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Effect of Stress Concentration on Various Shaped Hole Having Similar Cross Section Area

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ABSTRACT

In this study, taken a perforated steel plate (45C8) of square shape of dimension 50×50mm and thickness 10mm. and having different holes of shapes such as Square, rectangular, triangular, circular. Now after this step, we have fixed one side of model and applied a tensile stress on the remaining three sides. After that, we obtained nominal normal stress with the help of FEA (finite element analysis) through software. After getting the nominal normal stress, Calculated the value of stress concentration factor (K_t) for every hole of different shape and compared with each other. For our study and simulation we have used CAD software (solid works). Purpose of the study is that to find out which shape is best in point of view less concentrated with stress concentration, so we can use this particular shape for various applications.

I. INTRODUCTION

The project is based on the analysis of stress concentration so introducing some important facts;-

1)*Stress concentration*- it is defined as the localization of high stress due the irregularities present in the component and abrupt changes of the cross- section

2)*Stress concentration factor* – in order to consider effect of the stress concentration and find out the localized stress , a factor is called stress concentration factor

3)*Origin of stress concentrations*- Machine members often have regions in which the state of stress is significantly greater than theoretical predictions as a result of

a) Geometric discontinuities or stress raises such as holes, notches, and fillets

b) Internal microscopic irregularities (non-homogeneities) of the material created by such manufacturing processes as casting and moulding

c) Surface irregularities such as cracks and marks created by machining operations.

These stress concentrations are highly localized effects which are functions of geometry and loading. In this tutorial, we will examine the standard method of accounting for stress concentrations caused by geometric features. Specifically, We will discuss the application of a theoretical or geometric stress-concentration factor for determination of the true state of stress in the vicinity of stress raises.

4)*Reduction of stresses*

a)Additional notches and holes in tension member

b)Fillet radius, under-cutting and notch for member in bending c)Drilling additional holes for shaft

d)In threaded member – notch and under-cut provided 5)*Theories of failure-*

a)Maximum principal stress theory-

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According to this theory, the machine member will fail when the maximum principal stress obtained through bi-axial, stress system at a strained particle of that member reaches the limiting strength of the member when it is subjected to a simple tension test. Generally the limiting strength for ductile material is yield stress and for brittle material is the ultimate tensile stress.

b) Maximum shear stress theory- According to this theory, the machine member will fail when the maximum shear stress due to bi-axial stress system reaches the shear yielding stress in simple tension test.

c) Von misses hanky or Distortion energy theory-According to this theory failure of mechanical component subjected to biaxial or triaxial forces occurs when the strain energy distortion per unit volume at any point of component becomes equals to the strain energy of the standard specimen. This theory applicable for both ductile and brittle material.

II. PROBLEM IDENTIFICATION AND METHODOLOGY

The methodology is used in this study is the principal of failure of theories is von Mises hanky‟ s. Which states that "the theory states that the failure of the mechanical component subjected to biaxial or triaxial stresses occurs when the strain energy of distortion per unit volume at any point in the component becomes equal to the strain energy of distortion per unit volume in a standard specimen of tension test when yielding starts. So we have used this theorem for study and simulation.

1) Stress-concentration factor, K_t

In order to predict the "actual" stress resulting from a geometric stress raiser, a theoretical stress concentration factor is applied to the nominal stress. For a part subjected to a normal stress, the true stress in the immediate neighbourhood of the geometric discontinuity is calculated as:

$$\sigma_{max} = K_t \sigma_n \quad so, \quad K_t = \sigma_{max} / \sigma_n \tag{1}$$

Where,

K_t=Theoretical stress-concentration factor σn =Nominal normal stress

Similarly, we can also estimate the highly localized amplification of shear stress in the vicinity of geometric stress concentration,

$$\tau_{max} = K_t \times \tau_n \tag{2}$$

Where,

K_t=Theoretical stress-concentration factor for shear τ_n =Nominal shear stress

The nominal stress of the above equations is typically derived from the elementary strength of materials equations, using either a net or a cross section.

2) Characteristics of Stress-Concentration Factors:-

a) Function of the geometry or shape of the part, but not its size or material;
b) Function of the type of loading applied to the part (axial, bending or torsional);
c) Function of the specific geometric stress raiser in the part (e.g. fillet radius, Notch or hole)

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c) Always defined with respect to a particular nominal stress;

d) Typically assumes a linear elastic, homogeneous, isotropic

3) Model and Material properties-

a)Plate Dimension- 50mm×50mm

b)Thickness 10 mm

c)Hole Area 80mm^2

d)Remaining area 420mm^2

e)Material Grade 45C8(AISI1045 Steel cold drawn)

Shapes of cavity taken-

1) Rectangle 2) Square 3) Triangle 4)Circle *4)Volumetric Properties*

Mass:0.18997 kg

Density:7850 kg/ m^3

Weight:1.86171N

5) Model properties-

Table 1 Physical Properties of Taken Steel Plate 45c8

Material Name:	AISI 1045 Steel
failure criterion:	Vone mises
Yield strength:	530 N/mm^2
Tensile strength:	625N/mm^2
Elastic modulus:	205N/mm^2
Poisson's ratio:	0.29
Mass density:	7850 kg/m^3
Shear modulus:	800 N/mm^2
expansion coefficient:	120×10^{-005}(K)

III. SIMULATION AND STUDY

The simulation has been done on the CAD software like Solid Works where according to the Vone mises theory of failure the bi-axial loads applied on the steel plate of grade AISI 1045 Steel. In simulation process first of draw the square plate and make a desire hole of similar cross section area.

