Investigation of Stress Concentration Factor of Composite for Bending Specimen Using Polariscope

Poornachandra D C[1] Prajwal S K[2] Madan Gopal P[3] Shashidhar Hugar[4] Pradeep Kumar Ilay[5]
[1,2,3,4]UG Scholars [5]Assistant Professor
[1,2,3,4,5]Department of Mechanical Engineering
[1,2,3,4,5]Jain Institute of Technology, Davangere-577 003, India

Abstract— This paper presents the experimental estimation of stresses in the epoxy based material for varying weight percentage of copper particles using Photoelasticity method. The study deals with the stress distribution within the diametrical disc under compression loading which uses the property birefringence. Photoelasticity method used to calculate the stresses for the intricate shapes models where the analytical solutions are too complex. The significance of the method is to do the variety of stress analyses and even for routine use in design, particularly before the advent of numerical methods, such as for instance finite elements or boundary elements. It is very important for the engineer to be aware of the effects of stress raisers such as notches, Holes or sharp corners in his/her design work. Stress concentration effects in machine parts and Structures can arise from internal holes or voids created in the casting or forging process, from excessively sharp corners or fillets at the shoulders of stepped shafts, or even from punch marks left during layout work or during inspection of parts. The photo-elastic method has been employed to determine stress concentration factor (SCF) for square plates containing circular hole, elliptical hole, and crack model when the plate edges are subjected to in-plane tension combined with compression. Analyses given of the isochromatics fringe pattern surrounding the hole provides the SCF conveniently. The model material is calibrated from the known solution to the stress raiser arising from a small circular hole in a plate placed under biaxial tension-compression. These results also compare well with a plane stress FE analysis. Consequently, photo-elasticity has enabled SCF's to be determined experimentally for a biaxial stress ratio, nominally equal to –4, in plates containing a long, thin slot arranged to be in alignment with each stress axis. The two, principal stresses lying along axes of symmetry in the region surrounding the notch are separated within each isochromatics fringe. FE provides a comparable full-field view in which contours of maximum shear stress may be identified with the isochromatics fringe pattern directly. The principal stress distributions referred to the plate axes show their maximum concentrations at the notch boundary. Here up to a fourfold magnification occurs in the greater of the two nominal stresses under loads applied to the plate edges. Thus, it is of importance to establish the manner in which the tangential stress is distributed around the slot boundary. Conveniently, it is shown how this distribution is also revealed from an isochromatics fringe pattern, within which lie the points of maximum tension and maximum compression.

Key words: Birefringence, Polariscope, Epoxy, Stress Concentration; Photoelasticity; Isochromatics; Finite Elements; Vertical and Horizontal Slots; Bi-Axial stress

I. INTRODUCTION

Many researchers are using the principle of Photoelasticity to determine experimental stress and strain analysis when elastic component deforms due to various type of loading. In this method, the isochromatic fringes are extracted, and photo-elastic parameters, isochromatic fringe orders or relative retardations and isoclinic angles, are assigned to the respective fringes. The isochromatic fringe order is linearly related to the principal-stress difference. In general, to obtain each stress, the principal-stress difference and principal-stress direction are used in the shear difference method. After preparing a composite beam specimen with material having good polarization properties, we adopted bending test in the load frame of polariscope equipment. The results obtained are included in the paper. The experimental results obtained are discussed. Finally the conclusions are drawn.

II. LITERATURE SURVEY

P. P. Kamble [1] et. al., carried out an experimental and software analysis of composite plate under shear loading. Glass fiber is a light weight, extremely strong, and robust material**.** Experimental and Software results from testing on composite plate under shear loading containing the stress values are calculated. They found that the variation in results occurs may be because the Photo Stress coating applied over the surface of By considering all results there are some error due to some experimental and software problem but in each type of analysis they have observed that by increased load on composite plate, stress values of composite plate increase. composite structure takes some of the applied load.

Sangram S. Jadhav [2] et. al., carried out the work on carbon FRC laminate with elliptical cut out by varying major minor axis dimensions for stress analysis using reflection polariscope as a photoelasticity technique. For this laminate the variation in the elliptical cut out dimensions of major & minor axes were taken. The values observed from experimentally and using ANSYS. From the result they have conclude that the when the dimensions of elliptical cut out when minor axes kept constant & variation of major axes gives minimum stress & strains in FRC laminate. The analysis for the orientation [02±45/90]s and elliptical dimensions major axis=25mm & minor axis=15mm gives minimum stress & strains in laminate.

T. D. Kale [3] et. al., have applied photoelastic technique here confirms FE predictions where the former has been shown to agree with the analytical solution to the known stress concentration arising from a hole in a plate. The model material Makralon is calibrated previously within the photoelastic bench from the simpler plane geometry of a strip in tension, as used here, or for a beam in four-point bending. Following its validation, this preliminary study shown that photo-elasticity is a useful experimental technique for providing a full stress field around slots subjected to bi-axial loadings. In particular, when slots are aligned with applied stress axes their straight boundaries distribute tangential stress uniformly in tension and compression. A maximum concentration in stress usually occurs within the end radii, their precise positions depending upon the slot orientation.

