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Studying the Ratio of Different Diameters of the Central Hole to the Width of the Plate on the Stress Concentration Factor by Ansys

Haneafa Yahya Najm [a]

[a] *Department of Medical Instruments Engineering Technology, Engineering Technical College, Northern Technical University, Mosul. E-mail: haneafa.najem@ntu.edu.iq*

Abstract

The FEM is a computational method for solving a wide range of electric and mechanical engineering issues, including structural, heat transfer, thermal and fluid flow. The matter used in the present work is stainless steel with fixed dimensions (l=200, w=100, t=2) mm for a rectangular plate with central circular hole for five cases of diameter hole (10,15,20,25,30) mm. In the current paper resulted, maybe conclusion a max. of stress happens on the holes angles for the five cases of (d/w) for the matter under study. Three method are used to analysis (FEA, Analytical and Graphical), it is observed that, if the ratio of (d/w) increases, the max. stress will be increased with decrease of SCF value for all the five cases for three type of calculation. The P.E.% was calculated in the current work and very close values were obtained, which was the lowest value (0.38%) and the highest is (4.03%) which is very little. It is a small value, which indicates the accuracy of the measurements for the three methods, we can say FEM is a powerful method for determining stresses in a variety of materials.

Keywords: Ansys R2 (2020), Rectangular Plate, Circular Hole, σ_{max}, SCF, Kt.

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Introduction

Geometric imperfections such as notches, holes, and keyways are common in machine elements. As a result of these abnormalities of machine components, the (σ) stress apportionment About infractions is disrupted, the basic equation of stress is unable to describe the stress condition in concentrated stress locations inside the machine components. Types manner analysis for stress involve empirical procedure as an example brittle of paint, photo elasticity, electric gauges of strain etc. with analytical and numerical ways like FEA & Boundary component Analytics [1][2]. Pawar et al studied the distribution of stress for a different materials of plate have a circular hole by ANSYS[3]. Gunwant et al investigated by Ansys the stress raisers of different shape of holes such as elliptical and circular and double semicircular of notches[4]. The maximum values of von-Mises stress is calculated using of ANSYS from researchers Sachin et al , the impact of hole-cutout geometry on stress distribution concerning the cutout was also investigated [5]. Examination of a circular hole in a plate as a homogeneous stress is applied acting on two opposite end and note the differences in the results achieved using different meshes is performed by [6]. the study of stress for the composite plate (carbon/epoxy) have a square, circular and rectangular hole by constant area of cutout holes subjected to load of uniaxial tensile it has proven by[6]. Matter used by Nagpal is the plate isotropic, the conclusion drawn from this study is difference in the (Kt) for various ratio (th/a) between (0.1-0.5). For this work the Kt is decreased through introduced additional crater in a circular pattern around the principal hole. The difference of stresses in various directions for the ratio (th/a) is studied graphically[7]. The critical review for SCF and its reduction Techniques in Plate with circular cutout hole submitted by[8]. AlJubory used Ansys Program and studied the effect of the angle distribution of the fibers on the deformation and stress for all the layers prepared in both cases, Symmetry and Asymmetry[9]. [10] They studied the effect of plate thickness of two different materials on the stress concentration factor using three different methods through the Ansys program. The aim of this paper is the ratio impact of the variation of (d/w) on the von miss stress and SCF.

Methodology Description

At current work, the effect of ratio (d/w) hole diameter on the width of plate at (σ_{max}, σ_{nom}, SCF) due to applied force on opposite side of a plate. The material used here is Stainless Steel and its properties are shown in the table (1), the plate under study is apparent in fig. (1). The calculation is carried out in three method (Graphical or Theoretical, Analytical and FEA) were determined and validate the values of (σ_{max}, σ_{nom} and Kt), the calculation were performed on the plate for five cases of diameter of hole (10,15,20,25,30) mm, where we created the five models in ANSYS (2020 R2) according to the parameters shown in fig(1). The force applied to the both short sides of the plate is (1000) N, which is the stretched. The equations used to calculate (Kt).

