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The Stress Concentration Effect of Stress Raiser Present in a Tensioned Plate with Elliptical Hole by FEM and Photo Elasticity

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Abstract - *Steel is widely used in the construction engineering industry in various combinations to construct various types of structures as flyovers, skyscrapers, plants, heavy machinery vehicle structures etc. Plates with various types of cut outs are also becoming very important due to their high applications in mainly aerospace industry and vehicle industries. These cut outs are made into plates to meet the requirement in the design of the final structures. However these cut-outs create stress concentration and eventually reduce the mechanical strength of the structure.*
The present study aims at reducing this stress concentration of tensioned plate having stress raiser at varying distance. Reduction in stress concentration with Elliptical and circular stress raisers is studied. Findings of the study are made available here as numerical data and in graphical form and comparing the results with photo-elasticity test results.

Key Words: Elliptical, strength, stress, elasticity, plates

1. INTRODUCTION

As the name implies, stress analysis is the completes and comprehensive study of stress distribution of specimen under study. The most important task before design engineer is to maintain the working stresses within Plates and shells of various constructions find wide uses as primary structural elements in aerospace, mechanical and civil engineering structures. In recent years, the increasing need for lightweight efficient structures has led to structural shape optimization. Different cut-out shapes in structural elements are needed to reduce the weight of the system and provide access to other parts of the structure. It is well known that the presence of a cut-out or hole in a stressed member creates highly localized stresses at the vicinity of the cut-out. The ratio of the maximum stress at the cut-out edge to the nominal stress is called the stress concentration factor (SCF). The understanding of the effects of cut-out on the load bearing capacity and stress concentration of such plates is very in designing of structures.

Making cutout is not only for connecting but also reducing the weight of structural member. In most application the plate with cutout causes stress concentration near the cutout. It is predicted that the stress pattern near the cutout will be different as compared to plate without cutout. Actually stress concentration depends upon the different parameter; the type of shape of cutout, the plate with linear or nonlinear elastic material, orientation of cutout, and loading condition etc.

Most research on stress concentration focuses on structural member that are mostly subjected to stress concentration. This study mainly focuses on stress concentration analysis of steel plate with different type cutout and at different cutout orientation. In reality, other cutout shapes, rather than circulars, are widely used for plate-like structures. In the polygonal cases, it is known that significant design variables or factors are edge bluntness and rotation.

2. EXPERIMENTAL STRESS ANALYSIS OF TENSIONED PLATE HAVING STRESS RAISERS

The stress analysis of elliptical hole present in a Tensioned plate is carried out by using photo-elastic models of plate having stress raisers.

2.1. Preparation of Model

For experimentation (photo-elasticity) analysis of Photo-elastic plate with elliptical hole are considered. The tensioned plate having dimension 200 mm (x direction) 100 mm (y direction) 5 mm (z direction) shown in fig. The location of elliptical hole is the center of plate. And circular hole located at varying distance from central ellipse. The major axis of ellipse is 40 mm and minor axis is 20. This is same for all plates. The diameter of circular hole is varying form 5mm, 10mm, 15mm, and 20mm. The distance is varying from center are 40 mm and 60 mm. One side of plate is fixed and other side 200 N force is applied shows in figure.

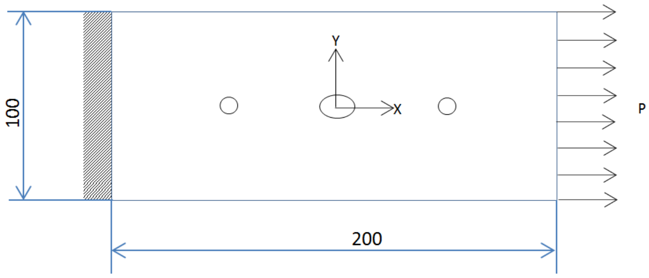


Fig.2.1 Model of plate (all are dimensions in mm)

2.2 THE STRESS ANALYSIS OF TENSIONED PLATE WITH ELLIPTICAL HOLE BY FEM

The specification for the plate having elliptical hole used for stress analysis is as follows. The Fig. 4.1 shows the specification of the plate.

