Stress analysis of perforated plates under uniaxial compression using FEA and photoelasticity.

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Abstract - The article represents new approach to design Perforated plate by using FEA. By changing the different patterns of hole and apply gradually increasing load on plate and find the value of shear stress for different patterns of plate. Design parameters are hole diameter, thickness of plate, dimensions of plate , Load. These values of shear stress is compared with experimental values which taken by with the help of circular polariscope or by using ESA.

***Key Words*: - Analysis by FEA and, Simulation.**

I.INTRODUCTION

In day to day life there are number of applications of perforated plates in engineering and architecture e.g. in pressure vessel, oil refineries, space craft, air craft, robots, heat exchangers etc. In the project of analysis of perforated plate using ESA and FEA technique under uniaxial compressive loading, different patterns of the perforated sheets are analyzed and optimum design is found out. Initially analysis is done with the help of ESA and then results are compared with FEA results and we found approximate same results. So, we assumed that analysis process adopted in ANSYS is correct. Then by using FEA techniques different patterns are analyzed.

A numerical procedure, which combines two hybrid finite element formulations, was developed to analyse the stress intensity factors in cracked perforated plates with a periodic distribution of holes and square representative volume elements. The accuracy of the method in predicting the stress intensity factor was verified by a comparison with experimental measurements, carried out by a photoelasticity method, and by commercial finite element software.[1] The analysis of perforated plate has immediate application to tube sheet design. However successful stress analysis required knowledge about elastic properties. Considerable effort has been directed towards their determination. Moe ever ASME has accepted the codes for the tube seats with triangular pitch pattern, but the codes standard for square pitch patterns have not been accepted so far. This is the motivation behind solving the present problem. Various design methods has been proposed by number of researchers for analysing stress and deflection in multi-perforated plates, properly known as tube sheets. The purpose for this dissertation work is to show the different techniques developed by various researchers in the analysis of perforated plates..[2] In this paper an analytical investigation is used to study the stress analysis of plates with different central cutout. Particular emphasis is placed on flat square plates subjected to a uni-axial tension load. The results based on analytical solution are compared with the results obtained using finite element methods. The main objective of this study is to demonstrate the accuracy and simplicity of presented analytical solution for stress analysis of composite plates with central cutout.[3] Plates with various shaped cutout are often used in both modern and classical aerospace mechanical and civil engineering structure. The understanding of the effect of load bearing capacity and stress concentrationof such plate is very important in designing of structure. The main objective of this paper is for stress analysis of finite plate with special shaped cut out for stress distribution and Stress Concentration Factor (SCF).AnExperimental investigation is taken to study the stress analysis of plate with special shaped cut out

II .SIMULATION:-

1.Finite Element Analysis Of Perforated Plate.

Analysis has been carried out in ANSYS . Constrained perforated plate geometry is as shown in figure 2.1.

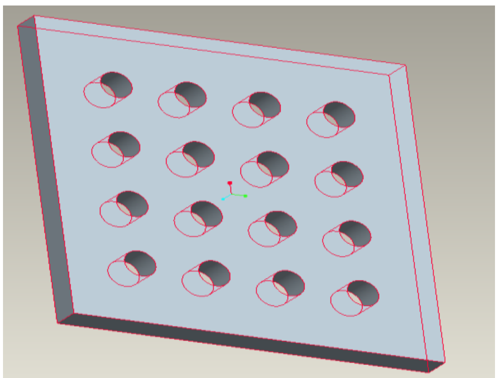

Fig.2.1 Geometry of the Perforated plate in ANSYS

2.Stress Analysis Of Perforated Plate By Using FEA.

Finite element analysis originated as a method of stress analysis in the design of aircrafts. It is a numerical method which provides solutions to problems that would otherwise be difficult to obtain. In terms of fracture, FEA most often involves the determination of stress intensity factors. FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition. In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition. The method is often used as an alternative to the experimental test method set out in many standards.