$\sigma_{nom} = (F / A)$, ……(1)

where σ_{nom}= nominal stress, it is from [13]

F= load, A= area, A = (W – D). t, W = width, D = diameter, t = thickness. then

$Kt = \sigma_{max} / \sigma_{nom}$ ……(2)

where: σ_{max} = maximum stress & Kt stress concentration factor (SCF),

The Kt also depend on the ratio of (d/w) and we can find from the eq.(3) [2] [14]

$SCF = 3 - 3.130 (D/W) + 3.660 (D/W)^2 - 1.530 (D/W)^3$ …… (3)

and the Errors of Percentage % is given by[3]

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

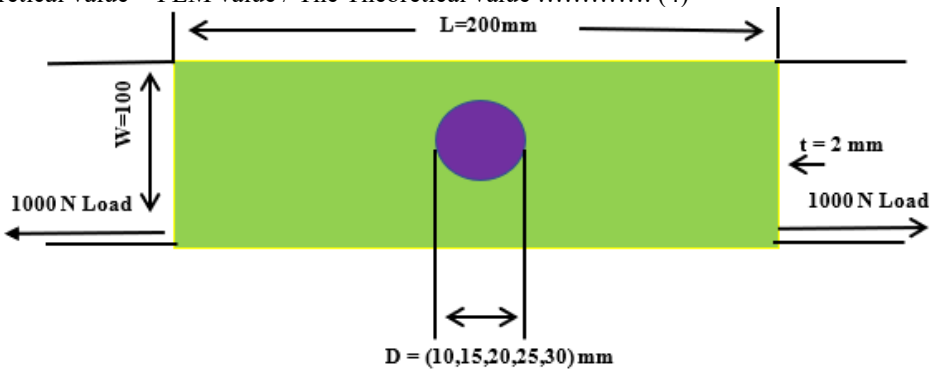


Fig. 1: Plate with Different Diameter of Circular Hole

The analysis of stress is performed to around the hole of stainless Steel, and their characteristic were taken into account for analysis in the hole's vicinity.

Table 1: Properties of Materials

Material	Young's Modulus MPa	Bulk Modulus MPa	Shear Modulus MPa	Poison's Ratio	Density Kg mm^{-3}
Stainless Steel	**1.93 x e^{5}**	**169300**	**73664**	**0.31**	**7.75 x e^{-6}**

Results & Discussion

One of the most important scales for forecasting yielding in engineering materials is Von Mises stress. In this paper, Calculation of Von mises stress, nominal stress and SCF with Percentage Error% was achieved by three method Graphically (Theoretically), Analytically & FEA for five values of (d/W) (0.1,0.15,0.2,0.25, 0.30) on the plate with central hole subjected to the load of (1000) N for two side. The SCF we denote it by symbol Kt, which can be determined theoretical (Graphically) with hand book data, which is based on the hole diameter and width the plate. These parameters were used to design of plate have a central hole that exposed to load of biaxial shown in fig. (2).