- Plate length : 200 mm
- Plate thickness : 8 mm
- Plate width 100 mm
- Load(P) : 200 N Tensile load
- Ellipse : 40 mm major axis,
  20 mm minor axis

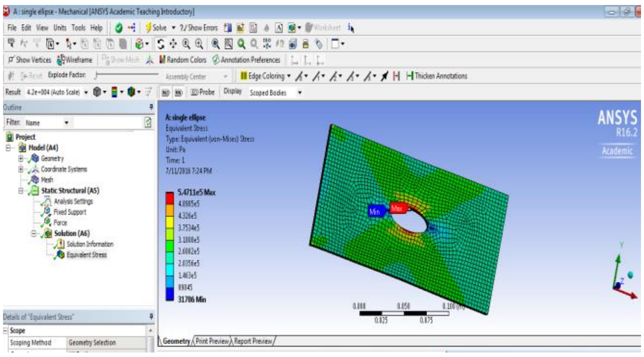
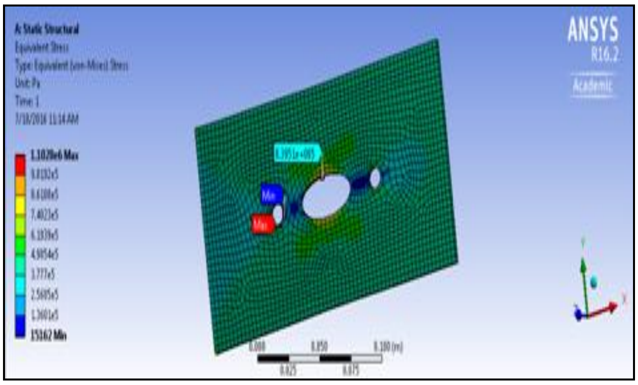


Fig 2.2 The result show the stress value is maximum at the central elliptical hole in a tensioned plate. The value of stress is 0.87285 N/mm². By adding circular hole in same plate by varying distance from center and increasing diameter of circular hole stress value find out compare the result.

2.3 PLATE HAVING CIRCULAR HOLE AT 40 MM FRO CENTER AND ELLIPTICAL HOLE AT CENTRE.

Fig 2.3 shows Von Misses stress at the central elliptical hole in a tensioned plate is 0.83451 N/mm². This result is compare with the analysis of tensioned plate having circular hole 40 mm apart from center keeping elliptical hole size constant.



2.4 PLATE HAVING CIRCULAR HOLE AT 60 MM FROM CENTER AND ELLIPTICAL HOLE IS CONSTANT AT CENTRE

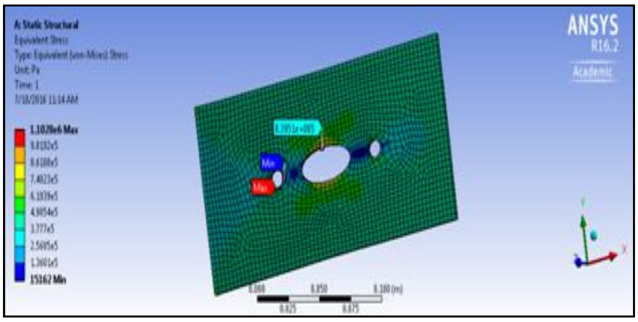


Fig 2.4 The Von Misses stress at the central elliptical hole in a tensioned plate is 0.84058 N/mm². This result is compare with the analysis of tensioned plate having circular hole 60 mm apart from center keeping elliptical hole size constant.

Table. 2.1 Comparison of Equivalent Von-Misses stress by varying distance of circular hole from center by keeping elliptical hole constant.

