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Analysis and Design of Adhesive-Bonded Corner Joints

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Abstract
A corner joint was investigated using finite element method. Since the geometry along the width of the corner joint is uniform and load does not change in that direction, the problem was assumed to be plane strain. In addition, it was assumed that the adherents (aluminum) and adhesive (epoxy resin) had linear properties. The joint was analysed under one loading condition, a bending moment applied at the upper end of the right-angled plate. The stress distributions in the joint area are given by the stress contours and *XY* plots. Since the geometry of the joint affects the analysis, in addition were investigated the influences on the stress distributions of the bonding length and adhesive thickness. From the results it was found that the stress distributions are similar for different bond lengths, but the maximum stresses are increased with decreasing adhesive thickness. These results can be useful in adhesive-bonded corner joints design.
Keywords: corner joint, stress analysis, finite element method.

1. Introduction

The adhesive-bonded joint technique has been applied successfully in many structural components. Due to their advantages – light weight, economic benefits – the adhesive-bonded joints have been studied by many researchers, thus: single- and double-lap joints [1-2], tubular joints [3], tee joints, corner joints, and so on. Due to their simple geometries, most of the studies have covered lap joints. The analyses showed that high stress concentrations occur around the adhesive free ends and that the adhesive fillet size had significant effect in reducing the peak stresses [4]. The tee joints have been analysed for many loading and boundary conditions [5-6].

This paper analyses, using finite element method, a corner joint in which a right-angled plate is bonded to a horizontal plate with an adhesive. The aim is to determine the dimensions of the corner joint on the basis of a stress analysis. In addition, the effects of bonding length and adhesive thickness have been investigated.

2. Joint configuration and stress analysis

A corner joint, in which a right-angled plate is bonded to a horizontal plate, was investigated, as shown in *Figure 1*. The main dimensions of the corner joint are shown in *Table 1*. Since the geometry along the width of the corner joint is uniform and the load does not change in that direction, the problem was assumed to be plane strain. In addition, it was assumed that the adherents (aluminum with a modulus of elasticity E = 70000 MPa and Poisson's ratio ν= 0.33) and adhesive (epoxy resin with E_a = 1250 MPa and ν_a = 0.38) had linear properties.

In order to analyse the stresses in the corner joint, the finite element software CosmosM [7] was used (version 2.95 developed by Structural Research and Analysis Corporation). The six-node triangular plane elements (TRIANG) with three integration points were used to model the plates and the adhesive layer. Because the local mesh refinement around the adhesive free ends and transition regions, in which high stress concentrations occurred, is essential in order to get reasonable accuracy from the computation the element sizes were established in according with the plate and adhesive layer thicknesses. Four layers of elements were used across the adhesive thickness.

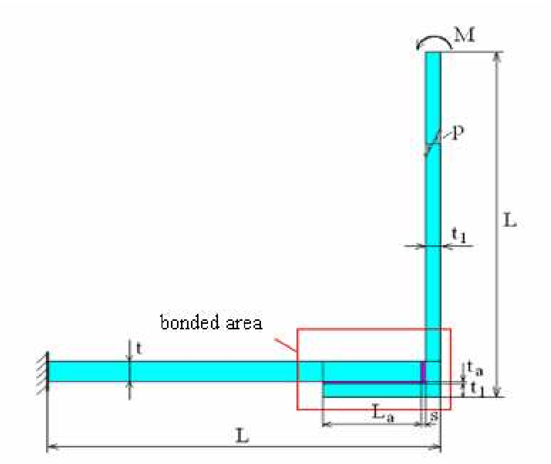

Figure 1. Model of the corner joint

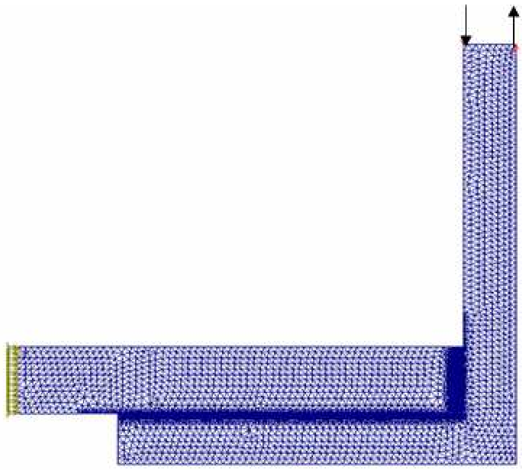

Figure 2. Finite element mesh

The mesh of finite element model for the corner joint is shown in *Figure 2*. The joint was analysed under one loading condition, a bending moment applied at the upper end of the right-angled plate, which induces a maximum absolute value of the normal stress in the cross-section p = 10 MPa. At the left free end of horizontal plate, the nodes were fixed in the x- and y- directions, such as boundary condition.