Calculation of stress concentration factor

Material: 45C8 (AISI-1045)

From the table 1 the value of ultimate tensile stress

S_{ut} = 625 N/mm^2 (3)

The maximum nominal normal stress is define as the ratio of ultimate tensile stress to the factor of safety

σ_{max}= ultimate tensile stress÷ factor of safety (4)

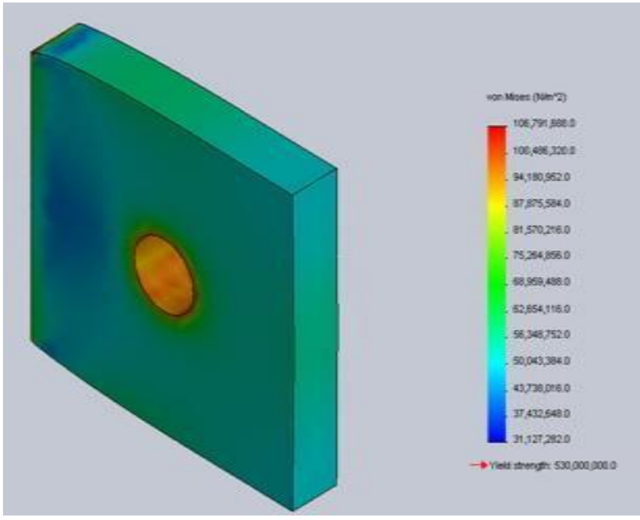
=625÷2

=312.5 N/mm^2

here, Factor of safety=2 (assume)

TABLE 2 Values of Stress in Circle After Simulation

Name of study	Type of failure theory	Min	Max
Stress analysis	Von Mises	31 N/mm^2	106 N/mm^2



“Fig.1,” shows the simulation of circle hole where one hole is made by extrudes cut. The dark red color

1) Simulation of circle hole

Fig.1 stress distribution of circular cross section area represents the higher stressed zone. In the fig.1 it is

2) Simulation of square hole

clearly shown that stress is distributed over whole area so “Fig.2,” shows the simulation of square hole where one hole is the intensity of stress also distributed so the possibility of made by extrudes cut. The dark red color represents the higher failure reduces compare to another cross section shape. stressed zone. In the fig.2 it is clearly shown that stress is The blue color represents safer area compare to red zone.

After the simulation results generated by software is concentrated on the corners of the body. The intensity of the After the simulation results generated by software is stress is higher compare to circle .The stress is concentrated at shown on table1 where 106 N/mm2 is the maximum nominal corner because irregularities is occurring here and stress is stress and 30.821 N/mm^2 is minimum normal stress. The occurring where more irregular shape is presence. Compare to stress concentration factor is defined as the ratio of circular cross section square cross section higher chances of

maximum stress to the nominal normal stress. failure. The blue color represents safer area compare to red Stress concentration factor zone.

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$K_t = \sigma_{max} \div \sigma_n$

5)

shown on table1 where 126.162N/mm2 is the maximum

$(\sigma_n)_{circle}$=106.628 N/mm^2 (from table 2)

nominal stress and 30.821 N/mm^2 is minimum normal stress

$(K_t)_{circle}$ =312.5÷106.628

(Table3).

=2.93

$(\sigma_n)_{square}$=126.162N/mm^2

$K_t = \sigma_{max} \div \sigma_n$

(6)

$(K_t)_{square}$ = 312.5÷126.162

=2.47

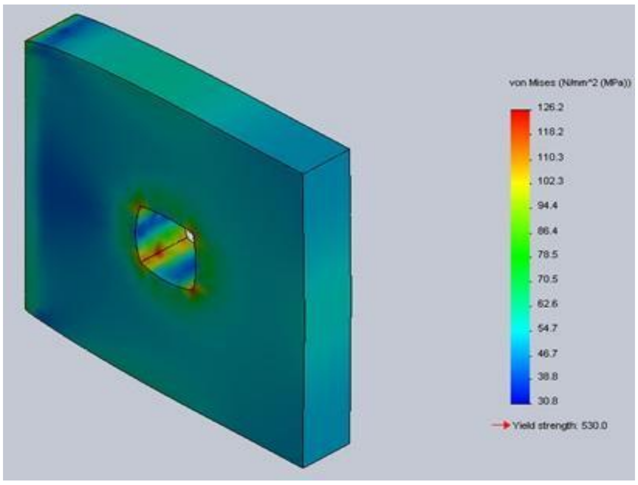

Fig.2 stress distribution of square cross section area

TABLE 3 Values Square Hole After Simulation

Name of study	Type of failure theory	Min	Max
Stress	Von Mises	30.821 N/mm^2	126.162 N/mm^2