Assumptions:-

1. Rectangular perforated sheet is subjected to uniaxial compressive load having fixed number of holes i.e. 16.
2. Properties used for photoelastic sheet are as given below:
    A) Young's modulus $E=2*10^7$ N/mm^2
    B) Poisson's ratio μ=0.27.
3. By using shear stress theory maximum shear stress is calculated.
4. Material properties of model used for analysis are isotropic in nature.
5. For analysis of model element used is solid-8 node 183.
6. Element behavior is considered as plane stress with thickness of 6.22 mm.
7. Element selected has quadratic displacement behavior.
8. A constant Dia. of 10.mm is assumed for analysis in ANSYS.

A) SQUARE ARRAY 4444

The schematic diagram for this array pattern is as shown in Fig. no 2.2

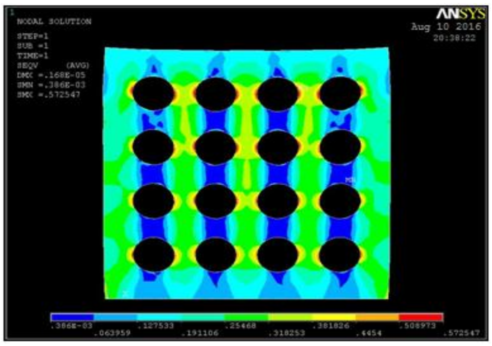

Fig2.2 Screenshot of square array 4444

The calculated results of maximum shear stress and graph of Load Vs maximum shear stress are shown in Table no 2.1& Fig no 2.3 respectively.

Load (Kg)	τ_{max} (N/mm^2)
10	0.2293
20	0.2449
30	0.2378
40	0.2478
50	0.2637
60	0.2827
70	0.2972

Table 2.1

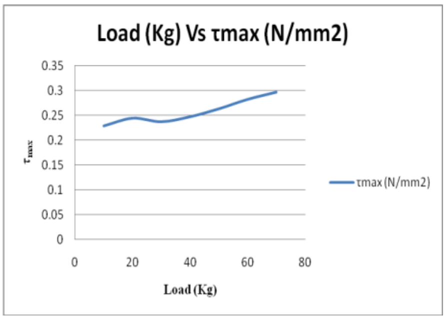

Fig no 2.3 Graph of Max. shear Stress Vs Load

B) HORIZONTAL 5335

The schematic diagram for this array pattern is as shown in Fig no 2.4

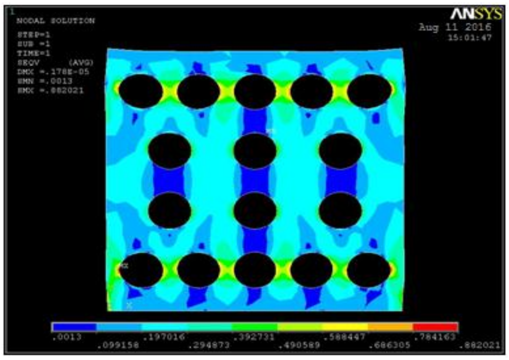

Fig no 2.4 Screenshot of horizontal 5335

The calculated results of maximum shear stress and graph of Load Vs maximum shear stress are shown in Table no 2.2 & Fig no 2.5 respectively

Load (Kg)	τ_{max} (N/mm²)
10	0.2706
20	0.3097
30	0.3403
40	0.3527
50	0.3649
60	0.3965
70	0.4377

