Stress Analysis of Plate With Oblique Hole

B.C.Patle, D.V. Bhope

Abstract-In this study, the wok is carried out to analyzed, the stresses of plate with oblique hole with the Finite Element Analysis. Stress analysis of a series of flat plates with oblique holes subjected to axial tension has been carried out using the finite element method (FEM). Different plate hole diameter-width ratios, angles of hole obliquity have been considered to provide stress concentration factors at such holes. The work covers plate hole diameter- width (d/w) ratios from 0.1 to 0.9, hole obliquity angles from 0^0 to 80^0 and inclination of hole axis in widthwise, lengthwise and diagonal wise direction, 30^0 direction and 60^0 direction.

Keywords-Finite Element Method, Oblique Hole, Stress Analysis.

I. INTRODUCTION

Localized stress around geometric discontinuities such as holes, shoulders, and grooves cannot be predicted accurately using elementary stress formulas. The concentration of stress resulting from these abrupt transitions is frequently too high to be attributed solely to the decrease in net cross sectional area. Stress concentration factors, often determined experimentally or computationally, are used to scale the nominal stress in a continuous structure to account for the effect of the discontinuity. Stress analysis of thick flat plate with oblique hole subjected to axial tension has been carried out using the finite element method (FEM).

An oblique may be defined as one having its axis at an angle with respect to the normal to a surface. At the intersection with a plane surface an oblique cylindrical hole gives rise to an elliptical trace and produces an acute angled edge which, for large angles of obliquity with respect to the normal, may be very sharp. Such holes are, for example, commonly found at interpenetrations in pressure vessels and as lacing-wire passages in steam turbine blades.

II. TECHNICAL DETAILS

The photoelastic analysis by H. W. McKENZIE and D. J. WHITE[1], reports the experimental work for determination of stress concentration factor in an oblique hole in flat plate with thickness of 5 mm, width of 97 mm and overall length of 254 mm as shown in Figure 1. The hole diameter(d) is 9.5 mm and four angles of obliquity with respect to normal are considered as, ø=30°, 50°, 65° and 75.5°. Tension loading is applied in the direction of the length of the specimen and the stresses are frozen in the model. These same geometrical parameters of plate are considered for present work. The experimental results are verified using FE approach.

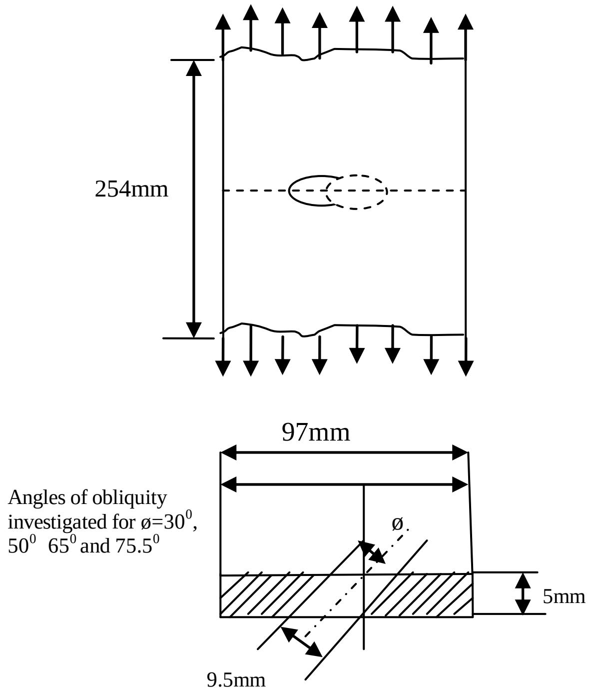

Figure 1: Model Detail

III. METHODOLOGY

To find out the stresses in a plate, a plate under tensile load are considered. Finite element method is used with 3D element. The plate is assumed with constrained at one end. It is expected that the stress concentration effect will be vary with respective obliquity of the hole and effort will be made to correlate the experimental existing result with FE result.

