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Finite Element Analysis and Fatigue Life Estimation of Plate with Different Stress Levels

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ABSTRACT

A number of analytical and numerical techniques are available for the two dimensional study of stress concentration around the hole(s) and notches in isotropic and orthotropic plates subjected to in-plane or transverse loading conditions. The influence of the structural dimension D/A (where D is hole diameter and A is plate width) ratio upon stress concentration factor for different cases is studied in the present work but plate with center hole is created and adjacent small holes created but diameter is varied and distance between one hole to another is also varied so finally study the stress concentration around the holes using ANSYS software. work is to investigates how part geometry can influence the maximum stress found at critical points for a rectangular plate with a large hole in the center and changing the adjacent small hole diameters to see the effects on the magnitude of the maximum stress and understand how this influences the stress concentration factor. The symmetry of this condition will be used to make the analysis simpler by dividing the part into quarters and finally estimating the fatigue life of the plate with varied parameters.

Keywords: *Adjacent Holes; Crack; Fatigue Life Estimation; Plate with Center Hole; Stress Concentration Analysis; Stress Levels.*

1.0 Introduction

In practice virtually all engineering components have to have changes in section and / or shape. Common examples are shoulders on shafts, oil holes, key ways and screw threads. Any discontinuity changes the stress distribution in the vicinity of the discontinuity, so that the basic stress analysis equations no longer apply. Such 'discontinuities' or 'stress raisers' cause local increase of stress referred to as 'stress concentration'. A stress concentration (often called stress raisers or stress risers) is a location in an object where stress is concentrated. An object is strongest when force is evenly distributed over its area, so a reduction in area, e.g., caused by a crack, results in a localized increase in stress. A material can fail, via a propagating crack, when a concentrated stress exceeds the material's theoretical cohesive strength. The real fracture strength of a material is always lower than the theoretical value because most materials contain small cracks or contaminants (especially foreign particles) that concentrate stress.

Geometric discontinuities cause an object to experience a local increase in the intensity of a stress field. Examples of shapes that cause these concentrations are cracks, sharp corners, holes, and changes in the cross-sectional area of the object. High local stresses can cause objects to fail more quickly, so engineers must design the geometry to minimize stress concentrations. Fatigue cracks always start at stress raisers, so removing such defects increases the fatigue strength.

2.0 Literature Survey

Shigley's [1] Machine members often have regions in which the state of stress is significantly greater than theoretical predictions as a result of:

1. Geometric discontinuities or stress raisers such as holes, notches, and fillets;
2. Internal microscopic irregularities (non-homogeneities) of the material created by such Manufacturing processes as casting and molding;
3. Surface irregularities such as cracks and marks created by machining operations. Maintaining the Integrity of the Specifications

Avinash Kharat [2] et al reviewed some of the current developments in the determination of stress concentration factor in pressure vessels at

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openings. The literature has indicated a growing interest in the field of stress concentration analysis in the pressure vessels. The motivation for this research is to analyze the stress concentration occurring at the openings of the pressure vessels and the means to reduce the effect of the same. Most of the researchers have worked on the stress concentration occurring at circular and radial openings in the shell under internal pressure.

B. Mallikarjun [3] et al reported stress analysis of infinite isotropic plate with a cylindrical circular whole and oblique hole. Their work deals with infinite isotropic plate under uniform tensile load. Three components of different material with different obliquity angle were used for analysis. These components having holes circular & oblique at angles 0, 30 and 60 degree are considered for study. The long twisted blades of gas turbine blade will be treated as infinite plate with oblique holes/cooling holes constituting a geometrically complex, three-dimensional body that is subjected to the action of systems centrifugal force. Stress concentration and stress field around oblique holes is a major challenge area in design of aerofoil in aerospace applications for safety because of their highly specialized applications in aerospace field under severe operating conditions.

