FEA ANALYSIS OF THE SQUARE HOLE AT THE CENTER OF THE 6061 T6 ALUMINUM PLATE.

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ABSTRACT

The stress concentration factor, maximum stress, and deformation of the plate are very crucial in the design. These parameters decide the strength and life of the component. In the present work, the analysis was carried out on a square aluminum plate with a rounded square hole at a central location to determine maximum stress, displacement, equivalent elastic strain, and safety factor with varying tensile load conditions. The material used for the plate is aluminum 6061 T6.The ANSYS workbench 2022 was used to carry out the analysis and CAD drawing.

Keywords. FEA analysis, Stress concentration, and center hole locations.Aluminum 6061 T6.

INTRODUCTION:

Stress concentration

Stress concentrators cause high stresses in the structure. There are different formulas for nominal stress, usually it is stress in the absence of concentrator. “Stress concentration is defined as the localization of high stresses due to the irregularities present in the component and abrupt changes of the cross-section”. In order to consider the effect of stress concentration and find out localized stresses, a factor called stress concentration factor (SCF) is used. It is denoted by Kt and defined as,

$$Kt = \frac{\text{Highest Value of actual stress near the discontinuity}}{\text{Nominal stress obtained by elementary equations for minimum cross-section}} \quad (1)$$

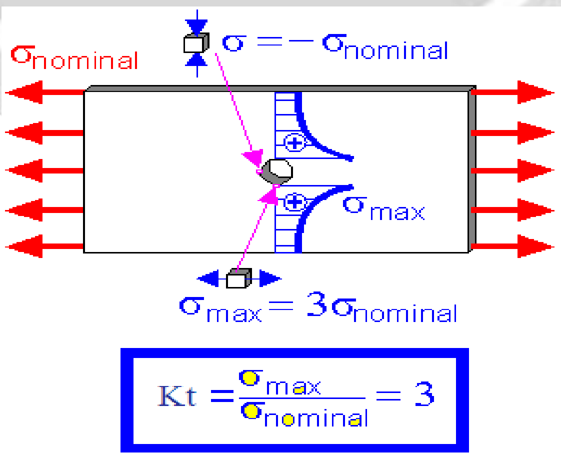


Fig 1. Stress concentration factor.

Materials

As one of the most popular aluminum grades, 6061 is often chosen for structural applications, welded assemblies, electronics, and a variety of industrial and household items. 6061 aluminum tube, aluminum bar, and aluminum plate offer high-to-moderate strength, excellent corrosion resistance, and superior machinability and weldability. 6061 aluminum offers greater strength over other alloys in the 6xxx series, which is why it is chosen for applications that require tough, yet light material.

I pick the Pick 6061 T6 Aluminum for our Project because the 6061 T6 is a highly popular type of aluminum because of its versatility, strength, and forming characteristics. It's ideal for projects that require a light, yet strong material.

Finite Element Method for Stress Concentration Factor

In general, hand calculations are often used for finding nominal stress and FEA for peak stress but either method can be used. The following example shows a flat plate with a hole in it and a load applied in tension. The stress is foundwith the hand a calculation and the results are then compared with FEA

Young's Modulus.

Young's modulus is the stiffness of a material. For a stiff material such as steel at room temperature, it is typically 205 GPa or 205,000 MPa. For a soft material such as nylon it may be 3 GPa or 3000 MPa.

Young's Modulus is the slope of the straight elastic part of the stress-strain curve as shown in the graph below fig 2. The linear static analysis applied to the majority of FEA models follows the principle of Hooke's Law of elasticity. i.e. the stiffness of the part follows the elastic portion of the stress-strain curve.