IV. FE ANALYSIS OF PLATE WITH OBLIQUE HOLE

The values of Maximum Von-Misses stresses for different angles of obliquity are given in table 1 and maximum Von-misses stress contours are shown in figure 2 to figure 6.

Table: 1 Von-Misses Stresses for Different Angles of Obliquity

Angle of Obliquity ($ø^0$)	0^0	30^0	50^0	65^0	75.5^0
Von-Misses Stress (MPa)	3.04	3.88	5.39	9.08	18.26

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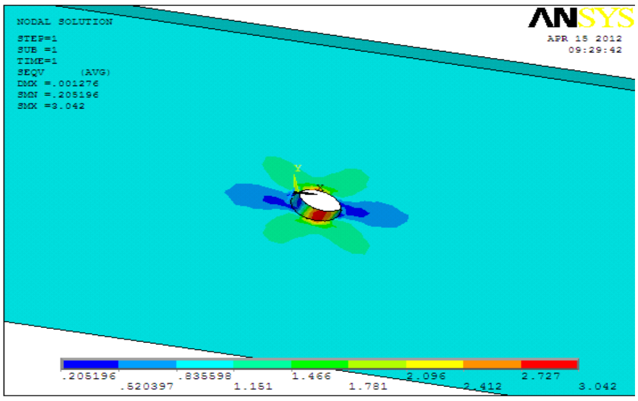

Figure 2: Von-Misses Stress Contour for Angle of Obliquity ø = 0^0.

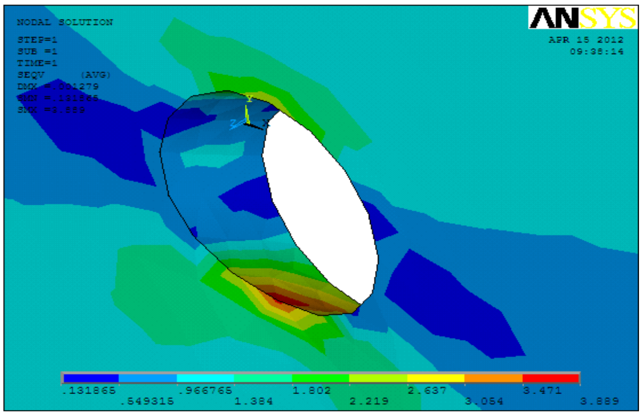

Figure 2: Von-Misses Stress Contour for Angle of Obliquity ø=30^0.

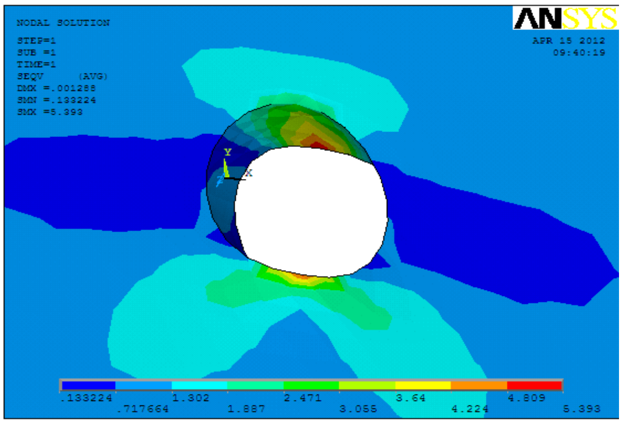

Figure 4 Von-Misses Stress Contour for angle of obliquity ø = 50^0.