Equivalent stress (Von- Misses) in Mpa (at Ellipse)		
Hole Size (dia)	40 mm distance from center	60 mm distance from center
5 mm	0.8609	0.8686
10 mm	0.8345	0.8405
15 mm	0.7985	0.8216
20mm	0.7376	0.7806
25 mm	0.6925	0.7011

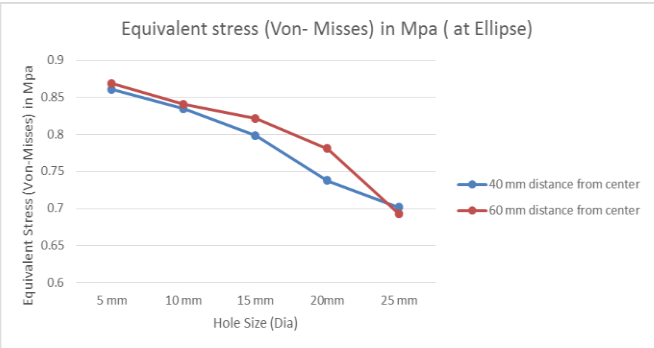


Fig.2.5 The graph of variation in stress with increase in diameter of hole.

Table 2.1 and fig 4.5 shows that Equivalent von- misses stress at central ellipse the tensioned plate having elliptical hole at center and circular hole having different diameter present at 40 mm and 60 mm distance from center stress raiser 40 mm from center of plate as compare to 60 mm distance from center of tensioned plate.

3. EXPERIMENTAL STRESS ANALYSIS OF ELLIPTICAL HOLE PRESENT IN A TENSIONED PLATE

The steps carried out for experimentation are as follows:

1) For analysis circular Polariscope setup bright field arrangement is used in order obtain isochromatic fringe pattern from which magnitude of stresses determined.
2) Photoelastic model of plate with stress raiser is mounted on loading fixture.
3) The load is applied on the model by putting weight in pan.
4) The weight in plan and the lever ratio is adjusted so that it will create the required value of tension.
5) When the model is loaded fringes are generated in the Model.
6) Now the lower order fringe is passed to the point of intersect by rotating analyzer in the clockwise direction and it is added to it to get the actual fringe order.
7) When the higher fringe is passed to the point of intersect by rotating analyzer anticlockwise direction and is subtracted from higher order fringe to get actual fringe order.
8) Average of both the taken to calculate fringe order and stresses are determined by using $\sigma = NF\sigma/h$ N/mm^2

4. OBSERVATIONS

The observation is made I Polariscope by keeping load constant that is 66 kgf in pan. The applied load on plate is 200 N and observation table is shown in table no 4.1 for elliptical hole as follows.

Sr. No	Variable distance	Model plate elliptical hole with varying circular hole dia	Fringe order (N)	$\Sigma=NF\sigma/h$ N/mm^2
1	-	Single ellipse	0.5+0.22=0.72 1.5-0.8=0.7 Avg=0.72	1.56
2	60 mm distance from center	10 mm	0.5+0.1=0.6 1.5-0.9=0.6 Avg =0.6	1.28
		15 mm	0.5+0=0.5 1.5- 1.0 =0.5 Avg=0.5	1.07
3	40 mm distance from center	10 mm	0.5+0.=0.5 1.5 -1.06=0.44 Avg=0.47	1.01
		15 mm	0.5+0.01=0.51 1.5-1.01=0.49 Avg=0.5	0.97

Table 4.2 shows that comparing the results it is seen that tensioned plate having single elliptical hole by theoretical analysis, FEM analysis and Experimental analysis is in close agreement.

Hole in tensioned plate	Maximum stress by Theoretical analysis N/mm^2	Maximum stress by FEM analysis N/mm^2	Maximum stress by Experimental analysis N/mm^2
Elliptical hole	1	0.8723	1.56

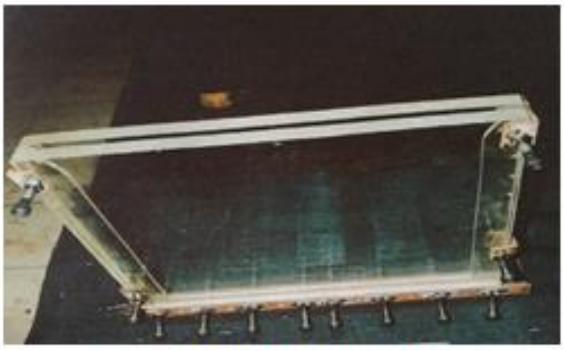
Table 4.3 shows that the experimental photoelasticity test is carried out on photoelastic model loaded uniaxially for elliptical and circular hole. The same analysis is carried out by FEM and the results are compared. By computing the results it is seen that the maximum stresses by experimentation and FEM are in close agreement.

