International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 – 5161

Available at http://inpressco.com/category/ijcet

Research Article

Stress analysis of perforated plates under uniaxial compression using Experimentation and Finite Element Analysis

Umesh Balaso Andh[#*], S.M. Chavan[#] and S.G. Kulakrni[#]

[#]Department of Mechanical Engineering, SKN Sinhgad College of Engineering, Korti, Pandharpur Dist- Solapur, Maharastra, India

Accepted 25 April 2017, Available online 27 April 2017, **Vol.7, No.2 (April 2017)**

Abstract

*The perforated plate element constitute very important structural components in many structures, such as ship grilling, hulls, dock gates, plate, box girders of brides, platforms of offshore structure and used in aerospace industries. In this project work we have select a rectangular plate having a circular hole in 4x4 pattern with hole dia. 17mm. The same plate was created in CATIA V5 & the model of plate is import in ANSYS 14 for shear stress analysis. The shear stress developed in plate under the load of 70 Kg is 0.4377 N/mm2. In development phase we create a new plate of advanced material Epoxy resin. The pattern of the hole also changes from turbulent to laminar [4*4]. The same loading and boundary condition applied for the newly formed plate as for the existed plate. The final results came for these plate are 0.2972 N/mm2. The comparison between results of existed plate & newly formed plate shows the shear stresses goes on decreasing in newly formed plate. To validate the results of newly formed plate we create on experimental setup using the selected boundary condition to conduct the experimental work we use circular polariscope and apply load stepwise up to 70 Kg. In experimental analysis we get stress value of 0.2850 N/mm2 for Epoxy resin plate.*

Keywords: *Perforated plate, Epoxy resin, Shear stress, ANSYS 14 Workbench, Experimental analysis*

1. Introduction

The perforated plate element constitute very important structural components in many structures, such as ship grilling And Hulls , dock gates, plate and box girders of brides, platforms of offshore structure and structures used in aerospace industries.

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. After this by using Newton forward interpolation technique prediction of results is made for different patterns of holes on perforated. The hole pattern and how should be its orientation under uniaxial compression is tested. This project also suggests which orientation should be used for minimum stress concentration at different hole patterns.

The paper deals with stress analysis of plates perforated by holes arranged in rectangular plate with square pitch hole pattern. For this, in-plane loads are considered. Photo elasticity models were casted using photoelastic materials for rectangular plate with square pattern of holes. The testing of perforated plates is done by using the polariscope in experimental method. The results obtained by experimental are compared with the Finite Element Method (R. D. Patil *et al,* 2015). From the experimental analysis for plate with circular, square and triangular cut out without bluntness, the stress concentration for circular cut out is less than the square and triangular cut out and the stress concentration for square cut out is less than the triangular cut out. The stress concentration for triangular cut out is highest. By comparing the results it is found that, the stress concentration by experimentation and by FEM are in close agreement (D.B. Kawadkar *et al,* 2012). 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 analyzing stress and deflection in multi perforated plates, properly known as tube sheets. The purpose for this dissertation work is to show the different techniques

*Corresponding author **Umesh Balaso Andh** is a Research Scholar

developed by various researchers in the analysis of perforated plates (Prashant Jayavant *et al,* 2015).

2. Simulation

Finite element analysis of perforated plate

Finite element analysis originated as a method of stress analysis in the design structural components in many structures, such as ship grilling And Hulls, dock gates, plate and box girders of brides, platforms of offshore structure and structures used in aerospace industries. 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. The technique is based on the premise that an approximate solution to any complex engineering problem can be reached by subdividing the component into smaller more manageable (finite) elements. Analysis has been carried out in ANSYS. Constrained perforated plate geometry is as shown in figure 1.