In this analysis, an adhesive thickness t_a of 2 mm and a bonding length L_a of 12.5 mm were used, and other dimensions are shown in *Table 1*.

Table 1. Dimensions of the corner joint

Dimensions	mm
Bonding length, L_a	5 – 37.5
Right-angled plate thickness, t_1	2
Horizontal plate thickness, t	$1.5t_1$
Adhesive thickness, t_a	0.15 – 0.75
Plate length, L	$1.5L_a$

In order to show the stress distribution in the corner joint, stress contours of the three components σ_x, σ_y and τ_{xy} were represented in *Figure 3*. As shown in *Figure 3*, the horizontal plate and the left area of the adhesive layer are subjected to high normal stress σ_x, and the inside corner of the right-angled plate is also subjected to high normal stress σ_y. The shear stress τ_{xy} are relatively small, the concentration occurring in the inside corner of the joint.

The normal stresses variation σ_x, σ_y, σ_z and of the tangential stress τ_{xy}, traced along the centre line of the adhesive show that the effect of the stress concentration is produced in the adhesive, at the ends of the layer, *Figure 4*.

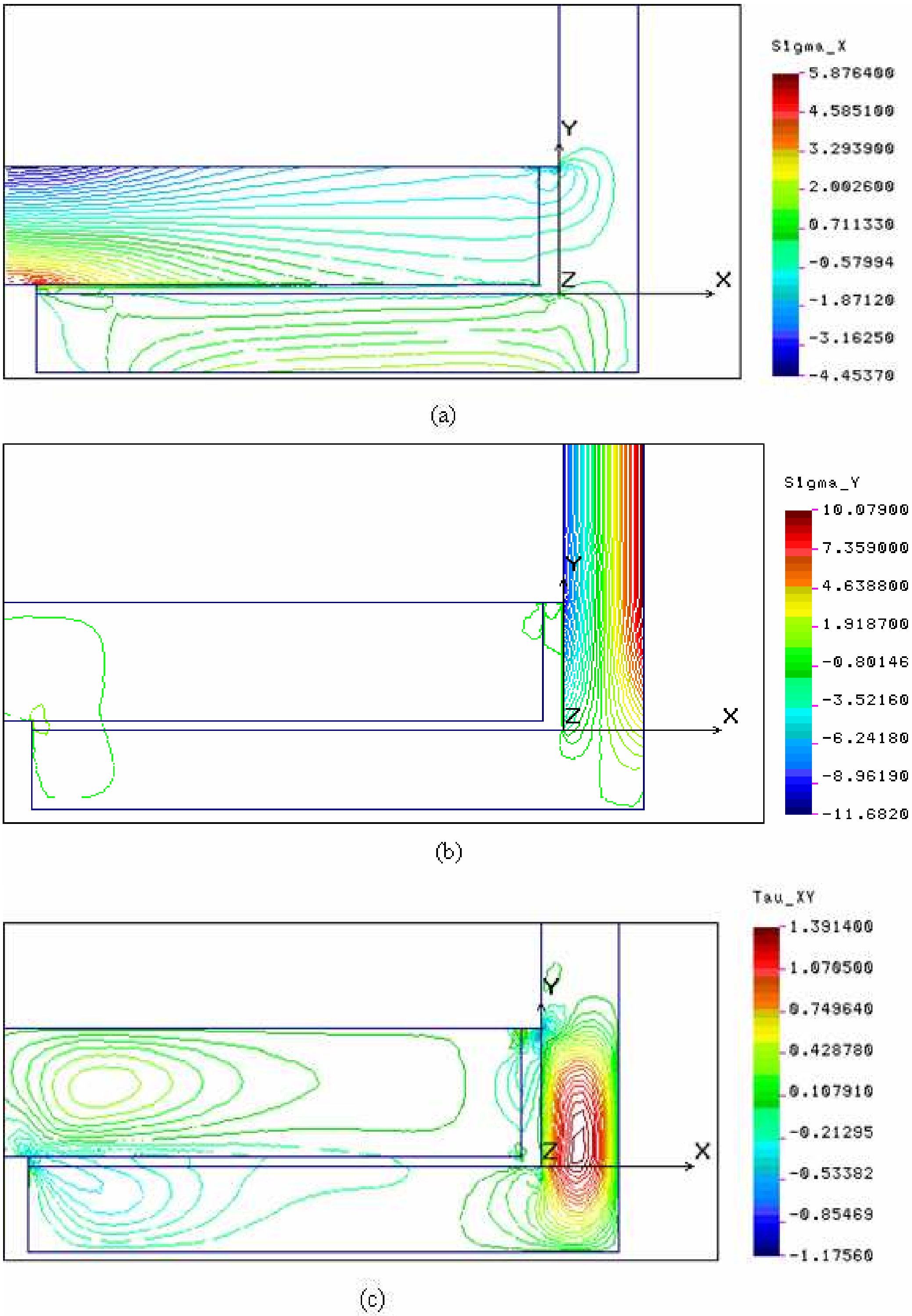

Figure 3. Stress contours in the joint: (a) normal stress σ_x; (b) normal stress σ_y; shear stress τ_{xy} (All stresses in MPa).

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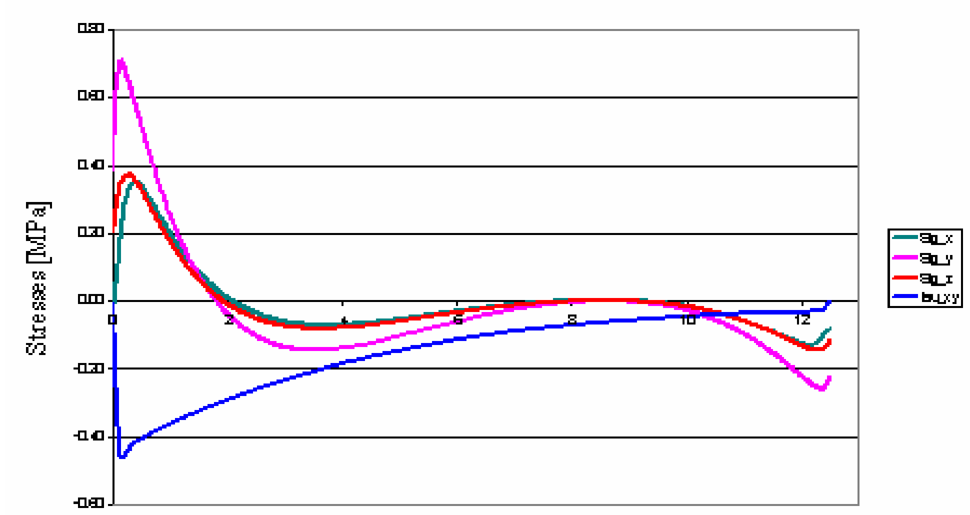

Figure 4. distribution of stresses along the middle of adhesive layer for t_a = 0.25mm and L_a = 12.5mm

3. Effect of bonding length

It is known that the distribution of stresses in the adhesive depends on many factors, as follows: the adhesive depth, the length of the adhesive layer, the adhesive rigidity, the geometry of the bond at the free ends, etc. If for a set of input data all the parameters are kept constant excepting one, then the structure response defines the sensitivity at the variation of that parameter.

In order to study the effect of bonding length, bonding lengths of 5, 7.5, 12.5, 25, 37.5 mm were investigated. The adhesive thickness was kept constant as 0.25 mm, as were the other dimensions. The results obtained are presented in *Figure 5.*

