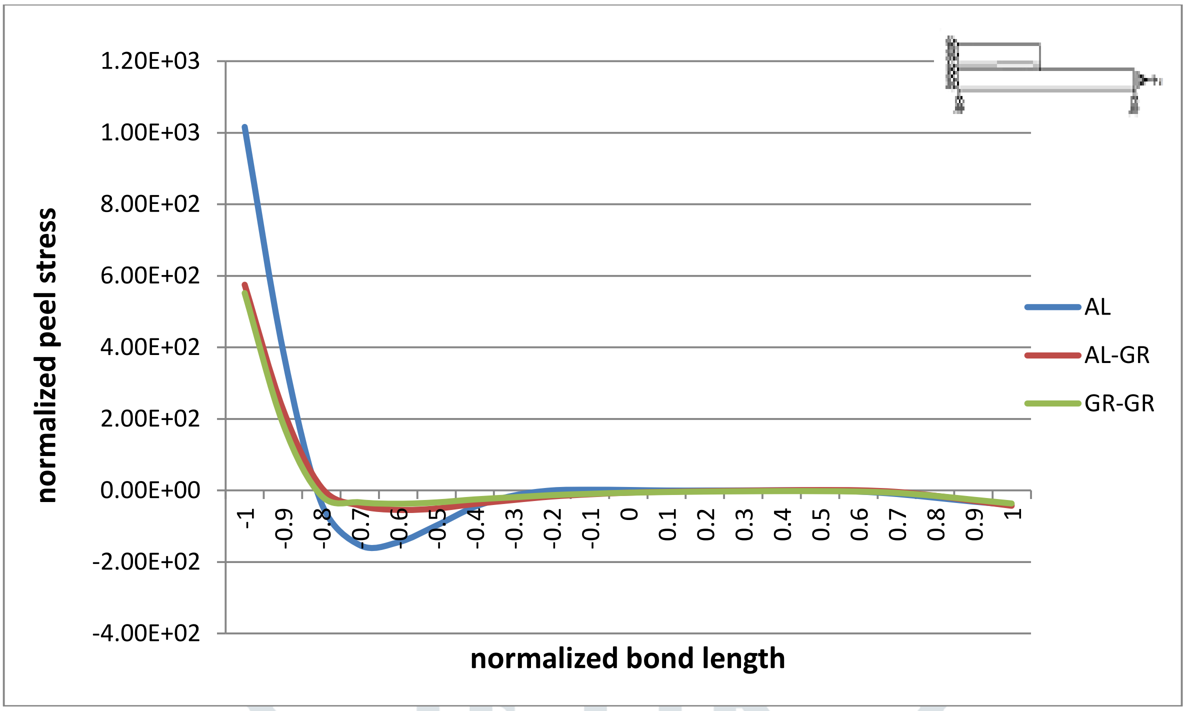

Fig.3.1. Comparison of peel stress distribution along midline for 3 different adherent.

Shear stress distribution along mid bond line:

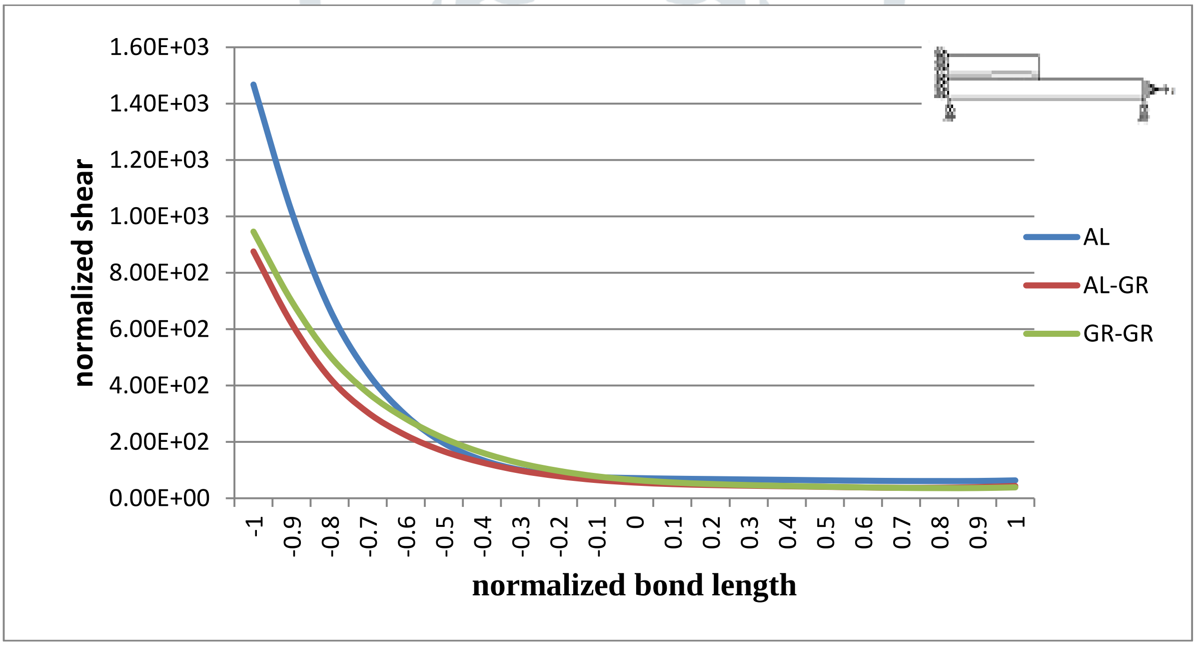

Fig.3.2. Comparison of shear stress distribution along midline for 3different adherents

