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Study the Stress Analysis of a Rectangular Plate with a Central Cut for Different Mesh by Ansys

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Abstract

The stress study of concentration factor and maximum stress (σmax) of the rectangular plate with fixed dimensions in two cases with a central circular hole in case-1& three holes in case-2 are analyzed through analytical, graphical methods, and FEM by using Ansys version (2020 R1) with calculated the percentage error (P.E %) for five readings of elements of mesh (1, 2, 3, 4, 5) mm is achieved, each case alone. The results for two cases are fixed at the short end and loaded by (1000 N) on the other side as they stretched from this end, the results for the values of (σmax) and SCF are shown the good agreement with the result of (FEA) for the two cases which is the aim of this study. The best value of (P.E %) in case-1 is (0.8423-0.9778) which is very less compared with case-2 due to the increases in the number of holes with different ratios of (d/w) "the less ratio of d/w which means the more complexity then more SCF", where the values of (P.E %) is increased also then the value SCF is increasing. This indicates if the element size in the mesh increases, the number of elements will decrease & therefore the percentage error will decrease and the accuracy of the results will increase.

Keywords: Ansys (2020 R1), FEM, Circular Hole in Rectangular, SCF, σ_{max}.

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Introduction

The factor of stress concentration (SCF or Kt) plays a crucial role in the manufacturing, designing, and production of industrial; they are taken into consideration when sizing the pieces because this is the most common cause of failure [1-3]. The (Kt) is the relation ratio of the (σ_{max}) greatest stresses generated at the discontinuity to the average normal or nominal stress ($\sigma_{nom} = \sigma_{avg}$) at the hole [4,5]. The curves of SCF had to be produced for each modification in the shape of geometry, making this a time and space-consuming task. More versatile and effective computer strategies have gradually supplanted these experimental procedures [6-8]. Currently the capabilities of computing are effective and powerful, and usually depend on the (FEM) [9,10]. Whereas, FEM is a method that was recently introduced as a geometric tool that provides relationships between geometric parameters with high accuracy whose results can be compared with those results that have been calculated experimentally [11]. Gunwant et al using FEM to determine the SCF in linearly elastic structure for different stress [12]. Roman study the numerical of the (Kt) in the geometries for machine element by ANSYS and Autodesk for a flat plate, where they found that the similarity between practical and simulation (0.02%) and (0.3%) between the two software [13]. Sachin et al study the analysis of plate component with tapered at hole subjected on load of tensile was done using (FEA) techniques [14]. A critical review of the flat plate was made by Nagpal et al to study the SC and its Mitigation Techniques [15]. The effect of initial stretching of plate with a puncture on the (σ & U) distributions around upon puncture, which it generated due to the extra loads, is examined by using the FEM on a plate have a circular cutout-hole subjected to regular stress [16]. Chintala done some validation about Peterson's contribution in the field of SCF using cutting-edge technology such as (FEA) and Computer Aided Design (CAD) and extends it to display SCF as charts for complicated 3D & 2D structures [17]. Lai et al study the composite plate (carbon/epoxy) for a cutout of various shapes, which is subjected to in-plane tensile loading. the FEM is based plane stress analysis is performed, then in MATLAB program for the analysis was done. The influence of the hole's geometry on the distribution of stress around it is also investigated [18]. Nagpal used the FEM to determine the (Kt) to a rectangular plate have a square central hole under some load, the author found through this investigation fluctuation in the Kt for varied S/A ratios between (0.1 to 0.5). The Kt was reduced in this study by installing auxiliary circular holes surrounding the primary square hole and the variation of (σ) in multi directions in relation to the (S/A) values is graphically investigated [19]. Bhanu worked to introduce automation by APDL in ANSYS for finding out SCF to a square or rectangular plate have a shape circular hole, for two materials – Aluminum 6061-T6 and Structural Steel [20]. Konieczny and Gasiak worked to investigation the (stress) for a plate at a two-axial load [21]. According to Pawar et al the FEA is a very useful approach for determining stresses caused by a variety of materials [22]. Srinivas et al, found by changing the (a/w) ratio, and through FEM analysis to perform for steel – IS2062 material plate with an elliptical hole in the middle, then an association between the (a/w) ratio and von mises stresses was further explored using a mathematical regression equation [23]. Burjes studied some physical properties of some composite materials using FEM [24], also Burjes and et al studied the stress of plate with central cut with two different materials and obtained a good result [25]. The aim from this work is to investigate the plate in two cases (central circular hole & three holes) a hole subjected to regular load and observe the variation in the calculation of results obtained through analytical, graphical and FEM in various meshes

