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Numerical and Experimental Photo Elastic Stress Analysis on a Epoxy Circular Disc

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Abstract: ***The main objective of the paper is to present elastic stress analysis on Epoxy circular disc. With the approach of theory of elasticity, the elastic stress distribution on the face of disc has been computed. To validate the stress distribution computed analytically , two specimen are prepared using photo elastic materials and tested them on a refractive poloariscope . The two specimens are circular disks . Stress are determined on disk by loading diametrically in polariscope. The experimental stress analysis is based on pattern, colour and counting of fringes obtained on the surface of disks when they are stressed in the prsence of Monochromatic lights of the polariscope. The stress distribution expressions are implemented in MATLAB and these qualities are being contrasted with the experimental qualities all together validate to Numerical method that we proposed in this paper.***

Keywords: ***Test Specimen ,Photo Elasticity, Simulation.***

I. INTRODUCTION:

Lot of literature is available to study the stress distribution on elastic materials with the help of principle of Theory of Elasticity.The prominent work on stress analysis carried out by R. Barber[1] and A.E.H. Love [2] well appreciated by many researchers. Discs are common shape that many mechanical components resemble to it. The stress distribution on disc play important role in order to understand the failure pattern. In the text book of Dr. R K Bansal [6], the explanation of how to evaluate an average stress developed in a circular disc is explained. But how to find the distribution of stress on the surface of circular disc is prsented in the text book of Timoshenko[7].In this paper we attempted to implement the stress distribution expressions of discs in MATLAB code so that the evaluation of stress distribution can be extended even for composite materials. Presently many researchers are focusing experimental stress Analysis rather than simulation techniques due to more complexity of mathematical elasticity expressions.

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The researchers Trushant Suresh Majmudar , realized the further difficult level of applying elasticity equations to the materials like composites to compute stress distribution. Atur K Kaw [7] developed a software promol and a method to evaluate stresses in various composite specimen. Its validation is not presented. In this paper we attempted to validate the method of stress distribution computed based on elasticity principles with the experimental photo elastic stress method. The experimental method we adopted in this paper is photo elasticity optic method based principle of refractive polariscope.

The paper is organized in the following manner: The principle of polariscope and specimen preparation is detailed in section 2.Section 3 describes the computation of theoretical stress distribution. Results & Discussion and conclusions are drawn in sections 4 and 5 respectively.

II. POLARISCOPE AND SPECIMEN:

A. Polariscope:

Photoelasticity is a test technique to decide the pressure appropriation in a material. The strategy is for the most part utilized in situations where scientific techniques become very lumbering. The technique fills in as a significant instrument for deciding the basic emphasize focuses in a material and is regularly utilized for deciding pressure fixation factors in unpredictable geometries. The strategy depends on the property of birefringence, which is shown by certain straightforward materials. Birefringence is a property by virtue of which a beam of light going through a birefringent material encounters two refractive files. The property of birefringence or twofold refraction is shown by numerous optical precious stones. In any case, photoelastic materials show the property of birefringence just on the use of stress and the 4 magnitude of the refractive records at each point in the material is straightforward identified with the condition of worry by them. Along these lines, the primary assignment is to build up a model made out of such materials. The model has a comparative geometry to that of the structure on which stress investigation is to be performed. This guarantees the condition of the worry in the model is like the condition of the worry in the structure.Many photo elastic optical devices are developed ;out of which polariscope are more versatile devices.

A polariscope comprises of two polarizers., Light source, Polarization plate, Quarter wave plate, Model (specimen) and Load frame (See Figure.1).

The specimen is placed on load frame and stressed mechanically by placing weights in a load hanger. The light source is passed on specimen through polarizer. The fringe pattern and count of fringes are made by looking specimen through quarter wave plate.

Quarter wave plate can also be tilted angularly to measure orientation of fringes.

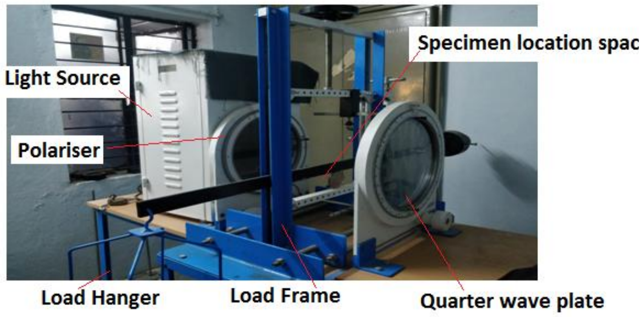


Fig .1 Polariscope

B. Specimen:

Specimen selected for the stress analysis study is circular disc made of material photoelastic material. This material has a stress dependent refractive index. When placed between crossed polarizers, the rotation of the polarized light by the stress field in the material generates a fringe pattern displaying contours of equal stress.

The photo elastic material used for the specimen is Epoxy . It is the cured end products of epoxy resins and it has refractive index 1.4 to 1.7.

