International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-8 Issue-3, September 2019

Measurement of Stress Concentration Factor for Shoulder Fillet on Flat Plate under Axial Tension using Photoelasticity Method and FEA

Bhavesh Patel, Hiren Prajapati

Abstract: *Many researchers have made attempt to investigate stress concentration factor (SCF) for different discontinuities under different loading conditions and applications, but still failures of components take place which having discontinuities. Number of applications under which the components or parts working under tensile loading. Here, efforts are made to investigate the SCF of flat plate with shoulder fillet under axial tension loading using the approach of Photoelasticity for different D/d ratios. The Finite Element Analysis (FEA) approach used to validate the results of experimentation and found that the results are reasonably at acceptable level. One can utilize the outcome of this research for similar application having same discontinuity and loading condition.*

Keywords: *Axial tension, Finite element of analysis (FEA), Photoelasticity, Stress concentration factor (SCF),*

Nomenclature:

D = Height of largest end of the plate
d = Height of smallest end of the plate
P = Applied load
r = Fillet radius
h = Fillet height
b = Width of the plate
t = Thickness of the plate
σ_0 *= Nominal stress*
σ_{max} *= Maximum stress*
k_t *= Stress concentration factor (SCF)*
N = Fringe order
f_σ *= Material fringe value*

I. INTRODUCTION

The geometric discontinuities such as notches, various grooves (U, V, Square) shoulders fillets, keyway, holes, threads etc. on flat bars (plates) are unavoidable features due to their functional requirement. These geometric discontinuities will cause significant stress concentrations. Therefore, the estimation of stresses and strains at these geometries is essential and useful in the designing of a component or a structures. In lots of mechanical design textbooks, the stress concentration factors (SCFs) for the step shoulders with different fillets on plates are fully explained and sets of stress concentration factor (SCF) curves are presented [1]. Augusto et al. [2] were developed number of techniques to determine the SCF i.e. analytical methods, experimental methods and computational methods. Fillets are widely used in mechanical parts to provide smooth transition in regions where there is an abrupt change in cross-section like in shoulders. Fig. 1 shows flat plate with shoulder fillet.

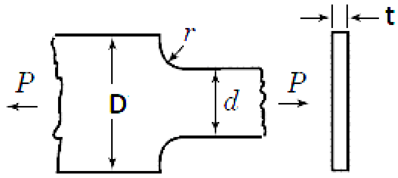

Fig. 1. Flat plate with shoulder fillet

Stress concentration factor is the ratio of the maximum stress (σ_{max}) to the nominal stress (σ_0).

$$k_t = \frac{\sigma_{max}}{\sigma_0} \quad (1)$$

Where, σ_0 = Nominal stress and it is equal to $\frac{P}{bt}$ for thick plate and $\frac{4P}{\pi d^2}$ for round bar under axial loading.

Photoelasticity technique is an optical method for measurement and experimental analysis of material stress [3]. It is a non-destructive, whole-field, graphic stress-analysis technique used based on an opto-mechanical property called birefringence, possessed by many transparent non crystalline materials. Such materials become anisotropic when it is loaded and behaves like crystals and become isotropic when free from the applied loading. Such phenomenon is known as Stress Optic law. When a photo elastic material is strained under load and viewed under polarized light, beautifully colored pattern can be observed. This colored pattern provides information on stress-state of the strained material. This method of measuring SCF is an important part of engineering mechanics for experiment technique in research as well as teaching in institutions of higher learning. This method works as significant tool for finding the stresses of any complicated shape of geometries and in turns, stress concentration factor. A considerable amount of time can be saved in the Photoelasticity method of experimental work if prior knowledge of critical areas or smart guess work is applied [4].

A. Polariscope

An optical setup polariscope, under loading allows the birefringence in the work piece to be analyzed.

Manuscript published on 30 September 2019
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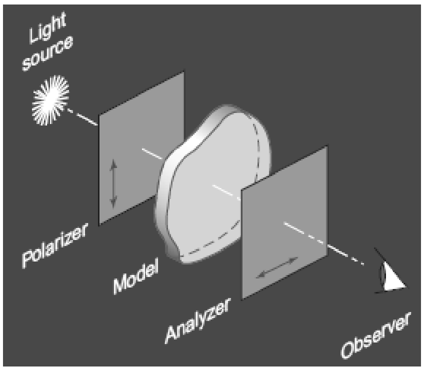
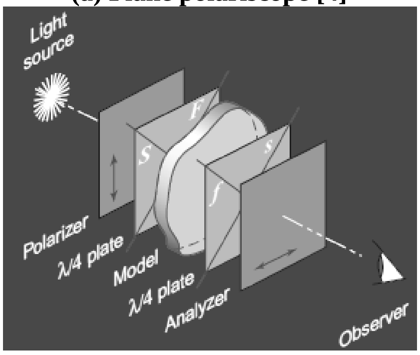
Polariscope consists of light source, a polarizer, an optional quarter-wave plate, a model work piece, another optional quarter-wave plate, and a second polarizer called the analyzer. Based on the arrangement of quarter wave plates, two types of polariscope are commonly in used. First one is the plane polariscope and the second one is circular polariscope. Plane polariscope consists a light source, a linear polarizer (called as polarizer), the model work piece and second linear polarizer (called as analyzer). An analyzer is always perpendicular with respect to the polarizer. Circular polariscope consists of a light source, a linear polarizer, a quarter wave plate, the model work piece, a second quarter wave plate and second polarizer. Fig. 2 (a) and (b) shows plane polariscope and circular polariscope respectively [4].



(a) Plane polariscope [4]

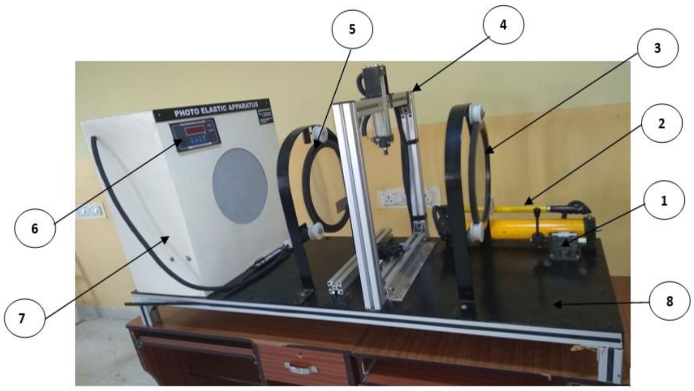


(b) Circular polariscope [4]

Fig. 2. Different arrangement of polariscope [4]

II. EXPERIMENTAL SET UP AND MATERIAL SELECTION

In this paper an attempt is made to determine the SCF of the shoulder fillet on the flat plate by Photoelasticity method under axial tension. Fig. 3 shows image of photo elastic apparatus which is used to perform experimental work. This setup was made with the help of Aeolus Aerotech Pvt. Ltd, Bangalore. This experimental unit is designed to illustrate the behavior of materials versus the forces that act on them. The stress pattern can be observed and stress concentration factor calculated by applying forces and/or stresses on specimens with the photo elasticity theory.