K h. Fuad et al [4] analyzed stress concentration factor (SCF) of adjacent holes in a spherical pressure vessel by considering a thin plate undergoing hydrostatic stresses. They adopt the approach to investigate the SCF of various adjacent holes configurations in a spherical pressure vessel using finite element analysis. The von Mises stress is considered to determine the SCF. Various arrangements of adjacent holes are investigated i.e., two, three, four, and five adjacent holes are taken into account. The SCF curves with respect to the ratio of the distance between adjacent holes to the diameter of hole, L/d, and for a certain ratio of the diameter of hole to the plate thickness, d/t, are then plotted. The results show that the decreasing of L/d will affect the increasing of SCF, while for the case of five adjacent holes configuration, the increasing of d/t doesn’t make any significant effect to the increasing of SCF.

Patel Dharmin et al [5] In this study an effort is made to review the investigations that have been made on the “stress analysis of an infinite plate with cut-outs”. A number of analytical and experimental techniques are available for stress analysis around the different types of cut-outs for different condition in an infinite plate, made up of different materials under different loading condition has been reported in this article. The methods compared are tabulated with their findings. Singularities of circular hole in rectangular plate and elliptical hole in rectangular plate are considered in present study.

Dheeraj gun want et al [6] In the present paper investigation, a continuous elastic plate of size 400mm x 100mm x 10mm and made up of steel with a central elliptical hole of major radius of 10mm has been modeled and descritized using a commercially available finite element solver ANSYS. The minor radius has been determined in each case with the help of the aspect ratio for each case. The model is analyzed for different aspect ratios (0.2, 0.4, 0.6, 0.8 and 1.0) of the elliptical hole by keeping the dimensions of plate fixed and value of maximum equivalent Von-Mises stress and deflection of plate under a constant pressure is determined with the help of ANSYS. Effect of the geometry of hole on the stress distribution around the hole is studied. The results of various analyses have been presented with the help of tables, graphs and nodal plots as provided by ANSYS.

Shobeir arshadnejad et al [7] Stress analysis for a rock medium is essential for determination of stress concentration between two neighboring circular holes and prediction of fracture behavior. In this study, Finite Element (FE) analysis using a Phase2 computer code was employed to study the stress concentration between two neighboring circular holes under internal pressure induced by the NEEM. The effects of different hole diameters and spacing’s, rock properties and NEEM pressures were analyzed The developed statistical models were shown to be in a very good agreement with the FE analysis.

The developed models can be used with confidence to determine stress distribution and concentration factors around two neighboring circular holes, which are excavated in a hard -brittle rock and loaded internally by the pressure induced from the NEEM.

Shubhrata Nag pal et al [8] a number of analytical and numerical techniques are available for the two dimensional study of stress concentration around the hole(s) and notches in isotropic and orthotropic plates subjected to in-plane or transverse loading conditions. The influence of the structural dimension D/A (where D is hole diameter and A is plate width) ratio upon stress concentration factor for different cases is studied in the present work and introduction of auxiliary holes. The finite element formulation and its analysis are carried out using ANSYS package. This research work can provide structure engineers a simple and efficient way to estimate the effect of SCF and its mitigation in plate structures made of isotropic and orthotropic materials.

M Mohan Kumar et al [9] Plates with variously shaped cut-out are often used in engineering structures. Different cut-out shapes in structural elements are needed to reduce the weight of the structure or provide access to other parts of the structure. Extensive studies have been carried out on stress concentration in perforated panels which consider cut-out shapes, boundary conditions and bluntness of cut-outs. This study focuses on the stress concentration analysis of perforated panels with not only various cut-outs and bluntness but also different cut-out orientations. Therefore once the direction of a major tensile force is known, the cut-outs can be aligned properly based on the findings of the work to reduce the stress concentration at the cut-outs there by increasing the load bearing capacity of the panel.

