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EVALUATION OF STRESS CONCENTRATION FACTOR FOR A PLATE WITH DIFFERENT POSTION OF THE HOLE

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Abstract: The stress concentration factors are widely used to predict the maximum stress value above which the mechanical structure can be destroyed. Many chart data of those factors are available in literature but they are conditioned by the structure shape and the principal geometric dimensions. This paper compares, for thin plate with eccentric hole, the stress concentration factors values calculated by classical formulas given in ulterior studies and a numerical simulation using commercial software. The effects of the relative hole position with central hole in axial loading and compressive loading, varing the distance along the x axis, Displacement along the x-axis the in the plate and the in near the edge hole axis are examined.

***Index Terms* - Axial tension; finite element analysis; stress concentration factor;Hole equivalent (Von Mises) stress.**

I. INTRODUCTION

In industries many unexpected failure of machine components and equipments have occurred. These failures of machines components and equipments are due to either poor design or sudden changes that happen during working conditions. However, in so many cases, pre-existing geometrical irregularities are also a major causes for the failures. The geometric discontinuities such as keyways, notches, shoulders fillets, holes, various grooves (like U, V, square), threads etc. on different machine parts (i.e. on plates) are unavoidable due to their functional requirementThe plates with discontinuities like circular holes exist in all metal structures. Those areas represent dangerous zones because of the multiplication of the stresses values under the effect of the stress concentration phenomenon. These stress concentration zones are often areas of crack initiation. They can be dangerous if the loading conditions allow the brutal propagation of the cracks and than promote the rupture. The stresses concentration phenomenon is measured by a parameter called stress concentration factor (SCF), noted Kt. This factor is the ratio of the maximum elastic stress value by the nominal stress calculated in the discontinuity area. The values of this factor are calculated using analytical approaches based on the stress and deformation distributions evaluation around the discontinuity or by numerical models or also by experimental studies using the photoelasticity method. The results of these investigations are resumed in curves according to the structure geometry dimensions.

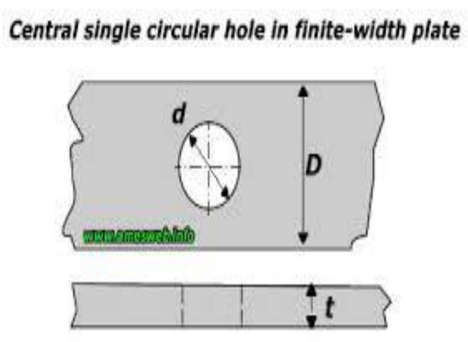
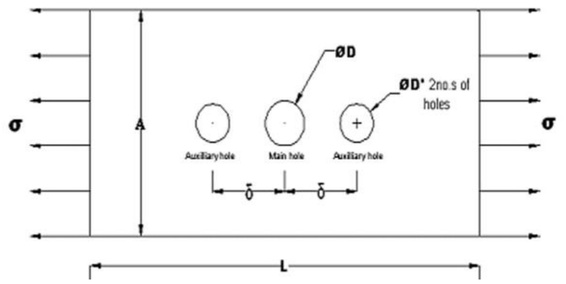


Fig : 1 Central hole with plate

Fig : 2 Rectangular plate with Central hole with Auxiliary hole[1]

II.STRESS CONCENTRATION FACTOR CALCULATION



The localization of high stress is known as stress concentration and is evaluated by a factor known as stress concentration factor (SCF). Common definition of stress concentration factor (SCF) is the ratio of the maximum stress (σ_{max}) to the nominal stress(σ_{nom}). Mathematically SCF can be written as,

$$k_t = \frac{\sigma_{max}}{\sigma_{nom}}$$

For plate with hole/holes stress concentration factor (SCF) is defined by two different way. Stress concentration factor is K_{tg}, for which the reference stress is based on the gross cross-sectional area, or K_{tn}, for which the reference stress is based on the net cross-sectional area [2].

$$K_{tg} = \frac{\sigma_{max}}{\sigma}$$

K_{tg} is the stress concentration factor based on gross stress, is the maximum stress, at the edge of the hole, σ is the stress on gross section far from the hole, and

$$K_{tn} = \frac{\sigma_{max}}{\sigma_n}$$

Where,K_{tn} is the stress concentration factor based on net (nominal) stress and σ_n is the net stress $\sigma/(1-d/H)$, with d the hole diameter and H the width of element.

The equations presented in this paragraph are widely used in the literature. However, it does not take into account all dimensions of the plate, as indicated in Fig. 1, like the length D, the thickness t and distance b. In the finite elements model, presented in the following section, all mentioned dimensions are specified and consequently the numerical simulations results are influenced.