1. One directional valve, 2. Hydraulic pump, 3. Circular polariscope, 4. Mechanical load frame 5. Circular analyzer, 6. Digital load indicator, 7. Monochromatic light source, white light source 8. Leveling table

Fig. 3 Experimental setup - Photo elasticity apparatus

This photo elasticity unit consists of:

- Circular polariscope and analyzer,
- Monochromatic light source,
- Rotatable analyzer with angle measurements,
- Monochromatic light source
- White light source
- Mechanical load frame with load capacity of 1 kN with digital load indicator (Tension and compression),
- Bending loading and torsion loading provision

A. Materials for experimental work

Many polymers exhibit sufficient birefringence to be used as photo elastic specimen material. Some of the most common model material for Photoelasticity experiment with their properties are tabulated in the Table 1. For experimental work on plate, three different thickness (4 mm, 6 mm and 8 mm) of acrylic material is used as work piece material. Acrylic material is easily available in the markets and also it is cheaper as compared to other photo elastic materials. Specification of acrylic material is listed in Table 1. Acrylic is cut in to require shape of shoulder fillet by acrylic laser cutting machine. Seven samples of 110 mm length are cut from each thick sheet with different D/d ratios for photo elastic experiment under axial tension loading.

Fig. 4 shows the 2D diagram of the slice model with D/d = 2, having larger width D = 40 mm and smaller width d = 20 mm.

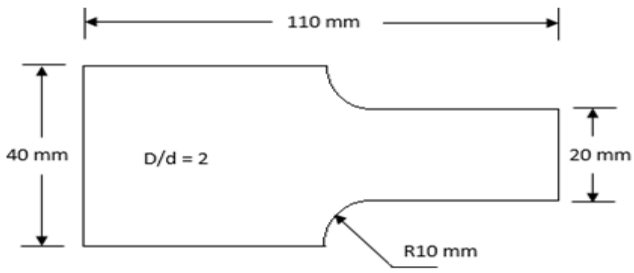


Fig. 4. 2D diagram of a slice model (flat plate) with D/d =2

Table 1 Properties of photo elastic model materials [5]

Material	Generic type and Generic names	Stress fringe value, fσ (green light λ = 546 nm)	Room temperature properties		
		Fringe (KN/m)	Young modulus E (MPa)	Proportional limit (MPa)	Poisson's ratio
Glass	---	-300 to +400	70,000	60	0.25
Plexiglas	Polymethyl methacrylate	129	2800	---	0.38
Celluloid		30 – 300	2200	35	0.33
Homolite 100	Polyester	24	3900	7	0.35
Epoxy	Araldite, Bakelite	11	3300	8	0.37
Polycarbonate	Makrolon PSM 1	7	2600	5	0.28
Acrylic	---	27	3000	---	0.30

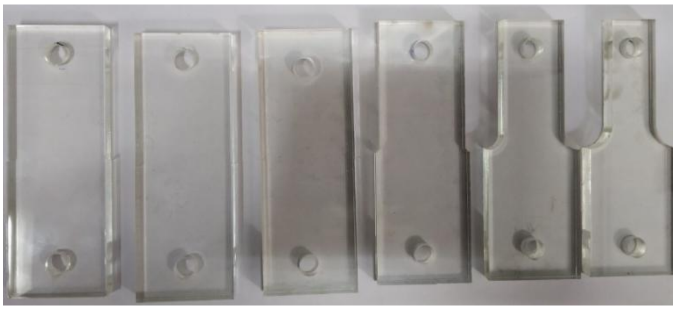


Fig. 5. Sample of acrylic after machining

Fig. 5 shows test specimen of acrylic material for experimental work after laser cutting.

III. EXPERIMENTAL WORK AND EVALUATION METHOD OF SCF

In the experimental setup, provision is made to apply different loads i.e. tensile, bending and torsisonal loading. For experiment work, workpiece to be held in such a way that the tension loading can apply. Fig. 6 (a) shows photoelastic apparatus which was used for the experiment work on acrylic material under axial tension loading. Fig. 6 (b) shows the test specimen position for axial tension loading.

(a)

(b)

Fig. 6. (a) Photoelastic experimental setup (b) Test specimen position

For optimum condition of (h = r), seven experiments of different D/d ratios are performed [6]. SCF is the ratio of maximum stress at the fillet region to the nominal stress computed by flexure formulas of that particular geometries. So, the SCF can be written as:

$$k_t = \frac{\sigma_{max}}{\sigma_0} \tag{2}$$

Where,

σ_{max} = Maximum stress at the fillet on the plate and is to be occurring in the test specimen during experiments and is to be evaluated by formula derived from stress optic law theory for Photoelasticity method.

$(\sigma_1 - \sigma_2) = \sigma_{max} = \frac{N f_\sigma}{t}$, σ_2 is zero as uniaxial directional loading and nominal stress [7].

$\sigma_0 = \frac{P}{bt}$ for thick plate under axial tension

N = Fringe order

f_σ = Material fringe value in kN/m and it depends on the wavelength of the light

t = Thickness of the plate in mm

Fig. 7 to 9 shows the images captured during photoelastic experimental work on 4 mm, 6 mm and 8 mm thick plates.