The peel stress and shear stress distribution drawn for the models with different adherents are compared. The peel stress and shear stress distribution of mid bond line are also drawn for the adhesively bonded joints with de-bond. The stress distribution along the bonded joints.

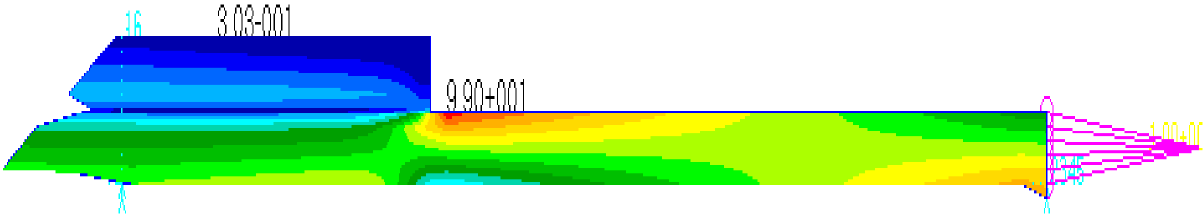

Fig.3.3. Stress distribution in adhesively bonded joint

The de-bond analysis of single lap adhesively bonded joints is been done. The adherents of aluminium material is considered and de-bond analysis is performed using MSc NASTRAN software. The SERR(G) values are calculated by using MVCCI technique. In this analysis, large deformations are obtained due to the presence of de-bond. These deformations are used in calculating SERR. However this deformation doesn't affect much, since the G_{II} values are always larger since the primary load transfer is by shear.

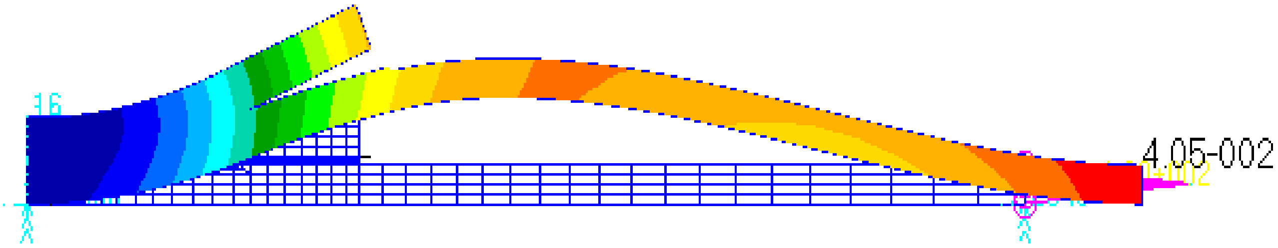

Fig.3.4. Deformation pattern of bonded joints with de-bond

Variation of Stain energy release rate with de-bonds length:

