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Stress Concentration: An Experimental And Analysis Of Plate With Rectangular Cutout

[1]Swapnil Fegade, [2]Prof. R. D. Patil

Mechanical Engg. Department, North Maharashtra University
J T Mahajan College of Engg.Faizpur,India.

Abstract: 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. For finding the stress concentration, a finite element program ANSYS is used. From this study we compare the stress concentration around cutouts in various materials and finding strength of the material. 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 test is carried out on metallic plate loaded in one direction for circular, square and rectangular cutout. Results are compared with FE results. By comparing the results, it is found that the stress concentrations by Experimentation and software are relatively same.

INTRODUCTION

Stress concentration is universally computed on the basis of the theory of elasticity. Holes of different shapes are widespread application in engineering, such as aerospace, marine, automobile & mechanical. Stress concentration arises from any abrupt Change in geometry of plate under loading .As a result, stress distribution is not uniform throughout the cross section. Failures such as fatigue cracking & plastic deformation frequently occur at points of stress concentration. Hence for the design point of view the plate with different whole shapes plays an important role & accurate knowledge of stress. Stress concentration factor at the edges of the hole under the tensile concentration factor at the edges of the hole under the tensile loading is required. Analytical solution are available for different geometrical shapes like circular, triangular elliptical.

Various shaped cutouts are made in structures and machines to satisfy certain service requirements. These cutouts work as stress raisers and may lead to catastrophic failure. The behavior of isotropic plates with such cutouts, under different loading conditions is already studied extensively by many researchers. But, the anisotropic media with various shaped discontinuity has received very little attention.

Stress Concentration:

Stress concentration is defined as the localization of high stresses due to irregularities or abrupt changes of cross-section. The stresses obtained by the elementary equation are modified to account for the effect of stress concentration.

Stress concentrations are deviations from the nominal stress on a part. What causes a stress concentration is an abrupt change in the flow of stress through a part. This abrupt change can cause a higher stress or a lower stress by a certain factor in comparison to the nominal stress.

LITERTURE SURVEY

Dharmendra S Sharma et al (2011): 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.

J. Rezaeepazhand et al (2010): Variously shaped cutout are often used in both modern and classical aerospace, mechanical and civil engineering structures. The understanding of the effects of cutout on the load bearing capacity and stress concentration of such plates/shells is very important in designing of structures. An analytical investigation is undertaken to study the stress analysis of plates with different central cutouts. Particular emphasis is placed on flat infinite plates subjected to a uniaxial tension load. The results based on analytical solution are compared with the results obtained using finite element methods. The main objective of this study is to demonstrate the accuracy and simplicity of presented analytical solution for stress analysis of plates with central cutout. The varying parameters, such as cutout shape and bluntness, load direction or cutout orientations, which affect the stress distributions and SCF in the perforated plates, are considered. The results presented herein indicated that the stress concentration factor of perforated plates can be significantly changed by using proper cutout shape, bluntness and orientation.

J. Rezaeepazhand et al (2009): Panels and shells with variously shaped cutout are often used in both modern and classical aerospace, mechanical and civil engineering structures. The understanding of the effects of cutout on the load bearing capacity and stress concentration of such plates/shells is very important in designing of structures. An analytical investigation is undertaken to study the stress analysis of plates with different central cutouts. Particular emphasis is placed on flat infinite plates subjected to a uniaxial tension load. The results based on analytical solution are compared with the results obtained using finite element methods. The main objective of this study is to demonstrate the accuracy and simplicity of presented analytical solution for stress analysis of plates with central cutout. The varying parameters, such as cutout shape and bluntness, load direction or cutout orientations, which affect the stress distributions and SCF in the perforated plates, are considered. The results presented herein indicated that the stress concentration factor of perforated plates can be significantly changed by using proper cutout shape, bluntness and orientation.

D.B.Kawadkar et al (2012) :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.

MATHEMATICAL MODELING AND DESIGN CALCULATION

Finite element analyses are carried out for the stress concentration of Mild steel plates. The steel plates having dimensions 100 mm (x-direction), 50 mm (y-direction), and 10 mm (z-direction). Material properties are Young’s modulus of 200 GPa and poisons ratio of 0.3. The location of cutout is at the center of the plates. To clearly observe the concentration effect, the plate size is modeled as rather large for the cutout size. ANSYS, a general purpose finite element program, is used for analysis. An eight-node solid element is used for modeling. To investigate stress concentration in an elastic range, the plates are modeled as a linear elastic material. The plate is fixed at one edge and the loading condition is 200 MPa pressure is applied at other edge.