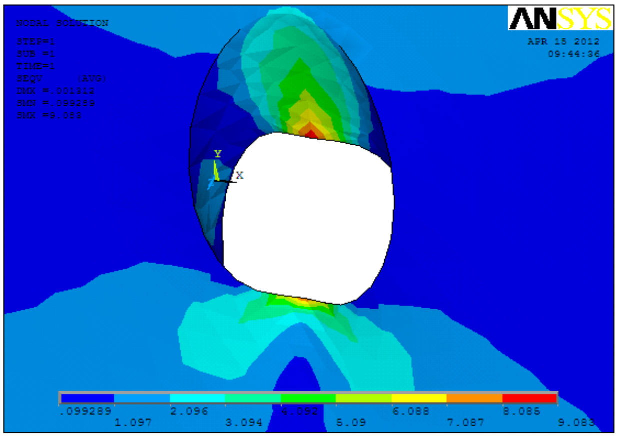

Figure 5 Von-Misses Stress Contour for angle of obliquity ø=65^0

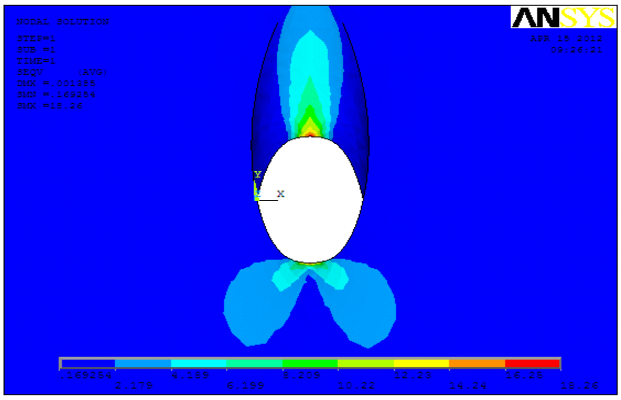

Figure 6. Von-Misses Stress Contour for angle of obliquity ø= 75.5^0

V. COMPARISION BETWEEN FE AND EXPERIMENTAL SCF

The Von – Misses stresses for 3D plate with oblique hole and 2D plate with elliptical hole are given in table 2.

Table 2: Von – Misses stresses for 3D and 2D plate

Plate type	Von – Misses Stress (MPa)				
	Angles of obliquity				
	0^0	30^0	5^0	65^0	75.5^0
FE stress for 3D plate with oblique hole	3.042	3.889	5.393	9.083	18.26
FE stress for 2D plate with elliptical hole	2.576	3.345	4.2198	6.0471	10.753
Analytical stress for 2D plate with elliptical hole	2.98	3.716	4.858	7.503	14.75
Analytical nominal stress based on net area	1.107	1.109	1.1273	1.304	1.643

Stress concentration factor is calculated by equation (1),

$$SCF = \frac{\text{Maximum Stress at Hole}}{\text{Nominal Stress Based on Net area}} \quad \ldots\ldots\ldots (1)$$

Table 3 shows stress concentration factor for above mentioned results. Nominal stress is based on the net area given in table 2. The FE and experimental results for 2-D Plate with elliptical hole and 3-D Plate with oblique hole are compared in table 3, and its variation is shown in figure 7.

Table 3: Comparison between FE and Experimental SCF

Type of plate	Stress Concentration Factor				
	Angles of obliquity				
	0^0	30^0	50^0	65^0	75.5^0
SCF for 3D plate with oblique hole(FE)	2.72	3.44	4.57	6.96	11.11
SCF for 3Dplate with oblique hole(Expt.)	2.8	3.2	4.3	5.5	7.3
SCF for 2D plate with elliptical hole(FE)	2.32	2.96	3.57	4.63	6.54

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SCF for 2D plate with elliptical hole(Expt.)	2.7	3.1	3.6	4.5	6.0
SCF for 2D plate with elliptical hole(Analytical)	2.68	3.29	4.11	5.75	8.97