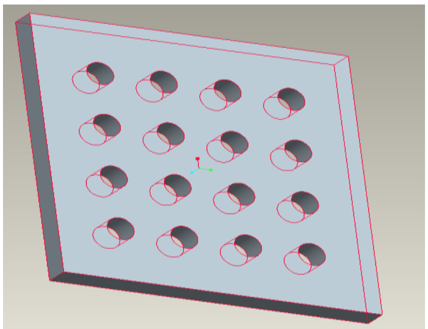

Fig.1 Geometry of the perforated plate in ANSYS

3. Stress analysis of perforated plate by using FEA.

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 behaviour is considered as plane stress with thickness of 15 mm.
7) Element selected has quadratic displacement behaviour.
8) A constant Dia. of 10.mm is assumed for analysis in ANSYS.

Square array 4444

The schematic diagram for this array pattern is as shown in fig. 2.

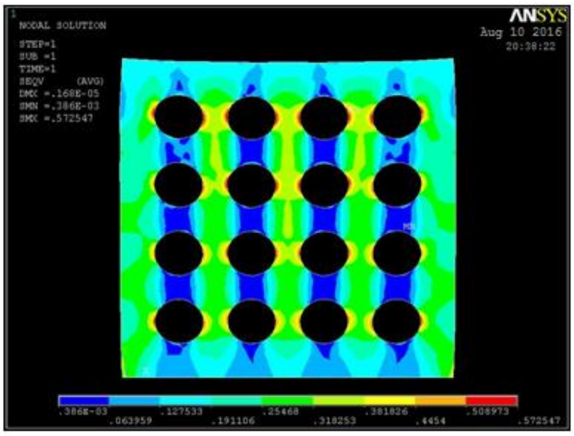

Fig. 2 Screenshot of square array 4444

The calculated results of maximum shear stress and graph of Compressive load Vs maximum shear stress are shown in Table 1 & Fig 3 respectively.

Table 1 Values of maximum shear stress for square 4444 pattern

Compressive Load (Kg)	τ_{max} (N/mm²)
10	0.2621
20	0.2923
30	0.3049
40	0.3260
50	0.3444
60	0.3867
70	0.4283

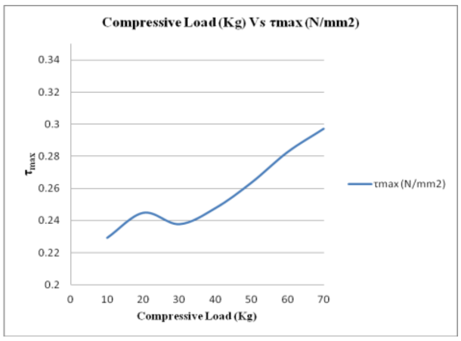

Fig.3 Graph of compressive load Vs maximum shear stress

Horizontal 3553

The schematic diagram for this array pattern is as shown in fig 4.

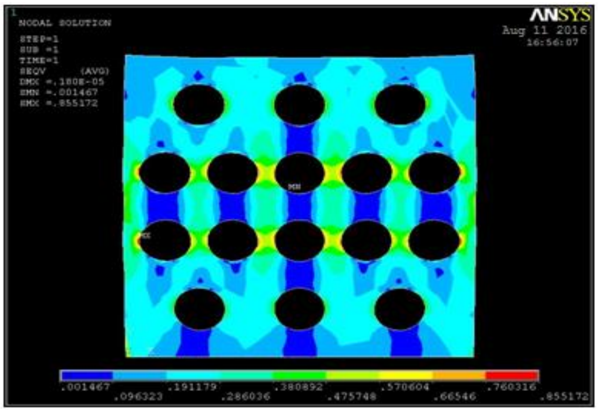

Fig.4 Screenshot of horizontal 5335

The calculated results of maximum shear stress and graph of Compressive load Vs maximum shear stress are shown in Table 2 & Fig 5 respectively.