Methodology

The calculations in three methods (Analytical, Graphical, and FEM) were achieved to determine and validate the values of SCF & stress, analysis was performed on a plate for two cases have the dimension which is shown in Table (1) & Fig. (1 & 2). Then we create the two models in ANSYS (2020 R1) and perform the analysis using the following parameters table.

Table 1: Dimension for Two Cases

case1	case 2
Circular Hole at Center of plate	Plate have Circular Hole on Center & 2- Holes of (30 mm) which are placed 90 mm away from the central Hole on both sides
L = 300 mm	L = 300 mm
W = 120 mm	W = 120 mm
T = 30 mm	T = 30 mm
D = 60 mm	D1 = 60 mm, D2= 30 mm, D3= 30 mm

Fig. (1) show the plate have a circular hole on the center & Fig (2) plate have three holes one on center & 2- Holes of (30 mm) which are placed (90 mm) away from the central Hole on both sides. The two cases are fixed at short end, then (1000 N) which is the load puts another end such that plat is stretched.

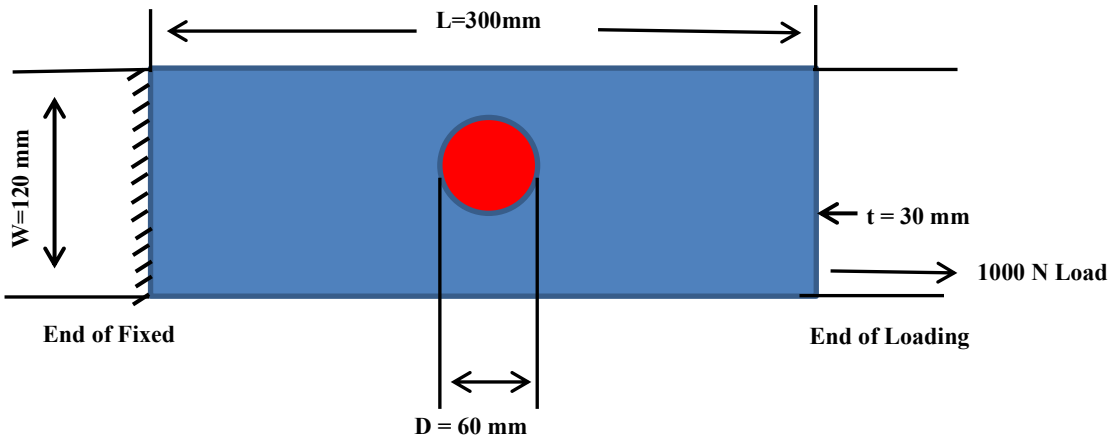


Fig. 1: Plate with Circular Hole at Center

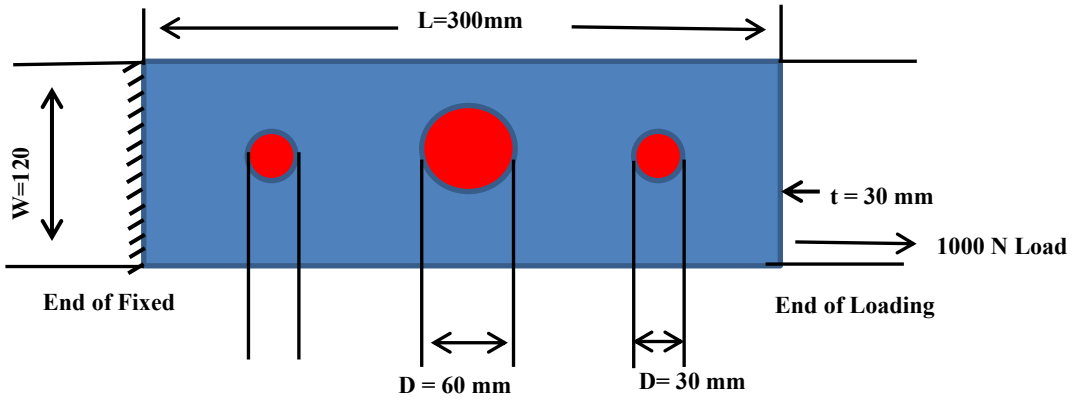


Fig. 2: Plate with Circular Hole at Center and Two Holes of (30 mm)

The dissection of SCF is done to stresses around the hole of Structural Steel & property was taken into account for analysis in the hole's immediate vicinity. The property of the matter is displayed in the table (2).

Table 2: Properties the Material

Material	Density Kg/mm^3 (Rho)	Elasticity Modulus Pa	Bulk Modulus Pa	Shear Modulus Pa	Poisson's Ratio
