STUDY OF EFFECT OF UNIAXIAL TENSILE STRESS ON CRACK PROPAGATION AND STRUCTURAL STABILITY WITH FINITE ELEMENT ANALYSIS (FEA)

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Abstract: The study describes the effect of uniaxial tensile stress on aluminum foil with three different crack characteristics. Firstly, aluminum foil with very small crack in the middle has been tested and effect of stress has been studied. After that aluminum foil with relatively small circular crack compared to first circular crack has been studied and characteristic of fracture mechanics discussed. Lastly, bigger circular crack in the middle of the aluminum foil has been tested and the results are analyzed for fracture mechanics properties. For all cases, FEA model using Abaqus has been utilized to understand the fracture characteristics, using von misses stresses. The aluminum foil is very useful to understand fracture characteristics and provides opportunity to learn more about shape of the fracture contour. The aluminum foil is very useful to understand the crack growth characteristics, stress contours, deformations. The experiment is also very useful to understand the plastic behavior of the aluminum foil and study the characteristics of the plastic zone of the aluminum foil with different crack size and shapes.

I. INTRODUCTION

To understand fracture mechanics, uniaxial tensile stress is conducted to understand the effect of the crack on the fracture of aluminum foil and characteristics of the fracture and dependence of fracture properties based on size and shape of the crack. The experiment is useful to understand the mechanical property of the aluminum foil and also it will explain the behavior of the material under uniaxial stress condition.

We have different analytical solutions available to study crack tip plastic zone, e.g. Inwin plastic zone correction, Dugdale approach. The available analytical model provides solution for plastic zone near crack tip and the experiment will help explain the plastic zone behavior near crack tip in mode detailed manner. Also Verification of obtained values of Tresca criterian and Von Mises criterion from analytical equations can be obtained using Finite Element Analysis model, which will allow detailed analysis of the shape of the plastic zone near the crack tip.

Uniaxial tensile test should be conducted to understand the shape of plastic zone near crack tip better. The experiment will also help for the better understanding of Irvin and Dugdale model. The experiment will also provide better understanding of plane stress and plane strain case understand fracture mechanics, uniaxial tensile stress is conducted to understand the effect of the crack on the fracture of aluminum foil and characteristics of the fracture and dependence of fracture properties based on size and shape of the crack. The experiment is useful to understand the mechanical property of the aluminum foil and also it will explain the behavior of the material under uniaxial stress condition.

II. PROCEDURE

Experimental procedure: 3 piece of aluminum foils of same size, material and shape have been obtained. Crack has been initiated in all three aluminum foils with different size and shape. (Circular (bIg and small size), Diamond). When the test components are ready uniaxial tensile load applied and on the top and bottom end of the aluminum foil. Effects of the load, plastic zone near crack tip, effect of shape have been studied to understand the crack behavior better.

FEA procedure: FEA model of standard size aluminum foil (8 in vs. 11 in) with the thickness of 0.5 mm have been developed to perform tensile test. Insertion of crack is done by modifying the shape as shown in Figures (1,4,7). After modification of shape to improve the mesh generation, partition edge has been created on the aluminum foil using partition edge command to have proper distribution of elements. After mesh generation, a set of all nodes have been created to apply load on the edges. Using the sets of top and bottom edges concentrated load has been applied to each node of the aluminum foil surface. Since there is symmetry in the load and aluminum foil should be allowed to move and rotate all the directions, distance boundary conditions are not applied for the mode. After the application of the load model was ready to run the simulations.

III. RESULTS

The results of experimental procedure and finite element analysis are very interesting and resembles with stress contours obtained by analytical solutions (Tuba) but not provide exact match for the results obtained with analytical solutions. In case 1, as we can see in the figures (1, 2) uniaxial tensile stress has been applied. Figure 3 shows Von Misses stress contours and as we can see the stress contours obtained resembles stress contours obtained by (McClintock, Irvin, et 1965). The analysis only shows the effect in mode-1 (uniaxial tensile), similar analysis can be done for mode-2 and mode-3 cracks. Figure 3 is very helpful to study the plastic zone and understand the effect of crack on the aluminum foil deformation.