D. B. Kawadkar et al [10] the plates with cutouts are widely used in structural members. A Plate is considered with different cutouts, such as circular, triangular and square cutout. The main objective of this study is to find out the stress concentration in plate with various cutouts and bluntness with different cutout orientation. For finding the stress concentration, a finite element program ANSYS is used. In this study Three Parameter is used, the more important finding is that the stress concentration increases as the cutout become more oriented from baseline. The experimental Results are compared with FE results. It is found that the stress concentrations by Experimentation and by FEM are in good agreement.

Y. Mohammed et al [11] The stress intensity factor of any fracture mechanics problems mainly depends on specimen geometry and loading conditions, to be measured. The composite structure has complex natural when dealing with fracture mechanics theory, therefore not only geometric conditions for these materials are numerically calculated but also it is related to their size. A new expression for the stress concentration factor for open composite plate for both case of finite and infinite width under remote uniform tensile stress. The results are valuable graphs and design tables which engineering designer needed.

3.0 Scope

Finite-element analysis eliminate the time consuming classical methods of solving for high stress locations and deflections on complex parts. By using computer power to break complex parts into finite sized elements, FEA provides engineers with a valuable model to optimize the design’s strength:

4.0 Objectives and Methodology

Objective of the work is to investigates how part geometry can influence the maximum stress found at critical points for a rectangular plate with a large hole in the center and changing the adjacent small hole diameters to see the effects on the magnitude of the maximum stress and understand how this influences the stress concentration factor. The symmetry of this condition will be used to make the analysis simpler by dividing the part into quarters and finally estimating the fatigue life of the plate with varied parameters.

The below shows the points are methodology of present work

- Defining the objective of the work
- Literature review
- Finite element analysis of plate with defined parameters like large hole in centre and changing the adjacent small hole
- Fatigue life estimation by finite element analysis of plate with defined parameters.

5.0 Finite Element Analysis

Finite-element Analysis (FEA) programs eliminate the time consuming classical methods of solving for high stress locations and deflections on complex parts. By using computer power to break complex parts into finite sized elements, FEA provides engineers with a valuable model to optimize the design’s strength.

Ansys will be utilized to provide Finite-element Analysis of a plate with one large hole in the center of the plate and two smaller holes placed near the vicinity of the large hole to determine the maximum stress, and fatigue life. Prior to that it is necessary to find the maximum stress acting on the model, optimized mesh element and optimized adjacent hole sizes for getting the convergent value of fatigue life.

6.0 Model

The following Block dimensions are used for analysis.

Length L = 1000 mm
Width W = 200 mm
Thickness t = 50 mm
Diameter of Centre hole D= 100 mm

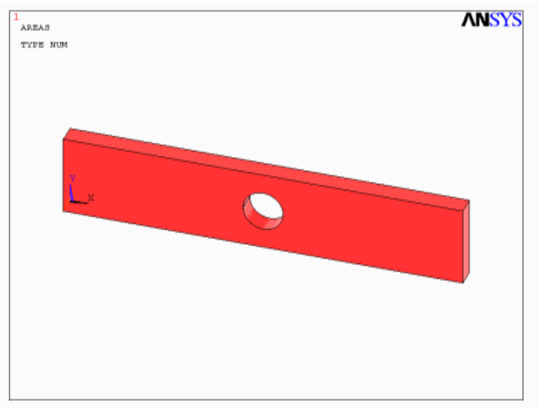
Type of Element = Plane 42

Material Properties:

Material = Aluminum 2024
Young's Modulus E = 73.1 GPa
Poisson Ratio = 0.33
Yield Strength = 324 Mpa