Sr.No	Varying Diameter of circular hole	40 mm distance from center		60 mm distance from center	
		Maximum stress on elliptical hole by FEM (N/mm^2)	Maximum stress on elliptical hole by experimental analysis (N/mm^2)	Maximum stress on elliptical hole by FEM (N/mm^2)	Maximum stress on elliptical hole by experimental analysis (N/mm^2)
1	10 mm	0.8345	1.01	0.8405	1.28
2	15 mm	0.7985	0.97	0.8216	1.07

5. CONCLUSIONS

This study presents stress analysis of tensioned plate having elliptical hole at center of plate. The stress concentration effect is studied by varying the diameter of circular hole and by varying the distance of circular hole from point of loading. For comparison of the result, in both the cases applied load is kept constant. It is observed that the maximum stress at the edge of elliptical hole is found to be decreased with the increase in distance of circular hole from the point of loading. Again it found that with increase in hole size, the stress near edge of elliptical hole is found to be decrease. The analysis is carried out theoretically, by FEM and by experimentally. The FE analysis results are found to be in close agreement with the results obtained by experimentally andtheoretically

6. PHOTOELASTICITY TEST IMAGES

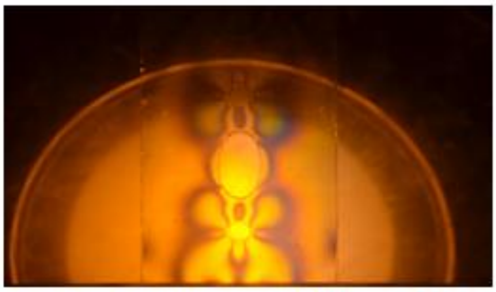


Photograph A- Mould for casting the sheet

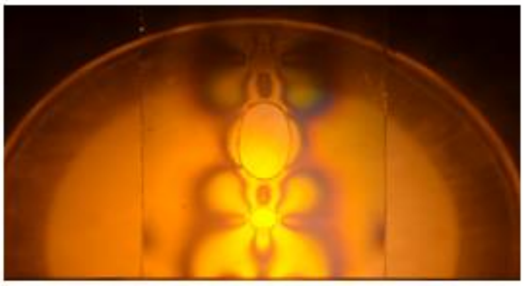
Photograph A- Models of plate

Photograph A- Polariscope

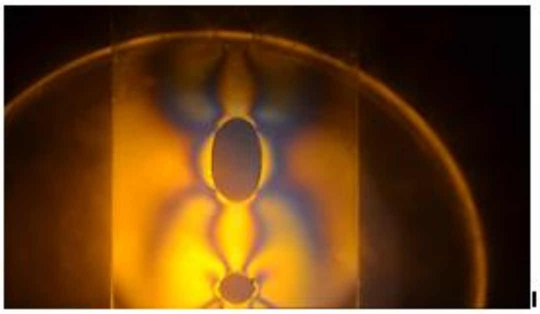
Photograph A- Calibration of sheet to determine material fringe value



Photograph A- Fringe pattern for tensioned plate having elliptical hole at center and circular hole having 10 mm is 60 mm apart from point of loading



Photograph A- Fringe pattern for tensioned plate having elliptical hole at center and circular hole having 10 mm is 40 mm apart from point of loading



Photograph A- Fringe pattern for tensioned plate having elliptical hole at center and circular hole having 10 mm is 40 mm apart from point of loading

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