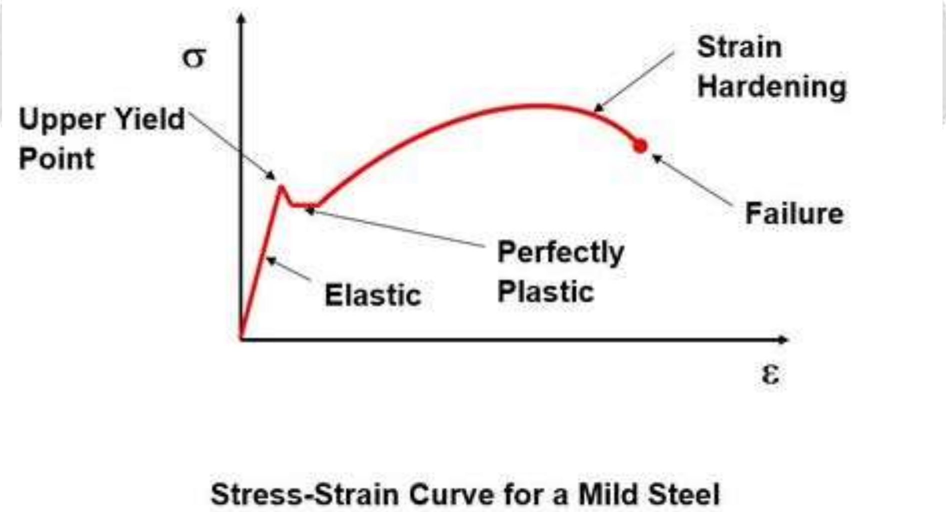


Fig 2. Stress strain curve for mild steel

The Effects of Poisson's Ratio.

Poisson's ratio is a measure of the lateral contraction of a material when under tensile stress in the longitudinal direction. For most cases, it has little effect on the results but for a few it is significant. Poisson's ratio varies from 0.2 for some grades of cast iron to 0.45 for some grades of polythene.

FEA Boundary Conditions.

The main types of loading available in FEA include force, pressure, and temperature. These can be applied to points, surfaces, edges, nodes, and elements or remotely offset from a feature.

Literature Survey

Mahesh Kadam et al. the authors studied the effect of loading conditions on a plate with a circular hole at the center of the plate. The authors plot the graph of how stress concentration varies with the D/W ratio. They also show that The Analytical values of the Stress Concentration Factor and that obtained by FEA decrease exponentially with an increase in D/W ratio but vary from each other by the small negotiable amount in all conditions and the behavior of the graph remains the same in all cases except in mixed loading which is almost linear.

Pawel J et al. the authors used a digital image correlation (DIC) system for the stress concentration analysis and plastic zoon development problem on mild S235JR + N steel, micro-alloyed fine-grain S355MC steel, and high strength 41Cr4 steel subjected to different heat-treatment. The study focused on the determinations of dangerous zones with large stress concentrations, plastic deformation growth, and prediction of the failure zone. Experimental analysis was carried out with different shape cutouts in the panel. Selected results of the total strain distributions were compared with FEM results, and good agreement was observed.

METHODOLOGY:

The methodology of the work has to follow certain steps to execute the work satisfactorily and compare the obtained result with theoretical results.

The discussion about the mythology to understand the process involved. The methodology of the processes can be studied from the different research articles and identify the research gap to carry the research in that direction.

The process steps for executing the research work are as follows,

1. Literature survey
2. Research gap identification.
3. Selection of materials and their properties.
4. CAD model from the CAD software.
5. Meshing of the cad model
6. Applying boundary conditions
7. Solutions
8. Discussion of the obtained results.

Selection of Materials.

The material chosen for the present work is aluminum 6061 T6. The properties of the material are shown in **Table 1**

Table 1**.** Properties of the Aluminum 6061 T6

Properties	Value	SI Unit
Brinell Hardness	93	
Elastic (Young's, Tensile) Modulus	60	GPa
Elongation at Break	10%	
Fatigue Strength	96	MPa
Poisson's Ratio	0.33	
Shear Modulus	26	GPa
Shear Strength	210	MPa
Tensile Strength: Ultimate (UTS)	310	MPa
Tensile Strength: Yield (Proof)	270	MPa

CAD Model and Meshing

The CAD model was done using the ANSYS Workbench, the dimension of the Drawing is shown in the table for the different cases.

Table 2.Dimensions of the model

Component	Case 1
Plate size	100 mm X 100mm
Hole size with the radius	5mm x 5mm (R1)
Number of holes at center	1

The meshing of the geometry has been done in the ANSYS Workbench 2022. The quadrilateral materials are used to mesh the geometry and the size of the element is 4 mm. The number of nodes and elements are 10228 and 5886 respectively.

Boundary Conditions

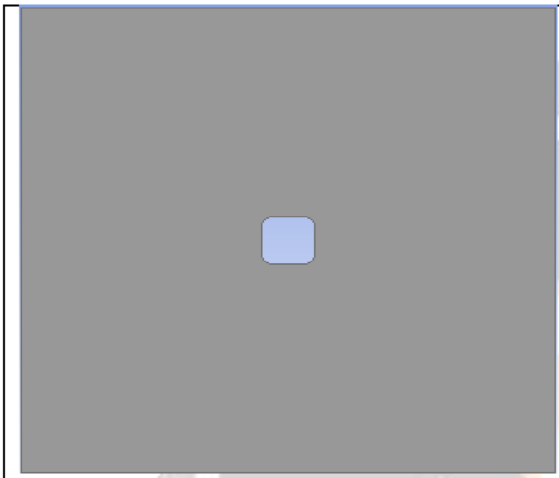
The boundary conditions are important to obtain accurate output in ANSYS. The boundary conditions are applied at the boundary to predict the accurate results. The boundary conditions used in the present work are load conditions. The tensile load was applied on the right side of the aluminum plate. The left side of the plate is fixed in all degrees of freedom. The values of loadapplied are shown in Table 3.

