

Stress Concentration of plate with rectangular cutout

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Abstract - A Plate is considered with different cut outs, such as circular, triangular and square cut out The plates with cut outs are widely used in structural members. These cut outs induce stress concentration in plate. The main objective of this study is to find out the stress concentration in plate with various cut outs. For finding the stress concentration, a finite element program ANSYS is used. From this study we compare the stress concentration around cut outs in various materials and finding strength of the material. The more important finding is that the stress concentration increases as the cut out 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 cut out. Results are compared with FE results. By comparing the results, it is found that the stress concentrations by experimentation and software are relatively same.

Key Words: Stress concentration, stress Analysis, Bluntness, orientation

1.INTRODUCTION

Stress concentration arises from any abrupt Change in geometry of plate under loading . *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. 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. Stress 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. Hence for the design point of view the plate with different whole shapes plays an important role & accurate knowledge of stress.

These cut outs work as stress raisers and may lead to catastrophic failure. The behavior of isotropic plates with such cut outs, under different loading

conditions is already studied extensively by many researchers. But, the anisotropic media with various shaped discontinuity has received very little attention. Various shaped cut outs are made in structures and machines to satisfy certain service requirements.

1.1 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.

1.2 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.

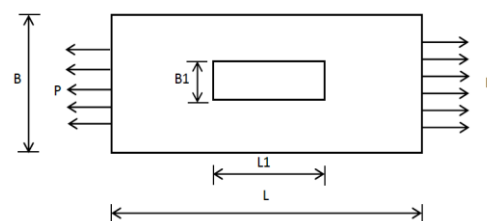


Fig-1: Loading Condition (Axial Tensile Pressure)

To study the different geometrical shape holes in an infinite plate of dimension 100 mm X 50 mm X 10mm with rectangular, 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

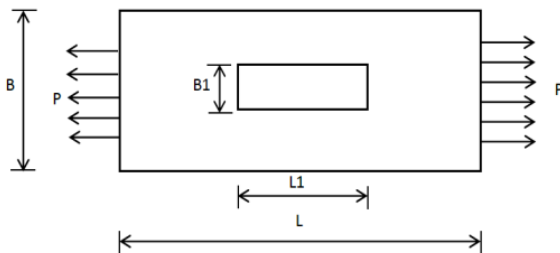


Fig -2 : Plate with Rectangular hole

- L = 100 mm
- B = 50 mm
- t = 10 mm
- B₁ = 20 mm
- L₁ = 30 mm
- P = 15 kN

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

Now,

$$\begin{aligned} \text{Stress} &= \frac{\text{Force}}{\text{Area}} \\ &= \frac{15000}{300} \\ &= 50 \text{ N/mm}^2 \end{aligned}$$

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

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

2. EXPERIMENTAL SETUP

The UTM 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) da/dN Fatigue Crack Propagation Test.
- (b) Merlin Testing Software for Tensile Test
- (c) Jic Fracture Toughness Test.
- (d) Kic 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.3) 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 - 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 -1: Tensile Properties

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

2.1 FEM Structural Analysis

Structural testing and analysis is a basic requirement for engineers in every industry. In fact ,the use of FEA for structural analysis has become so commonplace that some suggest it is—commodity technology|| that can be selected on the basis of price. Smart engineering and CAE managers, however, are recognizing that price and cost are not synonymous. Choosing structural analysis solutions that can grow with your evolving needs ,ANASYS Software provides a family of high performance solutions for structural FEA that meet the needs of beginning engineers and designers, experienced experts, and everyone in between.

These solutions help companies meet their business challenges by helping engineers to develop deeper insight in their products through virtual testing. Engineers using MSC structural analysis are able to evaluate many different types of designs, giving high confidence that the final design will successfully meet prescribed requirements, before the physical product is built. From single components to large complex systems, from linear static to highly non-linear dynamic problems, MSCs structural analysis capabilities are built to grow with your business, optimize your cost of ownership, and support you in achieving your goals.

Divide structure into pieces (elements with node). Describe the behavior of physical quantities on each element.

Connect (assemble) the elements at nodes to form an approximate system of equations for the whole structure.

Solve the system of equation involving unknown quantities at nodes (e. g. displacements).

Calculate desired quantities (stress and strains) at selected elements

2.2 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 preprocessor 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.

During the post processing stage, the corresponding frequency of the mode shape as well as the displacement of the plate plot on de formed or un deformed shapes. To simplify the analysis, only plates with circular/elliptical/triangular cross-section are modeled. The mesh was generated by ANSA with hex elements. We also use ANSA to assignment of the materials properties, define contacts, and set appropriate boundaries and loadings during analysis. The operation of a specific code is usually detailed in the documentation accompanying the software, and vendors of the more expensive codes will often offer workshops or training sessions as well to help users learn the intricacies of code operation.