Ultimate tensile strength = 469 MPa

Fig 1: Block With Hold at the Centre



7.0 Boundary Condition

One end = fixed
Other end = Tensile load

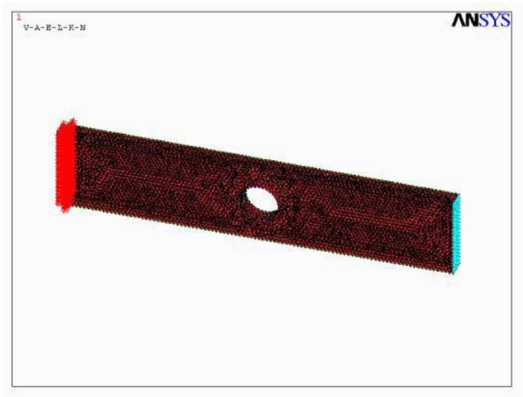
Table: Stresses with different loads

Table 1: Stress with Different Loads

Case	Load (N/mm2)	Max. stress(MPa)
1	50	211
2	80	337
3	100	422.402

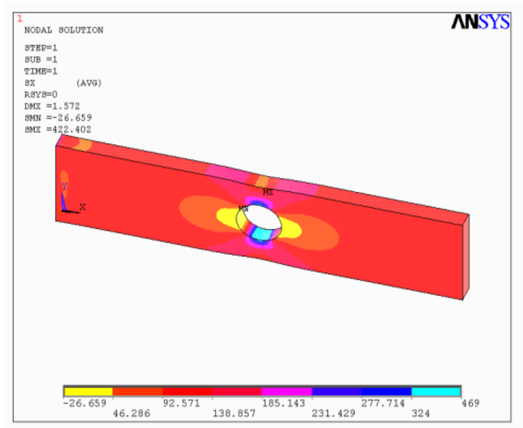
At the load of 80 N/mm2, block has reached the maximum stress of 337 MPa at the centre of the hole which lies between Yield strength and Ultimate Tensile strength ((UTS). Hence for further analysis, load 80 N/mm2 will be considered to analyze how the maximum stress reduces with the introduction of adjacent holes.

Fig 2: Application of Boundary Condition



Pictorial views of model with constant load of 80 N/mm2 load are displayed for showing the different displacement and stress values with the variation of different mesh element sizes.

Fig 3: Application of Boundary Condition



8.0 Optimization Of Mesh Element

Convergence of mesh takes a vital role in calculation of stress values of a part when it is loaded. The optimum mesh size is determined by analyzing Model with the following details. As the block is symmetric, 2D surface model would be considered for further analysis.

Consider Diameter of adjacent hole = 50 mm

Load = 100 N/mm2 (Tension) (Pressure load)