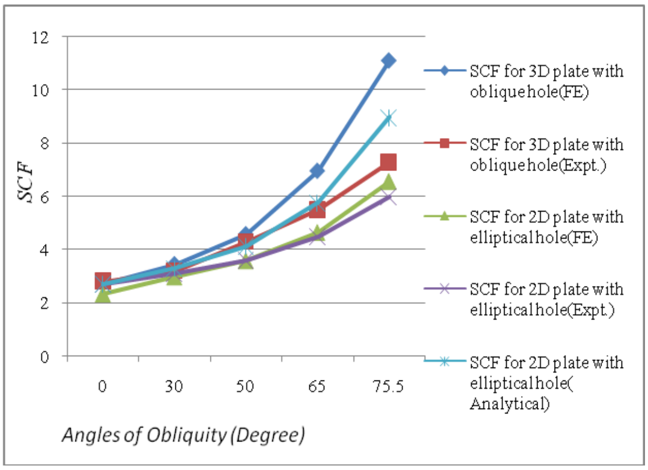

Figure 7: SCF vs. Angles of Obliquity

VI. EVALUATION OF STRESS CONCENTRATION FACTOR FOR DIFFERENT OBLIQUITY OF THE HOLE

A. Evaluation of stress concentration factor for widthwise obliquity of hole

In the previous work, the FE and experimental results obtained apply only to plates with a ratio of hole diameter '*d*' to plate width '*w*' of 0.1. It would be valuable to extend this work by measuring stress-concentration factors for other *d/w* ratios. So this work is extended by increasing the ratio of *d/w* from 0.1 to 0.9 and angle of obliquity of the hole form ø = 10^o to 80^o, further this work extended by taking the hole axis inclined with surface of the plate, in widthwise direction, lengthwise direction, diagonal wise direction, 30^o direction and 60^o direction (These angles of 30^o & 60^o are with respect to the longitudinal edge of the plate). The square plate having the length of 300 mm, width of 300 mm, thickness of 5 mm and diameter of 10 mm is shown in fig.8 The FE stresses, Theoretical stresses and Stress Concentration Factor are shown in table 4.

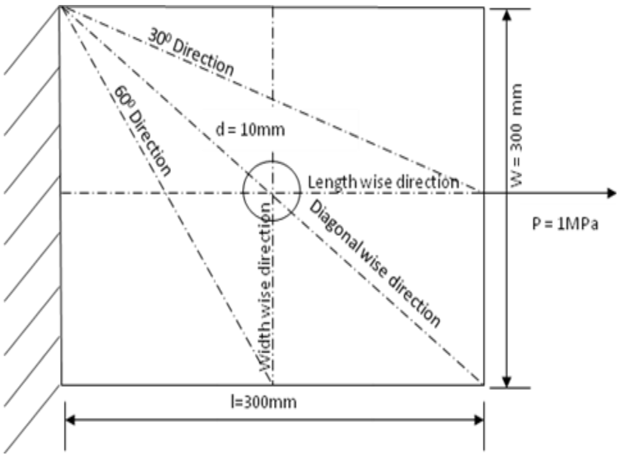

Figure 8 Square Plate with Hole.

Table: 4: The FE stresses, Theoretical stresses and Stress Concentration Factor

d/w		Angles of Obliquity							
		10^0	20^0	30^0	40^0	50^0	60^0	70^0	80^0
0.1	FE stress(MPa)	3.17	3.34	3.67	4.17	4.98	6.41	9.90	23.43
	TH stress(MPa)	1.113	1.11	1.13	1.15	1.18	1.24	1.4	2.1
	SCF	2.84	2.99	3.25	3.63	4.21	5.12	7.01	9.938
0.3	FE stress(MPa)	3.64	3.84	4.21	4.88	6.18	9.36		
	TH stress(MPa)	1.43	1.46	1.52	1.64	1.87	2.49		
	SCF	2.53	2.61	2.75	2.97	3.2	3.74		
0.5	FE stress(MPa)	5.20	5.64	6.63	8.44	13.91			
	TH stress(MPa)	2.03	2.13	2.36	2.87	4.50			
	SCF	2.56	2.64	2.80	2.93	3.09			
0.7	FE stress(MPa)	10.68	12.58	17.64	38.33				
	TH stress(MPa)	3.45	3.91	5.21	11.59				
	SCF	3.08	3.21	3.38	3.30				
0.9	FE stress(MPa)	64.73	152.48						
	TH stress(MPa)	11.61	23.65						
	SCF	5.57	6.44						