Retrieval Number: C5349098319/19©BEIESP
DOI:10.35940/ijrte.C5349.098319
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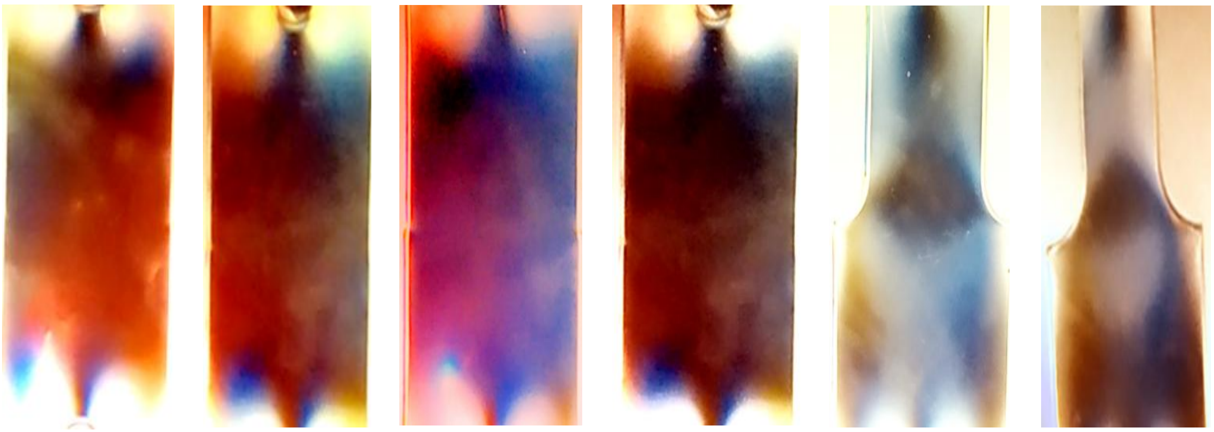
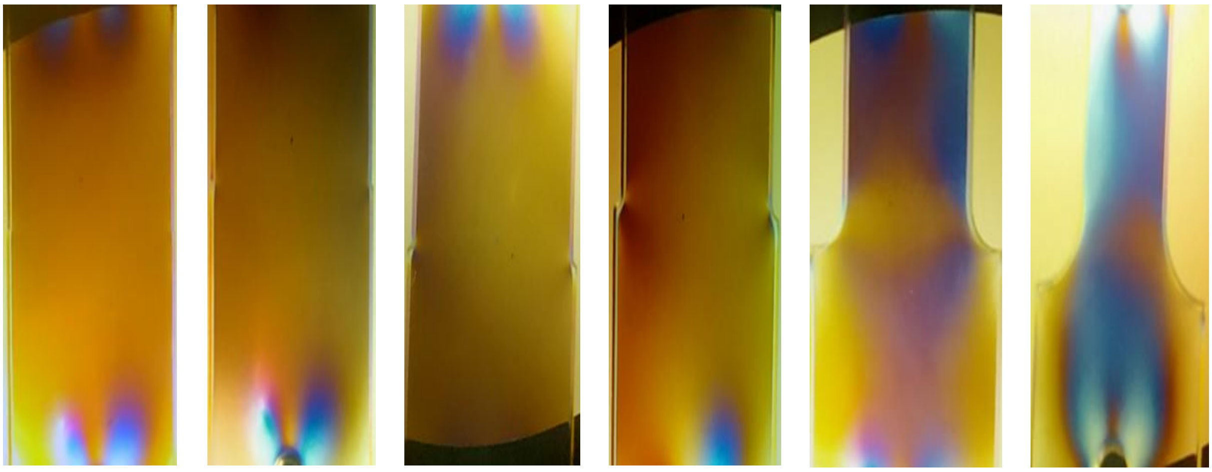


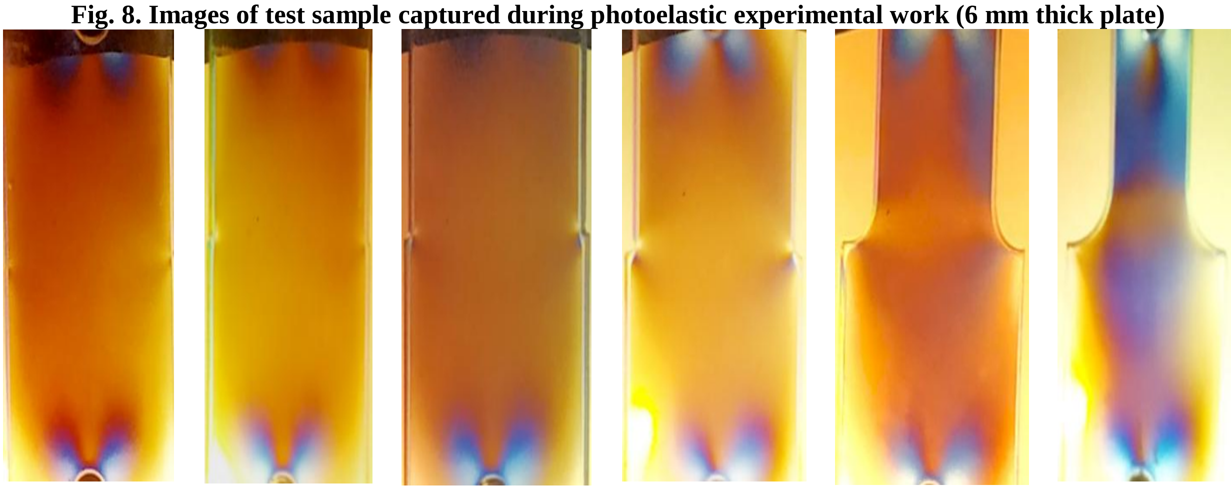
(a) D/d = 1.01 | (b) D/d = 1.02 | (c) D/d = 1.05 | (d) D/d = 1.1 | (e) D/d = 1.5 | (f) D/d = 2

Fig. 7. Images of test sample captured during photoelastic experimental work (4 mm thick plate)



(a) D/d = 1.01 | (b) D/d = 1.02 | (c) D/d = 1.05 | (d) D/d = 1.1 | (e) D/d = 1.5 | (f) D/d = 2

Fig. 8. Images of test sample captured during photoelastic experimental work (6 mm thick plate)



(a) D/d = 1.01 | (b) D/d = 1.02 | (c) D/d = 1.05 | (d) D/d = 1.1 | (e) D/d = 1.5 | (f) D/d = 2

Fig. 9. Images of test sample captured during photoelastic experimental work (8 mm thick plate)

Table 2 to 4 shows the results of photoelastic experimental work for 4 mm, 6 mm and 8 mm thick plates under axial tension loading. In the table 2, seven results of each for FEA and experimental work are tabulated for different D/d ratios. During the experiments, test specimen having D/d =3, is broken from the smaller end as it losses it strength because of reduction in cross sectional area. So results of this D/d = 3 is not achieved.