Rashmi Uddanwadiker [4] et.al., have studied the stress pattern of crane hook in its loaded condition, a solid model of crane hook is prepared with the help of CMM and CAD software. The stress distribution pattern is verified for its correctness on an acrylic model of crane hook using Diffused light Polariscope set up. Shown that by predicting the stress concentration area, the shape of the crane is modified to increase its working life and reduce the failure rates. From the stress analysis we have observed the cross section of max stress area. If the area on the inner side of the hook at the portion of max stress is widened then the stresses will get reduced. Analytically if the thickness is increased By 3 mm, stresses are reduced by 17%. Thus the design can be modified increasing the thickness on the inner curvature so that the chances of failure are reduced considerably.

Sandip kumar Bhagat[5] et. al., carried out an experimental estimation of stresses in the epoxy based material for varying weight percentage of alumina particles using Photoelasticity method and validated the results using ANSYS. The study deals with the stress distribution within the diametrical disc under compression loading by photoelasticity method. By applying the birefringence expression it has been seen that the value of stresses obtained experimentally are matched with the FE analysis results i.e. ANSYS results.

III. Fabrication of Composites

The composite material was prepared which contains epoxy resin (araldite AW106) as a matrix material and copper as reinforcement. Epoxy resin 50% and reinforcement 50% of weight.

Fig. 1: Hardner

Fig. 2: Epoxy resin

In order to prepare composite, resin and matrix mix together manually and also machines. The time for mixing process 1 to 3 minutes later, the hardener added to mix together gently. Then, allow to settle down. The cooling time for composite are 24 hours.

Fig. 3: Copper powder

In the very first attempt, copper wire flakes of diameter 1mm and length 5mm has been used as reinforcement. 0. 1% of copper flakes by mass was added with resin. But copper flakes got settled at the bottom. Hence it was not suitable to be used as reinforcement. So copper powder of 60 micron has been used as reinforcement in epoxy resin (Araldite AW106).

Araldite AW106 is an pole orange colored viscous fluid. Addition of excess copper powder will results in an opaque composite. Hence it is required to adopt trial and error method in order to get considerable transparency in the composite material.

In the initial stage, the trial and error method. An amount of 0.1% of copper powder was added with 99.9% of epoxy resin. But that. Resulted in an opaque material as shown in figure 4. Hence amount of 0.025% of copper powder was used and which resulted in good transparency of epoxy composite as shown in the figure 5. Hence it was adopted for the fabrication.

Fig. 4: 0.1% of Copper added to 99.9% of Epoxy resin

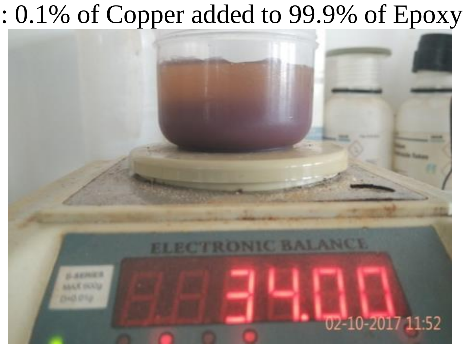

Fig. 5: 0.025% of Copper added to get good transparency

A. Properties

General purpose, solvent-free Araldite epoxy resin. The bond formed by using Araldite AW106 resin with various hardeners is tough, resilient, shows excellent mechanical properties and good resistance to dynamic loading, water and many different chemicals.

Shear modulus (DIN 53445)
Cure: 16 hours/40°C
-50°C - 1.5GPa
0°C - 1.2GPa
50°C - 0.2GPa
100 C - 7.0Mpa
Density at 25 °C
Epoxy resin - 1.6797 gm/cc
Hardener - 0.917792 gm/cc
Flexural Strength - 60.4 MPa
Flexural Modulus - 1904.1 MPa

In order to calculate the proportion of powder and epoxy resin to be mixed by mass, the density is necessary. To find the density of epoxy resin and hardener, we have

Density $\left(\frac{kg}{m^3}\right)$ = specific gravity * 997.6
According to ASTM D-792
Specific gravity of resin = 1.17
Specific gravity of hardener = 0.92
Density of resin $\left(\frac{kg}{m^3}\right)$ = 1.17 * 997.6
= 1167.192 $\left(\frac{kg}{m^3}\right)$
Density of resin = 1.167192 $\left(\frac{gm}{cm^3}\right)$
Density of Hardener = 0.92*997.6
= 917.792 $\frac{kg}{m^3}$
$=\frac{917.792*1000}{10^6}$
Density of Hardener = 0.917792 $\frac{g}{cm^3}$
Density of copper powder=8.96 $\frac{g}{cm^3}$

A acrylic mould of dimension 30*30*5cm was prepared. To bind the amount of copper powder and resin required to prepare a composite material of dimension 30*30*1 cm is as follows.