Structural Steel	7850	2 x 10 ^{11}	1.5152 x 10 ^{11}	7.8125 x 10 ^{11}	0.3

Results of the Calculations & Discussion

In engineering materials, Von mises stress is one of the most useful scales for predicting yielding. In this context, Calculation of Theoretically (Graphically), Analytically and FEM was used to extract the Von mises stress, SCF with Percentage Error for five readings of Mesh (element size) in the plate with the circular hole for two cases (rectangular plate has a circular cutout- hole & three holes).

Calculation

The (SCF) which we can denote by (Kt), theoretical can calculated in hand book data, which based on width and Diameter(d) of hole for a panel. This information was utilized to create a plate for a circular hole that was subjected at load of uniaxial shown in Fig (3).

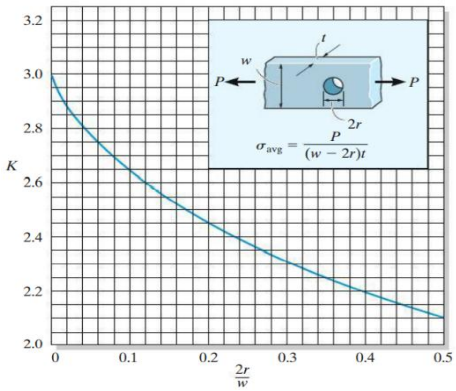


Fig. 3: Stress Concentration Factor [4,5]

In this study we calculate for two cases the Maximum stress (σ_{max}) by three methods (Theoretical or Graphical, Analytical and FEM) with Percentage Error (P.E%), and the (Kt) by two method {Graphical, Analytical}, In the Ansys we modeled and choose the (Mesh) element size (1,2,3,4,5) mm as shown in the steps below. The combined result is shown in table (3).

Calculation for Case 1

Calculate Theoretical (Graphically) (σ_{max}) [4,5]by

$\sigma_{max} =$ Kt. σ_{avg} …… (1)

where: $\sigma_{avg} = \sigma_{nom}$ is the average or nominal stress which equal to

$\sigma_{avg} =$ (F / A), ……(2)

F= load, A = (w – d). t, A= area, w = width, d = diameter, t = thickness.