Table 2 Values of maximum shear stress for square 5335 pattern

Compressive Load (Kg)	τ_{max}(N/mm²)
10	0.2293
20	0.2449
30	0.2378
40	0.2478
50	0.2637
60	0.2827
70	0.2972

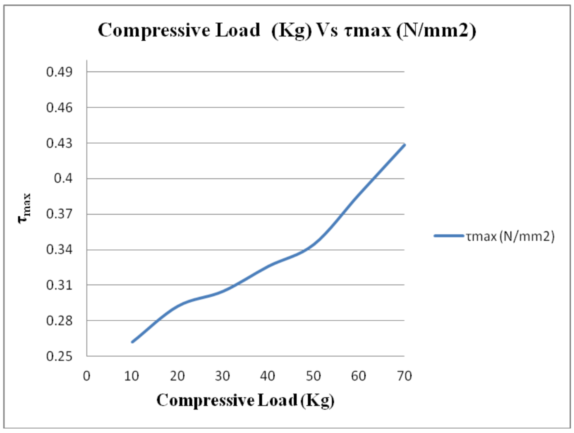

Fig.5 Graph of compressive load Vs maximum shear stress

Vertical 5335

The schematic diagram for this array pattern is as shown in fig 6.

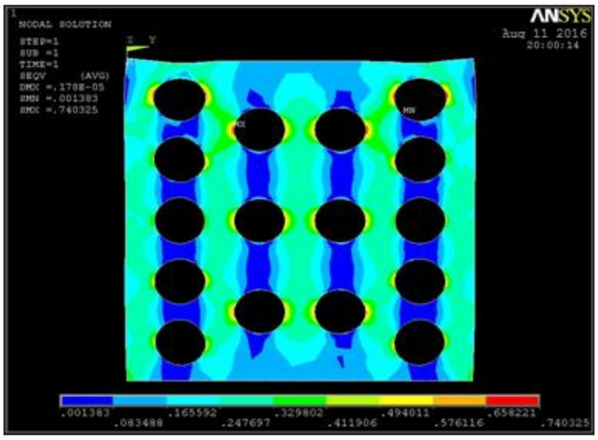

Fig.6 Screenshot of vertical 5353

The calculated results of maximum shear stress and graph of Compressive load Vs maximum shear stress are shown in Table 3 & Figs 7 respectively.

Table 3 Values of maximum shear stress for square 5353 pattern

Compressive Load (Kg)	τ_{max} (N/mm²)
10	0.2631
20	0.2652
30	0.2861
40	0.2918
50	0.3136
60	0.3377
70	0.3696

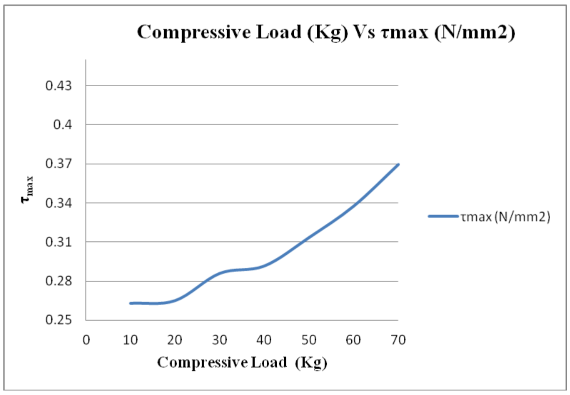

Fig.7 Graph of compressive load Vs maximum shear stress

Vertical 5353

The schematic diagram for this array pattern is as shown in fig. 8

The calculated results of maximum shear stress and graph of Compressive load Vs maximum shear stress are shown in Table 4 & Fig 8 respectively.

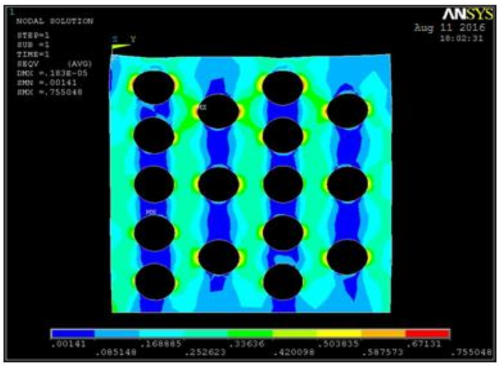

Fig.8 Screenshot of vertical 5353

Table 4 Values of maximum shear stress for square 5353 pattern

Compressive Load (Kg)	τ_{max} (N/mm^2)
10	0.2548
20	0.2687
30	0.2811
40	0.2983
50	0.319
60	0.3431
70	0.3768