In case-2 as shown in figures 4, 5, the crack shape is circular is initiated in the specimen. In figure 6, we can see the deformed specimen and effect of tensile uniaxial load on the specimen. As we can see in the von misses stresses the stresses are very high on the sides since the width of the aluminum foil is smaller as compared to the length of the aluminum foil, since the crack shape is circular the aluminum foil will going to deform from the sides rather than in longitudinal direction. From figure 3 and 6, we can observe the difference between the shapes of von misses stress contours and plastic zone in the crack of two different shapes. As we can see the stresses are more concentrated in figure 3 as compared to figure 6. So we can conclude that the aluminum foil specimen with diamond shape crack is more vulnerable to the deformation under tensile load as compared to the aluminum foil with circular shape crack.

In case-3, (figure- 7, 8) the specimen has bigger circular crack. The deformed shape of the aluminum foil has been shown in figure 9. As we can see, stresses are more concentrated on the sides since the length of the aluminum foil is longer than the width, so the specimen will have crack propagation in side. If we compare figure 3 with figure 9, we can see that stresses are more concentrated in figure 3 as compared to figure 7. So, as long as the crack is not too big as compared to the size of the aluminum foil the specimen with diamond shape crack is more vulnerable than the circular shape crack. If we compare figure 6 with figure 9, because of the size of the crack the specimen with crack size bigger will be more vulnerable compared to the one with the smaller sized crack with the same shape. Figures 10 and 11 shows shape of the specimen after deformation due to crack propagation.

Results of the shape of the stress contours of Von misses can be compared to the von misses stress obtained using analytical equations to understand the shape of the plastic zone. The study will also be helpful to understand the effect of crack size and shape on the stability of the specimen.

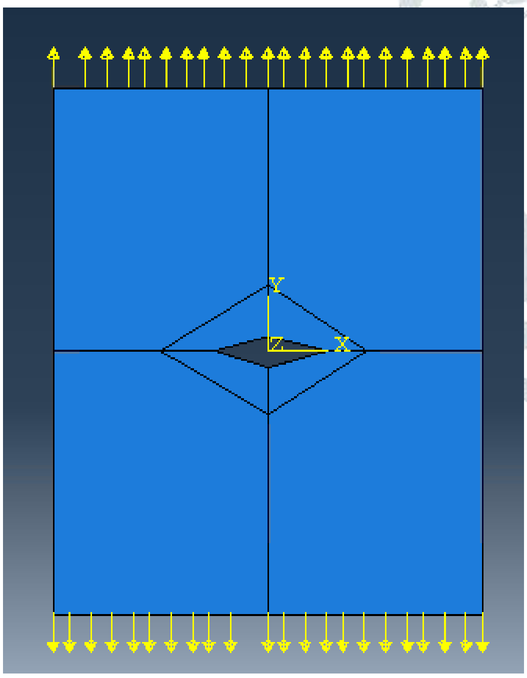


Figure 1
Dimond crack (Caese-1, Mesh view)

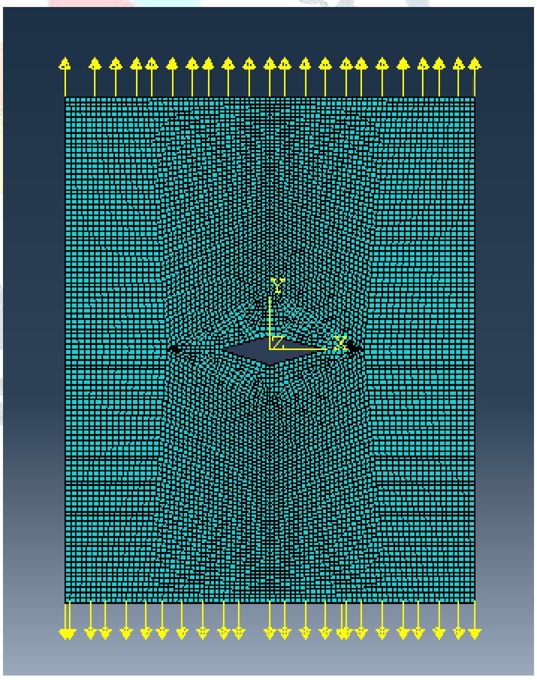
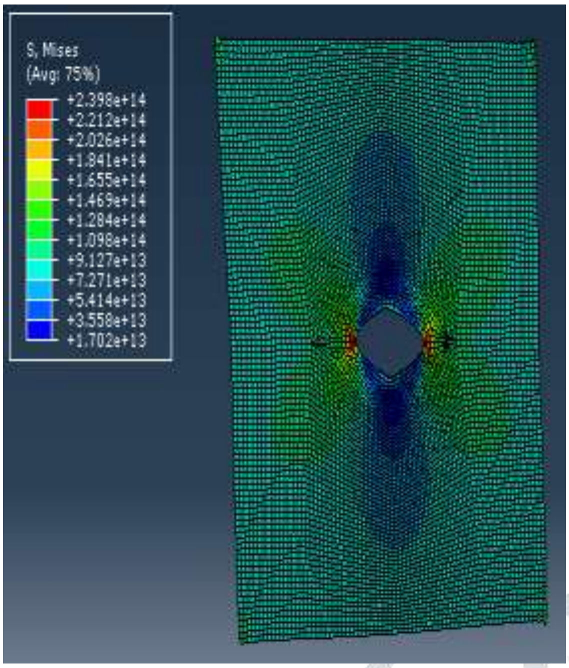


