# Tensile Stress Concentration Due to Counter Sunk Holes in Adhesively Bonded Layered Aluminum

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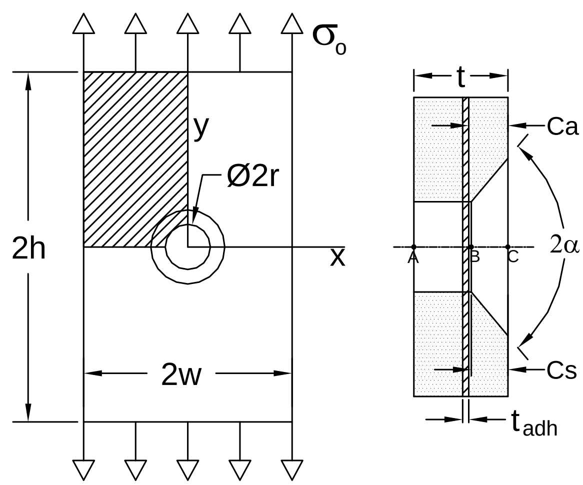
**Abstract**: The adhesively bonded layered aluminum is used in aircraft structures to avoid knife edge situations when flush head fasteners are used with minimum gage skins. A 3-D finite element model was used to estimate the location and magnitude of stress concentration under remote tension for aforementioned. The influence of the countersunk depth and adhesive properties on the stress concentration was investigated for a counter sunk angle of 100 º.The stress concentration was found to be maximum at the countersink edge for $E_{adh}/E_{al}$ >0.1 whereas it is slightly below the countersink edge in straight shank portion for $E_{adh}/E_{al}$<0.1. Stress concentration was found to be minimum when the adhesive is positioned in the countersunk section.

## 1. Introduction

Riveting is the most common process used to join aircraft structures. Countersunk holes are used in aircraft structures to accommodate flush head fasteners to attain aerodynamically smooth surface. Due to the counter sunk holes, skins with minimum gage thickness are subjected to heavy localized stresses. To support these structures, a doubler is bonded to the skin using adhesives. The adhesively bonded layered aluminum is also used to avoid knife edge situation when the flush head fasteners are used with minimum gage skins.

*Definition of stress concentration*. Stress concentration [1] $K_t$ (z) is defined as the ratio of hoop's stress $\sigma_{yy}$ (z) to the applied remote tension $\sigma_0$, as shown in the Figure.1.




## 2. Analysis

A quarter symmetry model of the geometry was modeled using ABAQUS. A detailed evaluation of present finite element model with available data [3][4][5] was done to validate accuracy of the model .The test of convergence was carried out on one of the models with fine tuning of mesh and no: of elements to ensure if the solution will converge as shown in the Figure 2 . FE model for a range of configurations such as ratio of young's modulus of adhesive to aluminum, different positions of adhesive ($C_a$) for different $C_s/t$, ratio of thickness to radius and ratio of width to radius by maintaining the loading far off from the hole by using h/r=15. The thickness of adhesive was maintained constant for all simulation as $T_{adh}$ =0.005in. The investigation was conducted for $\sigma_0$=1000 psi and stress along the nodal line A-B-C were taken which gave the stress concentration $K_t$(z). A constant countersink angle of 100 º was used in all simulation, as the effect of counter sunk angle can be ignored for small change in angle as published by Shivakumar et.al [3].

## 3. Results

Simulation was carried out for different modulus ratio such as $E_{adh}/E_{al}$= 0.1,0. 2, 0.4, 0.5 and 0.8 for a configuration of Cs/t =0.5, $C_a$ /t=0.5and w/r=15. The results were presented in the Figure3. The value of $K_t$ (z) is observed to be monotonically decreasing with increasing ratio of $E_{adh}/E_{al}$. For higher ratios (such as $E_{adh}/E_{al}$ >0.1) the maximum stress concentration is observed to be at the countersink edge, whereas for the smaller ratios

(such as $E_{adh}/E_{al}$ <0.1) the maximum $K_t$ (z) was observed to be in the straight shank portion slightly below (5% of thickness) the countersink edge.
The value of $K_t$ (z) decreases with increasing width of the plates .These results were in concurrence with the experimental results of Shivakumar et.al [3].For very wider plates (such as w/r>15), $K_t$ value for monolithic specimen is higher than that of the bonded specimen as shown Fig.4

The value of $K_t$ (z) increases monotonically with increase in ratio of thickness to radius for various sets such as t/r=0.5, 1, 2 and 4.The results obtained are in agreement with the trend obtained by Shivakumar et.al [3] and Young et.al [5] The shear stress $\sigma_{\theta z}$ along the circumference of adhesive was found to be minimum at x=r and y=r and it is maximum at an angle 45 º from the x=0.

Different configurations were made by altering the position of $C_a$ /t=0.2,0.5,0.6and 0.8 for different $C_s$/t=0.5 and 0.25 respectively. The value of $K_t$ (z) is lowest when the adhesive layer is positioned in the countersunk section far from the counter sunk edge.

## 4. Conclusion

The results established that the stress concentration value is higher for bonded specimens when compared with monolithic sheets as shown in the fig. 4 and fig 5. Ratio of young's modulus adhesive to aluminum, position of adhesive, countersunk sunk depths, and radius and width are the factors which affect $K_t$ (z) in bonded layered specimens.

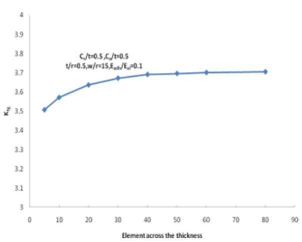


Fig 2 Mesh sensitivity

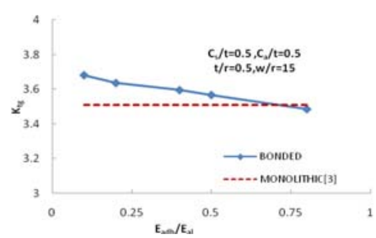



Fig.3 Effect of young's modulus of adhesive to aluminum

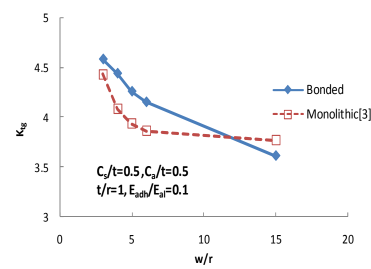



Fig4. Finite width effects

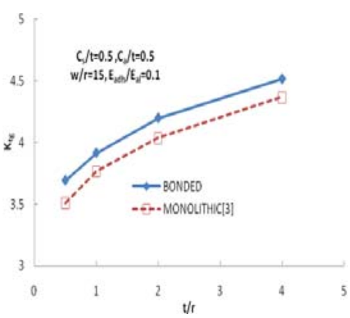



Fig5.Effect of thickness to radius ratio

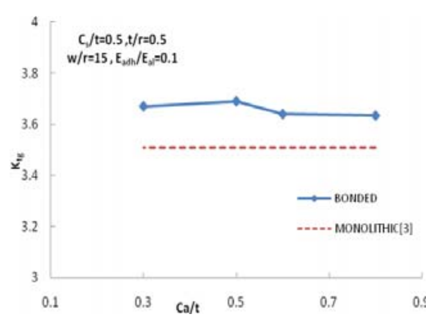



Fig.6 Altering the position of adhesive

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