Stress Concentration In Metallic Plates With Rectangular Cutout

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1. ABSTRACT

Thin panels and shells of various constructions find wide uses as primary structural elements in both modern and classical structures. In recent years, the increasing need for light weight efficient structures has led the structural engineer to the field of structural shape optimization. Different cutout shapes in structural elements are needed to reduce the weight of the system and provide access to other parts of the structure. In rectangular cases, a cutout is not a part of initial design of the structures. In other words, structural elements are being damaged during their service life. It is well known that the presence of a rectangular cutout or hole in a stressed member creates highly localized stresses at the vicinity of the cutout. The ratio of the maximum stress at the cutout edge to the nominal stress is called the stress concentration factor (SCF).The design is based on rectangular cutout. For the modeling of cutout CATIA is used. For the analysis purpose ANSYS software is used.
Keywords**:** Stress Analysis, Cutout Shape, Load bearing, uniaxial tension, cutout orientations.

2. LITERATURE REVIEW

Dharmendra S Sharma et al (2011) researches the general stress functions for determining the stress concentration around circular, elliptical and triangular cutouts in laminated composite infinite plate subjected to arbitrary biaxial loading at infinity are obtained using Muskhelishvili's complex variable method. The generalized stress functions are coded using MATLAB 7.0 and the effect of fiber orientation, stacking sequence, loading factor, loading angle and cutout geometry on stress concentration around cutouts in orthotropic/anisotropic plates is studied.

D.B.Kawadkar et al (2012) studied the plates with cutouts are widely used in structural members. These cutouts induce stress concentration in plate. A Plate is considered with different cutouts, such as circular, triangular and square cutout. The main objective of this study is to find out the stress concentration in plate with various cutouts and bluntness with different cutout orientation. For finding the stress concentration, a finite element program ANSYS is used. In this study three parameter are used as the shapes of cutout, the bluntness and the rotation of cutout. From analysis it is found that as the bluntness increases, stress concentration increases. The more important finding is that the stress concentration increases as the cutout become more oriented from baseline. This fact demonstrates that orientation is also relatively significant factor to reduce stress concentration factor. The experimental photoelastic test is carried out on Araldite model loaded in one direction for circular, square and triangular cutout. Results are compared with FE results. By comparing the results, it is found that the stress concentrations by Experimentation and by FEM are in good agreement.

M Mohan Kumar et al (2013) studied plates with variously shaped cut-out are often used in engineering structures. The understanding of the effect of cut-out on the load bearing capacity and stress concentration of panels is very important in designing of structures. Different cut-out shapes in structural elements are needed to reduce the weight of the structure or provide access to other parts of the structure. Extensive studies have been carried out on stress concentration in perforated panels which consider cut-out shapes, boundary conditions and bluntness of cut-outs. This study focuses on the stress concentration analysis of perforated panels with not only various cut-outs and bluntness but also different cut-out orientations. Therefore, at the design stage, once the direction of a major tensile force is known, the cut-outs can be aligned properly based on the findings of the work to reduce the stress concentration at the cut-outs thereby increasing the load bearing capacity of the panel.

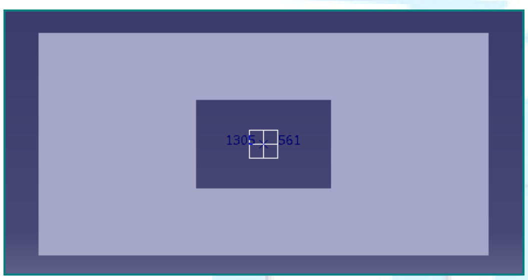
3. MATHEMATICAL MODELING AND DESIGN CALCULLATION

The UTM (Instron 1342) is a servo hydraulic fluid controlled machine, consists of a two column dynamically rated load frame with the capacity of load up to 200kN (dynamic), hydraulic power pack (flow rate 45 litre/minute) and 8800 Fast Track 8800 Controller test control systems is stand alone, fully digital, single axis controller with an inbuilt operating panel and display. The controller is fully portable and specifically designed for materials testing requirement. This controller has position, load and strain control capability. The software available with the machine are:

(a) Merlin Testing Software for Tensile Test
(b) da/dN Fatigue Crack Propagation Test.
(c) Kic Fracture Toughness Test.
(d) Jic Fracture Toughness Test.