Table no 2.2

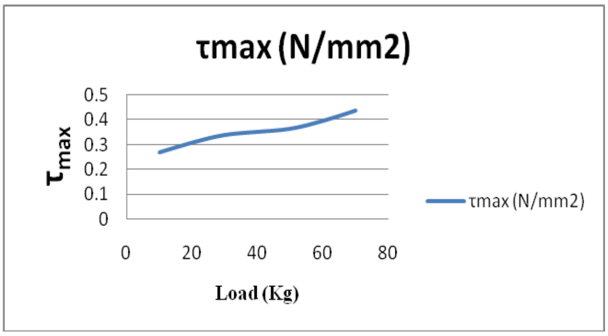

Fig no 2.5 Graph of Stress Vs Load

C) HORIZONTAL 5353

The schematic diagram for this array pattern is as shown in Fig no 2.6

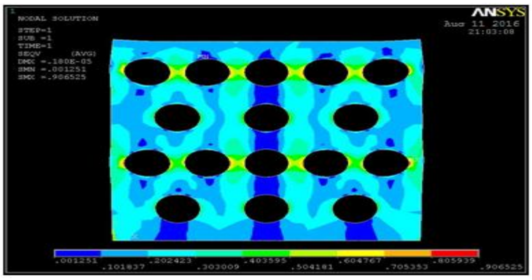

Fig no 2.6 Screenshot of horizontal 5353

The calculated results of maximum shear stress and graph of Load Vs maximum shear stress are shown in Table no 2.3 & Fig no 2.7 respectively.

Load (Kg)	τ_{max} (N/mm²)
10	0.2885
20	0.312
30	0.3108
40	0.3609
50	0.3655
60	0.4081
70	0.4513

Table no 2.3

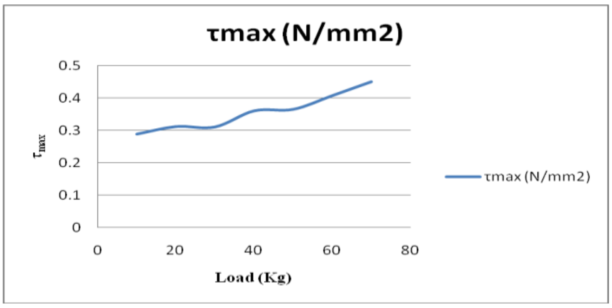

Fig 2.7 Graph ofMax. shear Stress Vs Load

D) HORIZONTAL 3535

The schematic diagram for this array pattern is as shown in Fig no 2.8

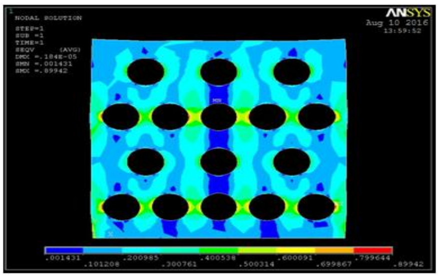

Fig no 2.8 Screenshot of horizontal 3535

The calculated results of maximum shear stress and graph of Load Vs maximum shear stress are shown in Table no 2.4 & Fig no 2.9 respectively.

Load (Kg)	τ_{max} (N/mm²)
10	0.2654
20	0.2725
30	0.3202
40	0.3363
50	0.3767
60	0.3970
70	0.4551

Table No 2.4

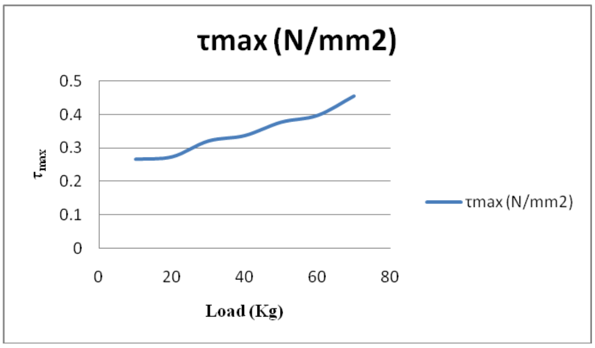

Fig 2.9 Graph of Max. shear Stress Vs Load

E) COMPARATIVE STUDY TO FIND OPTIMUM HOLE PATTERN:-

After completing these analysis, four patterns of perforated plates are analysed on single platform. The combined graph of maximum shear stress Vs load is plotted as shown below in Fig 2.10

