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FE Analysis on Circular Disc under Diametrical Compression using ANSYS

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***Abstract*— Contact stress is an important analysis for several automobile components; common type of load is seen as compressive load, which plays an important role in a structural safety. In present work, circular disc is subjected to diametrical compressive load for 4, 6, 8, 10kg; compressive loads are common in contact assemblies. The contact stress are investigating using two methods, first method is using FEA package ANSYS and other method is 2D photoelasticity for contact stress analysis of circular disc under diametric compression. Finally the results are compared.**

Keywords—Circular disc; compressive load; epoxy resin with hardener material ; contact stress analysis; FEM; photoelasticity
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I. INTRODUCTION

Stress analysis is play an important role in a engineering field of applications, this analysis is the determination of the effects of loads on physical components, components subjected to this type of analysis include a different loads, such as vehicles, machinery (Automobiles and aerospace components) etc., Stress analysis is a base of the engineering design of structures.

The analysis work will be carried on circular disc is subjected to diametrical compression will be predicts contact stresses. Primarily collecting literature background (from text books) for two dimensional modeling of circular discs like geometrical parameter, material properties, boundary conditions which supported with experimental results on contact stress analysis. Two methods will be used for contact stress analysis such as initially numerical analysis using FEA package, i.e. circular disc is modeling and stress analysis will be done under compressive loads by using ANSYS software [5] [7] [8], later 2D photo Elastic Investigation using for contact stress analysis of circular disc under diametric compression [1] [2] [3] [4], finally the analysis results correlating with each other.

II. PROBLEM DEFINITION AND SCOPE OF PRESENT EXPERIMENT

A. Definition

1. In present scope of work, circular disc is subjected to diametrical compression will be predict contact stresses?
2. Two methods will be used for contact stress analysis,
    a) Numerical analysis using FEA package ANSYS
    b) 2D photo Elastic Investigation

B. Methodology

1. Collecting the literature background for circular disc form text books
2. Taking ASME standard dimensions and boundary conditions form design data hand book.
3. Initially, modeling and applying boundary conditions using ANSYS, then analyzing the two dimensional circular disc under compressive load acting at a point to know the stress distribution and deformed shape of the model using ANSYS.
4. Photoelastic method is used to analysis two dimensional circular disc behavior
    a. First fabricating araldite model.
    b. Analyzing contact stress at the point of loading by using photoelastic work bench under compressive load.
5. Finally results are compared with both ANSYS and photo-elastic valves and correlating the percentage error of both methods.

C. Assumptions

- Model is under contact stresses.
- Material is considered as elastic, homogenous and isotropic.
- Material has constant temperature before and after loading.
- Model is consider as plane state of stress.

C. Geometrical Parameters of The Problem

i. Specifications of the disc

Photo-elastic Model: Circular Disc
Material: Araldite (Epoxy Resin and Hardener)
Diameter of Disc: 60mm
Thickness of disc: 6mm

ii. Formulae used in calculations of photoelastic model [3]

Load on pan, $W = mg$ in N (1)
Length ratio, $L_R = l/l_1$ (2)
Effective load, $P = W L_R$ in N (3)
Average fringe order, $P_{AV} = (P/N)$ in N/fringe (4)

Material fringe constants, $F = (8P_{AV})/(\pi d)$ in N/mm/fringe (5)

Modular fringe constant, $f = (F/t)$ in N/mm^2/ fringe (6)

iii. Two Dimension FEM Geometrical Models And Boundary Condition.

a. Two Dimension Geometrical FEM model.