The deformation of the structure is recorded by the ESPI system. Using digital analysis and correlation methods, the specimen displacements and deformations are calculated automatically from the changes in the pattern on the specimen surface. The visual information obtained by Q-100 is ideal for the comprehension of the behavior of the specimen. The numerical values of displacements and deformations can be employed for a comparison of the real behavior of the specimen with the calculations obtained by finite elements.

The geometrical aspect of the test specimens were performed in accordance with ISO 527 or NF T57-301 standards which are applied to plate. These standards suggest the use of test specimens with a length of 100 mm and a width of 10 or 15 mm. The ESPI system is placed on the surface painted in white to improve the quality of the captured images.



(A)

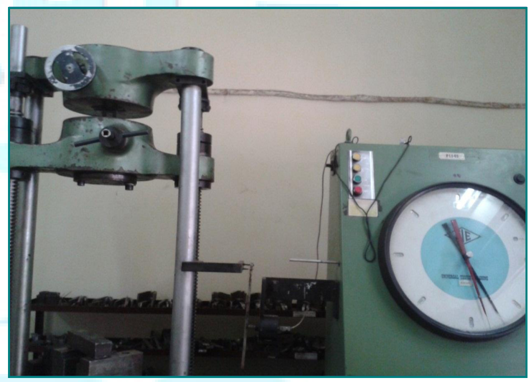
(B)

Figure No.3.1. Al. Plate with Hole

(A) CATIA Model
(B) Experimental Model

The testing on the plates are carried out by using Universal Testing machine by applying the tensile force on both side of the plate as 100 KN and 200 KN as shown in the following Figure.

(A)



(B)

Figure No. 3.2 Mounting of Plate

The mounting of the plates with various types of cutout are shown in Figure No. 3.2. And tensile force (100kN & 200kN) is applying on the plate which is equally distributed on both side of the plate, measures the total elongation after applying the forces as well as measures the stresses by using formula which is validates or compares with software results, While applying forces the beams are pull the plate both sides i.e. upward and downward sides and the gauge pointer is stopped while specimen (plate) breaks and the output graph of Load Vs.

Specimen Width (mm)	16
Original Gauge Length (mm)	50
Final Gauge Length (mm)	63.3
Specimen Thickness (mm)	10
Cross-sectional Area (mm2)	160.96

Table No. 1. Input Parameters for Plates

4. ANALYSIS PROCEDURE:

The geometry of the model was created using CAD program based on the original shape of the model. The model is then imported to FEA program to perform the modal analysis. In the pre-processor stage, the FFE (fast finite element) solver used subspace method to calculate 20 modes in addition to any rigid body modes available in the model. The default FFE solver detects rigid body modes (modes with zero frequency) automatically. All the four bolts holes are fixed. In addition, the rigid body modes are not counted among the requested number of modes. In the solution processing stage, the program runs a linear static analysis to calculate the deformed shape and then calculates the frequencies and mode shapes.

The actual model of plate created in the CATIA V5 R20 software which shown in Figure. No.4.1. Then that model is import in the Ansys 14.0 software and taking the various results plotted by applying the material properties, boundary conditions shown in figure No. 4.2 and figure No. 4.3.