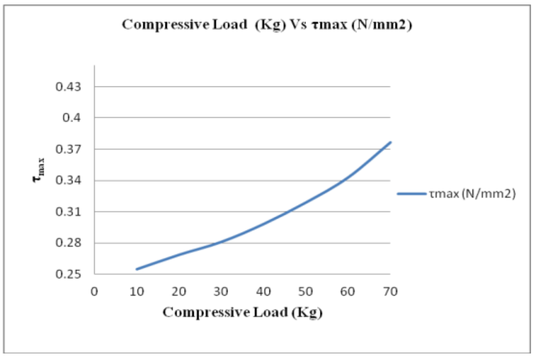

Fig.9 Graph of compressive load Vs maximum shear stress

Circular Pattern

The schematic diagram for this array pattern is as shown in fig 10.

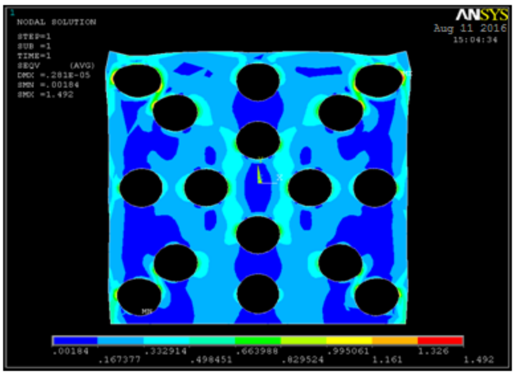

Fig.10 Screenshot of circular pattern

The calculated results of maximum shear stress and graph of Compressive load Vs maximum shear stress are shown in Table 5 & Fig 11

Table 5 Values of maximum shear stress for square Circular pattern

Compressive Load (Kg)	τ_{max} (N/mm^2)
10	0.3404
20	0.3773
30	0.4168
40	0.4964
50	0.5594
60	0.6284
70	0.7401

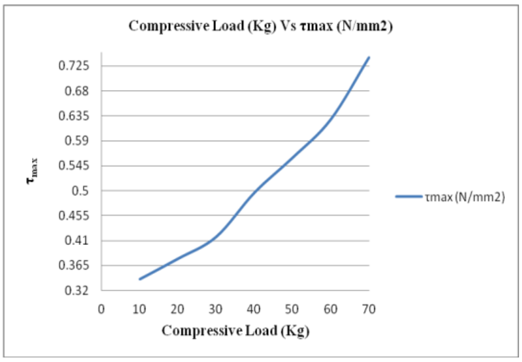

Fig.10 Graph of compressive load Vs maximum shear stress

Hexagonal Corner

The schematic diagram for this array pattern is as shown in fig.12.

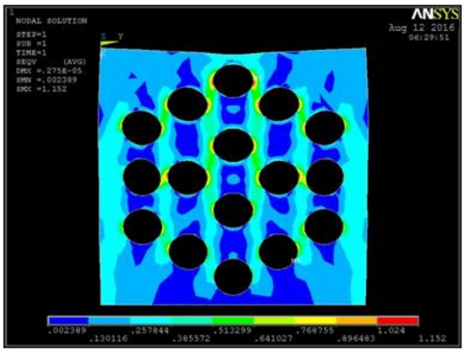

Fig.12 Screenshot of hexagonal corner

The calculated results of maximum shear stress and graph of Compressive load Vs maximum shear stress are shown in Table 6 &Figs 13 respectively.