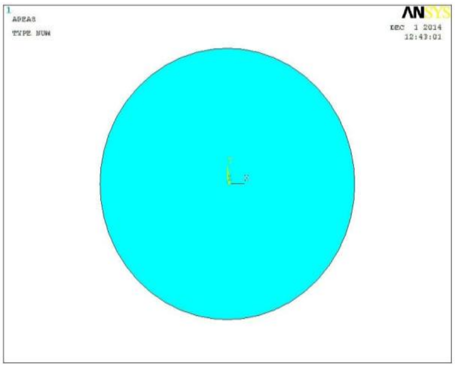

Fig. 1. 2D Model of Circular Disc

Two dimensional model of the circular disc of a 60mm diameter and 6mm thickness is as shown in fig. 1.

b. Mesh plots and Boundary conditions in FEM

i. Mesh plots

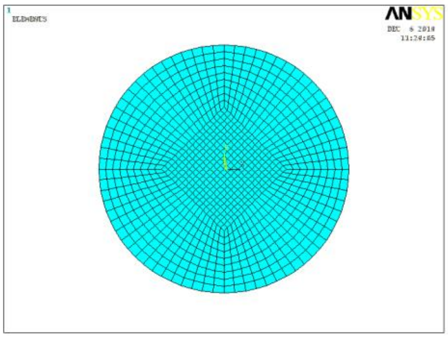

Fig. 2. Mesh Plot and Refine Model

The fig. 2. shows Mesh and Refine model of the circular disc (Mesh plot).

ii. Boundary Conditions

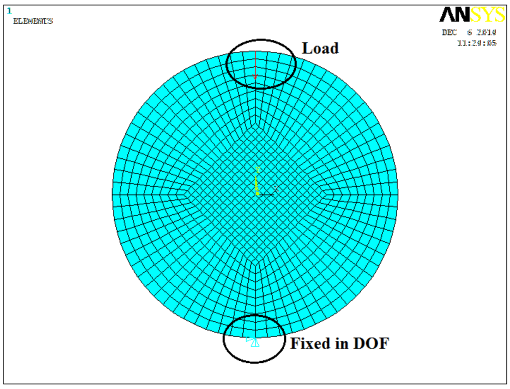

Fig. 3. Boundary Conditions

The fig. 3. shows the Boundary condition applied at a point (displacement on lower side and force on upper side) of the circular disc. Various loads are applied on upper node such as 4kg, 6kg, 8kg and 10kg.

iv Two Dimension Photoelastic Model and Boundary Conditions

a. Two Dimension Photoelastic Model.

Fig.4 Photoelastic Model of Circular Disc

Photoelastic model of the circular disc with a 6mm thickness along with a 60mm diameter dimension is as shown in fig. 4.

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b. Boundary Condition

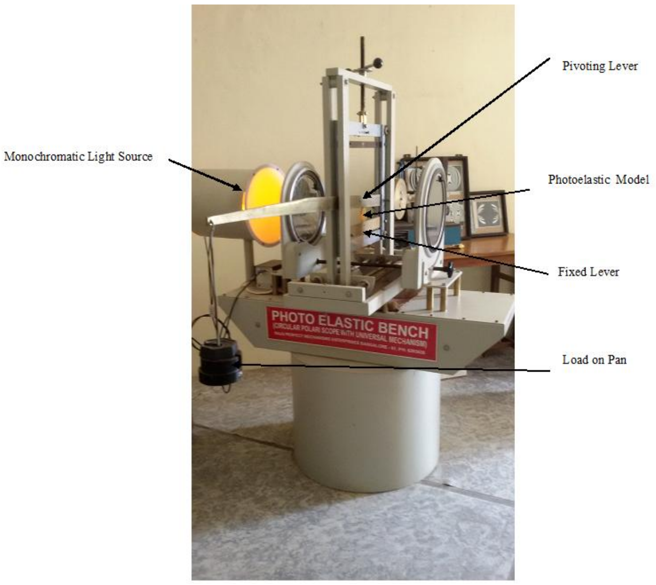

Fig. 5. Photoelstic Bench and Boundary Conditions

The fig. 5. shows the Photoelstic Bench, Boundary condition applied at a point of the circular disc by by using two levers. Various loads are applied on load pan such as 4kg, 6kg, 8kg and 10kg.