Figure 2
Dimond crack (Caese-1, Solid view)



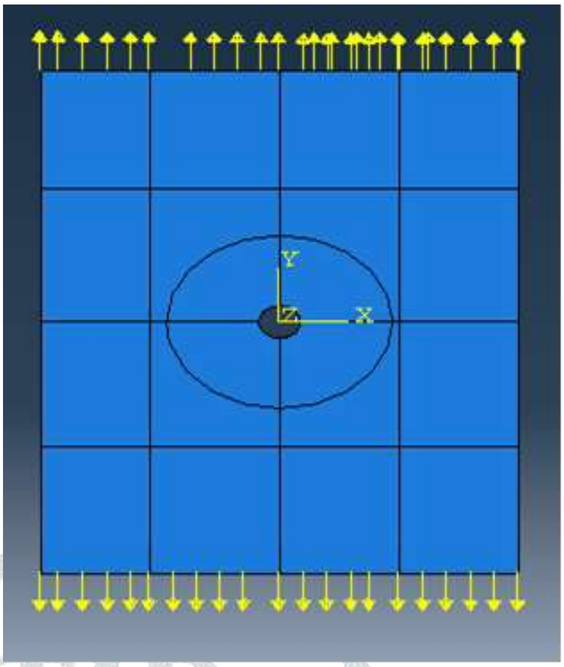
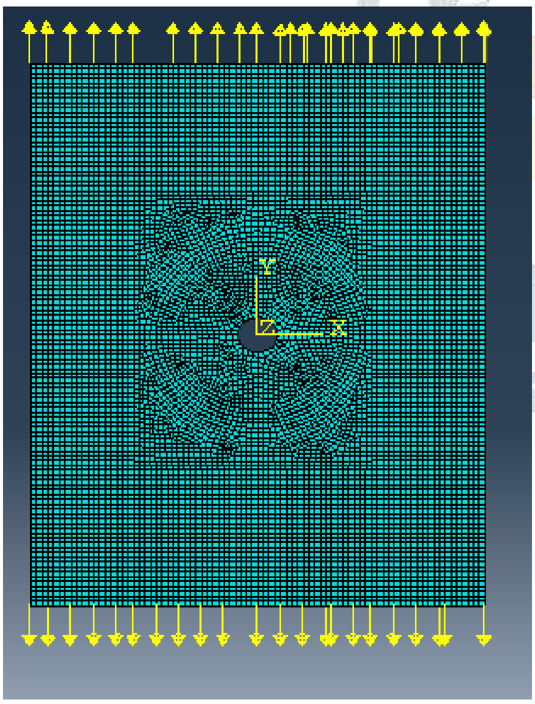


Figure 3

Dimond crack (Caese-1, deformed viewm, von misses stresses)

Figure 4

Small circular crack (Caese-2, Solid view)