Table 2 Results of photo elastic experimental work of 4 mm thick plate

D (mm)	d (mm)	D/d	h (mm)	r (mm)	Load P (N)	C/S area A (mm^2)	Ave. stress (MPa)	Fringe No. (N)	Stress fringe value, (f_σ)	Max. stress (MPa)	SCF (K)
40	39.6	1.01	0.20	0.20	1000	31.09	6.313	1.62	27	10.94	1.73
40	39.21	1.02	0.40	0.40	1000	30.78	6.376	1.62	27	10.94	1.72
40	38.095	1.05	0.95	0.95	1000	29.90	6.563	1.06	27	7.16	1.09
40	36.36	1.10	1.82	1.82	1000	28.54	6.876	1.81	27	12.22	1.78
40	26.67	1.50	6.67	6.67	1000	20.94	9.035	1.2	27	8.10	0.86
40	20	2.00	10	10	1000	15.70	12.500	2.5	27	16.88	1.35
40	13.33	3.00	13.34	13.34	1000	10.46	18.755	---	27	0.00	0.00

Table 3 Results of photo elastic experimental work of 6 mm thick plate

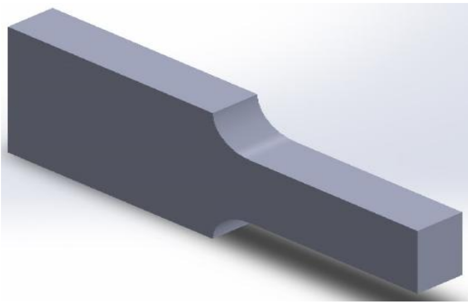
D (mm)	d (mm)	D/d	h (mm)	r (mm)	Load P (N)	C/S area A (mm^2)	Ave. stress (MPa)	Fringe No. (N)	Stress fringe value, (f_σ)	Max. stress (MPa)	SCF (K)
40	39.6	1.01	0.20	0.20	1000	31.09	6.313	2.5	27	11.25	2.67
40	39.21	1.02	0.40	0.40	1000	30.78	6.376	1.38	27	6.21	1.46
40	38.095	1.05	0.95	0.95	1000	29.90	6.563	1.38	27	6.21	1.42
40	36.36	1.10	1.82	1.82	1000	28.54	6.876	1.2	27	5.40	1.18
40	26.67	1.50	6.67	6.67	1000	20.94	9.035	2.67	27	12.02	1.92
40	20	2.00	10	10	1000	15.70	12.500	3	27	13.50	1.62
40	13.33	3.00	13.34	13.34	1000	10.46	18.755	--	27	--	--

Table 4 Results of photo elastic experimental work of 8 mm thick plate

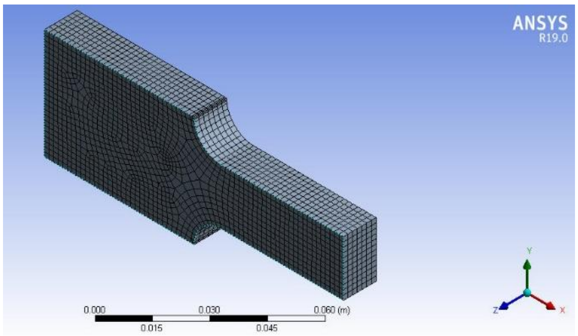
D (mm)	d (mm)	D/d	h (mm)	r (mm)	Load P (N)	C/S area A (mm^2)	Ave. stress (MPa)	Fringe No. (N)	Stress fringe value, (f_σ)	Max. stress (MPa)	SCF (K)
40	39.6	1.01	0.20	0.20	1000	31.09	6.313	2.67	27	9.01	2.85
40	39.21	1.02	0.40	0.40	1000	30.78	6.376	1.38	27	4.66	1.46
40	38.095	1.05	0.95	0.95	1000	29.90	6.563	1.38	27	4.66	1.42
40	36.36	1.10	1.82	1.82	1000	28.54	6.876	2.5	27	8.44	2.45
40	26.67	1.50	6.67	6.67	1000	20.94	9.035	2.5	27	8.44	1.80
40	20	2.00	10	10	1000	15.70	12.500	2.5	27	8.44	1.35
40	13.33	3.00	13.34	13.34	1000	10.46	18.755	--	27	--	--

IV. FINITE ELEMENT ANALYSIS

Computational results of various geometries of the flat plat for different D/d ratios are analyzed by finite elements of analysis (FEA). For all the seven geometries of flat plate are modelled in the Solid works 16.0 [8]. ANSYS workbench 19.0 is used for the FEA of all the geometries [9]. Fig. 10 (a) shows the 3D model of the flat plate with D/d = 2.



(a) 3D model of plates



(b) Meshed model of flat plate
Fig. 10 Flat plate model for FEA

EN31 was modelled as a linear elastic material as it is widely used in various industries for making plates and shafts.

Table 5 shows the material properties of EN31. The flat plate was fine meshed with an average value of the mesh size is 0.05 mm (fine size), resulting in 38355 nodes and 8190 elements. The meshed flat plate with dimensions of D = 40 mm, d = 20 mm (D/d = 2) and fillet radius as 10 mm is shown in the Fig. 10 (b).

Table 5 Material properties of EN31 [9]

Property	Value	Unit
Density	7600	Kg/m^3
Isotropic properties		
Young's modulus	207	MPa
Poisson's ratio	0.3	--
Bulk modulus	172.5	GPa
Shear modulus	80	GPa
Tensile Yield strength	460	MPa
Tensile Ultimate strength	560	MPa

As shown in Fig. 11, axial tension load is applied to one end face of the flat plate and other face of the plate is fixed. Equivalent (von Mises) stress is calculated from the FEA results for all the test samples.

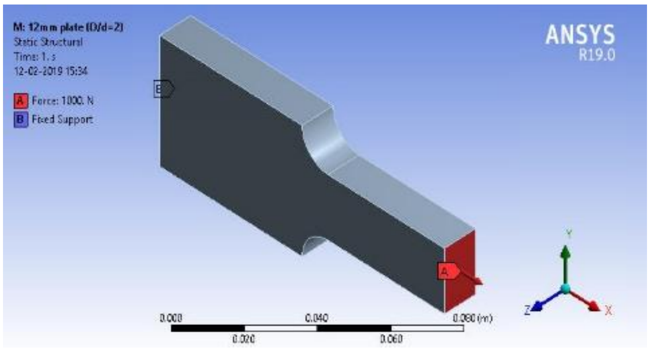
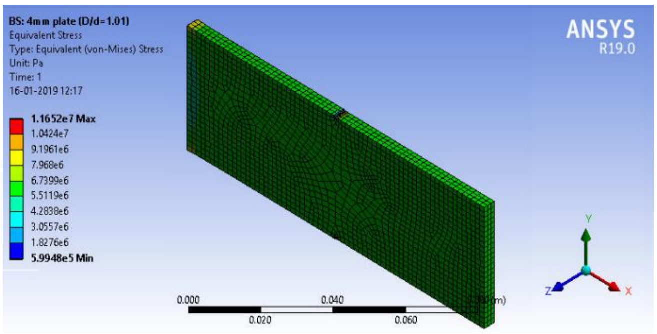
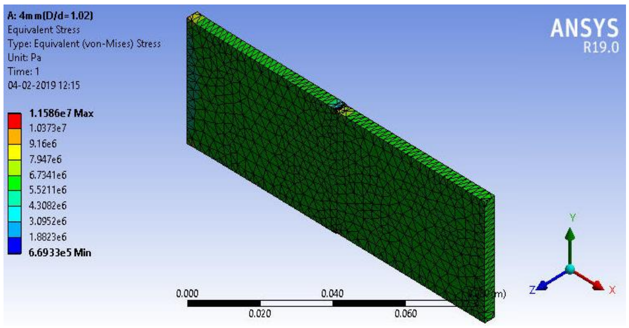