III. Result and Discussion

A. Results

i. FEM analysis investigation

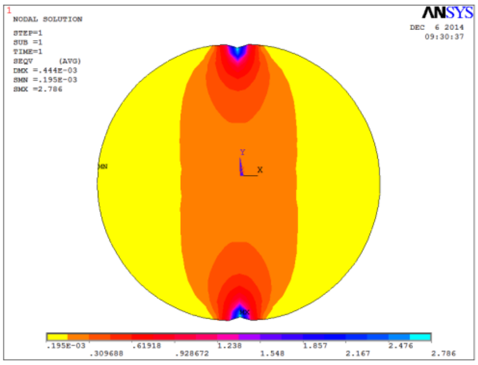

Fig. 6. Contact stress at a point of 4kg (39.24N)

Fig. 6. shows the maximum stress distribution by the compressive load acting on the circular disc (σ_{Avg} = 1.238/mm^2)and also it will shows the fringes with the color code for knowing the stress at a point in the disc.

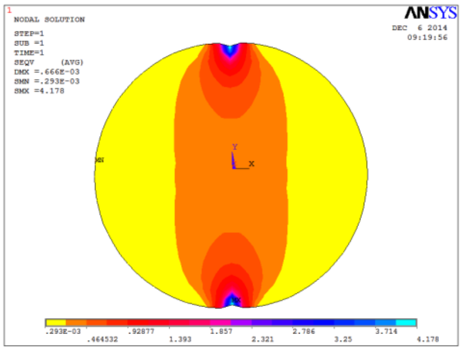

Fig. 7. Contact stress at a point of 6kg (58.86N)

Fig.7. shows the average maximum stress distribution by the compressive load acting on the circular disc (σ_{Avg} = 1.857 N/mm^2) and also it will shows the fringes with the color code for knowing the stress at a point in the disc.

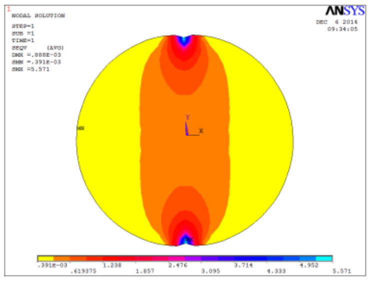

Fig. 10. Contact stress at a point of 8kg (78.48N)

Fig. 10. shows the average maximum stress distribution by the compressive load acting on the circular disc(σ_{Avg} = 2.476 N/mm^2) and also it will shows the fringes with the color code for knowing the stress at a point in the disc.

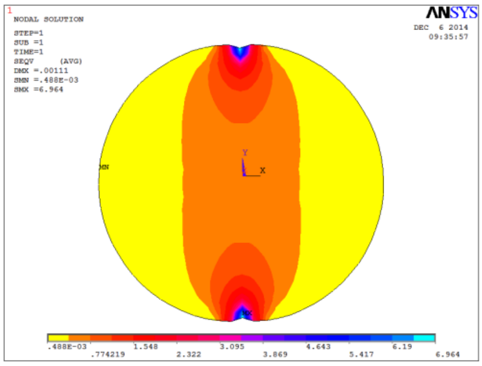

Fig. 8. Contact stress at a point of 10kg (98.10N)

Fig. 8. shows the average maximum stress distribution by the compressive load acting on the circular disc (σ_{Avg} = 3.095 N/mm^2) and also it will shows the fringes with the color code for knowing the stress at a point in the disc.

ii. 2D-Photo elastic investigation

a. Observations

Length of the loading beam laver (l) : 1010mm

Distance between axis of specimen and pivot (l_1): 210mm

TABLE I. LOAD ON PAN OF PHOTOELASTIC BENCH

Sl. No.	Load on pan (kg)	Load on pan in N (W)	Effective load $P=W*L_R$
1	4	39.24	188.705
2	6	58.86	283.057
3	8	78.48	377.410
4	10	98.1	417.762

TABLE II. LOAD ON PAN OF PHOTOELASTIC BENCH

Sl. No	Fringe order						Avg. fringe order
	Higher			*Lower*			
	Integral	*Fraction*	*Total*	*Integral*	*Fraction*	*Total*	
1	1	105/180	0.416	2	25/180	2.13	1.273
2	2	125/180	1.305	2	25/180	2.13	1.717
3	2	125/180	1.305	3	20/180	3.11	2.208
4	3	130/180	2.277	4	14/180	4.07	3.173

b. Calculations

1. Length ratio
   $L_R = (l/l_1) = (1010 \div 210)$ [from Eq. (2)]
   $L_R = 4.809$

2. Effective load
   $P = W \times L_R$ in N [from Eq. (3)]
   i. $P_1 = 39.24 \times 4.809 = 188.705$ N
   ii. $P_2 = 58.86 \times 4.809 = 283.057$ N
   iii. $P_3 = 78.48 \times 4.809 = 377.410$ N
   iv. $P_4 = 98.10 \times 4.809 = 417.762$ N