Table 4. Load values for the analysis

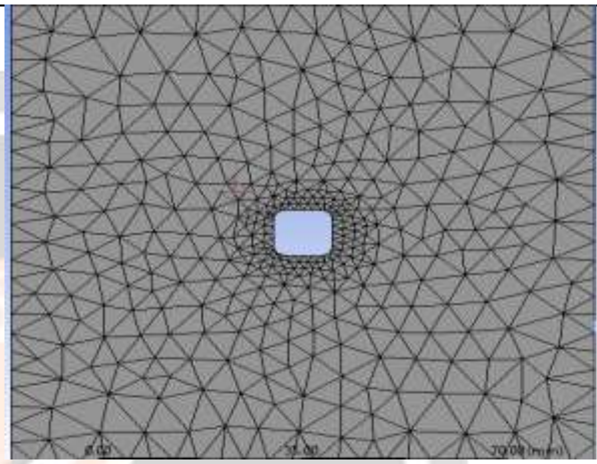
Load (kN)	100	80	60	40	20	10

RESULTS AND DISCUSSIONS:

Model of the Geometry.



(a) Model of the Geometry



(b) Meshed Geometry

Fig 3. Modelled geometry and meshed

Von Mises stresses, when the Square Hole at the Center of the Aluminum Plate.

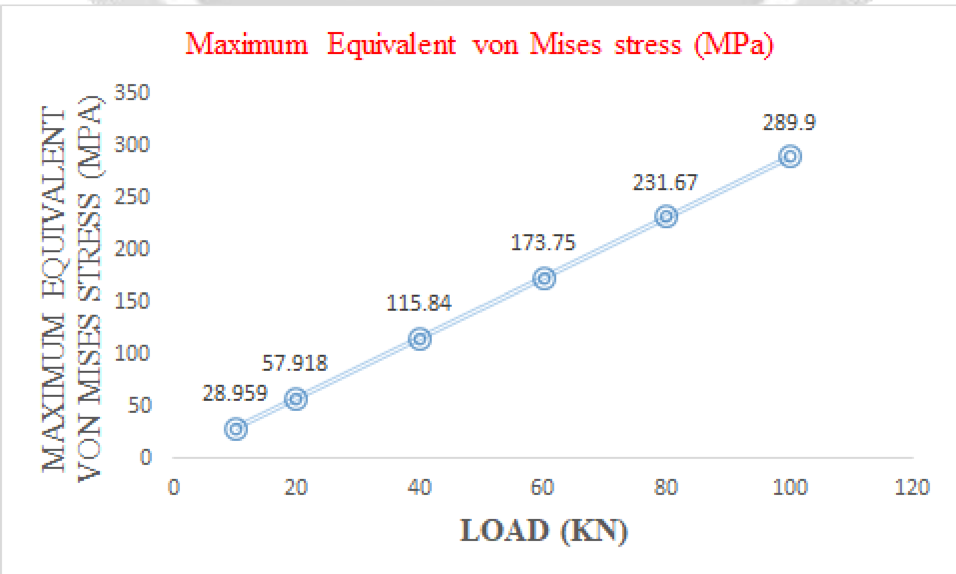


Fig 4. The Von Misses Stresses with varying load.

The maximum von Mises stress increases with increases in the loading conditions from the 10 kN to 100 kN load. The minimum value 28.959 MPa at the 10 kN and the maximum value is 289.9 MPa at the 100 kN. Hence, the safer load is 10 kN for which minimum von Mises stress. The maximum von Mises stress are found around the hole at the center and the minimum stress at the other side of the components.