Fig. 11 Loading and boundary conditions for axial tension loading

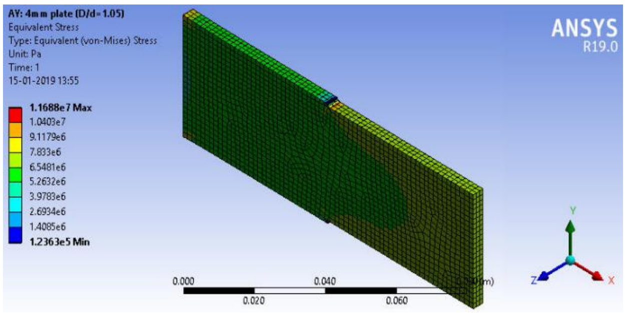
Here, for analysis purpose, the applied load is considered constant as 1000 N for all iterations with different D/d ratios. The selected value of load is considered based on feasible load range applied through experimental set up and same load applied during experimentations. Fig. 12 (a) to (g) shows various flat plate models having 4 mm thickness for different D/d ratios under axial tension loading.



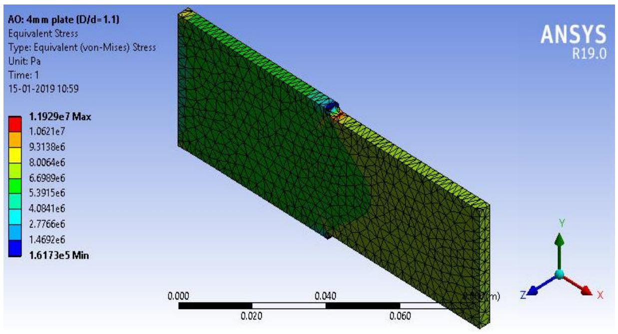
(a) D/d = 1.01 (D = 40 mm and d = 39.60 mm)



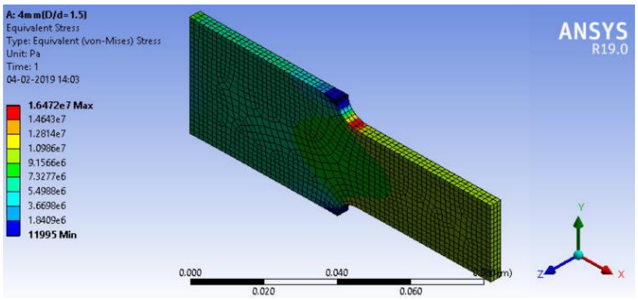
(b) D/d =1.02 (D = 40 mm and d = 39.21 mm)



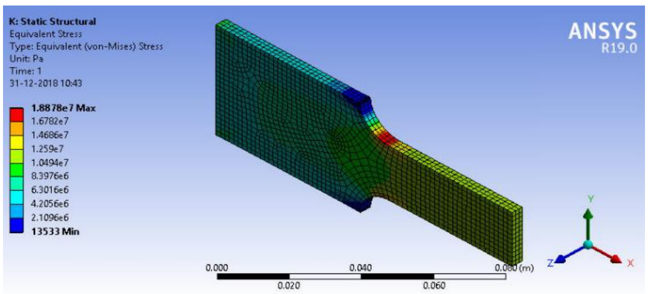
(c) D/d = 1.05 (D = 40 mm and d = 38.095 mm)



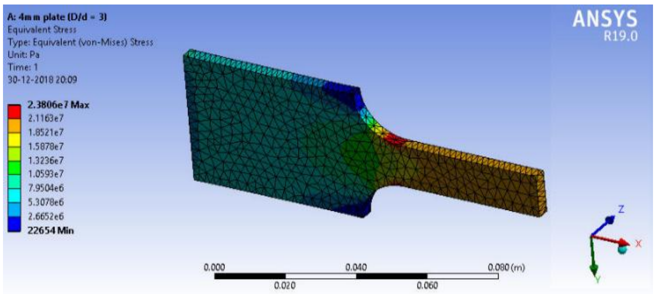
(d) D/d = 1.1 (D = 40 mm and d = 36.36 mm)



(e) D/d = 1.5 (D = 40 mm and d = 26.67 mm)



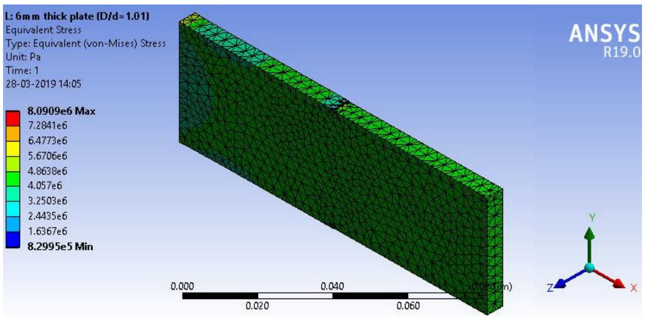
(f) D/d =2 (D = 40 mm and d = 20 mm)



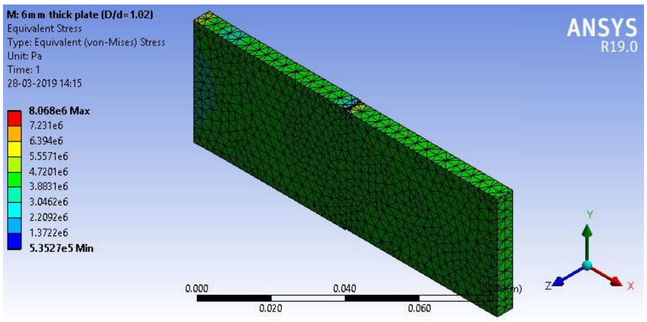
(g) D/d =3 (D= 40 mm and d= 13.33 mm)

Fig. 12 Equivalent (von-Mises) stress for 4 mm thick plates

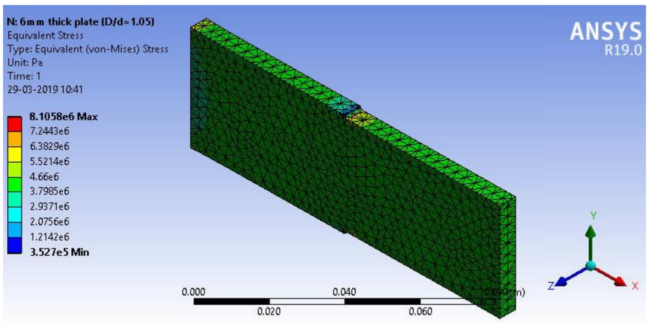
Similarly, Fig. 13 (a) to (g) shows various flat plate models having 6 mm thickness for different D/d ratios under axial tension loading.