Chart 1 shows stress concentration factors $\boldsymbol{K_{tg}}$ and $\boldsymbol{K_{tn}}$ for the tension of a finite-width thin element with a circular hole.

Chart 2 shows Stress concentration factors for the tension of a thin semi-infinite element with a circular hole near the edge [2].

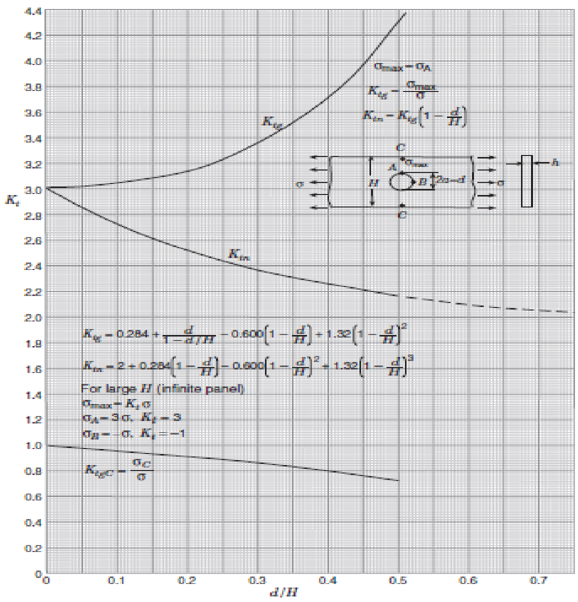


Chart 1 1 Stress concentration factors K_{tg} and K_{tn} for the tension of a finite-width thin element with a circular hole (Howland 1929–1930).(From Peterson's Handbook) [2]

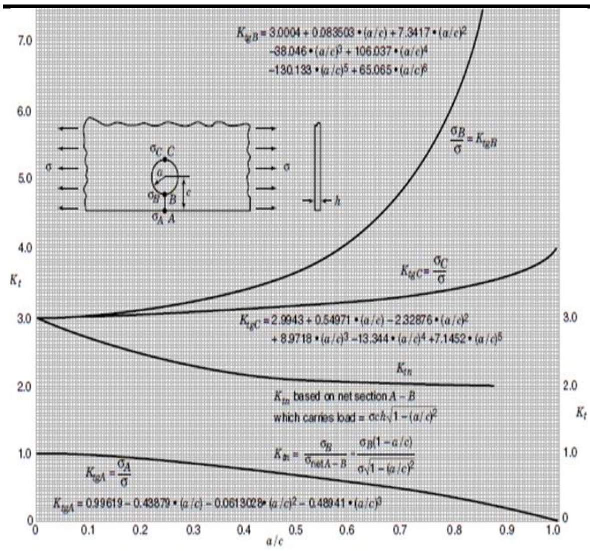


Chart 2 Stress concentration factors for the tension of a thin semi-infinite element with a circular hole near the edge (From Peterson's Handbook) [2]

III.LITERATUREREVIEW

The immense literature review has beendone on analysis of stress concentrationon a plate by considering hole position,materials for plate and applied load.

OZKANETAL.(DETERMINED THE STRESS CONCENTRATION FACTOR (KT) IN A RECTANGULAR PLATE WITH A HOLEUNDERTENSILE STRESS USING DIFFERENT METHODS .IN THIS STUDY, THE STRESS CONCENTRATIONFA CTOR (SCF) IN A PLATE WITH A CIRCULAR HOLE UNDER AXIAL TENSION STRESSES WAS INVESTIGATED. THE EMPIRICAL (PETERSON'S) STRESS CONCENTRATION FACTOR (K_T) WAS COMPARED WITH THERESULTS OFANALYTICAL MODEL, REGRESSION ANALYSIS(REGA), FINITE ELEMENT ANALYSIS (FEA), AND ARTIFICIA L NEURAL NETWORK (ANN) MODEL. THE STRESS CONCENTRATION FACTOR (K_T) WAS MODELED USING 5 DIFFERENT METHODS AND THE ACCURACY OF PETERSON'S MODEL WAS TESTED.[3]

S.G. Sarganachari et al.(2019), assess the stress reduction techniques in a uniaxially loaded plate with a Hole [5]. Various stress reduction techniques are available to determine stress concentration factor under different loading conditions such as experimental, analytical and numerical method. Though experimental methods give the most reliable results, it is very costly, as it requires special equipments, testing facilities etc. Analytical solution of every problem is almost impossible because of complex boundary conditions and shapes [4].

E Devaraj et al. (2019) have does numerical and analytical analysis of SCF for a rectangular plate with holes as discontinuities for static loading. They have analysed von-Mises stress for a rectangular plate of dimensions 100 mm x 50 mm x 1 mm with a hole of different radius by analytical and numerical methods.Plate with hole of major radius of 10mm, 8mm and 6mm has been modelled and descritized with SOLID95 elements in ANSYS [5].