The value of stress concentration factor plotted against the angles of obliquity of the hole, for different d/w ratios are shown in figure 9 to figure 13

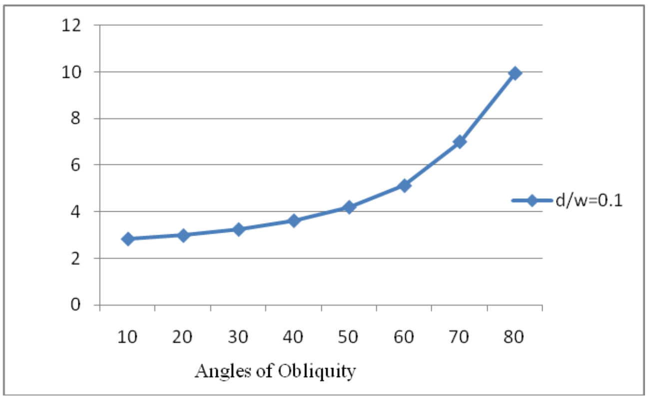

Figure 9: scf Vs Angles of Obliquity for d/w=0.1

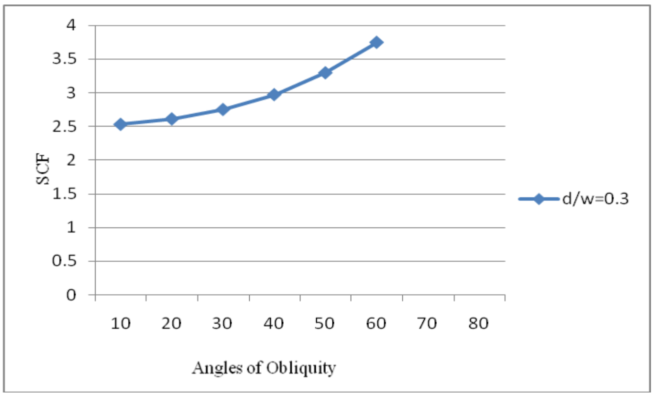

Figure 10: scf Vs Angles of Obliquity for d/w=0.3

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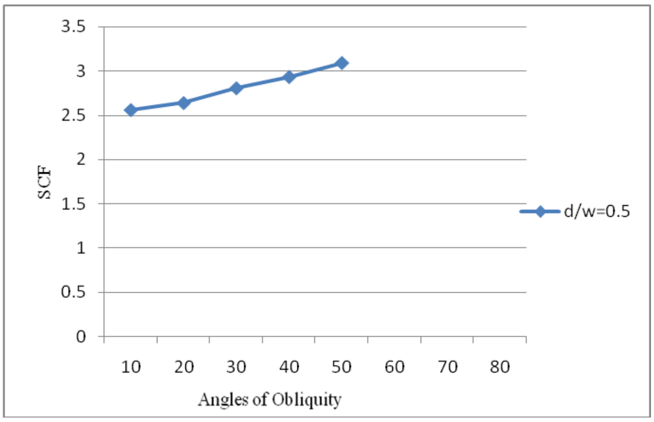