Table 6 Values of maximum shear stress for square hexagonal corner pattern

Compressive Load (Kg)	τ_{max} (N/mm^2)
10	0.2939
20	0.3396
30	0.3522
40	0.3819
50	0.4291
60	0.4915
70	0.5306

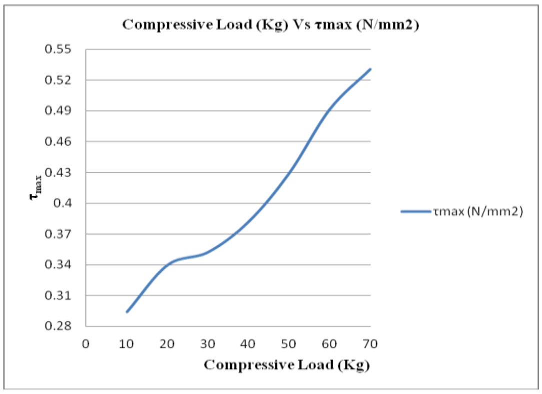

Fig.12 Graph of compressive load Vs maximum shear stress

Comparative study to find optimum hole pattern

After completing these nine analyses, all curves are analyzed on single platform. The combined values of load Vs maximum shear stress is written as shown below in table 7.

Comparison of all the values of maximum Shear stress in all patterns

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

Table 7 Comparison of all values of Max. Shear stress in all patterns

Compressive Load(Kg)	H3553	V5353	V5335	Circle	Hexa Corner	Sq4444
10	0.2621	0.2548	0.2631	0.3404	0.2939	0.2293
20	0.2923	0.2687	0.2652	0.3773	0.3996	0.2449
30	0.3049	0.2811	0.2861	0.4168	0.3522	0.2378
40	0.326	0.2983	0.2918	0.4964	0.3819	0.2478
50	0.3444	0.319	0.3136	0.5594	0.4291	0.2637
60	0.3867	0.3431	0.3377	0.6284	0.4915	0.2827
70	0.4283	0.3768	0.3696	0.7401	0.2306	0.2972

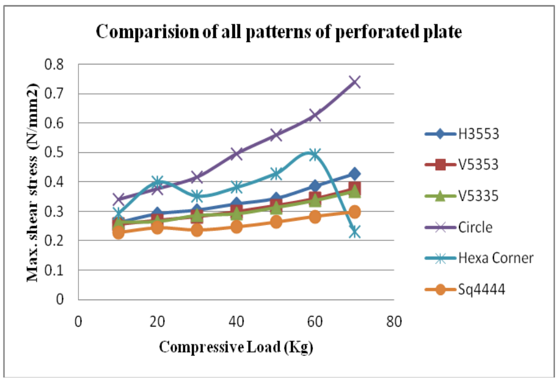

Fig.13 Graph of Compressive Load Vs max shear Stress for all patterns of perforated plate

4. Introduction to experimental stress analysis

Casting of photo elastic sheet

1) 100 parts of araldite is to be mixed with 10 parts of hardener by weight, for casting photo elastic sheet. Specific gravity of araldite is 1.05 & that of hardener is 1 at 20°C. For every l00 cm^3 of araldite, 10.5 cm^3 of hardener is to be mixed
2) Before mixing resin and hardener are heated separately, in the oven to about 80^0C to 100^0C for about 2 hours to remove all air bubbles and then they are cooled slowly to room temperature.
3) The hardener and resin are then poured simultaneously slowly stirring the mixture continuously for proper and thorough mixing. The mixture should be stirred in one direction continuously for 15 min. till it is transparent & clear. Now, it is ready for pouring in the mould for preparation of sheet.
4) The mixture is slowly poured from one corner of the opening to avoid trapping of air using funnel & glass rod.
5) When the mould is filled up to certain level at the top, it is kept in this position for curing at room temperature. For easy removal of sheet from the mould curing time is 16 to 18 hours.