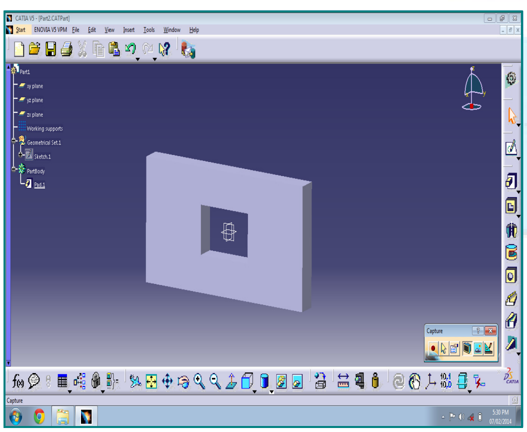
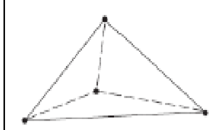


Figure No. 4.1. CATIA Model

Table No.2 Element used and load applied on MS Plate

SN	Description	Figure	Value
1	Mesh Element: Solid 285 a) No. of Element : 4765 b) No. of Nodes: 1265		4- Node tetrahedron (tet)
2	Force Applied	On +ve X - Direction	150kN
3	Force Applied	On -ve X - Direction	150kN

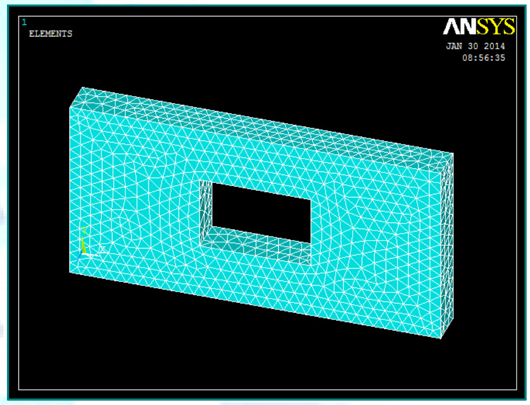


Figure No.4.2. Meshing for MS Plate

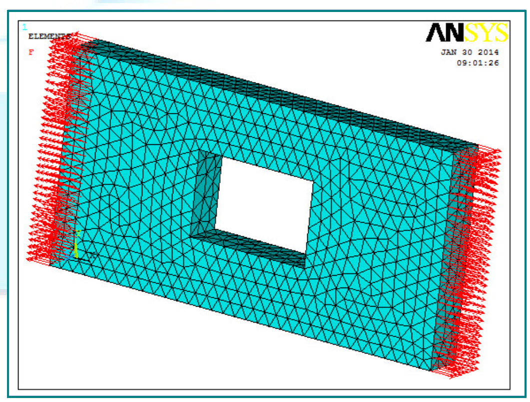


Figure No.4.3. Boundary Condition for MS Plate

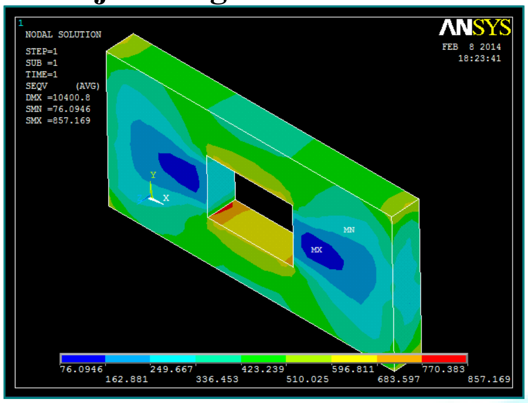


Figure No.4.4. Von-Mises Stresses for MS Plate

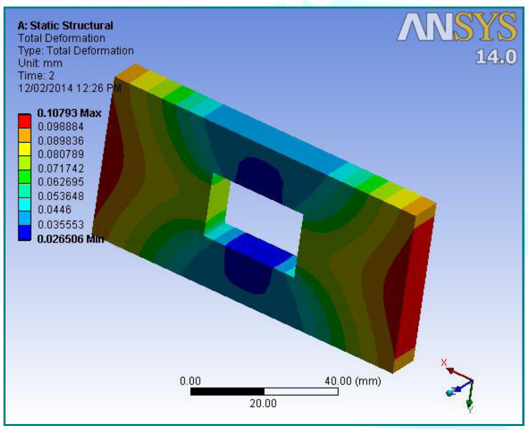
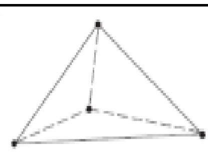