Load (Kg)	H5335	H5353	H3535	Sq4444
10	0.2706	0.2885	0.2654	0.2293
20	0.3097	0.312	0.2725	0.2449
30	0.3403	0.3108	0.3202	0.2378
40	0.3327	0.3609	0.3363	0.2478
50	0.3649	0.3655	0.3767	0.2637
60	0.3965	0.4081	0.327	0.2827
70	0.4377	0.4513	0.4551	0.2972

Table no 2.5 Combined result table for all patterns

Above table shows the combined values of shear stress for all patterns by applying gradual load.

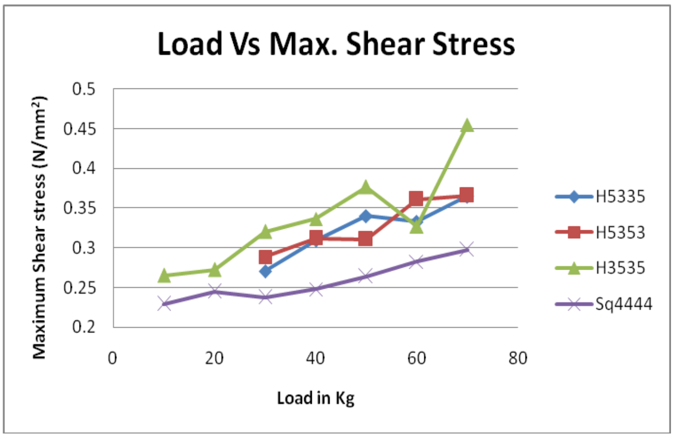

Fig 2.10 Graph of Max. shear Stress Vs Load

III) EXPERIMENTAL PROCEDURE:-

Preparation of Photoelastic model of perforated plate.

1. Cut two square plates each of size 200mm x 200mm from the transparent acrylic sheet.
2. Also, cut U shaped spacer which is to be placed between these two previously cut square plates. The thickness of the spacer determines free size (or volume) of the casting produced. It is generally 6mm to a maximum of 15mm.
3. Holes of size No (i.e. diameter = 16.75 mm) are drilled at equal distances along the sides of the square plates & spacer. The distance between two adjacent holes is kept 25mm.

By placing the spacer between the two square plates properly, bolts are inserted through the holes & nuts are fastened on the other side properly.

For experimentation this plate is fixed with circular polariscope and fixed with two ends. By applying gradually increasing load on this plate and observe the fringe order. By using this values of fringe order calculate the maximum shear stress.

A)EXPERIMENTAL SETUP FOR ANALYSIS OF PERFORATED MODEL ON POLARISCOPE

Fig. 3.1 Experimental setup of perforated model on polariscope

1. For getting uniform uniaxial compressive load on perforated sheet, the technique which is used in scew jack is used. For this purpose frame of polariscope is used.
2. Initially base is fixed, on which load cell is placed, so that it could not deflect due to compressive load.
3. On the load cell two metallic strips are placed for getting uniform fixed support at bottom of perforated plate.
4. On this metallic strips the perforated sheet is held vertically and below the base of frame of polariscope.
5. By rotating arm of the frame compressive loads are applied.
6. Picture of designed fixture is given below.

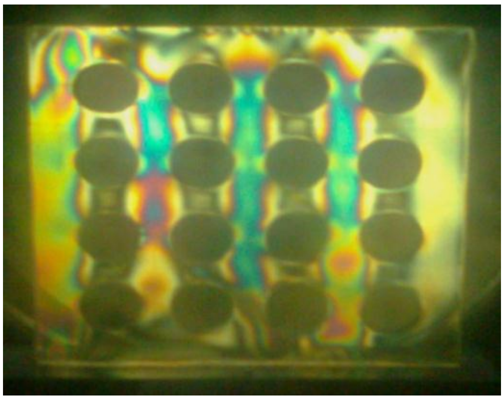

Fig 3.2 Fringe pattern are observed in polariscope

Calculations

$\sigma_1 - \sigma_2 = N * F_\sigma / h$

$\tau_{max} = (\sigma_1 - \sigma_2) / 2$

$F_\sigma = 11.57 N/mm$

$h = 6.12 mm$

By observing fringe patterns with the help of circular polariscope to calculate the maximum shear stress. The values of maximum shear stress calculated by using ESA technique is shown in table 3.1 and Graph of Maximum shear stress Vs load is Shown in Fig 3.3