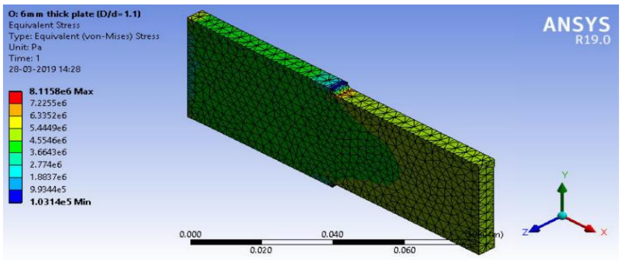
(a) D/d = 1.01 (D = 40 mm and d = 39.60 mm)



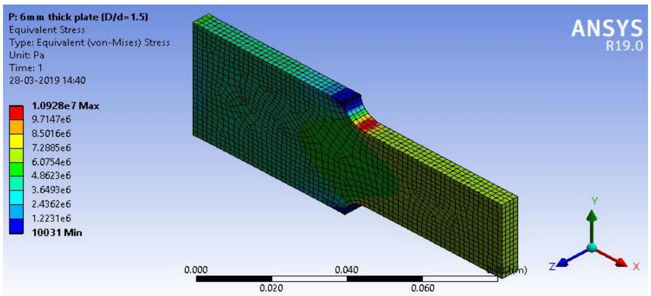
(b) D/d =1.02 (D = 40 mm and d = 39.21 mm)



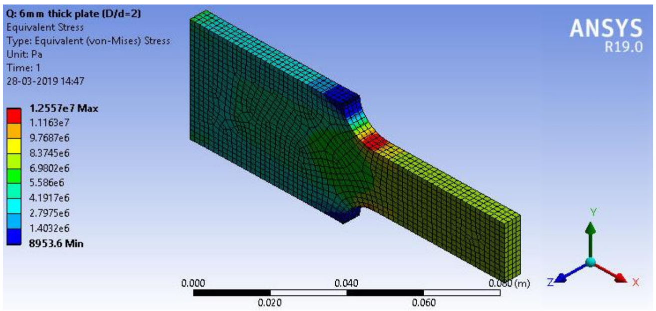
(c) D/d = 1.05 (D = 40 mm and d = 38.095 mm)



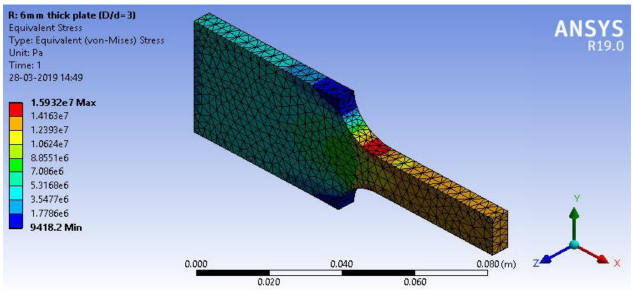
(d) D/d = 1.1(D = 40 mm and d = 36.36 mm)



(e) D/d = 1.5 (D = 40 mm and d = 26.67 mm)



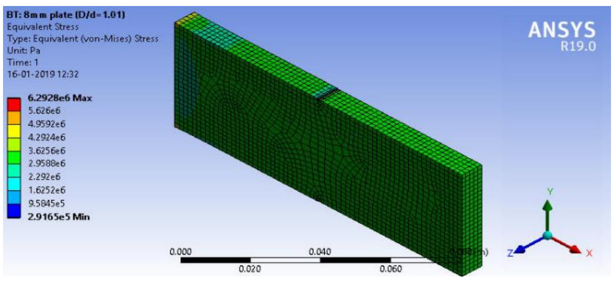
(f) D/d =2 (D = 40 mm and d = 20 mm)



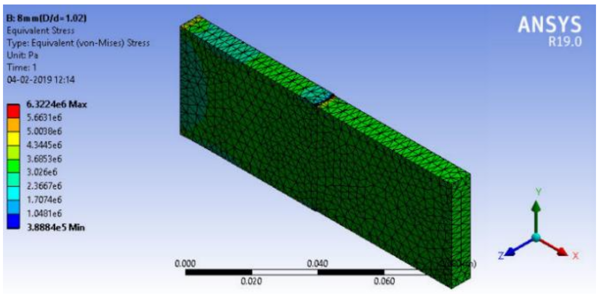
(g) D/d =3 (D= 40 mm and d= 13.33 mm)

Fig. 13 Equivalent (von-Mises) stress for 6 mm thick plates

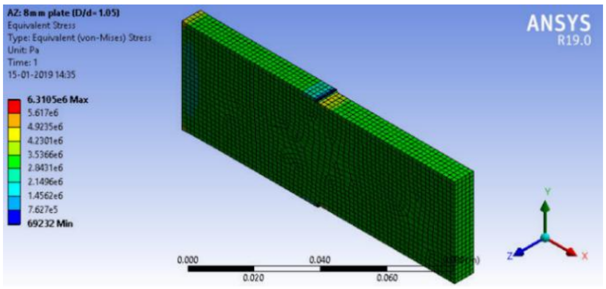
Similarly, Fig. 14 (a) to (g) shows various flat plate models having 8 mm thickness for different D/d ratios.