Total Deformation

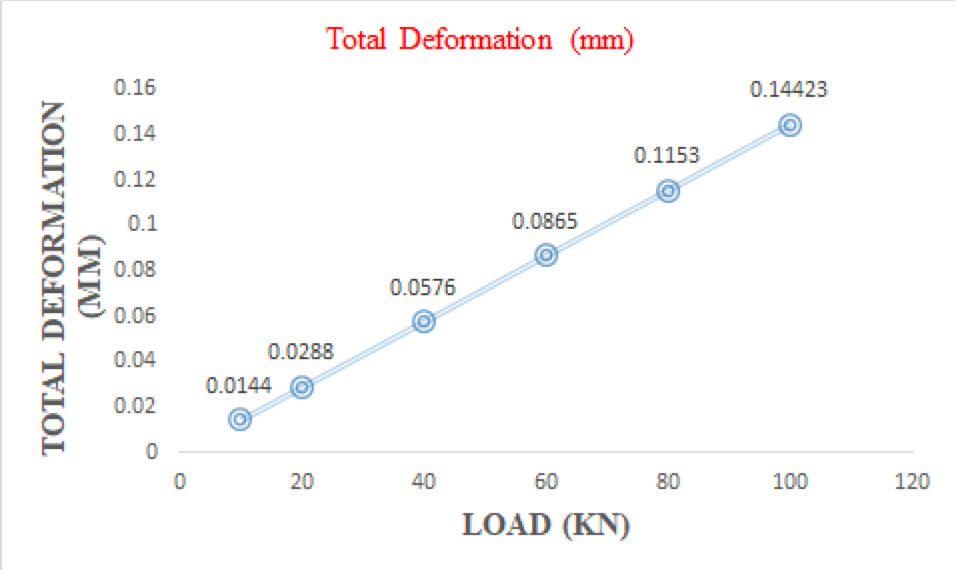


Fig 5. The total deformation varying with load.

The total deformation of the component of case 1 increases with the increase in the loading conditions. The minimum deformation occurred at the 10 kN the value is 0.0144 mm and the maximum value is 0.14423 is at the 100 kN. The maximum deformation occurred at the applying loading side and minimum deformation occurred at the fixed side of the component. Hence, the 10 kN is safer loading condition for minimum deformation.

The Safety Factor

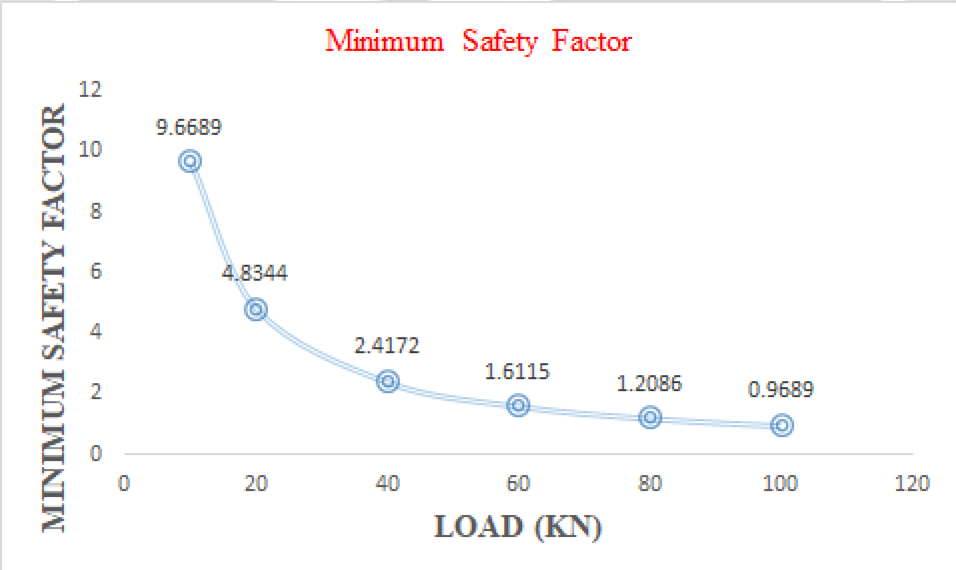


Fig 18. The minimum safety factor with varying loads.

The minimum safety factor is 0.9689 at 100 kN and the maximum safety factor is 9.6689 at the 10 kN. The safety factor decreases with increase in the loading condition from 10 kN to 100 kN. The design is safer at the maximum safety factor, which is at the 10 kN. Hence, the design is safer at the 10 kN. The minimum safety factor always occurred at the around the hole. Due to this failure start from the hole at the center.

CONCLUSIONS:

The analysis was carried out for the aluminum 6061 T6 plate square hole at the center with varying loads from 10 kN to 100 kN to determine the stresses and deformation of the plate.

1. Minimum Von Mises stress, total deformation, and maximum safety factor occurred at the 10 kN load.
2. Hence the design is safe at 10 kN load, at this load stress and deformation is very less. The safety factor is more at the 10 kN which is good for better durability and life of the design.

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