Figure No.4.5. Deformation for MS Plate

Table No.3 Element used and load applied on Aluminium Plate

SN	Description	Figure	Value
1	Mesh Element: Solid 285 a) No. of Element : 4765 b) No. of Nodes: 1265		4- Node tetrahedron (Tet.)
2	Force Applied	On +ve X - Direction	200kN
3	Force Applied	On -ve X - Direction	200kN

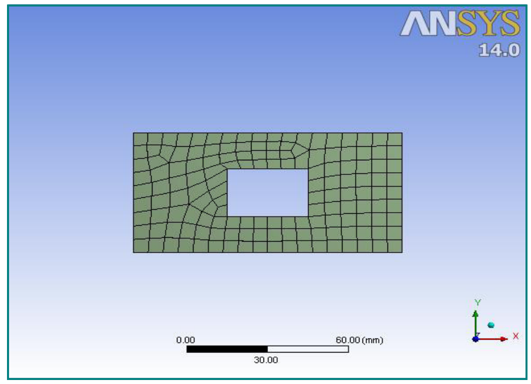


Figure No.4.6. Meshing for Al. Plate

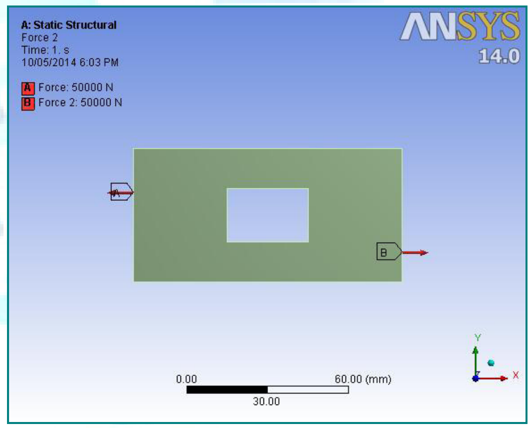


Figure No.4.7. Boundary Condition for Al. Plate

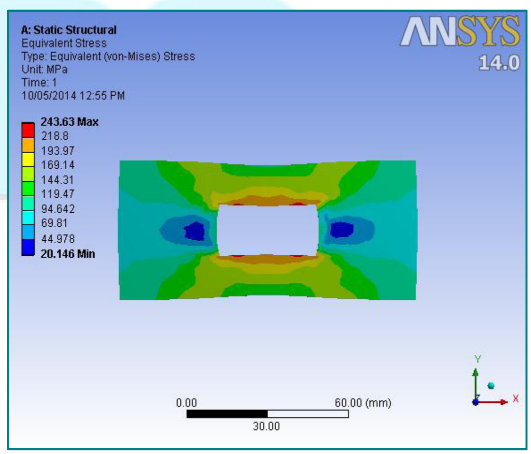


Figure No.4.8. Von-Mises Stresses for Al. Plate

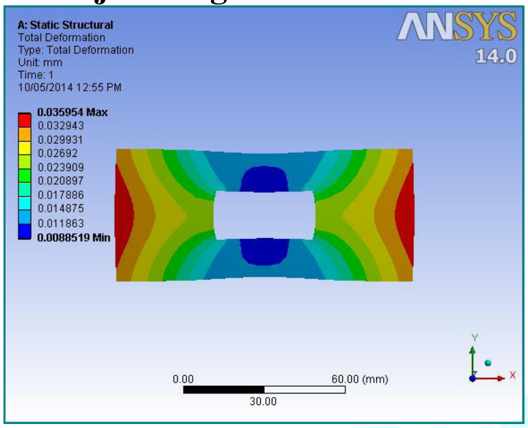


Figure No.4.9. Deformation for Al. Plate

5. RESULTS ON ANSYS:

A] Plate with Rectangular cutout in MS Plate:

The following figures shows the various results on the ansys software like von-mises stresses and deformation with various colors which shows the minimum and maximum values of the parameters like stress and deformation etc.