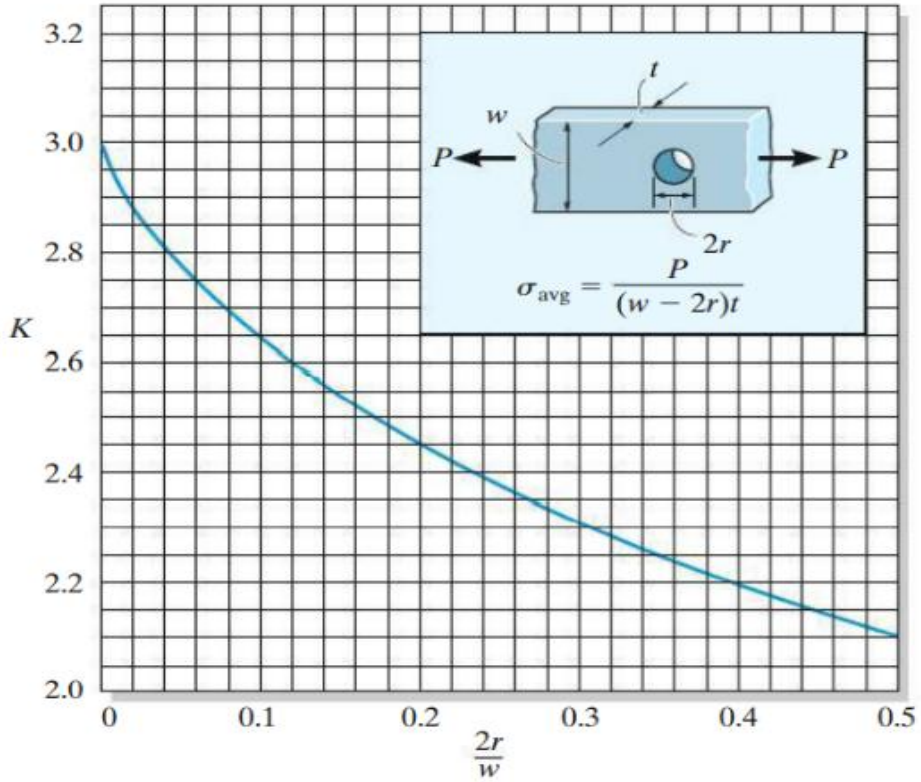


Fig. 2: Scheme of SCF [16][11]

In this context, we utilized the eqs. (1,2,3&4) to make calculations for the readings we need to compare with each other, through the following steps:

The Calculation of (σmax) by the FEA in (ANSYS) & eqs. (1&2)

The ANSYS (2020 R2) we used it to modeled the plate of central hole with different diameter and the results are shown in fig. (7) & Table (2), where we notice that by increasing the ratio of (d/w) the values of (σ_{max}, σ_{nom}) also increase but the value of Kt will decrease as shown in fig. (3).

Table 2: Max, Nominal-Stress & Kt Resulting from Ansys & Equations

Stainless Steel		
σ_{max} from Ansys	**σ_{nom} from equation (1)**	**$Kt = \sigma_{max} / \sigma_{nom}$ from equation (2)**
15.067	5.56	2.7098
15.605	5.882	2.653
15.726	6.25	2.516

16.234	6.67	2.433
16.888	7.14	2.365

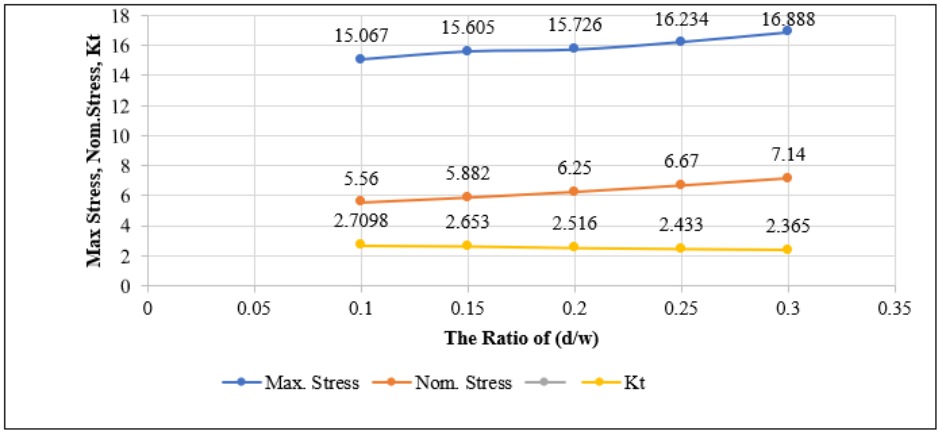


Fig. 3: The Relation Between (σ max, σ nom &Kt) for Different Value of (d/w)

Analytical Method Calculation for (σmax) by the eq. (3).