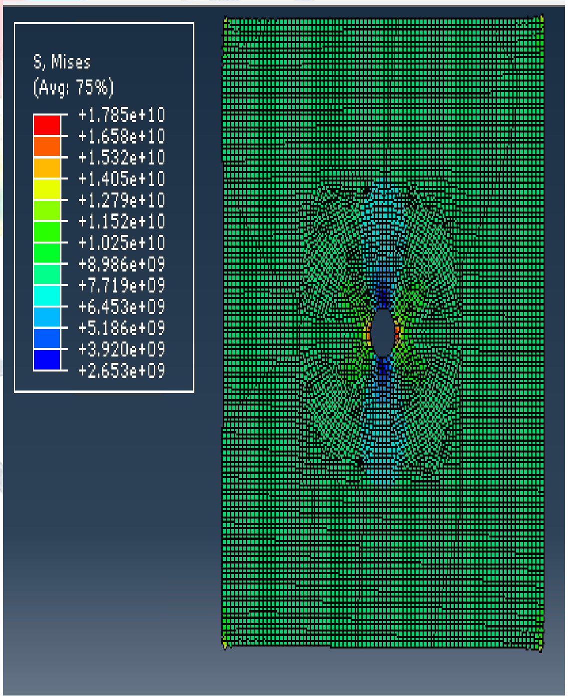


Figure 5
Small circular crack (Caese-2, Solid view)

Figure 6
Small circular crack (Caese-2, Solid view)

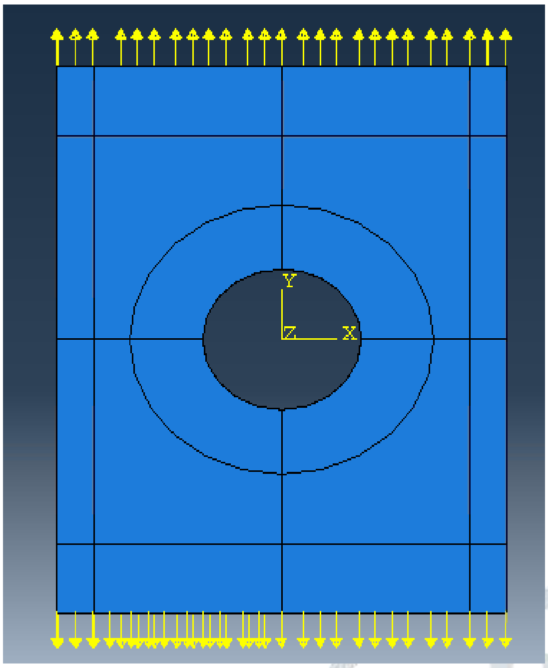


Figure 7
Circular crack (Caese-3, Solid view)

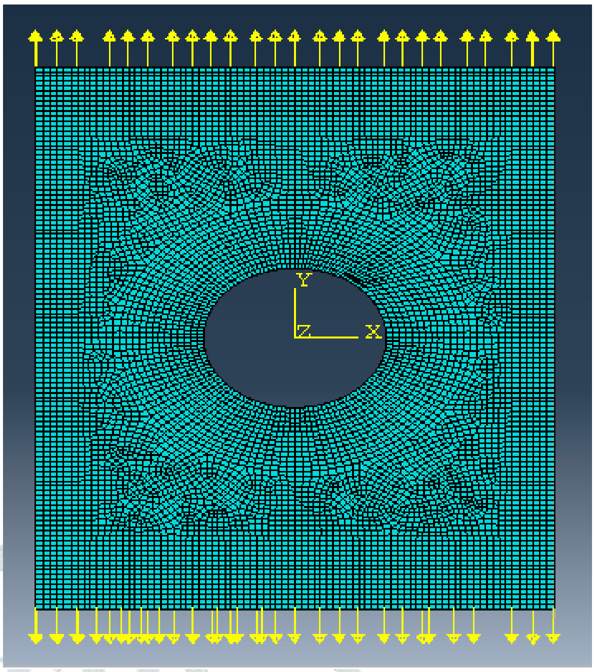


Figure 8
Circular crack (Caese-3, Mesh view)