Figure 11: scf Vs Angles of Obliquity for d/w=0.5

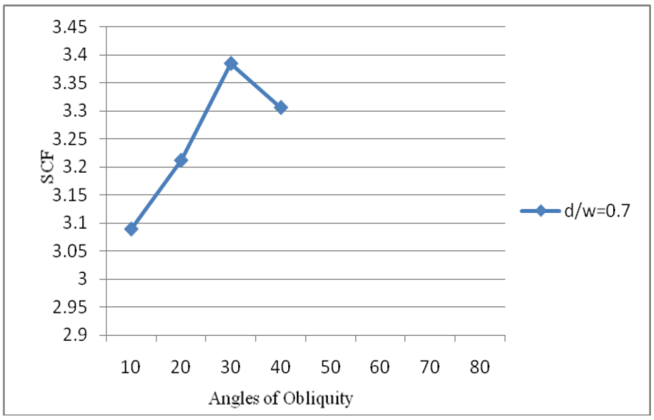

Figure 12: scf Vs Angles of Obliquity for d/w=0.7

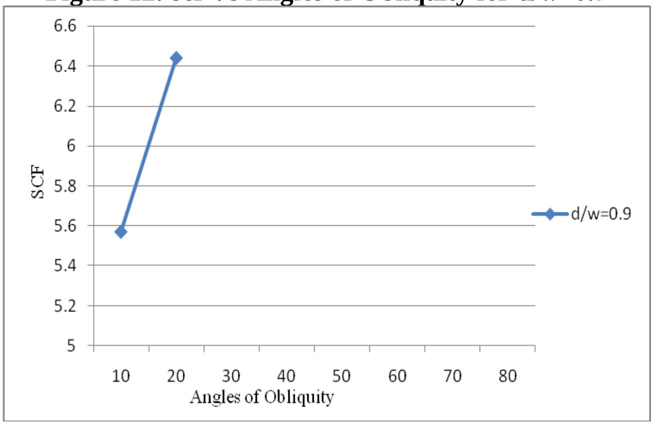

Figure 13: scf Vs Angles of Obliquity for d/w=0.9

B. Evaluation of stress concentration factor for lengthwise obliquity of hole

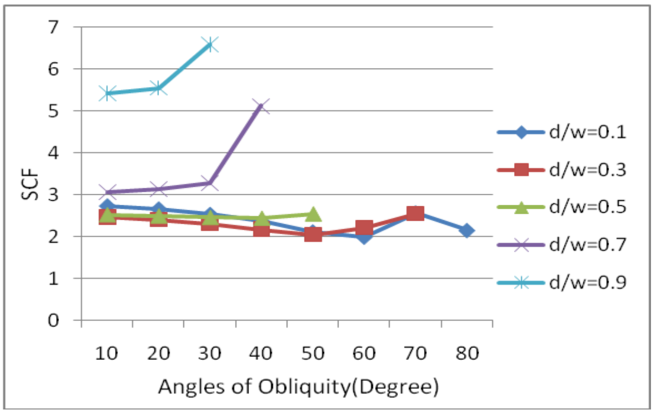

Figure 14: scf Vs Angles of Obliquity for different d/w

C. Evaluation of stress concentration factor for diagonalwise obliquity of hole

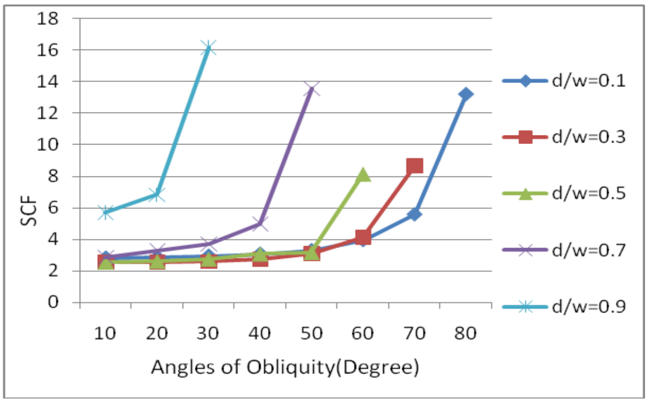

Figure 15: scf Vs Angles of Obliquity for different d/w

D. Evaluation of stress concentration factor for 30^0 direction obliquity of hole

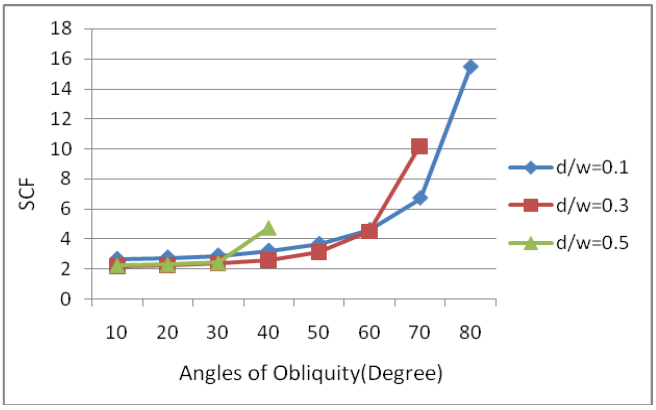

Figure 16: scf Vs Angles of Obliquity for different d/w

E. Evaluation of stress concentration factor for 60^0 direction obliquity of hole

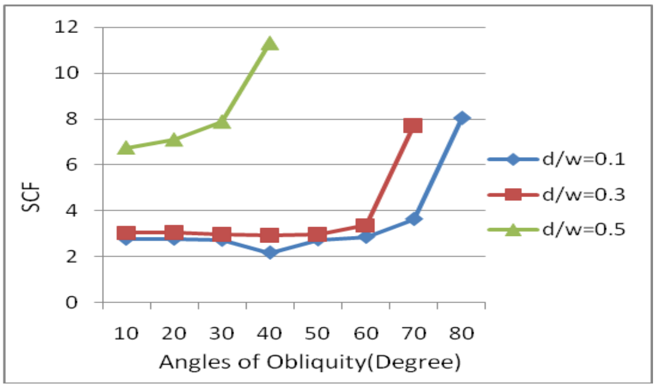

Figure 17: scf Vs Angles of Obliquity for different d/w

VI. DISCUSSION AND CONCLUSION

Though the detailed results are presented in earlier chapters, here the detailed discussions and conclusions are presented as follows.

1. The experimental work of H. W. McKENZIE AND D. J. WHITE is restricted to four angles of obliquity of the hole. Furthermore, the experimental results obtained apply only to plates with a ratio of hole diameter *d* to plate width *w* of 0.1.

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In the present work, a ratio of hole diameter *d* to plate width *w* increased from 0.1 to 0.9, and obliquity of the hole is also increased from 10^0 to 80^0. Further obliquity of hole has been considered in widthwise, lengthwise, diagonal wise direction, 30^odirection and 60^o direction.