At the point when a beam of plane energized light is gone through a photoelastic focused on example , it gets settled along the two principal stress directions and each of these components experiences different refractive indices. The difference between the refractive indices gives a relative phase retardation between the two waves. The magnitude of retardation is given as stress optic law:

$$R = C\,t\,\sigma$$

σ: stress(MPa); R: retardation(nm);t: test thickness(mm) and C: stress optic coefficient

Given the simple geometry of the circular disks, it is quite easy to determine the fringe number of any fringe appearing at the centre of a disk. The boundary conditions state that the free boundaries of a stressed elastic body must be free of stresses; thus the fringe value at the boundary must itself be zero. Then we can determine the fringe value at the centre of a loaded disk simply by counting the fringes inward from the boundary.

The photographs of specimen can be seen in section 4.

III. STRESSES IN CIRCULAR DISC :

In this section we derived the solution to the stresses created by two equal but diametrically opposed concentrated loads on a circular disk. We achieved this by using the solution for the system of stresses due to a single concentrated load for two separate loads. We leave the purpose of use of the first weight at the original position (i.e. at the top of the disk), and place the purpose of use of the second weight at the base of the disk. Thus, we are left with two systems of stresses and boundary stresses, in terms of the radial distances, r1 and r2, and angles of separation from the axis θ1 and θ2, from the respective points of application of the loads.

$$\sigma_{xx} = \sigma_{rr}^{(1)} \sin^2\theta_1 + \sigma_{rr}^{(2)} \sin^2\theta_2 + \frac{2P}{\pi t d},$$

$$\sigma_{yy} = \sigma_{rr}^{(1)} \cos^2\theta_1 + \sigma_{rr}^{(2)} \cos^2\theta_2 + \frac{2P}{\pi t d},$$

$$\sigma_{xy} = \sigma_{rr}^{(1)} \sin\theta_1\cos\theta_1 - \sigma_{rr}^{(2)} \sin\theta_2\cos\theta_2.$$

Substituting in our expressions for $\sigma^{(1)}rr$ and $\sigma^{(2)}rr$ and pulling out a common factor, We get

$$r_1^2 = x^2 + (R-y)^2,$$

$$r_2^2 = x^2 + (R+y)^2.$$

Further we note that,

$$\sigma_{xx} = -\frac{2P}{\pi t}\left(\frac{\cos\theta_1}{r_1}\sin^2\theta_1 + \frac{\cos\theta_2}{r_2}\sin^2\theta_2 + \frac{1}{d}\right),$$

$$\sigma_{yy} = -\frac{2P}{\pi t}\left(\frac{\cos\theta_1}{r_1}\cos^2\theta_1 + \frac{\cos\theta_2}{r_2}\cos^2\theta_2 + \frac{1}{d}\right),$$

$$\sigma_{xy} = -\frac{2P}{\pi t}\left(\frac{\cos\theta_1}{r_1}\sin\theta_1\cos\theta_1 - \frac{\cos\theta_2}{r_2}\sin\theta_2\cos\theta_2\right).$$

Substituting these relations into equations

$$\sigma_{xx} = -\frac{2P}{\pi t}\left(\frac{(R-y)x^2}{(x^2+(R-y)^2)^2} + \frac{(R+y)x^2}{(x^2+(R+y)^2)^2} + \frac{1}{2R}\right),$$

$$\sigma_{yy} = -\frac{2P}{\pi t}\left(\frac{(R-y)^3}{(x^2+(R-y)^2)^2} + \frac{(R+y)^3}{(x^2+(R+y)^2)^2} + \frac{1}{2R}\right),$$

$$\sigma_{xy} = -\frac{2P}{\pi t}\left(\frac{(R-y)^2x}{(x^2+(R-y)^2)^2} - \frac{(R+y)^2x}{(x^2+(R+y)^2)^2}\right).$$

These equations are in their most compact form for description in Cartesian coordinate. These equations are included in MATLAB code to decide the conveyance of three stresses on the outside of disk.

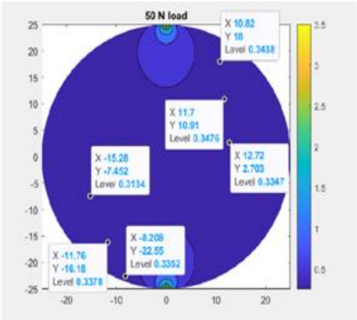
IV.RESULTS AND DISCUSSIONS :

With the help of MATLAB code the stress are computed on circular disk under different diametrical loads ,Experiments also conducted on the disc with the same loads that we used in theoretical analysis.

The results are presented in the form diagrams and its discussion is given here under.

Fig 2. shows the stress levels on the disc surface computed with the code when a diagonal load 5 kg is applied .Fig . 2 shows the stress contours in colors on the disc obtained in polariscope.

Similarly the stresses are computed on disk with loads 10 and 15Kg and its results are presented in Figures 4,5,6 and 7 .