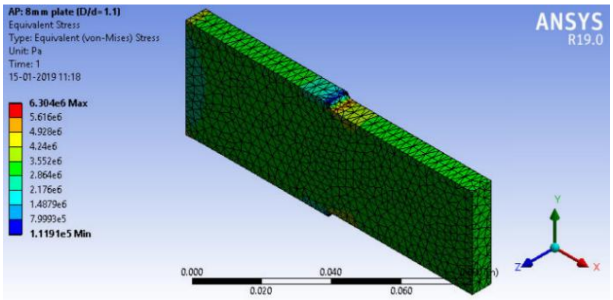
(a) D/d = 1.01 (D = 40 mm and d = 39.60 mm)



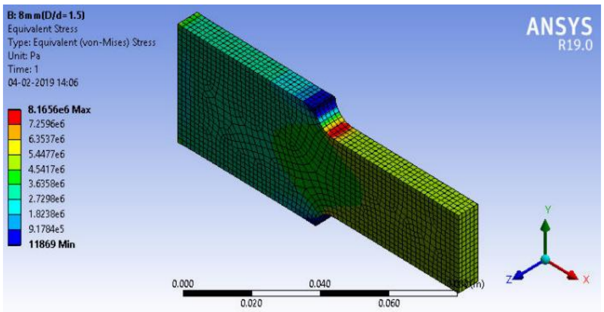
(b) D/d =1.02 (D = 40 mm and d = 39.21 mm)



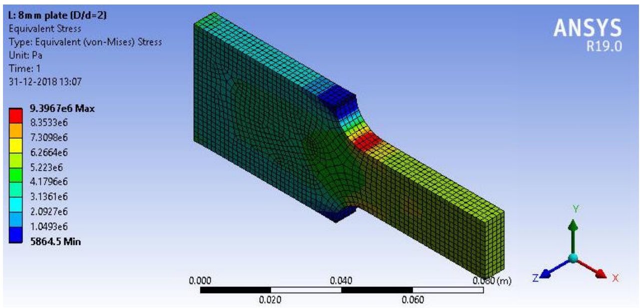
(c) D/d = 1.05 (D = 40 mm and d = 38.095 mm)



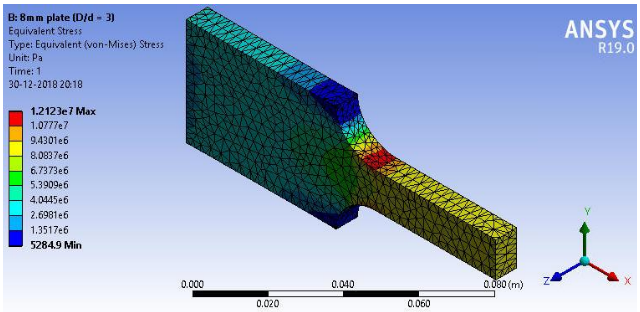
(d) D/d = 1.1 (D = 40 mm and d = 36.36 mm)



(e) D/d = 1.5 (D = 40 mm and d = 26.67 mm



(f) D/d =2 (D = 40 mm and d = 20 mm)



(g) D/d =3 (D= 40 mm and d= 13.33 mm)

Fig. 14 Equivalent (von Mises) stress for 8mm thick plates

From the above simulated results, equivalent (von Mises) stress of shoulder fillet of the flat plates are identified and used it for calculation of stress concentration factor (SCF). Table 6 to 8 shows the various parameters taken for flat plate geometries and FEA results for 4 mm, 6 mm and 8 mm plates respectively.

Table 6 SCF based on equivalent (von-Mises) stress under axial tension loading for flat plate (4 mm) for different D/d ratios

D (mm)	d (mm)	D/d	h (mm)	r (mm)	Thickness t (mm)	Load P (N)	Nominal stress (MPa)	Equivalent (von-Mises) stress (MPa)	SCF (K)
40	39.6	1.01	0.20	0.20	4.0	1000	6.313	11.652	1.846
40	39.21	1.02	0.40	0.40	4.0	1000	6.376	11.586	1.817
40	38.095	1.05	0.95	0.95	4.0	1000	6.563	11.688	1.781
40	36.36	1.10	1.82	1.82	4.0	1000	6.876	11.929	1.735
40	26.67	1.50	6.67	6.67	4.0	1000	9.374	16.472	1.757
40	20	2.00	10	10.00	4.0	1000	12.500	18.878	1.510
40	13.33	3.00	13.34	13.34	4.0	1000	18.755	23.806	1.269

Table 7 SCF based on equivalent (von-Mises) stress under axial tension loading for flat plate (6 mm) for different D/d ratios

D (mm)	d (mm)	D/d	h (mm)	r (mm)	Thickness t (mm)	Load P (N)	Nominal stress (MPa)	Equivalent (von-Mises) stress (MPa)	SCF (K)
40	39.6	1.01	0.20	0.20	6.0	1000	4.209	8.0909	1.922
40	39.21	1.02	0.40	0.40	6.0	1000	4.251	8.068	1.898
40	38.095	1.05	0.95	0.95	6.0	1000	4.375	8.1058	1.853
40	36.36	1.10	1.82	1.82	6.0	1000	4.584	8.1158	1.771
40	26.67	1.50	6.67	6.67	6.0	1000	6.249	10.928	1.749
40	20	2.00	10	10.00	6.0	1000	8.333	12.557	1.507
40	13.33	3.00	13.34	13.34	6.0	1000	12.503	15.932	1.274

Table 8 SCF based on equivalent (von-Mises) stress under axial tension loading for flat plate (8 mm) for different D/d ratios

D (mm)	d (mm)	D/d	h (mm)	r (mm)	Thickness t (mm)	Load P (N)	Nominal stress (MPa)	Equivalent (von-Mises) stress (MPa)	SCF (K)
40	39.6	1.01	0.20	0.20	4.0	1000	3.157	6.2928	1.994
40	39.21	1.02	0.40	0.40	4.0	1000	3.188	6.3224	1.983
40	38.095	1.05	0.95	0.95	4.0	1000	3.281	6.31	1.923
40	36.36	1.10	1.82	1.82	4.0	1000	3.438	6.304	1.834
40	26.67	1.50	6.67	6.67	4.0	1000	4.687	8.1656	1.742
40	20	2.00	10	10.00	4.0	1000	6.250	9.3967	1.503
40	13.33	3.00	13.34	13.34	4.0	1000	9.377	12.123	1.293

These computational results based on finite element of analysis (FEA) are compared and validated by experimental results of photo elasticity method.

V.RESULTS AND DISCUSSION

Table 9 to 11 shows the comparison of SCFs based on photo elasticity experiment and SCFs by FEA for different thickness of plates (4 mm, 6 mm and 8 mm).