2. A series of thick flat plates with oblique holes under axial tension is analysed using the finite element method. For the axial loading case, the stress concentration factors are compared with results obtained by the experimental photoelastic technique, as shown in Table 2, table3 and Figure 7. For the *scf* values the differences between the FE results and experimental results are within 5%, which showed good agreement. Models with holes at large angles of obliquity required large numbers of elements in order to achieve reliable results, but such numbers of elements were beyond the limitations on computer time and space. For ø= 60° to 80^0, for example, the accuracy of FE results is very poor and the differences between the FE results and experimental results are observed about 25% to35%.
3. Figure 2 show the stress distribution around the hole for ø= 0^0. It is seen from figure that maximum stress is equally distributed along the thickness the hole.
4. Figure 3 shows the stress distribution around hole for angle of obliquity ø=30^0. It is seen that the maximum stress is concentrated towards the one of the edge of hole. From figure 4, 5, 6, it is seen that maximum stress increases with increasing obliquity of hole.
5. Figure 9 to 13 shows that scf plotted against the obliquity of the hole, for widthwise obliquity of hole, From these figs it is observed that scf increases with increasing obliquity of hole, with some exceptions.
6. Figure 14 show that scf plotted against the obliquity of the hole for length wise obliquity of hole. It is observed from these figures that scf deceases with increasing obliquity of hole upto d/w=0.5 but, after that scf increases with increasing obliquity of hole.
7. It is seen from figures 15, 16, 17 that scf increases with increasing the obliquity of hole, when obliquity of hole taken in diagonal wise direction, 30^0 direction and 60^0 direction.

The stress concentration factor evaluated for oblique holes for various condition of obliquity will be use-full for designer to estimate the maximum stress in a plate with oblique holes.

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