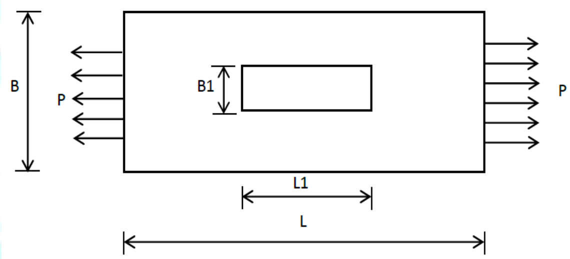

Fig. No. 1. Loading Condition (Axial Tensile Pressure)

To study the different geometrical shape holes in an infinite plate of dimension 100 mm X 50 mm X 10mm with circular, triangular & elliptical holes are used. These plates are subjected to a total transverse static load of P (N) for all cases analyzed for finite element method.

Calculation for Rectangular hole

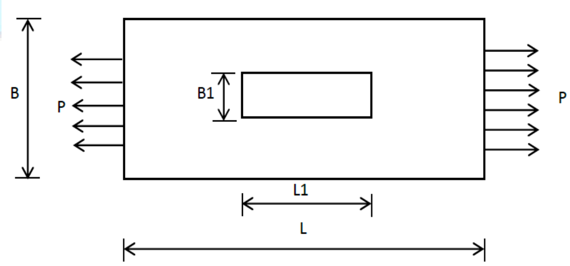

Fig. No. 2. Plate with Rectangular hole

L = 100 mm
B = 50 mm

$t = 10$ mm
$B_1 = 20$ mm
$L_1 = 30$ mm
$P = 15$ kN

Area of Plate $A = (B - B_1) \times t$
$= (50 - 20) \times 10$
$= 300 \text{ mm}^2$

Now,

$$\text{Stress} = \frac{\text{Force}}{\text{Area}} = \frac{15\,000}{300} = 50 \text{ N/mm}^2$$

$$\text{Stress Concentration Factor} = \frac{\text{Maximum Stress}}{\text{Nominal Stress}}$$

Maximum Stress = Nominal Stress x Stress Concentration Factor
$= 50 \times 3$
$= 150 \text{ N/mm}^2$

Experimental Setup:

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 (ESPI) 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 tests were realized with an universal testing machine (Fig.4.1) equipped with a 200 kN load sensor. Several parameters can be acquired a same time (time, applied load); data acquisition needs to use an extensometer and data processing equipment.

Fig. No. 3. Tensile testing machine.

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. The tensile properties are given in Table 1.

Table 4.1. Tensile Properties:

Material	E (GPa)	μ	Thickness (mm)
MS	200	0.3	10
Al	71.8	0.3	10

FEM Structural Analysis:

Structural testing and analysis is a basicrequirement for engineers in every industry. In fact,the use of FEA for structural analysis has becomeso commonplace that some suggest it is―commodity technology‖ that can be selected onthe basis of price. Smart engineering and CAEmanagers, however, are recognizing that price andcost are not synonymous. Choosing structuralanalysis solutions that can grow with your evolvingneeds,ANASYS Software provides a family of highperformance solutions for structural FEA that meetthe needs of beginning engineers and designers,experienced experts, and everyone in between.

These solutions help companies meet their businesschallenges by helping engineers to develop deeperinsight in their products through virtual testing.Engineers using MSC structural analysis are able toevaluate many different types of designs, givinghigh confidence that the final design willsuccessfully meet prescribed requirements, beforethe physical product is built. From singlecomponents to large complex systems, from linearstatic to highly non-linear dynamic problems,MSCs structural analysis capabilities are built togrow with your business, optimize your cost ofownership, and support you in achieving yourgoals.

- Divide structure into pieces (elementswith node).
- Describe the behavior of physicalquantities on each element.
- Connect (assemble) the elements at nodesto form an approximate system ofequations for the whole structure.
- Solve the system of equation involvingunknown quantities at nodes (e. g.displacements).