σ_{avg} = (1000 N / (120 – 60) . 30)

σ_{avg} = 0.5555 Mpa ≈ 0.56 Mpa

Calculating (Kt) from the Graph

the value of (Kt) for (D / W) = (60/120) = 0.5, is (Kt = 2.1)

then: $\sigma_{max} =$ Kt . σ_{avg}

$\sigma_{max} =$ (2.1) x (0.56) = 1.176 Mpa

4.1.B. Calculate Analytical Method for (σ_{max}) by the equation [4,24 & 25]

$Kt = 3.0 - 3.14(2r/W) + 3.667(2r/W)^2 - 1.527(2r/W)^3$ …… (3)

$Kt = 3 – 3.14\ (0.5) + 3.667\ (0.5)^2 – 1.527\ (0.5)^3$

(Kt = 2.155875)

$\sigma_{max} =$ Kt . σ_{avg}

$\sigma_{max} =$ (2.155875) x (0.5555) = 1.197588 Mpa

4.1.C. Calculate the (σ_{max}) by the FEM from ANSYS.

For element size in mm the (σ_{max}) in Mpa. the values are shown in table (3) according to the Fig. 4. (a,b,c,d,e,f). and by eq. of (P.E%) [20,22] is

P. E.% =Theoretical value − FEM value / The Theoretical value …….(4)

Calculation for Case 2

Calculate Theoretical (Graphically) (σ_{max}) for three holes by eqs.(1 & 2)

σ_{avg} = (1000 / ((120 -60) + (120 -30) +(120-30)). 30)

σ_{avg} = 0.1389 Mpa

Calculating (Kt) Graphically

the value of (Kt) for (D / W) = (30/120) = 0.25 , is (Kt = 2.4)

But in this case there are (3 – holes) in a plate, out of which the diameter of the larger hole is the same as the case one, so the theoretical SCF for this model is the same as before (i.e Kt = 2.1) and for remaining (2-holes) have (Kt = 2.4),then

Kt = 2.1 + 2.4 +2.4 = 6.9 , then from eq. (1):

σ_{max} = (6.9) . (1.389) = 0.95841 Mpa

Calculate Analytical Method for (σ_{max}) from eq. (3)

Kt = 3 – 3.14 (0.25) + 3.667 $(0.25)^2$ – 1.527 $(0.25)^3$

Kt = 2.4198990, therefore

Kt = 2.155 + 2.4198990 + 2.4198990 = 6.9947 ;

then from eq. (1)

σ_{max} = (6.9947) x (0.1389) = 0.97156383 Mpa

Calculate the (σ_{max}) by the FEM by ANSYS

For five reading of element size of mesh in mm the (σ_{max}) in Mpa. The values are shown in table (3) according to the Fig. 5. (a, b, c, d, e, f).

Table 3: Combined Outcomes

Cases	Parameters	Result from Analytical Mpa	Result from Graph Mpa	Result from FEM in Mpa With (1,2,3,4,5) - Element Size in (mm)	Percentage Error %	Nodes	No. of Elements
1	(σ_{max})	1.197588	1.176	1 = 1.2083	0.894-2.746	4279328	1032734
				2 = 1.207	0.785-2.636	573205	133840
				3 = 1.2052	0.761-2.482	181342	41041
				4 = 1.2102	1.053-2.908	76706	16784
				5 = 1.1875	0.8423-0.9778	43840	9380
	SCF	2.155875	2.1	……..			
2	(σ_{max})	0.97156383	0.95841	1 = 1.1891	22.39-24.07	4219404	1016955
				2 = 1.1872	22.19-23.87	566013	131792
				3 = 1.1979	23.29-24.98	179635	40513
				4 = 1.1911	22.59-24.27	75959	16520
				5 = 1.1738	20.81-22.47	43225	9170
	SCF	6.9947	6.9	……			

Discussion

The values of maximum stress (σ_{max}) and SCF are shown in the table (3) for the matter under – study, where the values of (σ_{max}) and SCF depend on eqs. (1,2&3) for Analytical and Graphical results. But through result in Ansys, we choose five-element sizes from the mesh(1, 2, 3, 4, 5) mm they are compared and from the eq.(4) the (P.E%) is calculated, it is noted that the value of (σ_{max}) show the good agreement with the result of (FEM) for two cases. The percentage error in case-1 is very less comparing with case-2 due to the increases of number of holes the percentage error is increased also and the SCF are increased. This indicates if the element size in the mesh increases, the number of elements will decrease & therefore the percentage error will decrease and the accuracy of the results will increase.

