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Effect of Supports on Stress Distributions in the Adhesive Joints

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Abstract. The aim of this paper is to investigate the effect of supports on the actual stress distribution of the single-lap adhesive joints under tension using the three-dimensional finite element methods. Five layers of elements were used across the adhesive thickness in order to obtain an accurate indication of the variation of stresses. All the numerical results obtained from the finite element analysis show that the spatial distribution of all components of stress are similar for different interfaces though the stress values are obviously different. The results also show that most of the maximum stresses occur at the interface 1. It can be seen from the results that the stresses are concentrated near the left free ends of the adhesive layer while the centre region of the adhesive layer is mostly stress-free.

Introduction

Adhesive joints are increasing alternatives to mechanical joints in engineering applications and provide many advantages over conventional mechanical fasteners [1]. It is also important for adhesive joints to benefit from the advantages of other joining techniques, such as self-piercing riveting (SPR), clinching, etc. [2, 3]. At present, however, the use of adhesive joints is largely applied to secondary non-critical structures. The use of adhesive joints in primary structural applications has been somewhat limited because of the difficulty in predicting joint stress distribution, and designing the joint geometry to optimize strength and reliability.

Many studies have been carried out to investigate the static and dynamic behaviour of adhesive joint. In Raos et al's study [4], the lap length and the thickness of the adhesive layer was optimized. Hashemi et al. [5] derived the peel stress distribution in a single lap adhesive joint by using the strength of materials approach. In the work by Rossettos et al. [6], an analytical model is developed to compare the effects of voids and debonds on the interfacial shear stresses between the adherends and the adhesive in single lap adhesive joints. Recent work by the present author [7] studied the influence of adhesive layer thickness on the dynamic behaviour of the single-lap adhesive joints.

The lap-joint problem is three-dimensional although it has simple geometry. The stress behaviour of the single-lap adhesive joints is rather complex since bending is induced during the deformation. Since these problems are mainly mechanical in nature, stress analysis is required to understand how the loads are distributed along the adhesive layers and adherends. The finite element method has advantage that the stresses in a body of almost any geometry under load can be determined. The aim of this paper is to investigate the effect of supports on the actual stress distribution of a single-lap adhesive joint with simply-supported bonded section and simply-supported end.

Boundary condition and FE model

The boundary condition of the single-lap adhesive joint is shown in Fig. 1. In this case, the bonded section of the joint and the free end of the upper adherend were restricted in the z direction (along its thickness), that is there is no displacement in the z direction.

The finite element mesh of the joint was created using the ABAQUS FEA pre-processing program operating in X-window environment. Most of the adherends and adhesive were modelled using the 20-node solid elements. But at the transition zones from the adherends to the adhesive,

some 15-node transition elements were used. The adhesive layer was divided into 64 equal parts along its length (x-direction) and 20 equal parts along its width (y-direction) and 5 equal parts along its thickness (z-direction) in order to obtain an accurate indication of the variation of stresses. The material parameters of the adhesive and adherends were input via the ABAQUS input file. This model was expected to be a good one as it had enough accuracy and a moderate number of elements.

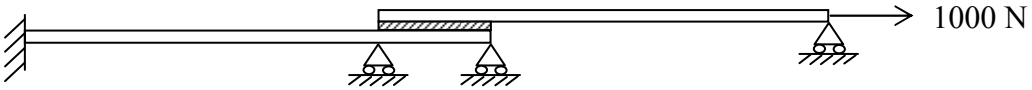


Fig. 1. Boundary condition of the single-lap adhesive joint

The original mesh and displaced mesh of the single-lap adhesive joint are shown in Fig.2. A careful study of the displaced shape in Fig. 2 shows that bending is induced in both the lower and the upper adherends.

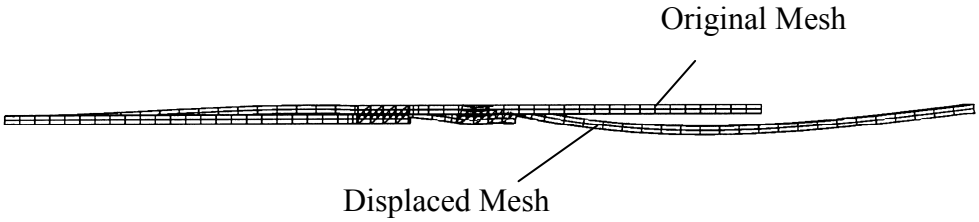
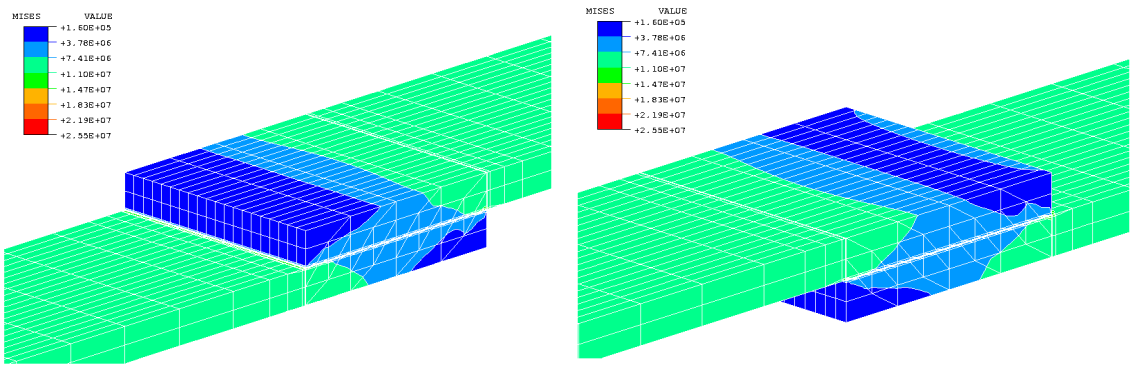


Fig. 2. Original mesh and displaced mesh of the single-lap adhesive joint

Stress distribution in the joint

The stress distributions in the single-lap adhesive joint are given by the stress contours in Fig. 3. It is seen that the stress distributions are almost the same in both the lower and the upper adherends and there are stress concentrations at the left and right free ends of the adhesive layer.