Calculate desired quantities (stress and strains) atselected elements

Analysis Procedure

The geometry of the model was created usingCAD program based on the original shape of themodel. The model is then imported to FEAprogram to perform the modal analysis. In the preprocessorstage, the FFE (fast finite element) solverused subspace method to calculate 20 modes inaddition to any rigid body modes available in themodel. The default FFE solver detects rigid bodymodes (modes with zero frequency) automatically.
All the four bolts holes are fixed. In addition, therigid body modes are not counted among therequested number of modes. In the solutionprocessing stage, the program runs a linear staticanalysis to calculate the deformed shape and then
calculates the frequencies and mode shapes.
During the post processing stage, thecorresponding frequency of the mode shape as wellas the displacement of the plate plot on deformedor undeformed shapes. To simplify the analysis,only plates with circular/elliptical/triangular cross-section
are modeled. The mesh was generated byANSA with hex elements. We also use ANSA toassignment of the materials properties, definecontacts, and set appropriate boundaries andloadings during analysis. The operation of aspecific code is usually detailed in thedocumentation accompanying the software, and
vendors of the more expensive codes will oftenoffer workshops or training sessions as well to helpusers learn the intricacies of code operation.

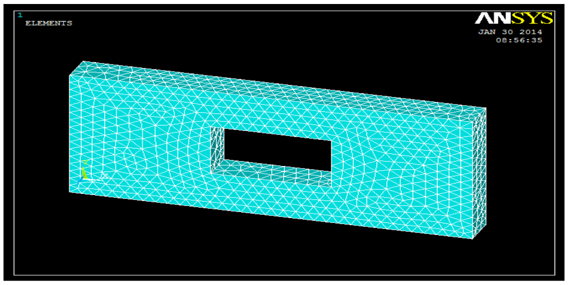

Fig. No. 4 Model Meshing

Result and Discussion

The experimental testing is done using universal testing machine and plot various graphs and tables which are compare with Ansys software results and discuss as follows. The various parameters are considered while designing the plate like Young modulus is $200*10^3$ MPa and Poisson's ratio is 0.27 to 0.3 which is shown in table no. 4.1. The following tables are shown the deformation or change in length with respect to load applying on plate like rectangular cutout.

1. For MS Plate:

SN	LOAD (kN)	DISPLACEMENT (mm)
1	50	10.13
2	100	13.18
3	150	15.50
4	154	17.00
5	154.60	17.50 (Breaks)

2. For Al. Plate

SN	LOAD (kN)	DISPLACEMENT (mm)
1	20	4.80
2	40	8.75
3	60	9.0
4	80	9.28
5	100	11.5
6	120	12.50 (Breaks)

While comparing above both tables the loads required for circular hole is greater than rectangular hole, so that circular cutout is preferred for mounting for any component to any assembly. But some structures required the rectangular or square cutout also, so that purpose this analysis is done.