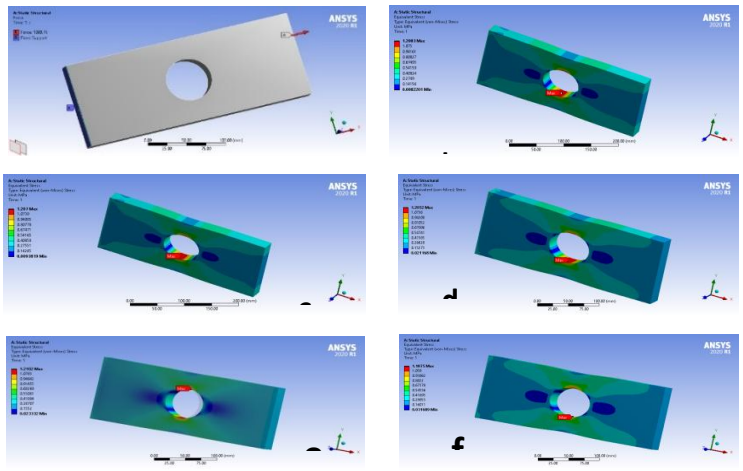


Fig. 4: Design a Plat with One Hole and The Results Combined

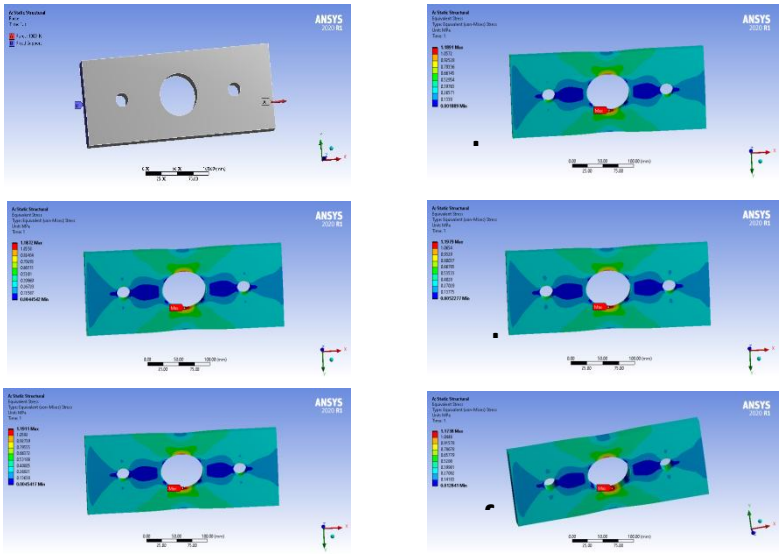


Fig. 5: Design Plat with Three Holes and The Results Combined

Conclusion

In this investigation, by using the FEM in ANSYS for modeling and analysis of two cases for rectangular plate (one hole & three holes) each case alone, the two cases are fixed at the short end with a load of (1000 N) at the other end such that the plate is stretched with different element sizes of meshes. The values of (Kt) obtained using analytical relations given in [26,27] and result from graph are compared with results FEM, we can obtain from these results in table (3) the (P.E.%) in the analytical and graphical concerning with the FEM for case-1 is very less, while comparing with case-2 when the Number of holes are increases then the (P.E.%) increased also and the SCF are increased which is high in comparison with case-1, this is due to the error associated with respect to the mesh in the FEM. When increase the number of element size in the mesh the error becomes neglected and increase in the accuracy of results.

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