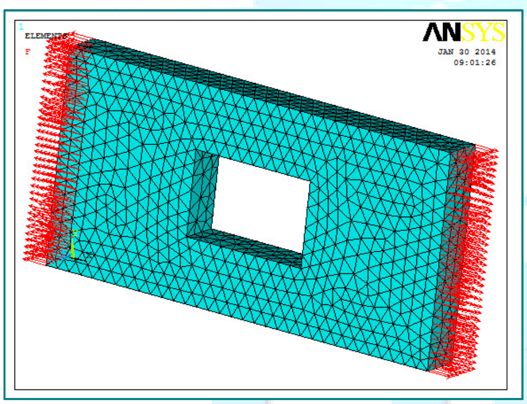


Figure No.5.1 MS Plate with Boundary Conditions

Forces are applied on the both sides of the plate shown in above figure with values 150kN in X – direction and taking result after solving the geometry. The stress and deformation results are plotted shown below.

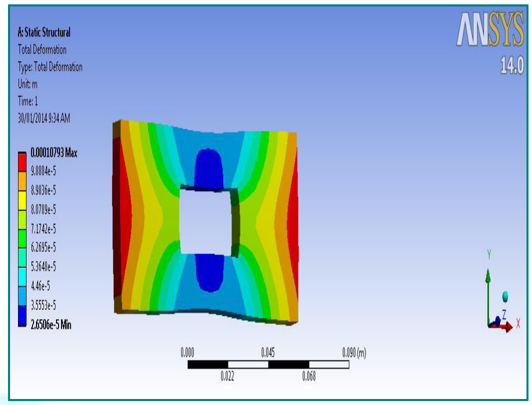


Figure No.5.2 Deformation for MS Plate

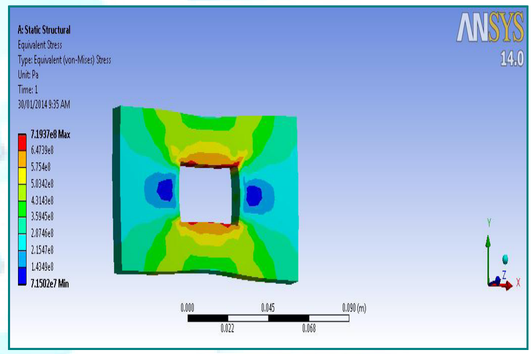


Figure No.5.3 Von – Mises Stress for MS Plate

B] Plate with Rectangular Cutout in Al. Plate:

The following figures shows the various results on the ansys software like von-mises stresses and deformation with various colors which shows the minimum and maximum values of the parameters like stress and deformation etc.

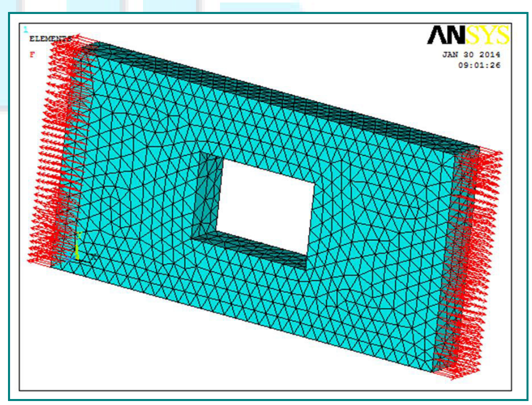


Figure No.5.4 Al. Plate with Boundary Conditions

Forces are applied on the both sides of the plate shown in above figure with values 50 KN in X – direction and taking result after solving the geometry. The stress and deformation results are plotted shown below.