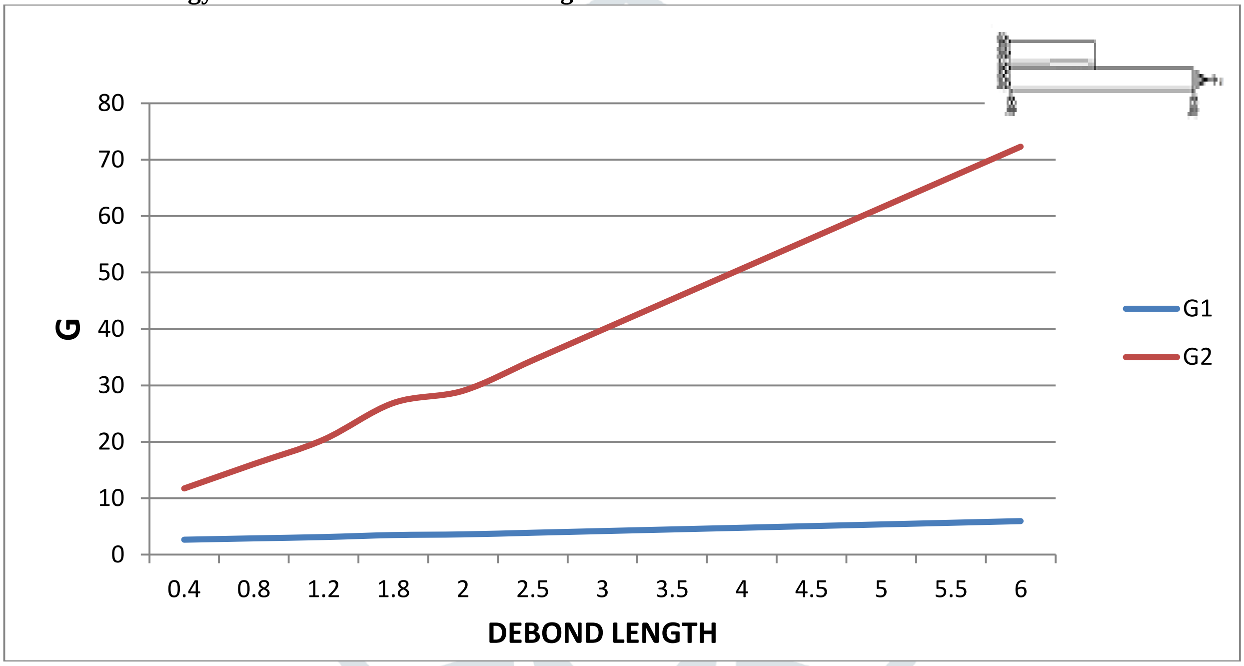

Fig.3.5. variation of strain energy release rate (G) with de-bond length

The de-bond analysis is also carried out on single and double lap adhesively bonded joints. The analysis is done with the increase in applied load for the adhesively bonded joints and the comparison is done between SERR (G_I) of both the single and double lap adhesively bonded joints. Fig.3.8. shows the plots between $G_I$to thickness of the adherent.

Variation of strain energy release rate with load:

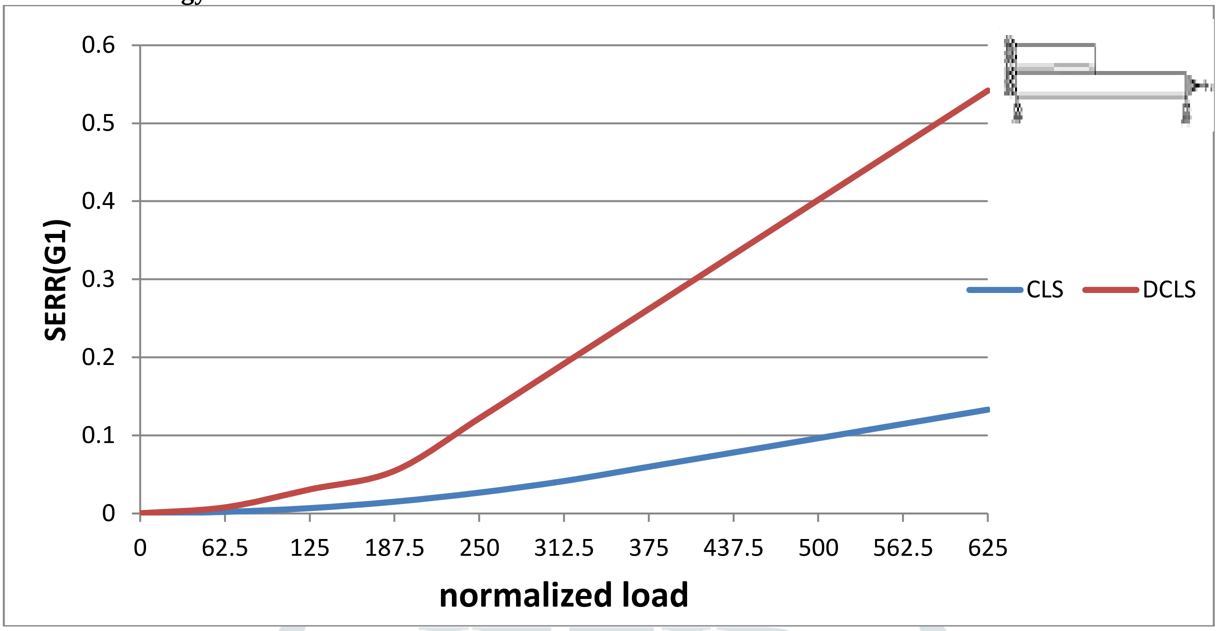

Fig 3.6 variation of normalized load to SERR

IV. CONCLUSION

Single lap joints were analyzed with the three-dimensional adhesive finite element model. 3-dimensional work is done on the adhesively bonded joints, which provide more accuracy and relief failure criteria. For relatively small loads or stiff structures, geometric non linearities do not produce important effects in single lap joints. The use of bonded lap joints of aluminium-aluminium specimens provide better results for von misses stress which are minimum compared to aluminium-graphite and graphite-graphite specimens. The two-dimensional adhesive finite element model together with the modified crack closure integral method yield reliable values of strain energy release rates. The SERR increases with respect to increase in loads.

V. REFERENCE

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