Calculations

Volume of casting to be produced: 1.5x20x20= 600 cm^3
Araldite: Hardener = 100:10
=100/1.05:10/1
=95.2381:10
Total volume= 105.23 8 l cm^3 of mixture
Mixture: araldite
105.23 cm^3 = 95.2381 cm^3
600 cm^3= (95.2331x600)/105.23= 542.999 $cm^3$of araldite
Therefore volume of hardener =163.2-147.7=23.2615 cm^3
Thus, the given mould is prepared properly and photoelastic sheet was casted

Observations

1) Size of the perforated plate is 20cmx20cm
2) Lower order fringe viz. the nearest to the centre of the disc = n = 0
3) Higher order fringe viz. the nearest to the centre of the disc = n^1 = 1
4) Angle of rotation of the analyzer for lower order fringe to pass through the centre of the plate = ß = 0.41 radian
5) Angle of rotation of the analyzer for higher order fringe to pass through the centre of the plate = ß'= 0.51 radian

Design of fixture for analysis of perforated model on polariscope

1) For getting uniform uniaxial compressive load on perforated sheet, the technique which is used in screw 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.

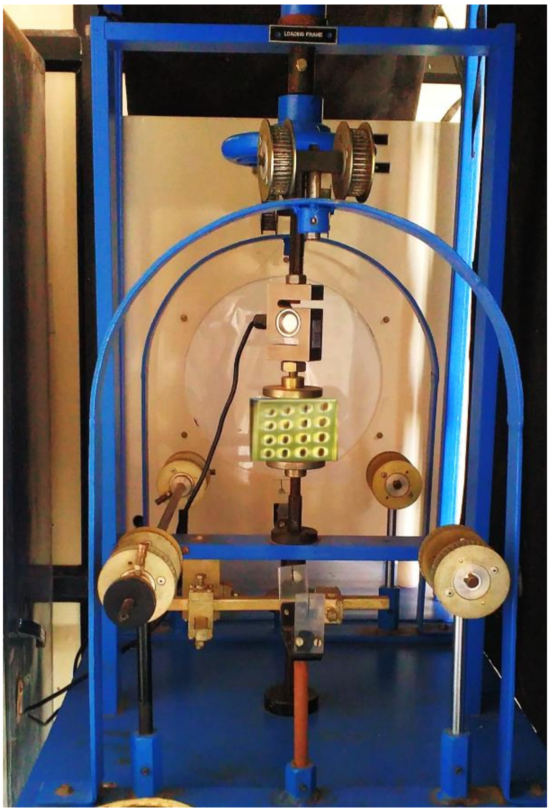

Fig.14 Experimental setup with Load Cell

Table 8 Observations from polariscope for plate

Sr. No.	Compressive load (Kg)	Max. shear stress at different points			
		1	2	3	4
1	10	0.1993	0.2078	0.2166	0.2293
2	20	0.2029	0.2156	0.2289	0.2449
3	30	0.1978	0.2011	0.2288	0.2378
4	40	0.2078	0.2213	0.2324	0.2478
5	50	0.2037	0.2358	0.2589	0.2637
6	60	0.2127	0.2457	0.2678	0.2827
7	70	0.2272	0.2465	0.2665	0.2972

Table 9 Values of Max. Shear stress by ESA

Compressive load (Kg)	Tmax N/mm²
10	0.2293
20	0.2449
30	0.2378
40	0.2478
50	0.2637
60	0.2827
70	0.2972

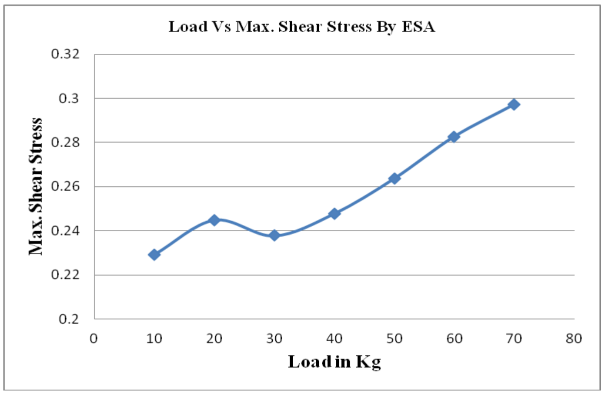

Fig.15 Graph of Experimental vs Load by ESA

5. Comparison of experimental values of max. shear stress with FEA

Table 10 Comparison Values of Experimental vs ANSYS

Compressive load (Kg)	τ_{max} (Experimental)	τ_{max} (ANSYS)	% Difference
10	0.216	0.2293	5.80
20	0.235	0.2449	4.04
30	0.226	0.2378	4.96
40	0.234	0.2478	5.56
50	0.258	0.2637	2.16
60	0.271	0.2827	4.13
70	0.285	0.2972	4.10