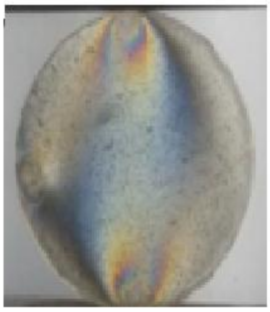
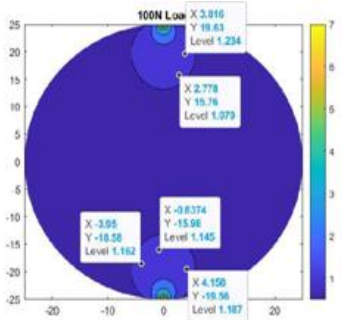


Fig:2 Stress values on disk at six locations

Fig:3 Colors of fringes on the disk



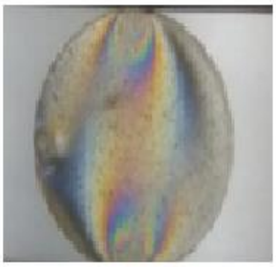


Fig:4 Stress values on disk at six locations

Fig:5 Colors of fringes on the disk

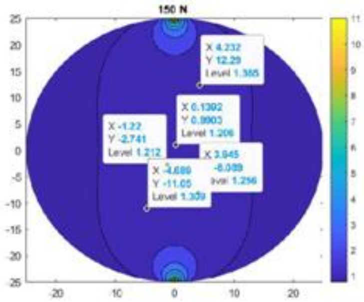
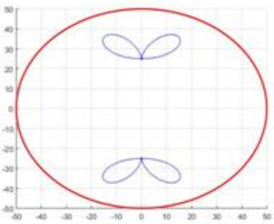


Fig:6 Stress values on disk at six locations

Fig:7 Colors of fringes on the disk

Critical stress zones are identified on a circular disk under different loading conditions by simulating expressions at many points on the surface of disc. Figures 8 and 9 show respectively the stress concentration zones and corresponding colors fringes when specimen subjected to a compressive load of 5Kg.



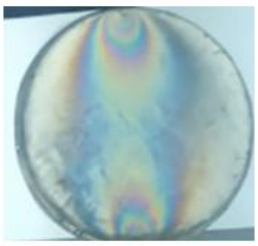
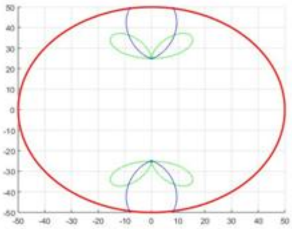


Fig:8 Stress concentration Zone

Fig:9 Colors of fringes on the disk

Figures 10 and 11 show respectively the stress concentration zones and corresponding colors fringes when specimen subjected to a compressive load of 10Kg.



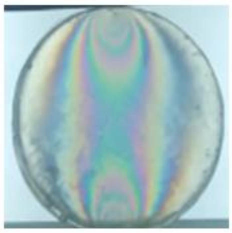
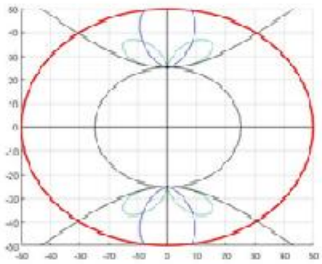


Fig:10 Stress concentration Zone

Fig:11 Colors of fringes on the disk

Figures 12 and 13 show respectively the stress concentration zones and corresponding colors fringes when specimen subjected to a compressive load of 15Kg



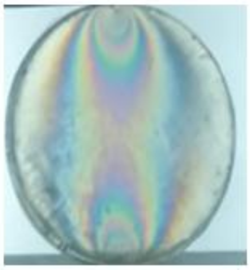


Fig:12 Stress concentration Zone

Fig:13 Colors of fringes on the disk

V.CONCLUSION:

The paper deals with the studies on Elastic stresses the composite resin disc which is acted upon by diametrical loads . The stresses on the disc analyzed in this paper using both analytical and experimental. The photo-elastic method has been used to determine stress distribution on disc experimentally. By looking at the results obtained in the both the methods one can say that the stresses are in agreement with each other. Thus, we can conclude that photo-elastic method can be used for elastic stress analysis on composite specimen of various application instead of applying complex expressions.

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REFERENCES

1. J. R. Barber. Elasticity. Springer Netherlands, 2010. [Fro41] Max Mark Frocht.Photoelasticity. J. Wiley, New York, 1941.

2. A.E.H. Love. A treatise on the mathematical theory of elasticity, volume 1 of A Treatise on the Mathematical Theory of Elasticity. University press, 1892.
3. Trushant Suresh Majmudar. Experimental studies of two-dimensional granular systems using grain-scale contact force measurements. PhD thesis, Duke University, 2006.
4. R.S. Sirohi and F.S. Chau. Optical Methods of Measurement: Wholefield Techniques.Optical Engineering. Marcel Dekker, 1999.
5. Photo elasticity by Jeremy Yeh Hsiang Lawrence May 2012, The Division of Mathematics and Natural Sciences.
6. A text book of Strength of materials by Dr. R K Bansal , Department of mechanical engineering, Delhi college of engineering.
7. Timoshenko - A text Book on Theory of Elasticity
8. Atur K Kaw - A Text book of Mechanics of Composite Materials

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