Mesh size 6

Fig 4: Deformation at Mesh Size 6

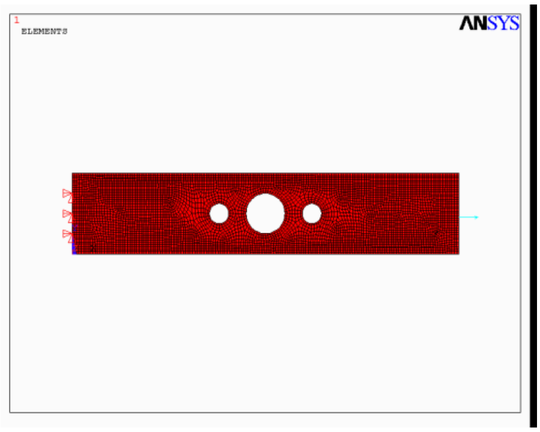


Fig 5: Stress Plot at Mesh Size 6

Mesh size 3

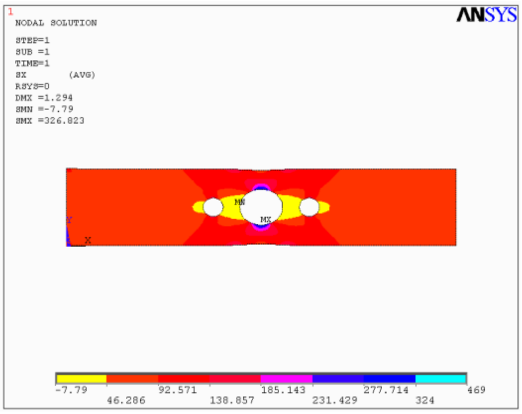


Fig 6: Deformation at Mesh Size 3

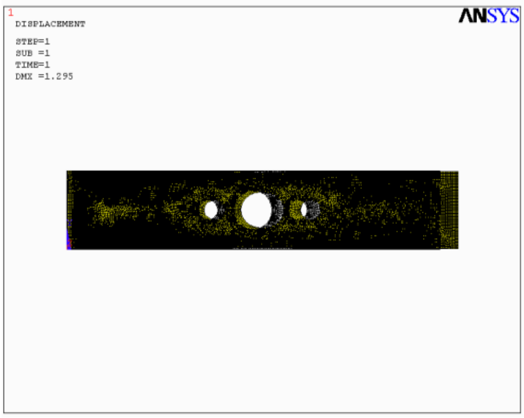


Fig 7: Stress Plot at Mesh Size 3

Mesh size 2.5

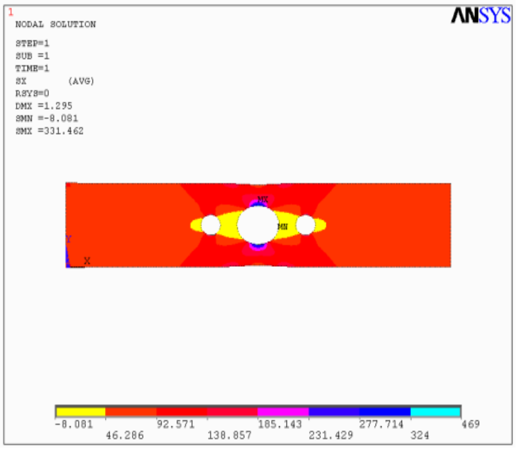


Fig 8: Deformation at Mesh Size 2.5

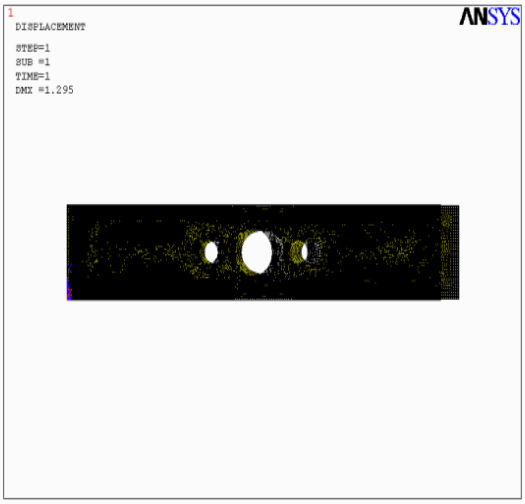


Fig 9: Stress Plot at Mesh Size 2.5

Mesh size 2

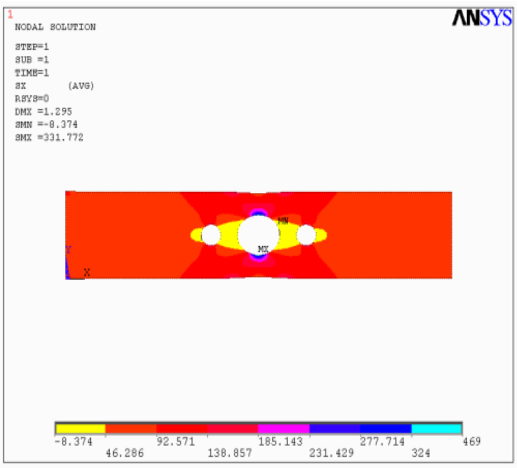


Fig 10: Deformation at Mesh Size 2

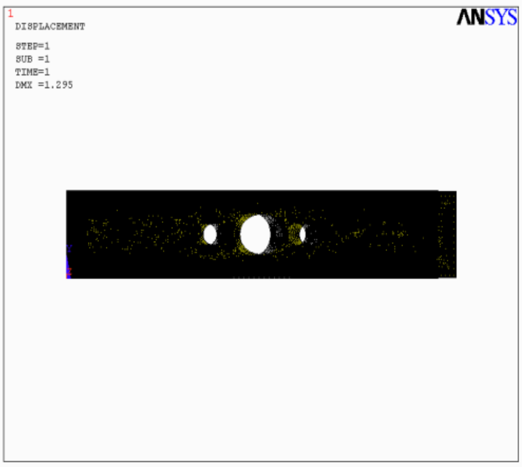


Fig 11: Stress Plot at Mesh Size 2
Mesh size 1.5

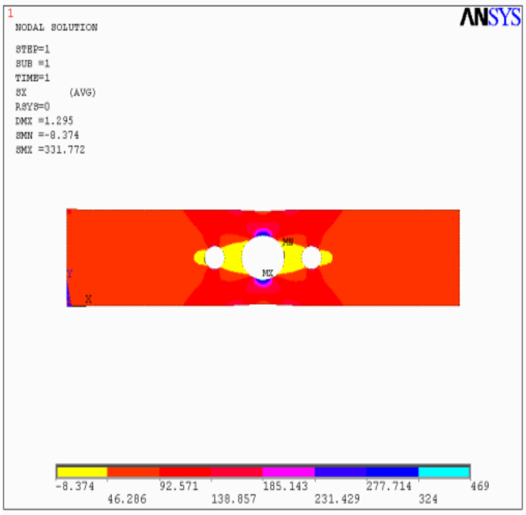