The value of Kt depend on the ratio of (d/w) and from eq.(3) [2], we found that the value of (Kt) decrease when the (d/w) increase as shown in the table (3) & Fig. (4).

Table 3: Values Respective of Ratios (d/w) & Kt

Ratios of (d/w)	Formula of (Kt)
0.1	**2.722**
0.15	**2.607**
0.2	**2.508**
0.25	**2.422**
0.3	**2.349**

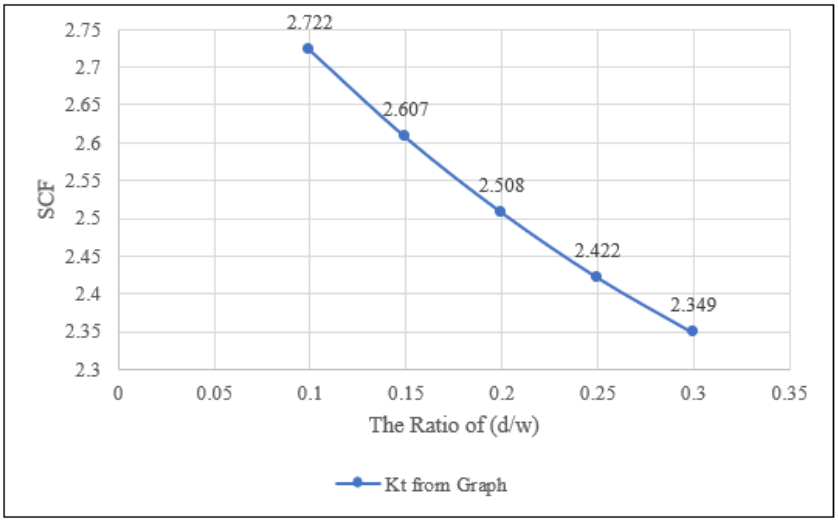


Fig. 4: The Relation Between (Kt) & Different Value of (d/w)

Theoretical (Graphically) Calculation of (σmax)

Calculating (Kt) from the Graph in fig. (2), the data are in table (4) shown the decrease in values of (Kt) when the ratio (d/w) increasing as shown in fig. (5)

Table 4: The Values of (Kt & d/w) Resulting from (Theoretical or Graph)