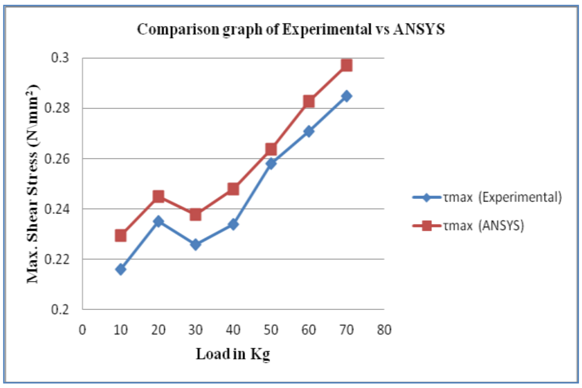

Fig.16 Comparison Graph of Experimental vs ANSYS

Comparison graph of Experimental vs FEA

Above graph shows the comparison of Experimental stress analysis vs FEA analysis. For ANSYS we consider the values of max. Shear stress is S4444 pattern because we use this pattern in experimental Analysis. The values of Experimental stress analysis & FEA analysis are near to same. Hence we use this pattern i.e.S4444 for further application

- **4444** **less variation**
- **V5335**
- **V5353**
- **H3553**
- **Hexa corner**
- **Hexa Face** **more variation**
- **Circle**

Fig.17 Gradation in patterns

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 three optimum patterns of perforated plate viz. Square 4444, V5353, V5335. These patterns develop less Maximum Shear Stress under uniaxial compressive loading.

By using Newton's Interpolation Method we can predict max shear stress value for any intermediate value of Load for all patterns; except the patterns Hexagonal Corner, Hexagonal Face because the curves of these are not linear.

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

References

R. D. Patil, Dr. Bimlesh Kumar (January 2015) Stress Analysis of Perforated Tube Sheet used for Pressure Vessel having Square Pitch Hole Pattern International Journal of Innovative Research in Science, Engineering and Technology, Vol. 4, Issue 1.

D.B. Kawadkar, Dr. D.V. Bhope, S.D. Khamankar (2012) Evaluation of stress concentration in plate with cutout and its experimental verification. International journal of engineering and research and applications (IJERA), Vol. 2 Issue 5, pp. 566-571

Prashant Jayavant Thorawat, Rahul A. Marme (2015) Stress Analysis of a Perforated Plate through Experimental and Computational Methods International Engineering Research Journal (IERJ)Volume 1 Issue 6 Page 482-487,ISSN 2395-1621.

Jeom kee Paik (2008), Ultimate strength of perforated steel plates under combined biaxial compression and edge shear loads thin-walled structures 46, 207-213.

Khaled M. EI-sawy, Aly S. Nazmy, Mohammad Ikbal Martini (2004), Elasto plastic buckling of perforated plates under uniaxial compression thin-walled structures 42,1083-1101.

Bin Cheng , Jianlei wang , Chun li (2013), Compression tests and numerical analysis of Perforated plates containing slotted holes in steel pylons. thin-walled structures 67,129-143.

M. Azhari, Shahidi, M.M. Saadatpour (2005) Local and post local buckling of stepped and perforated thin plates. Applied mathematical modeling,29 633-652.

H. Achtelik, G. Gasiak (2008),Strength tests of axially symmetric perforated plates for chemical reactors: Part 2 Experiments International Journal of Pressure Vessels and Piping 85 257–264.

Rezaeepazhand and M. Jafari (2008) Stress Analysis of Composite Plates with Non-circular Cut out Key Engineering Materials Vols. 385-387 pp 365-368.