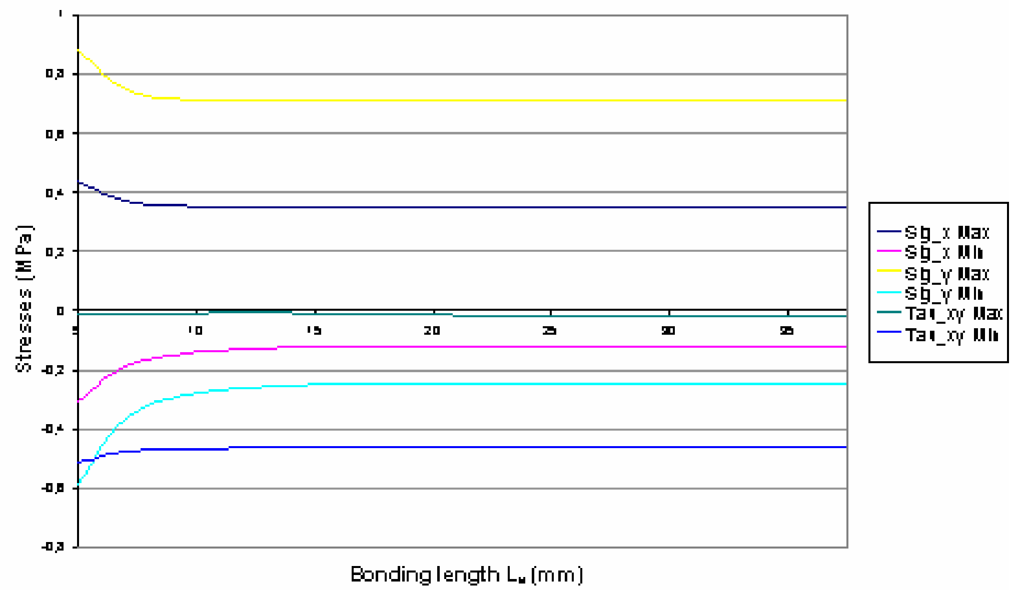

Figure 5. Variation of maximum stresses with the bonding length L_a

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The analysis shows that the maximum values of the stresses decrease together with the increase of the adhesive layer length comprised between 5 and 12.5 mm. Over these values of the adhesive length, the effect is much diminished.

4. Effect of adhesive thickness

In order to study the effect of adhesive thickness on stresses, adhesive thicknesses t_a of 0.15, 0.25, 0.30, 0.35, 0.5 and 0.7mm were investigated. The bonding length L_a was kept constant as 12.5 mm, as were the other dimensions.

There is noted from the maximum stresses variation, represented in *Figure 6*, a high sensitiveness of the joint at the variation of this parameter. The extreme values of the stresses continue to decrease on the whole range of values of the adhesive thickness.

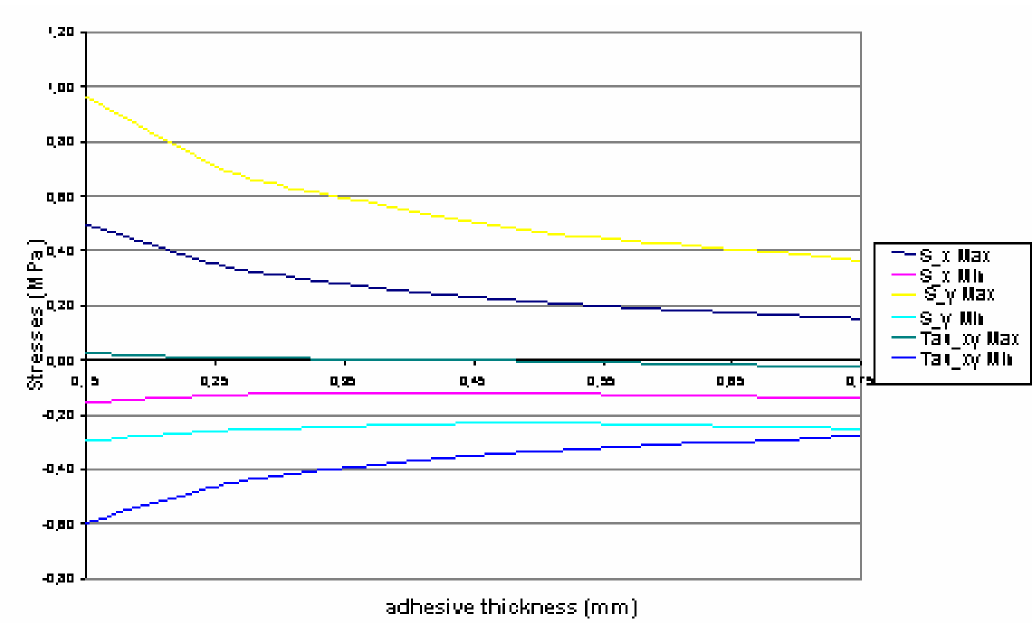

Figure 6. Variation of maximum stresses with the adhesive thickness t_a

5. Conclusions

By the finite elements analysis of the bending stresses soldered joint there was determined the stress state and there were identified the areas of stress concentration from the adhesive layer.

The sensitiveness analysis have shown that the extreme values of the stresses increase in the concentration areas together with the reduction of the adhesive layer tickness. The stress values are not significantly different far away from the stress concentration areas.

The sensitivity analysis at the overlapping length shows that the stress variations at this parameter is diminished, in comparison with the adhesive layer thickness. The results obtained are useful in the design of the edge bonds.

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