Ratio (d/w)	Kt from Graph
0.1	2.65
0.15	2.55
0.2	2.45

0.25	2.38
0.3	2.31

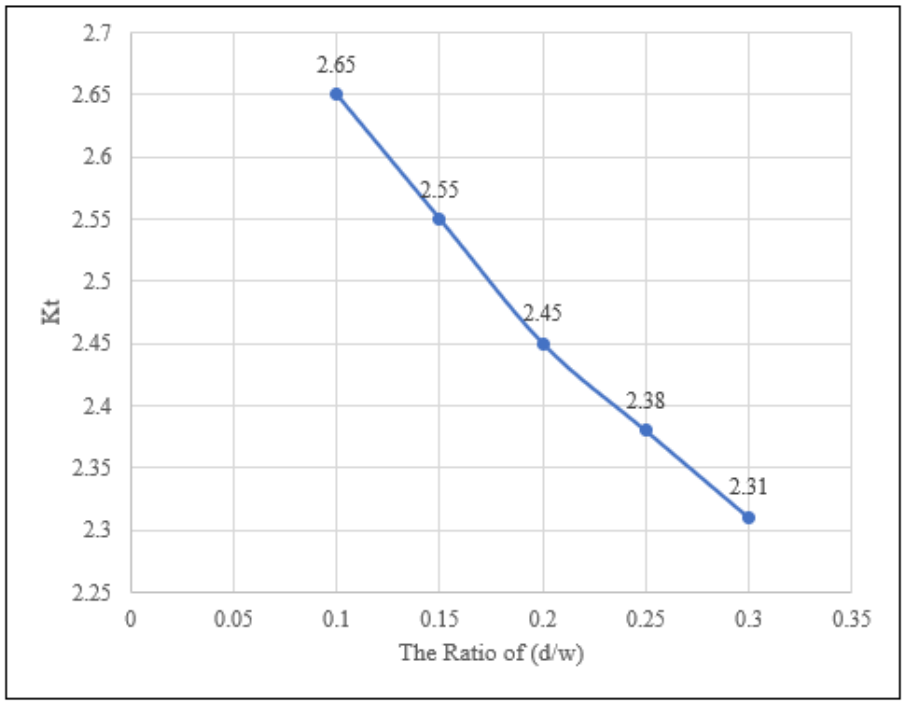


Fig. 5: The Relation Between (Kt) & Different Value of (d/w)

Then from eq. (5) the Percentage Errors % for three types of calculation are displays in the table (5). We note the P.E% is very low by comparison with the presence of very little fluctuation for the three methods of calculation.

Table 5: The Values of (Kt) Resulting from (Analytical, Theoretical, FEA) & P.E%

Stainless Steel			
Analytical	**Graphical/Theoretically**	**FEA**	**P.E%**
2.722	2.65	2.709	0.477 - 2.22
2.607	2.55	2.653	1.76 – 4.03
2.508	2.45	2.516	0.318 – 2.69
2.422	2.38	2.433	0.454 – 2.22
2.349	2.31	2.365	0.681 – 2.38

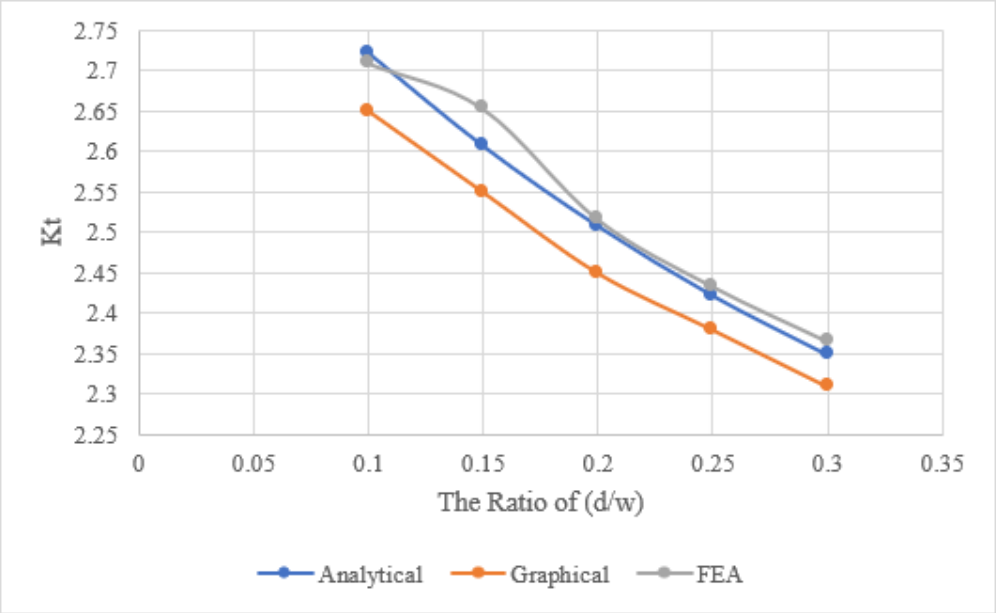


Fig. 6: The Relation Between (Kt) in Three Method & Different Value of (d/w)