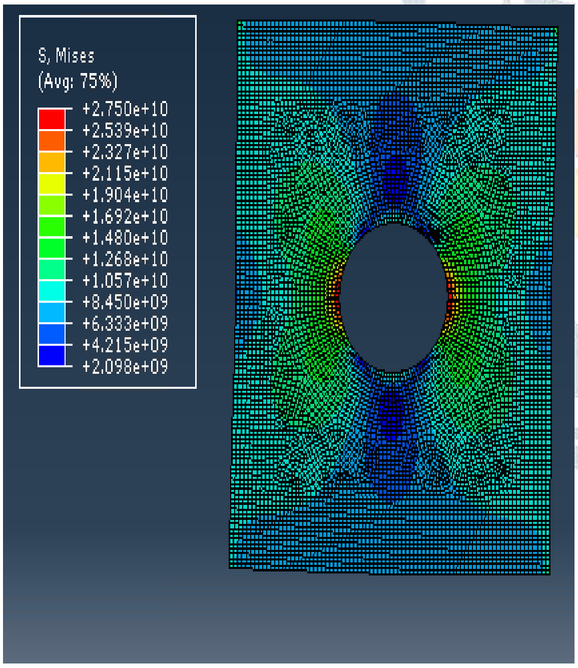


Figure 9
Circular crack (Caese-3, Solid view)

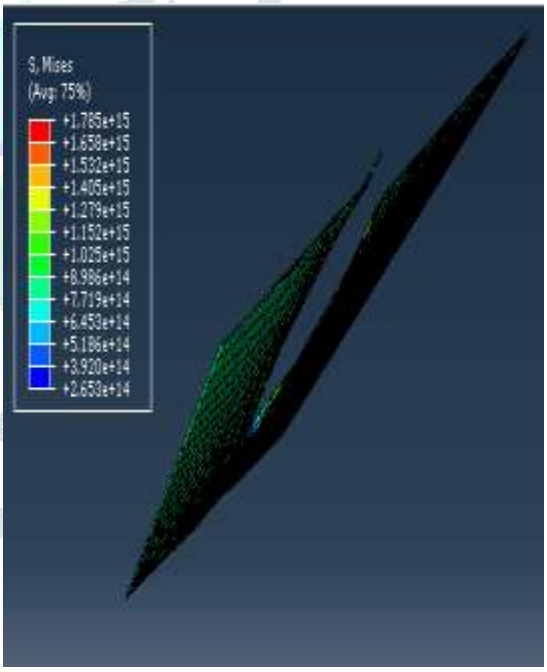


Figure 10
(failed crack component)

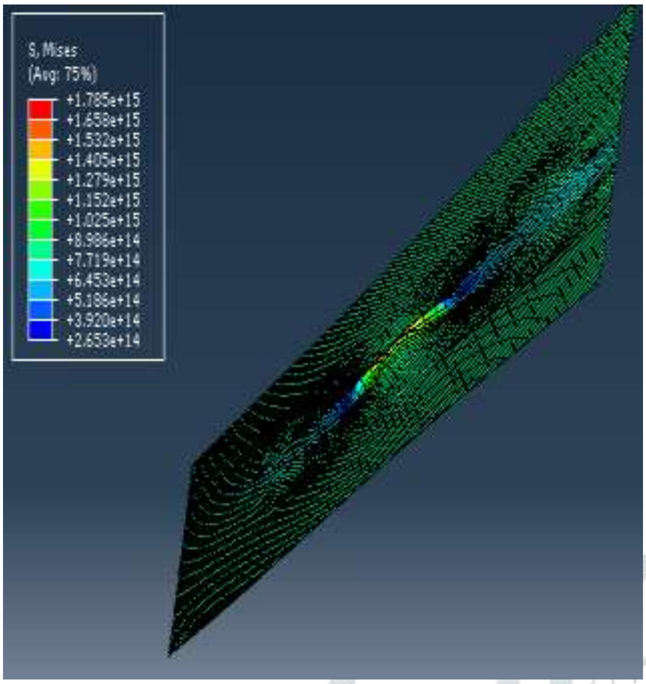


Figure 11
(Failed component contours)

IV. Conclusion

The Experimental procedure results and finite element analysis results resembles with stress contours obtained by analytical solutions but not provide exact match for the results obtained with analytical solutions. As mentioned by (Hahn and Rosenfield), none of the theoretical treatment provides satisfactory description of the zone shape. None of the existing theoretical approaches appeared to offer an accurate estimate of the plastic zone size at crack angle zero.

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