Estimation of Maximum Stress and Stress Concentration Factor for Crack Model using Circular Polariscope

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Abstract— In this paper an effort is made to find the stress concentration factor (Kt) by applying the compressive load on the rectangular plate with an edge crack having different crack length to width ratio (a/w) and calculating material fringe value by loading the circular disc under compression. After finding the material fringe value the stress concentration in the rectangular plate with an edge crack is determine & then graph is plotted between stress concentration factor and the crack length to width ratio of the rectangular plate.

Key words: Polariscope**,** Circular Polariscope, Stress Concentration Factor

I. Introduction

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 or stamp marks left during layout work or during inspection of parts. Such discontinuities in a part can cause a large rise in stress above the nominal P/A value that might be expected for example in a uniaxially loaded member such as a tensile specimen. In recent years, researchers have put enormous amount of effort in investigating techniques for analysis and mitigation of stress concentration. The failure of structures due to stress concentration at any discontinuity has been baffling engineers for long. It has been found that structure failures in ships, offshore structures, boilers or high rise buildings subjected to natural calamities is due to stress concentration. Stress concentration mainly occurs due to discontinuities in continuum. Due to stress concentration the magnitude of the maximum stress occurring in any discontinuity is comparatively higher than the nominal stress. Stress concentration cause strength degradation and premature failure of structures because of fatigue cracking and plastic deformation frequently occurring at these points.

Stress concentration is localization of high stresses mainly due to discontinuities in continuum, abrupt changes in cross section and due to contact stresses. To study the effect of stress concentration and magnitude of localized stresses, a dimensionless factor called Stress Concentration Factor (SCF), Kt as defined by $K_t = \sigma_{max}/ \sigma_{nom}$ where σ_{max} is maximum stress at the discontinuity and σ_{nom} is nominal or background stress.

II. Photoelastic technique

The photoelastic technique is one of the most powerful of experimental stress analysis techniques. The photoelastic technique is valuable because it gives an overall picture of the stress field, quickly showing regions of stress intensification. In addition, the direction of principal stresses is also easily determined. Like all experimental techniques, photoelasticity requires some practice to yield accurate results, in particular, the determination of the principal stresses σ_1 and σ_2 on the interior of the model requires considerable effort. Often, one is interested only in determining the stress on the boundary of the model where one of the principal stresses is zero. In the photoelastic method a model of the shape to be investigated is made from a suitable transparent material. The model is then loaded in a manner similar to the actual part and an accurate description of the stress magnitude and direction is obtained by measuring the change in optical properties of the transparent model. These changes in properties are measured by viewing the model in a special equipment called a polariscope, so named because polarized light or light vibrating in a single plane only, is used.

III. Objective

The experiment performed was aimed to investigate the stress concentration factor for specimens with varying crack length to width ratio, to study the stress concentration factor for specimens with different crack length. The specimen is sawed from epoxy resin sheet and a crack at an edge of the specimens is made, and by loading the model on circular polariscope and by observing the isochromatic fringe pattern the material fringe value is determined. This material fringe value helps in determining the maximum stress and the stress concentration on plate having an edge crack.

IV. The Method of Photoelasticity

Photoelasticity is an experimental method to determine stress distribution in a material. The method is mostly used in cases where mathematical methods become quite cumbersome. Unlike the analytical methods of stress determination, photoelasticity gives a fairly accurate picture of stress distribution even around abrupt discontinuities in a material. The method of photoelasticity has been used extensively in the past for investigating elastic stresses in cracked specimens. The method serves as an important tool for determining the critical stress points in a material and is often used for determining stress concentration factors in irregular geometries.

V. Material used for specimen

The material use for specimen is the epoxy resin having trade name Araldite CY-230 with 10% hardener. The properties of epoxy resin is shown in the below table. This material shows the property of birefringence necessary for the photoelastic experiment.

Name	Trade Name	Youngs Modulus	Poisson's Ratio

		(MPA)	
EPOXY RESIN	ARALDITE CY-230	2570.22	0.38

Table 1: Material use for specimen

VI. CALIBRATION OF PHOTOELASTIC MATERIAL

Calibration of photoelastic material means to find material fringe value (fσ) in order to find material fringe value let us consider a disc under diametral compression .For a circular disc of diameter D and thickness h when subjected to a diametral compressive load P the stress t distribution is given by

$(\sigma_1 - \sigma_2) = 8P/\pi Dh$---------------------equ (1)

According to the principal of stress optic law.

$(\sigma_1 - \sigma_2) = Nf\sigma/h$----------------------equ(2)

Where σ_1& σ_2 = maximum & minimum principal stresses at the point under consideration.N= fringe order; h= specimen thickness; fσ =the material fringe value

After equating equation 1 & 2 the material fringe value becomes

$$f\sigma = 8p/\pi DN$$

A. *Circular Disc under Diametral Compression*

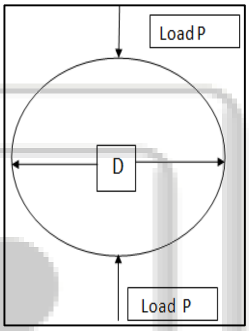

Fig. 1: Circular Disc under Diametral Compression

The above fig shows the circular disc having diameter D is under the compression of load P in Newton. The photoelastic material is calibrated by making a circular disc of 60 mm diameter from a sheet of epoxy resin material. The disc is loaded in increments under the diametric compression on circular polariscope to find the material fringe value (**fσ**) .The fringe order at the center of disc and corresponding load are determine. Stress fringe value of photoelastic material is calculated in the below table.