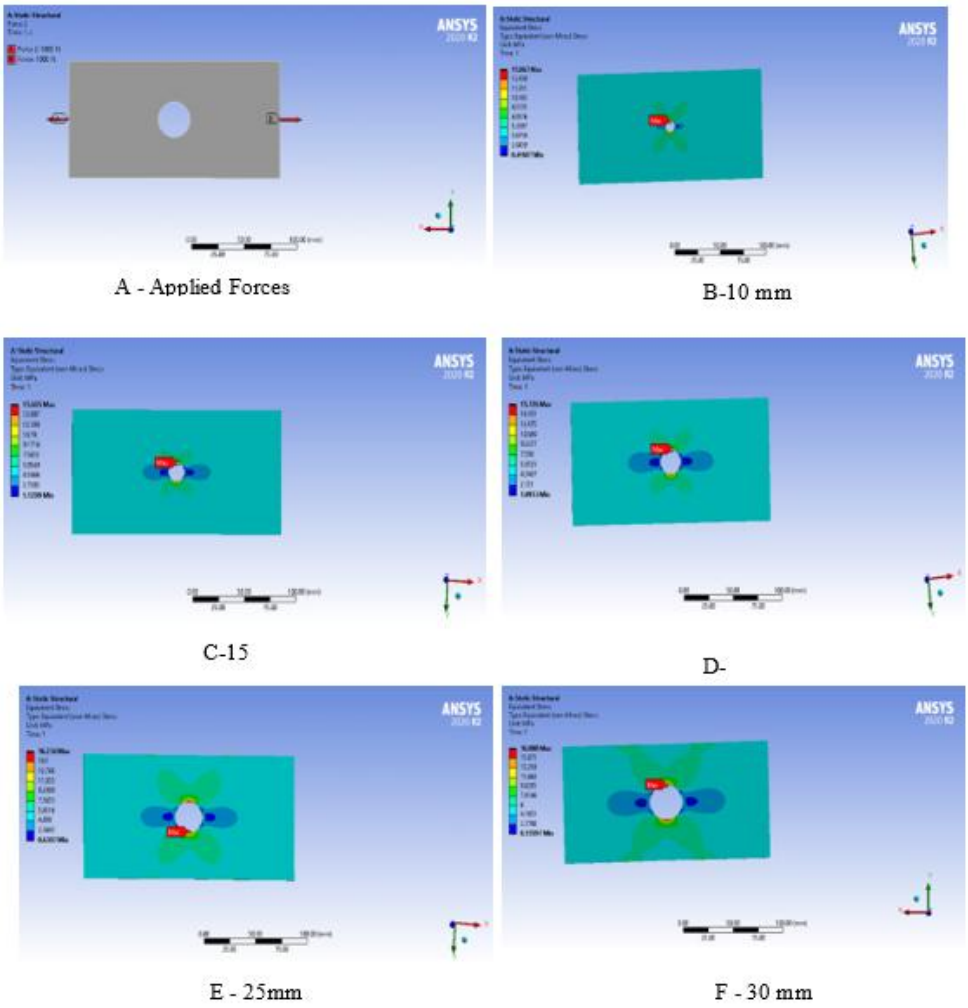


Fig. 7: The Five Models Designed Using ANSYS

Conclusions

In present work, plate of rectangular shape with central hole of five different diameters (0.1,0.15,0.2,0.25,0.3) has been studied in three method through the effect of the ratio (d/w) on the Von miss stress, nominal stress and SCF, also we calculate the P.E% for three method. All values are obtained from the equations (1,2,3&4) and by the ANSYS (2020 R2) were compared with each other, the study's findings can be summarized as follows:

1. all the maximum of stress is occurring on the hole angles regardless the ratio (D/W), as well von miss increases at increase of (D/W) ratios as in figs. (3&7).
2. The σ_{nom} increased with increasing of (D/W) but Kt decrease which is show in fig. (3). Also, for three method the Kt decrease at increased of ratio (d/w).
3. Values of Kt results from Ansys (FEA) it agrees well for the obtained values from analytical and graphical methods.
4. The P.E% from all results are obvious in the table (5) with a small percentage and not a large fluctuation, which mean that the FEA can be used to a useful tool for conclusion in studying SCF in structural & machine components.

Future Work

This paper is designed for a rectangular plate with central hole at fixed terms. In the future, it is possible to work with squares plates for different thicknesses with different geometric shapes such as circular and square types with many holes.

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