Sohanur Rahman (2018) did stress analysis of finite steel plate with a rectangular hole subjected to uniaxial stress using finite element method. In this paper, the effect of von-Mises stress on various types of reinforcements have been investigated and from this analysis it has been observed that single doubler plate gives the most suitable reinforced model. Also author performed the convergence test for the most suitable reinforced model and observe the effect of variation in reinforcement [6].

Olesya Maksymovych et al.(2017) have carried out stress calculation and optimization in composite plates with holes based on the modified integral equation method. They developed numerical method for solving integral equations by the mechanical quadrature method for systems of holes, which takes into account their Eigen-solutions. Precision of the approach and stability of obtained algebraic equations is illustrated in determination of holes shapes with low stress concentration; study of high stress concentration at slit of arbitrary width (additionally used asymptotic method). For a large number of holes with controlled accuracy they calculate the stress [7].

Soni Kumariet al.(2017) carried out stress analysis for an infinite plate with circular holes.Failures such as fatigue cracking and plastic deformation frequently occur at points of stress concentration. In the presented paper, study stress concentration in an infinite isotropic plate around circular hole subjected to transverse, longitudinal and biaxial loading is calculated using analytical approach. For calculating stress concentration around two holes they used complex variable and bipolar coordinate method [8].

Dr. Abdul siddique shaiket al. (2016) carried out finite element analysis (FEA) to do stress concentration analysis of rectangular plate with a hole made with composite material. Finite Element simulations using ANSYS done for stress analysis around the circular hole, made up of different materials. The materials considered are composite material i.e. carbon / epoxy and also with mild steel [9].

A Santos et. al.(2016)carried out simulation of stress concentration factors in combined discontinuities on flat plates. They determined the stress concentration factors for static load conditions (K_c) by using finite elements software. They used ANSYS software for the determination of different parameters flat plates with a central hole subjected to axial load conditions. They also obtained the graphs of K_c for flat plates with combined discontinuities, central hole, groove and central hole, fillet, under axial load conditions [10].

IV.FINITE ELEMENT ANALYSIS

Numerical analysis for a plate with circular hole geometries subjected to axial tension were carried out on ANSYS 19.0.

The plate with hole is meshed with rectangle elements. The fine mesh is selected to get more accurate results, which in turn resulting in 1650 nodes and 210 elements. Solid Works model and ANSYS meshed model of plate with center hole.