Sr no	Load (Newton)	fringe value (N)	Fσ = 8p/ πDN	Fσ (N/mm)
1	2	0.4	0.55	
2	5	1.3	0.42	
3	10	1.84	1.84	1.42
4	15	2.08	2.08	
5	20	2.22	2.22	

Table 2: Stress fringe value of photoelastic material calculation

Finally the material fringe value f are calculated for different load the average value is 1.42N/mm.

After calculating the material fringe value the next step is to determine the stress concentration factor in a plate with an edge crack for different crack length to width ratio . The below figure shows the plate with an edge crack having crack length (a), width (w) ,height (h), and thickness(t) under compression.

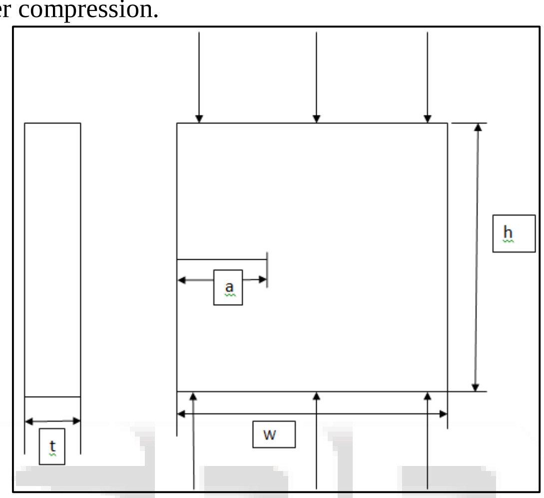

Fig. 2: Plate with an edge crack

The fringes of epoxy resin plate with an edge crack obtain after loading it on polariscope having width 40 mm & edge crack length 20 mm is shown below

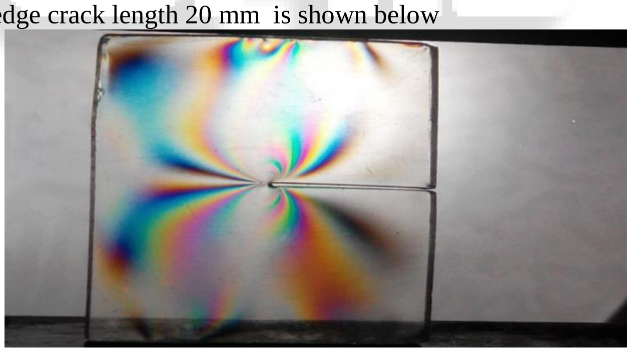

Fig. 3: Fringes of epoxy resin plate

Sr. No	Load p Newton	A mm	w mm	t mm	Crack length to width ratio (a/w)	Fringvalue N_{mean}	σ_{max} = Nfσ/h	σ_{nom}=P/A A=w*t	K_t
1	6	4	40	5	5/30=0.1	1.4	0.392	0.03	13
2	6	11	40	5	6/30=0.2	1.6	0.448	0.03	14.9
3	6	20	40	5	9/30=0.5	2	0.56	0.03	18.6
4	5	10	30	5	0.33	1.5	0.42	0.03	12.6
5	5	18	30	5	0.6	1.8	0.50	0.03	15
6	5	9	35	5	0.25	1.45	0.40	0.03	12
7	5	14	35	5	0.4	1.55	0.43	0.02	15

Table 3: Stress concentration

Where K_t is stress concentration factor

After calculating the stress concentration the graph is plotted between stress concentration factor & crack length to width ratio.

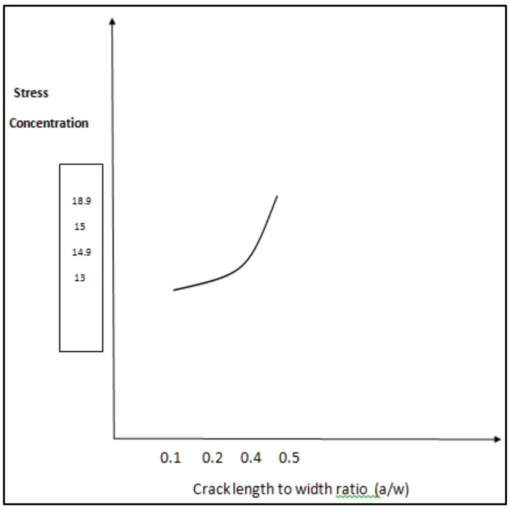

Fig. 4: The graph is plotted between stress concentration factor & crack length to width ratio

VII. CONCLUSION

The severity of crack is determined by using the stress concentration factor .It is found that larger the discontinuity near the crack increases the severity of crack .As load increases the value of stress concentration factor increases.

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