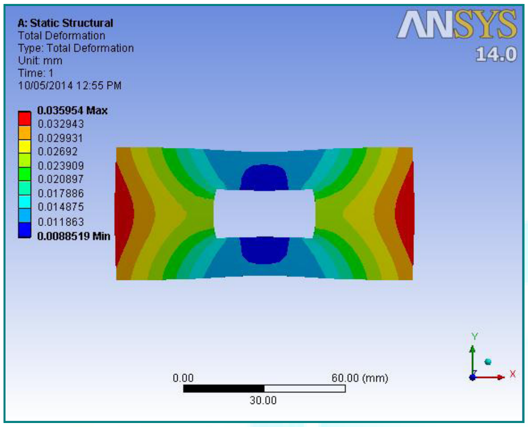


Figure No.5.5 Deformation for Al. Plate

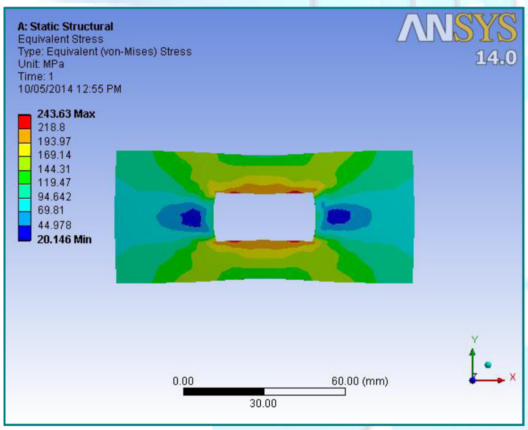
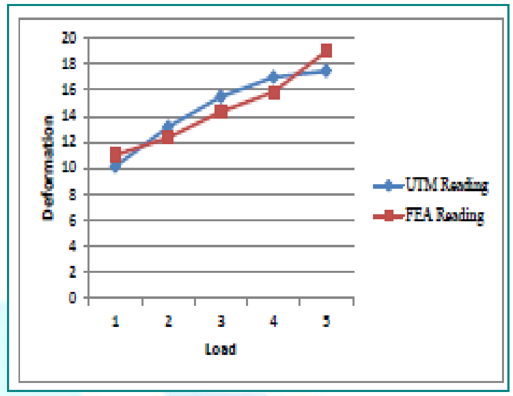


Figure No.5.6 Von – Mises Stress for Al. Plate

The above figures shows the actual results of the experimental set up and software (Ansys) which shows the stress and displacement.
The results shows the experimental and Ansys results which are co-related to each other i.e. the values occurring in experimental set up are nearly same as the software result and while thickness of plates is increases then increase in resultant stresses as well as displacement is increases. As the shape of the cutout is changes, the stress and displacement is also changes with respect to dimensions of plate and cutout. The following graph shows the comparative analysis of UTM and FEA reading Mild Steel and Aluminium plates.



Graph No.1 Comparison between UTM and FEA Reading of MS Plate.

The above graph shows the comparative difference between UTM and FEA reading of Mild Steel which are nearly same i.e. 90%. These both readings are related to each other and this shows the experimental and analysis properly done.

6. CONCLUSION:

We can safely conclude from these results that with proper knowledge of stress variation, we can suggest exact size and position of material removal area. These results enable us to find the optimum distance between center of main hole and center of auxiliary hole for maximum stress reduction.
This stress concentration characterization study of Mild (Structural) steel and Aluminum has been carried out. The precision of experimental measurements influences the results and this explains difference between the results found in experiments. Near of the hole, the stress obtained in experiments is definitely lower compared to the analytical and numerical models. The stress concentration in metallic plate with holes is influenced by the loading direction; there is a high agreement between those stresses for metallic plate with an on axis tensile load. Hence we conclude that the MS plate cutout is more useful and gives greater efficiency than Al plate cutout. But rectangular cutout Aluminium plate is also used for various purposes so we studied both material plates.

7. REFERENCES:

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