Table 9 Comparison of SCFs obtained by photoelasticity experimental work and FEA for flat plate with shoulder fillet (4 mm thickness)

D (mm)	d (mm)	D/d	h (mm)	r (mm)	SCF (K_t) from experiment	SCF (K_t) by FEA
40	39.6	1.01	0.20	0.20	1.73	1.846
40	39.21	1.02	0.40	0.40	1.72	1.817
40	38.095	1.05	0.95	0.95	1.09	1.781
40	36.36	1.10	1.82	1.82	1.78	1.735
40	26.67	1.50	6.67	6.67	0.86	1.757
40	20	2.00	10	10	1.35	1.510
40	13.33	3.00	13.34	13.34	0.00	1.269

Table 10 Comparison of SCFs obtained by photoelasticity experimental work and FEA for flat plate with shoulder fillet (6 mm thick plate)

D (mm)	d (mm)	D/d	h (mm)	r (mm)	SCF (K_t) from experiment	SCF (K_t) by FEA
40	39.6	1.01	0.20	0.20	1.73	1.922
40	39.21	1.02	0.40	0.40	1.72	1.898
40	38.095	1.05	0.95	0.95	1.09	1.853
40	36.36	1.10	1.82	1.82	1.78	1.771
40	26.67	1.50	6.67	6.67	0.86	1.749
40	20	2.00	10	10	1.35	1.742
40	13.33	3.00	13.34	13.34	0.00	1.269

Table 11 Comparison of SCFs obtained by photoelasticity experimental work and FEA for flat plate with shoulder fillet (8 mm thick plate)

D (mm)	d (mm)	D/d	h (mm)	r (mm)	SCF (K_t) from experiment	SCF (K_t) by FEA
40	39.6	1.01	0.20	0.20	1.73	1.994
40	39.21	1.02	0.40	0.40	1.72	1.983
40	38.095	1.05	0.95	0.95	1.09	1.923
40	36.36	1.10	1.82	1.82	1.78	1.834
40	26.67	1.50	6.67	6.67	0.86	1.742
40	20	2.00	10	10	1.35	1.503
40	13.33	3.00	13.34	13.34	0.00	1.269

These comparisons of SCFs are also presented in the form of graph in the Fig.13 to 15.

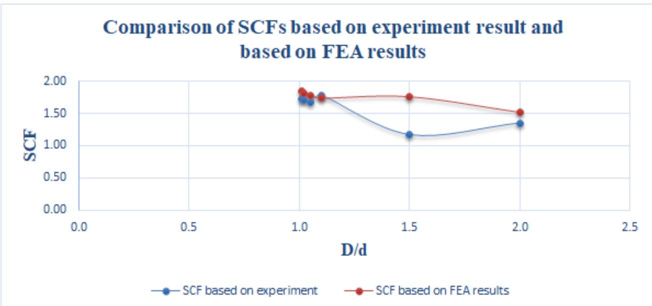


Fig. 15 Comparison of experimental SCFs and FEA SFCs (4 mm thick plate)

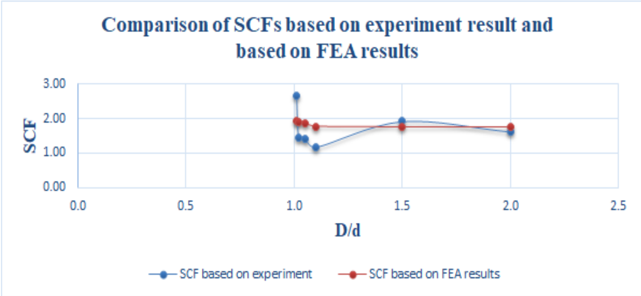


Fig. 16 Comparison of experimental SCFs and FEA SFCs (6 mm thick plate)

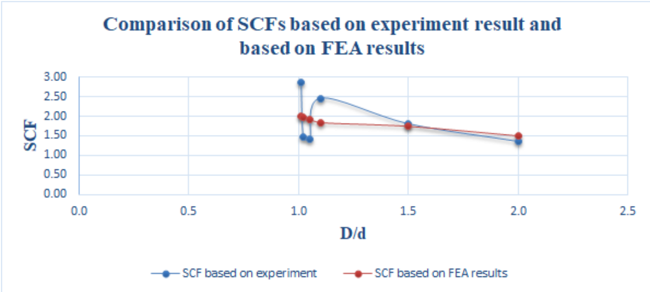


Fig. 17 Comparison of experimental SCFs and FEA SFCs (8 mm thick plate)

- **For 4 mm thickness plate**

From the table 9 and Fig. 15, it is clearly depicting that the results of SCFs from the Photoelasticity experiments have very good agreement with SCFs obtained from FEA for D/d ratio 1.01, 1.02, 1.1 and 2 but two results are deviates for D/d = 1.05 and D/d =1.5. Also for D/d = 3, experiment is not possible as during experiment, work piece is broken down from the one end (Fig.18) many times. So in the comparisons, only FEA result for D/d = 3 is shown in the Fig. 15 to 17 and in the tables 9 to 11.

Fig. 18 Broken Sample of D/d = 3

- **For 6 mm thickness plate**

From the table 10 and Fig. 16, it is clearly portraying that the results of SCFs from the Photoelasticity experiments have very good agreement with SCFs obtained from FEA for D/d ratio 1.02, 1.05, 1.5 and 2 but two results are deviates for D/d = 1.01 and D/d = 1.1.

- **For 8 mm thickness plate**

From the table 11 and Fig. 17, it is clearly depicts that the results of SCFs from the Photoelasticity experiments have good agreement with SCFs obtained from FEA for D/d ratio 1.02, 1.05, 1.5 and 2 but two results are deviates for D/d = 1.01 and D/d = 1.1.

The variations in the results for 4 mm, 6 mm and 8 mm plates may be due to human error occurred during experimental work.

VI. CONCLUSIONS

This paper addresses the investigation of stress concentration factor (SCF) by Photoelasticity method for the flat plats having three different thickness (4 mm, 6 mm and 8 mm) for different D/d ratios and its comparison by computational results obtained by FEA. The SCF in flat plate with shoulder for different D/d ratios by Photoelasticity experimental method and FEA methods are matched within difference of 10% for the D/d = 1.01, 1.02, 1.1 and 2. For D/d = 1.05 and D/d = 1.5 experimental results and FEA results are not matched. This is due to either human error and technical error that may occurred during experimental work. These results obtained by both the techniques are very useful to the industrial and engineering applications in which the SCF play an important role for shoulder fillet.

FUNDING

This research received grant from Centre for Advanced Research Studies (CARS), Ganpat University, Ganpat Vidyanagar-384012, Mehsana, Gujarat, India for the development of experimental set up.

ACKNOWLEDGMENT

The author gratefully acknowledges the constructive criticisms and suggestions and kind help given by Professor J. M. Prajapati, Associate Professor, M. S. University, Baroda, Gujarat and Professor H. P. Patolia, Associate Professor, BVM College of Engineering, V. V. Nagar, Gujarat.

DISCLOSURE STATEMENT

The authors declare that there is no conflict of interest.

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