3) *Simulation of rectangle hole*

"Fig.3," shows the simulation of rectangle hole where one hole is made by extrudes cut. The dark red color represents the higher stressed zone. In the fig.3 it is clearly shown that stress is concentrated on the corners of the body. The intensity of the stress is higher compare to circle .The stress is concentrated at corner because irregularities is occurring here and stress is occurring where more irregular shape is presence. Compare to circular cross section rectangle cross section higher chances of failure. The blue color represents safer area compare to red

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zone. After the simulation results generated by software is shown on table4.Where maximum nominal stress is 135.395N/mm^2 and 31.541N/mm^2 is minimum normal stress (Table3).

$(\sigma_n)_{rectangle} = 135.395\text{N/mm}^2$

$K_t = \sigma_{max} \div \sigma_n$ (7)

$(K_t)_{rectangle} = 312.5 \div 135.395 = 2.3$

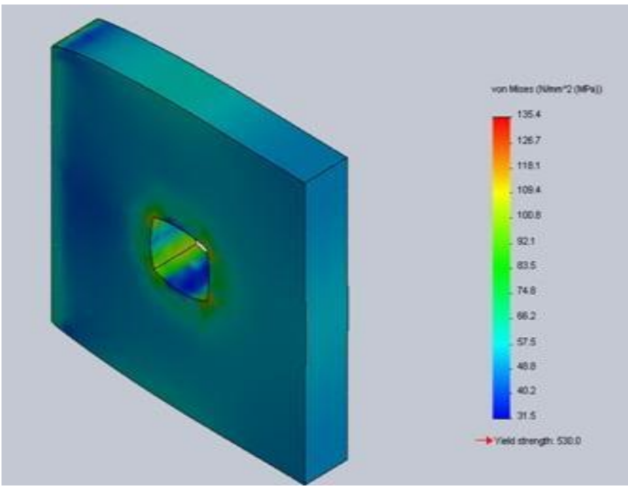

Fig.3 stress distribution of rectangle cross section area

TABLE 4 Values of Rectangle Hole After Simulation

Name of study	Type of failure theory	Min	Max
Stress	Von Mises Stress	31.541N/mm^2	135.395N/mm^2

4) Simulation of triangle hole

"Fig.4," shows the simulation of triangle hole where one hole is made by extrudes cut. The dark red color represents the higher stressed zone. In the fig.4 it is clearly shown that stress is concentrated on the corners of the body. The intensity of the stress is higher compare to circle .The stress is concentrated at corner because irregularities is occurring here and stress is occurring where more irregular shape is presence. Compare to circular cross section. Triangle cross section higher chances of failure. The blue color represents safer area compare to red zone. After the simulation results generated by software is shown on table5. Where 138.268 N/mm2 is the maximum nominal stress and 21.4504N/mm^2 is minimum normal stress (Table5).

$(\sigma_n)_{triangle} = 138.268\ \text{N/mm}^2$

$K_t = \sigma_{max} \div \sigma_n$ (8) $(K_t)_{triangle} = 312.5 \div 138.268 = 2.25$

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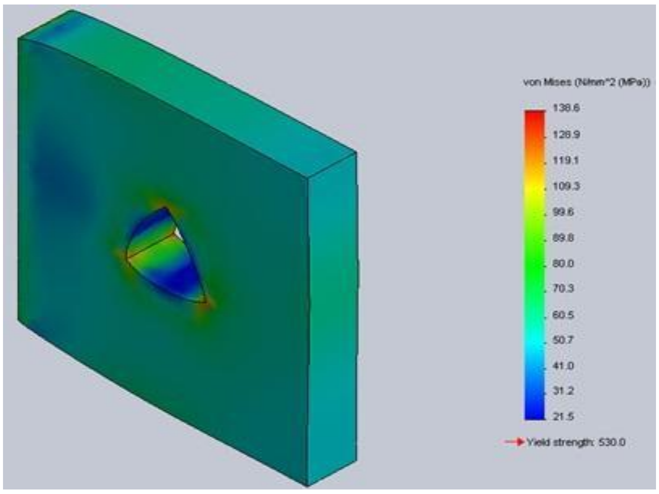

Fig.4 Stress distribution of triangle cross section area

TABLE 5 Values of Triangle Hole After Simulation

Name of study	Type of failure theory	Min	Max
Stress	Von Mises Stress	21.4504N/mm^2	138.628N/mm^2

IV. RESULT AND DISCUSSION

On this research discussed about the effect of stress concentration on various shaped having similar cross section area where result shows the circular cross section area is preventive compare to another cross section area like, square, rectangular, triangular etc.The stress concentration factor of the circular cross section is near 3 or 3 is preferable.

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