3. Plot the graph effective load (P) on Y-axis and average fringe order (N) on X-axis.

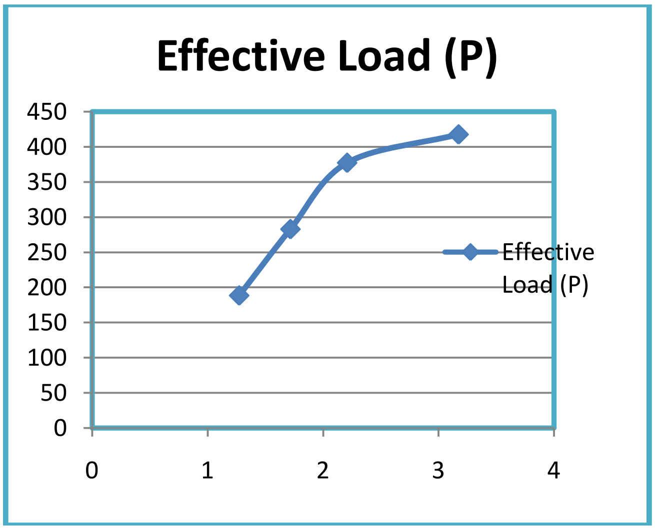

Fig. 9. Graph of effective loads

From slope of a graph (fig. 9) we obtained that

$P_{Av} = 120$ N/fringe.

4. Material fringe order constant [from Eq. (5)]

$$F = \frac{8P_{AV}}{\pi D} = \frac{8 \times 960}{\pi \times 60} = 5.093 \text{ N/mm/fringe}$$

5. Model fringe constant [from Eq. (6)]

$$f = \frac{F}{T} = \frac{5.093}{6} = 0.8488 \text{ N/mm}^2\text{/fringe}$$

6. From equation of stress optics law form reference [3]

Maximum stress = Model fringe constant × Average fringe order

$$\sigma_{max} = f \times avg\ fringe\ order \text{ in N/mm}^2$$

i) Maximum stress at 4kg of load
$=0.8488 \times 1.273 = 1.08052$ N/mm^2

ii) Maximum stress at 6kg of load
$=0.8488 \times 1.717 = 1.45730$ N/mm^2

iii) Maximum stress at 8kg of load
$=0.8488 \times 2.208 = 1.87415$ N/mm^2

iv) Maximum stress at 10kg of load
$=0.8488 \times 3.173 = 2.69320$ N/mm^2

B. Discussions

TABLE III. CORRELATING RESULTS TABLE

Sl. No.	Load in kg	Maximum Stress in N/mm^2		Percentage Error of Maximum Stress in (%)
		ANSYS Results	*Photo-elastic Results*	
1	4	1.238	1.08052	12.72
2	6	1.857	1.45730	21.52
3	8	2.476	1.87415	24.30
4	10	3.095	2.69320	12.98

From the table iii. we are calculate the error percentage between the ANSYS and photo-elasticity methods, so that we obtained a average percentage error of 17.88%.

IV. CONCLUSION

- The maximum stress obtained by the FEA method using software (ANSYS 10.0) & those values correlating with the 2D Photoelastic experimental values.
- In first step we loaded a 4 kg of mass in both ANSYS & Photoelastic bench, then we found the maximum average stress values as 1.238 & 1.08052 respectively. The percentage error of 12.72%.
- The load on pan is increase in order of 6, 8 & 10 respectively in both methods. Then the maximum average stress values & percentage error also increases, at last the total average percentage error is 17.88% obtained, because of there must be error in experimental setup & models. So we getting a slightly varies with fringes.

- If further we select a proper materials & source of light, then we will be obtain a correct fringe order so then error will be negligible.

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