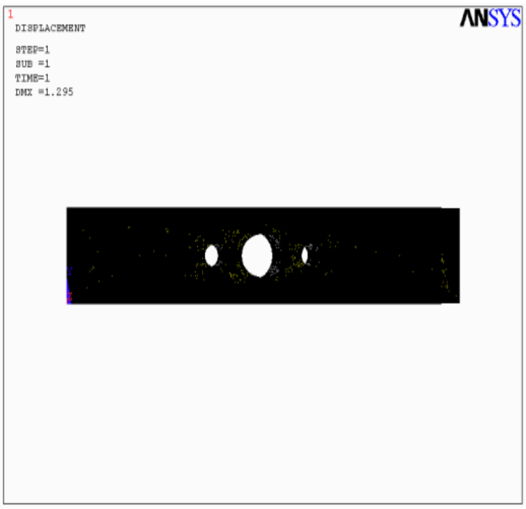


Fig 12: Displacement at Mesh Size 1.5



9.0 Derivation of Optimized Mesh Element Size

Constant factor called Stress Concentration factor to be derived to find out the convergent mesh element size.

Kt = Stress Concentration Factor

Kt = σ_{max} / $\sigma_{nominal}$

Where

Kt = Stress Concentration Factor

σ_{max} = Maximum stress for a particular load (Measured in ANSYS)

$\sigma_{nominal}$ = Nominal Stress

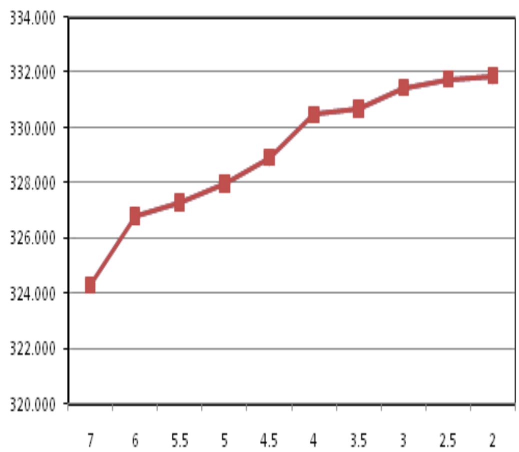
Nominal Stress ($\sigma_{nominal}$ = F/A)

Stress calculated on the basis of the net cross section of a specimen without taking into account of the effect of geometric discontinuities such as holes, grooves, fillets, etc…