As five layers of elements were used across the adhesive thickness, a total of six interfaces were obtained. The stress distributions at these six interfaces will be used to describe the variation of the stress in the adhesive layer of the joint under tension load condition. The dimensions in the x-direction and y-direction are displayed in non-dimensional form as x/c and y/b where b is the width of the joint and c is the length of the bonded section. All the numerical results obtained from the finite element analysis show that the spatial distribution of all the 6 components of stress are similar for different interfaces. Also, the numerical results show that most of the maximum stresses occur at interface 1 except S_{12max} which occurs at the interface 6. Interface 1 is, therefore, the critical interface.



(a) Top view (b) Bottom view

Fig. 3 Top and bottom view of the stress contour of the lap joint section

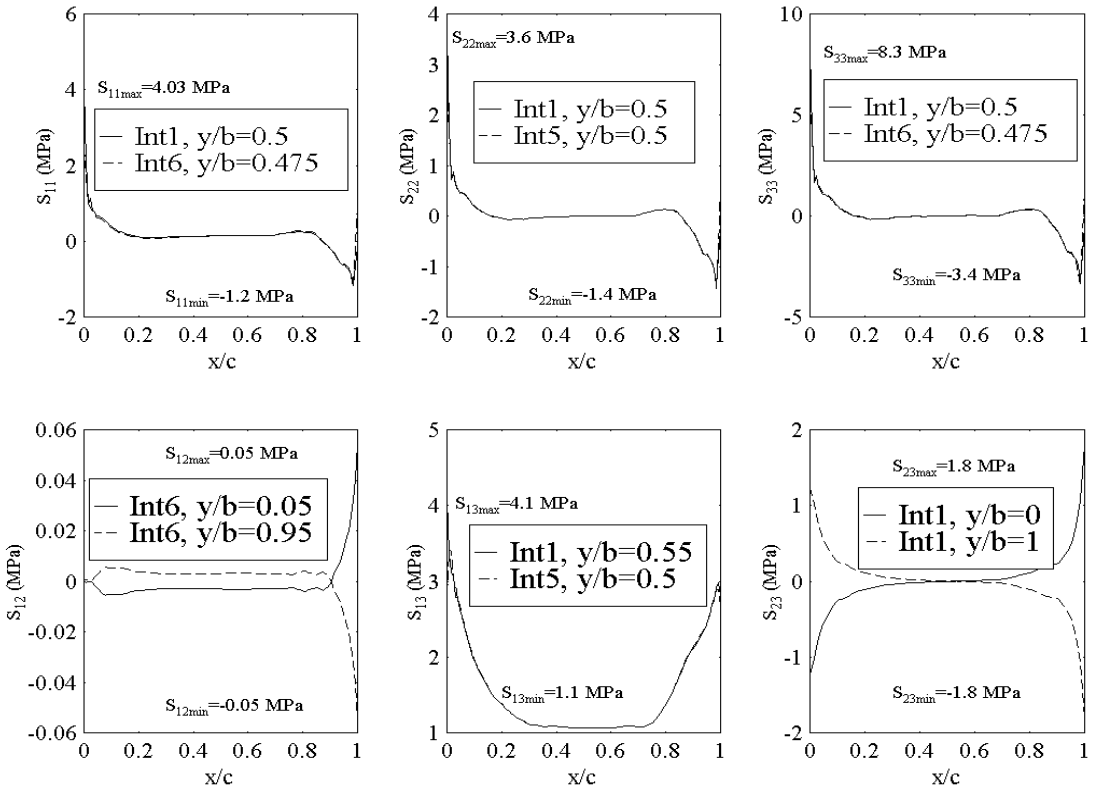


Fig.4. Maximum and minimum stresses of the single-lap adhesive joint

The maximum and minimum stresses of the joint

The maximum and minimum stresses of the single-lap adhesive joint are shown in Fig. 4. It is obvious that the left hand region (x/c=0) of the bonded section is mainly subjected to tensile stress but the right hand region is mainly subjected to compressive stress. The absolute values of the tensile stresses are higher than those of the compressive stresses. It is also obvious that the stresses are concentrated near the left free ends of the adhesive layer while the centre region of the adhesive layer is mostly stress-free. This implies that the adhesive material near the left free ends of the adhesive layer bear most of the load that is being transferred through the adhesive joint from the upper adherend to the lower adherend. From figures 3 and 4, it is clear that most of the maximum stresses occur at or near the centre line (y/b=0.5) of the left end of the adhesive layer, while S_{23max} occurs at the right-front corner of the adhesive layer.

Conclusions

The stress distribution of a single-lap adhesive joint under tension is studied in this paper using the three-dimensional finite element methods. As five layers of elements were used across the adhesive thickness, a total of six interfaces were obtained. All the numerical results obtained from the finite element analysis show that the spatial distribution of all the 6 components of stress are similar for different interfaces though the stress values are obviously different. The results also show that most of the maximum stresses occur at the interface 1. It can be seen from the results that the stresses are concentrated near the left free ends of the adhesive layer while the centre region of the adhesive layer is mostly stress-free.

Acknowledgement

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