Volume of composite required = 30*30*1 cm^3
= 900 cm^3
0.025% of copper powder = $\frac{0.025}{100}$*900
= 0.225 cm^3
Density of copper powder = 8.96 $\frac{g}{cm^3}$
Mass of metal powder = 8.96*0.225
=2.016 g
Volume of Epoxy resin and Hardener = $\frac{99.975}{100}$*900
=899.775 cm^3
Since the mixing ratio of resin and Hardener is equal by volume,
Volume of Epoxy = 899.720*$\frac{1}{2}$
= 449.8875 cm^3
Mass of Epoxy resin = Density*Volume
= 1.167192*449.8875
= 525.105191
= 525.1 g
Mass of Hardener = Density*Volume
= 0.917792*449.8878
= 412.90 g
Mass of Hardener = 413 g

Calculated proportion of copper powder was added in Epoxy resin and this mixture is carefully agitated to mix the copper particles uniformly through the resin. It was left for two days and after two days, solid composite is removed from the mould. This Epoxy composite was cut into the shapes of rectangular.

Rectangular specimen made by mixing of epoxy resin, hardener and copper powder. It is having a length of 145mm, width of 25mm and its thickness is 6mm. It is used to find the stress by using polariscope.

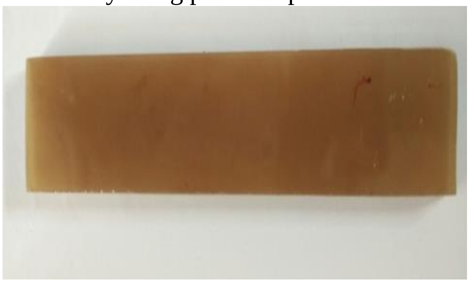

Fig. 8: Rectangular specimen for bending moment

IV. RESULTS AND DISCUSSIONS

The following are the observation for bending composite specimen.

Width of specimen W = 2.5 cm
Thickness of specimen h = 0.65 cm
Length of specimen L = 14.5 cm
Distance between supports and load a = 0.5 cm
Table I shows that, results of experimental and theoretical stress for bending specimen.

Serial Number	Load in pan P kg	Fringe order N	Material Fringe constant f_σ	Mean
1	4	1	3	3.096
2	9	2	3.3375	
3	13	3.344	2.91	

Table I Experimental & theoretical Stress for bending specimen

Following are calculation related to bending specimen

Fringe order $N = N_x \pm \frac{\alpha}{180}$ (4.1)

$$N = 1 \pm \frac{0}{180}$$

$$N = 1$$

Where N = Secondary Fringe order
N_x = Primary Fringe order
α = Fringe angle

Fringe constant $f_\sigma = \left(\frac{P}{N}\right) . \frac{6a^2}{W^2}$ (4.2)

$f_\sigma = \left(\frac{4}{1}\right) . \frac{6(0.5)^2}{2.5^2}$

$f_\sigma = 3$

V. CONCLUSION

A stress analysis plays a vital role in real time application an attempt as been made to find stress analysis for the composites specimen. By addition of copper powder with weight percentage on important in property, however in order to find the stress for epoxy based composites. A polariscope is a better solution in this research a composite wear develop by matrix as epoxy and reinforcement has copper powder the result reveals that a circular disc without hole specimen, the experimental and theoretical stress taken has a consideration to determine stress concentration factor K¬t = 2.2, where has circular disc without hole the material fringe constant has been determined in the value of 0.1835 N/mm¬¬2. For the fourth point bending specimen to determine fringe constant of average value of 3.096 N/mm2. So that by these results it conclude that by small percentage of addition of copper powder epoxy resin has a significant in real time application.

REFERENCE

[1] T.Lalitha et. al., “Experimental stress analysis of composite circular disc” IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 12, Issue 4 Ver. IV (Jul. - Aug. 2015), PP 45-49 www.iosrjournals.org
[2] P. P. Kamble et. al., “Experimental and software analysis of composite plate under shear loading” International Journal of Emerging Technology and Advanced Engineering Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 3, Issue 7, July 2013)
[3] Sangram S. Jadhav et. al., “FEM & Experimental analysis of compositelaminate with elliptical cut out usingreflection polariscope” Jadhav, et al., International Journal of Advanced Engineering Technology E-ISSN 0976-3945
[4] T. D. Kale et. al., Estimation of maximum stress and stressconcentration factorfor crack model using circular polariscopeijirst –International Journal for Innovative Research in Science & Technology| Volume 3 | Issue 02 | July 2016 ISSN (online): 2349-6010
[5] Rashmi Uddanwadiker Stress analysis of crane hook and validation by photo-elasticity Engineering, 2011, 3, 935-941 doi:10.4236/eng.2011.39115 Published Online September 2011 (http://www.SciRP.org/journal/eng).