Load w (kg)	Value of τ_{max}
10	0.216
20	0.235
30	0.226
40	0.234
50	0.258
60	0.271
70	0.285

Table 1.6 Experimental values of Shear stress.

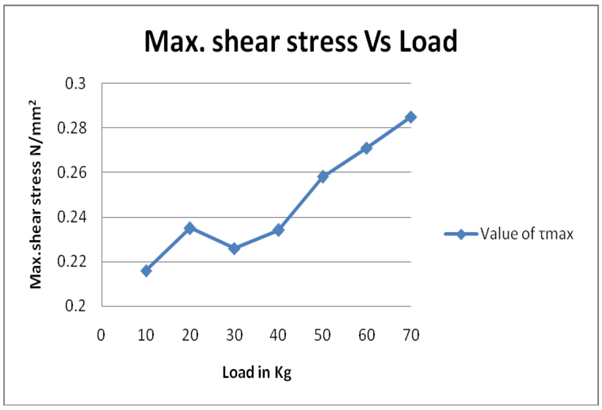

Fig.3.3 Graph of Max. shear stress Vs Load

IV) RESULTS AND CONCLUSION:-

Results obtained by ESA technique and FEA technique are approximately same with a variation of about 11%. The error is due to human and instrument. So procedure adopted for analysis of perforated plate by ANSYS 11.0 is correct.

From analysis of different patterns we found four optimum patterns of perforated plate viz. Square 4444, V5353, V5335, V3535. In these patterns Square 4444 develop less Maximum Shear Stress under uniaxial compressive loading. So we select this Square 4444 pattern for experimentation.

This project continued the work of Industrial Perforators Association manufacturing the available patterns and suggests the orientation and optimum pattern under uniaxial compression.

Result % difference = $(\tau_{max\,(ANSYS)} - \tau_{max\,(Experimental)}) / \tau_{max\,(Experimental)}$

Load (W)(kg)	τ_{max} (Experimental)	τ_{max} (ANSYS)	% difference
10	0.216	0.2293	1.33
20	0.235	0.2449	0.99
30	0.226	0.2378	1.18
40	0.234	0.2478	1.38
50	0.258	0.2637	0.57
60	0.271	0.2827	1.17
70	0.285	0.2972	1.22

Table.1.4 Result Comparison Experimental and ANSYS for perforated plate

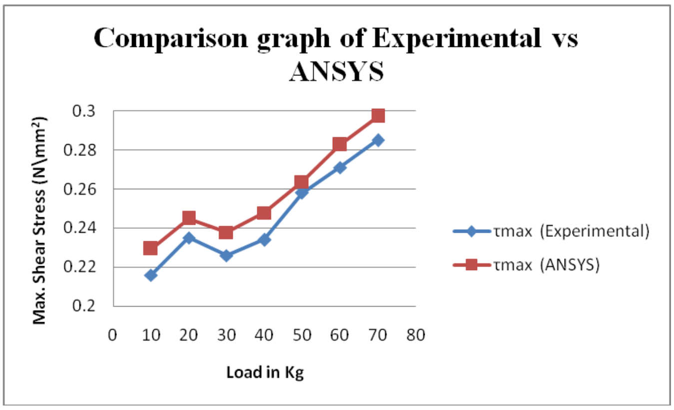

Fig.1.6 Result Comparison Experimental with ANSYS for perforated plate

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