1. For MS Plate:

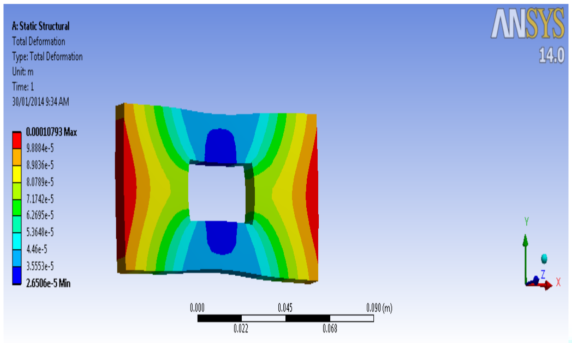

Fig. No. 5. Deformation

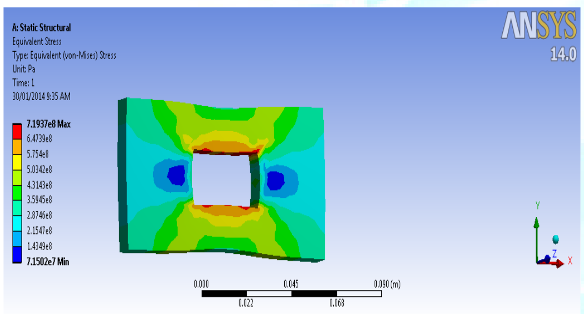

Fig. No. 6. Von-Mises Stresses

2. For Al Plate:

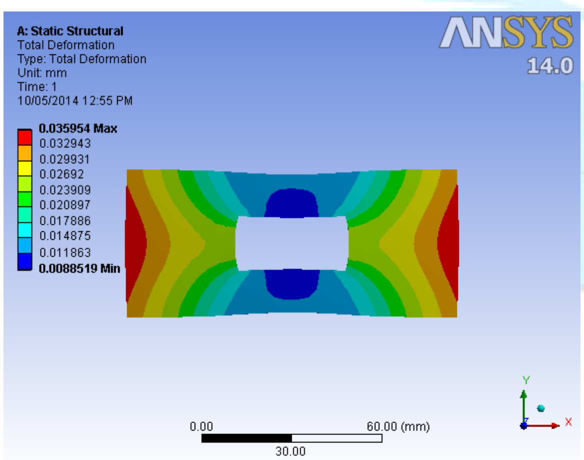

Fig. No. 7. Deformation

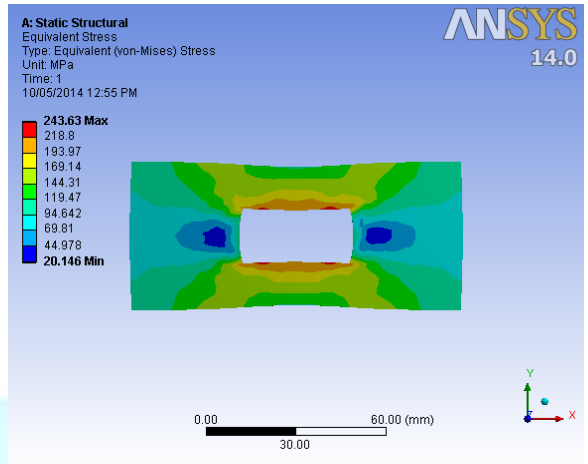

Fig. No. 8. Von-Mises Stresses

The above figures shows the actual results of the experimental set up and software (Ansys) which shows the stress and displacement. The following tables shows the values of stresses and displacement shown in software.

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 Mild Steel and Aluminium Plate.

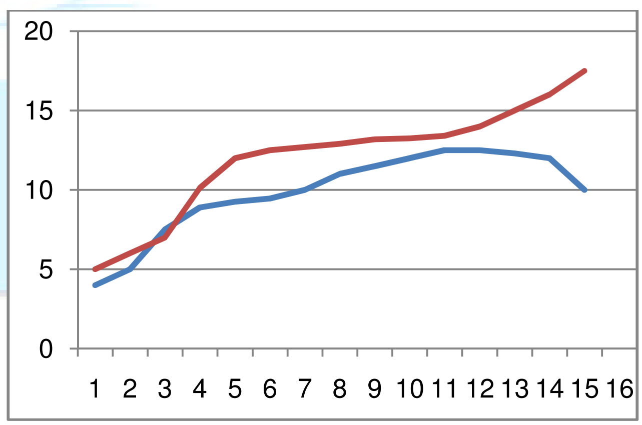

Fig. no. 9.. Comparison between Al. and MS plate.

The above graph shows the comparative difference between the aluminum (Blue Line) and mild steel (Red Line) plate, which shows the mild steel plate, is strong enough to withstand maximum load after tension and compression. After applying tensile loads on both plate we getting the all values from start to end i. e. up to breaking of the plate.

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 MS plate is also used for various purposes so we studied both material plates.

References

[1] D. K. Nageswara Rao, M. Ramesh Babu, K. Raja Narender Reddy and D. Sunil, "Stress around square and rectangular cutouts in symmetric laminates," Composite Structure, vol.92. pp. 2845-2859, 2010.
[2] G. N. Savin, Stress concentration around holes. New York-Pergamon Press, 1961.
[3] J. Daoust and S. V. Hoa, "An analytical solution for anisotropic plates containing triangular holes," Composite Structure, vol.19, pp. 107-130, 1991.
[4] J. Rezaeepazhand and M. Jafari, "Stress concentration in metallic plates with special shaped cutout," International Journal of Mechanical Sciences, vol.52, pp. 96–102, 2010.
[5] N. I. Muskhelishvili, Some basic problems of the mathematical theory of elasticity. Groningen- P. Noordhooff Ltd, 1963.
[6]S. G. Lekhnitskii, Theory of elasticity of an anisotropic elastic body. San Francisco-Holden-Day Inc, 1963.
[7] V. G. Ukadgaonker and Dr. K. N. Rao, "A general solution for stresses around holes in symmetric laminates under in-plane loading," Composite Structure, vol. 49, pp. 339-354, 2000.
[8] V.G. Ukadgaonker and V. Kakhandki, "Stress analysis for an orthotropic plate with an irregular shaped hole for different in-plane loading conditions-part-I." Composite Structure, vol. 70, pp. 255-274, 2005.
[9] V. G. Ukadgaonker and D. K. N. Rao, "Stress distribution around triangular holes in anisotropic plates," Composite Structure, vol. 45, pp. 171-183, 1999.
[10] V B Bhandari, "Design of Machine Element", Tata McGraw-Hill Publications, (2006) (pp. 67-100).
[11] Shigley's , "Mechanical Engineering Design" **,** Tata McGraw-Hill Publications, (2006) (pp. 933-955).