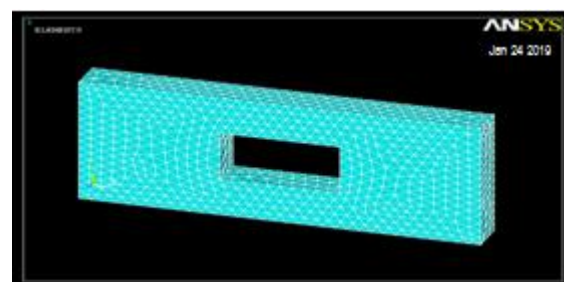


Fig - 4: Model Meshing

2.3 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 1. The following tables are shown the deformation or change in length with respect to load applying on plate like rectangular cutout.

Table -2: For MS Plate

SN	LOAD(kN)	DISPLACEMENT (mm)
1	50	10.12
2	100	13.19
3	150	15.51
4	154	17.01
5	154.60	17.50 (Breaks)

Table -2: For Al. Plate

SN	LOAD (kN)	DISPLACEMENT (mm)
1	20	4.81
2	40	8.74
3	60	9.01
4	80	9.29
5	100	11.6
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:

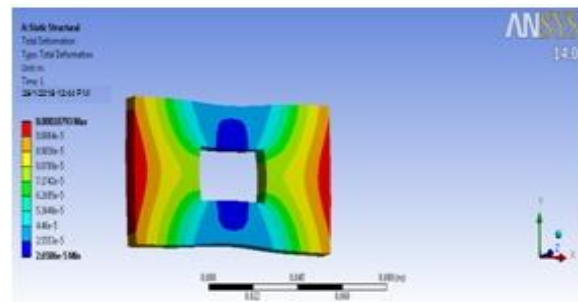


Fig - 5: Deformation

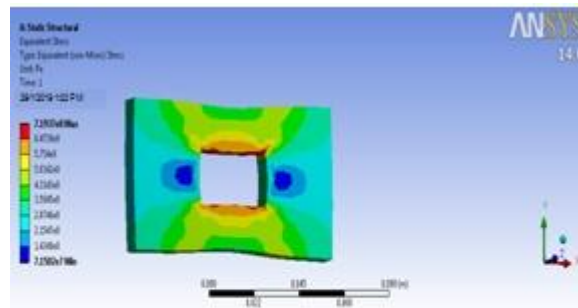


Fig -6: Von-Mises Stresses

2. For Al Plate:

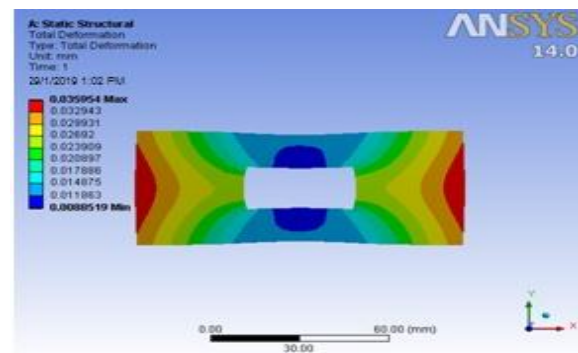


Fig - 7: Deformation

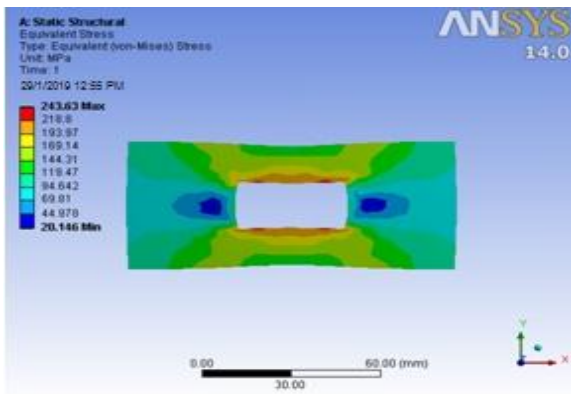


Fig - 8: Von-Mises Stresses

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 Aluminum Plate.

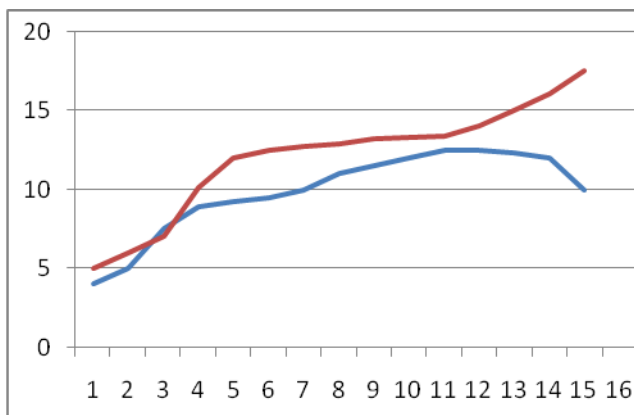


Chart -1: Comparison between Al. and MS plate.

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.

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

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