Table 2: Stress with Different Loads

Cases	Smart Size Mesh	Max Stress (psi)	Stress difference	Stress Concentration Factor	Stress Concentration Factor Difference	% "Error" (Ansys)
1	7	324.332	-	4.05	-	5.987
2	6	326.823	2.491	4.085	0.035	5.393
3	5.5	327.303	0.480	4.091	0.006	5.045
4	5	327.991	0.688	4.100	0.009	4.632
5	4.5	328.927	0.936	4.112	0.012	4.401
6	4	330.486	1.559	4.131	0.019	3.790
7	3.5	330.692	0.206	4.134	0.003	3.436
8	3	331.462	0.770	4.143	0.010	2.917
9	2.5	331.772	0.310	4.147	0.004	2.473
10	2	331.877	0.105	4.148	0.001	2.008

Graph: Stress Plot at Mesh Size 3
Fig 13: Stress Vs Element size



The optimum mesh size is determined by analyzing case 1 to 10 with Centre hole diameter = 100 mm and adjacent holes diameter = 50mm .The maximum stress converges between mesh size 2.5 and 2. Hence mesh element size 2.5 will be used for the further analysis.

References

[1] `Shigley's, Mechanical Engineering Design

[2] Avinash Kharat, V. V. Kulkarni, Stress Concentration at Openings in Pressure Vessels – A Review, International Journal of Innovative Research in Science, Engineering and Technology, 2(3), 2013

[3] B. Mallikarjun, P. Dinesh, K. I. Parashivamurthy, Finite Element Analysis of Elastic Stresses around Holes in Plate Subjected to Uniform Tensile Loading, Bonfring International Journal of Industrial Engineering and Management Science, 2(4), 2012

[4] Kh. Fuad, R. A. Siregar, Ch. Rangkuti1, B. Ariwahjoedi1, M. Firdaus1, Stress Concentration Factors of Various Adjacent Holes Configurations in a Spherical Pressure Vessel, 5th Australasian Congress on Applied Mechanics, 2007, Brisbane, Australia

[5] Patel Dharmin, Panchal Khushbu, Jadav Chetan, A Review on Stress Analysis of an Infinite Plate with Cut-outs" International Journal of Scientific and Research Publications, 2(11), 2012

[6] Dheeraj Gunwant, J. P. Singh, Stress and Displacement Analysis of a Rectangular Plate with Central Elliptical Hole, International Journal of Engineering and Innovative Technology, 3(3), 2013, Certified

[7] Shobeir Arshadnejad, Kamran Goshtasbi, Jamshid Aghazadeh, Stress concentration analysis between two neighboring circular holes under internal pressure of a non-explosive expansion material, Journal of the Earth Sciences Application and Research Centre of Hacettepe University. Yerbilimleri, 30 (3), 259–270

[8] Shubhrata Nagpal, S. Sanyal, N. K. Jain, Analysis and mitigation of stress concentration factor of a rectangular isotropic and orthotropic plate with central circular hole subjected to in-plane static loading by design optimization, International Journal of Innovative Research in Science, Engineering and Technology, 2(7), 2013

[9] M Mohan Kumar, Rajesh S, Yogesh H, Yeshaswini B R, Study on the Effect of Stress Concentration on Cutout Orientation of Plates with Various Cutouts and Bluntness, International Journal of Modern Engineering Research, 3(3), 2013, 1295-1303

[10] D. B. Kawadkar, D. V. Bhope, S. D. Khamankar, Evaluation of Stress Concentration in Plate with Cutout and its Experimental Verification, International Journal of Engineering Research and Applications, 2(5), 2012, 566-571

[11] Y. Mohammed, Mohamed K. Hassan, Osama M. Erfan, Abu El-Ainin H, Geometric correction and stress concentration factors of open hole composite plate through constant cohesive law, Swiss Journal of Statistical and Applied Mathematics, 2(1)