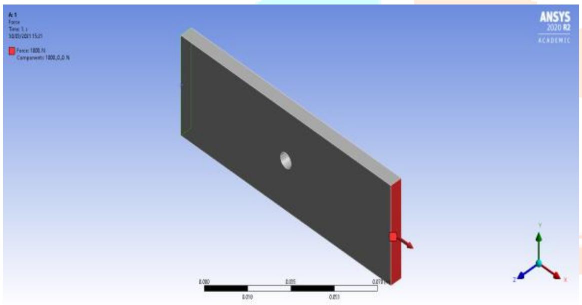


Fig. 3 Loading and boundary conditions

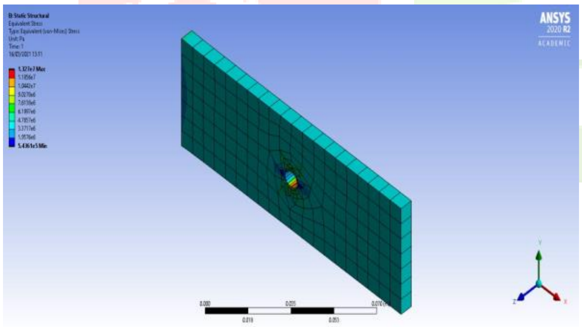


Fig. 4 central hole with axial load

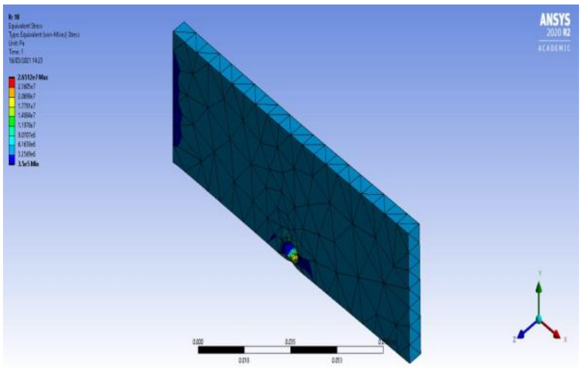


Fig. 5 Near the egde with axial load

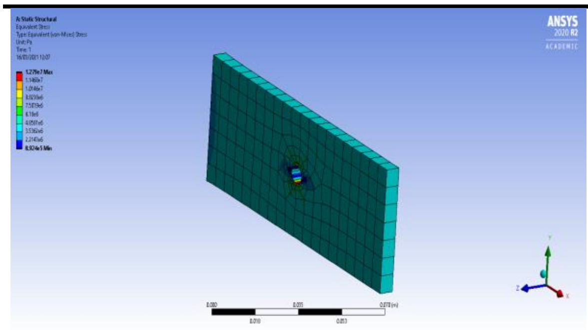


Fig. 6 central hole with compression load

The software used to carry out the finite elements simulation is ANSYS [14]. The developed finite element model is composed of the meshed geometry, the boundary conditions and the loads. Since SCF is independent of mechanical characteristics of the plate, the material chosen for the simulation is the ordinary steel with the conventional elastic mechanical characteristics = 0.3). The mesh is refined to ν(E=210 GPa, carry out at the same time the convergence and the optimization of the data-processing resources in memory and simulation times. All previous studies indicate that the SCF is independent of the applied stress on the structure and only the geometric characteristics are involved in the calculations.

5. Results and Discussion

The stress concentration factor (SCF) is calculated from the maximum stress, which can be determined from the finite element simulation results and the nominal stress.

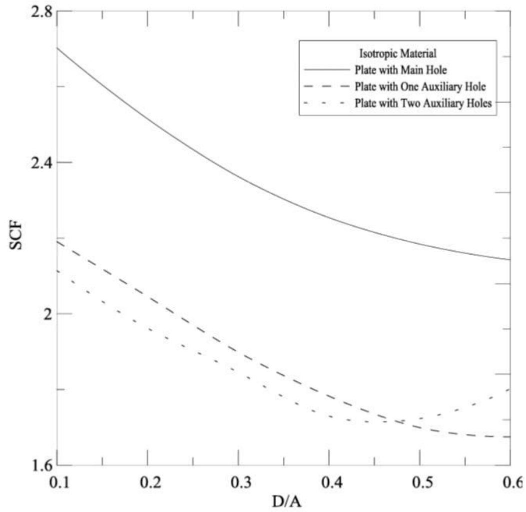
Fig.4 presents the distribution of the normal stress in the applied tensile load with central hole.It is clear that the normal stress is not uniform in the surrounding of the hole. The maximum value of this stress is localised on the bore perpendicular to the applied load direction.

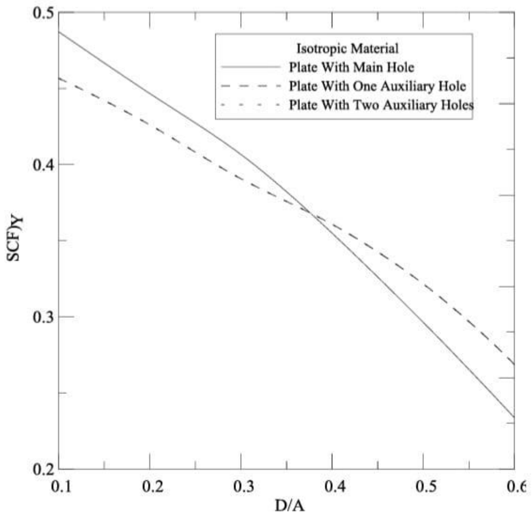
Fig.5 presents the distribution of the normal stress in the applied tensile load with near the edge of the hole.The SCF is maximum value as compared to the central hole.

Fig.6 presents the distribution of the normal stress in the applied compressive load with central hole.The SCF is less than the the central hole with tensile load .

L=Length=120 mm
B= Width=60 mm
D= Hole Diameter=6 mm
e= Dist. from top of the plate to Center of the hole
c= Dist. from bottom of the plate to center of the hole
a= Hole Radius=3 mm
P=Load=1000N
A=Area=204 mm^2

a/c	c/e	e/c	Nominal stress (MPa)	Equivalent (von Mises) stress (MPa	SCF (K_t) based FEA results
0.15	1	1	5	13.45	2.695
1	0.08	12.3	5	26.51	5.408
0.15	1	1	5	12.79	2.609





In general, the maximum stress concentration is always occurred on hole boundary in a finite width plate with central hole under in-plane static loading. The stress concentration factor is maximum at the tip of the hole (perpendicular to loading).

The SCF follows a symmetric trend with respect to D/A ratio in all cases. On the basis of results obtained, it has been seen that the SCF is sensitive to D/A and material properties. The results obtained show that for higher values of D/A, SCF is also higher. SCF reducing as D/A increases. Shear stress increases with introduction of auxiliary holes. Shear stress is maximum with set of auxiliary hole then reduces with two set of auxiliary hole. Deflection in X direction increases with D/A ratio for all the materials.

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