Experimental Investigation of Reduction in SCF of Rectangular plate with central circular hole by Providing Relief Holes

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Abstract - *The rectangular plate with the circular hole at the centre used to join to simple elements in lot many structures. The central hole results in high value of stress concentration factor. By provision of relief holes of optimum shape at optimum distance from the centre of the main hole, the value of SCF reduced by considerable amount. The original value of SCF as well as the altered value of Stress concentration factor observed experimentally. Universal testing machine is used here to apply load on the rectangular plate and maximum strain value sensed by strain gauge foils indicated on the digital strain indicator in microns. Calculations for the value of stress concentration factor have done using standard relations.)*

Key Words: Strain, strain gauge, relief holes

1. INTRODUCTION

The rectangular plate with central circular hole has been used everywhere as a connecting member. The hole provided on the plate make the plate weak and leads to earlier failure of structure. Because of that hole the flow stresses within the plate will get disturb. The stress value near the hole depends on the shape hole, size of hole and relative location of that hole.

1.1 Problem Definition

Experimental approach to reduce stress concentration factor of rectangular plate with central circular hole by providing relief holes on either side of main hole.

1.2. Literature Review

Basavaraj. R. Endigeri, Vinayak Mannur in "Fem for Stress Reduction by Optimal Relief Holes in A Uniaxially Loaded Composite Plate" carried out to work to locate relief holes with a optimum values of relief hole location and with optimum radii using numerical method. [1]

Shubhrata Nagpal1, Nitin Jain, and Shubhashish Sanyal in "Stress Concentration and its Mitigation Techniques in Flat Plate with Singularities: A Critical Review" discussed various stress mitigation techniques. [2]

Chavan Jyoti G., Dixit Supriya S., Pirjade Firdos I. in "Study of Experimental Stress Analysis" have given brief information about experimental stress analysis methods with the help of polariscope. [3]

Mr.V.G.Aradhye & Prof.S.S.Kulkarni in "Use of Strain Gauge Rosette to Investigate Stress concentration in Isotropic and Orthotropic Plate with Circular Hole" calculated stress concentration of rectangular isotropic and orthotropic plate with circular hole are in tensile loading on computerized Universal Testing Machine (UTM) and Strain gauge indicator. [4]

2. METHODOLOGY

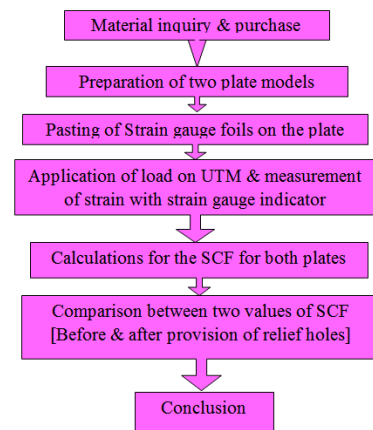Following flow chart shows the methodology used for the work.

Fig.-1: Flow chart of methodology

The material used for the experimentation work is the Steel having the Modulus of elasticity =240 GPa

Poisson's ratio=0.3 and Material density = 7900 Kg/m3.

3. EXPERIMENTATION

All the steps used during experimentation are described below.

3.2 Preparation of Plate

Material Steel G550 is used for the work. Two rectangular plate models are prepared for testing purpose. Both the plate models are having 200 mm length, 100 mm width and 1 mm thickness. The difference between two is that one plate is having only centre hole of 10 mm dimension. And another one is having centre hole of 10 mm and relief holes of ellipsoidal shape on either side of main hole at 15 mm from the centre of the main hole. The major axis of ellipse (a) is 9.89 mm and minor axis (b) is 2.47 mm. The machining of plate models is done by wire cutting method. Images of the plate models after machining are shown below.

Fig.-2 Plate without Relief holes

Fig.-2 Plate with Relief holes

3.2 Strain gauge application on the plate

The strain gauge foils are used to find local strain in the high strained region of the plate. The quarter bridge arrangement of the strain gauge foils is used here because its high sensitiveness than other arrangements of strain gauge foils. Following figure shows the schematic view of strain gauge foil and table shows the specifications of strain gauge foils used for experimentation
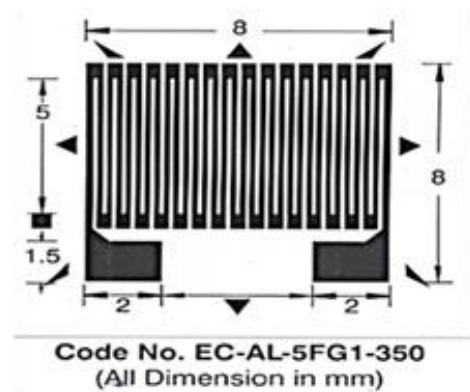

Code No. EC-AL-5FG1-350
(All Dimension in mm)

Fig.-4 Strain gauge foil

Table 1 Specifications of Strain Gauge Foil

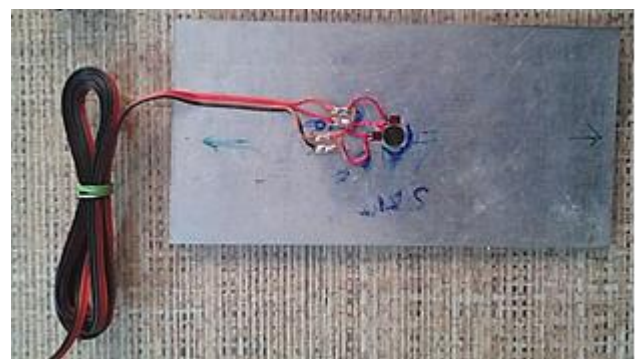| Gauge Resistance	350 + 0.5 Ohms
Gauge length	5 mm
Backing material	Epoxy
Gauge factor	1.9 – 2.2
Maximum excitation voltage	12 V
Temperature range	5 to 100˚C
Temperature co-efficient	-
Insulation resistance	5000 Mega Ohms at 30 V
Creep compensated for	Aluminium alloy-2024
Temperature compensated for	Aluminium alloy-2024
Maximum repeatable strain allowed	1500 Microstrains
Fatigue life	More than 1 million cycles

. **Fig.-5** Plate without Relief holes after application of strain gauges

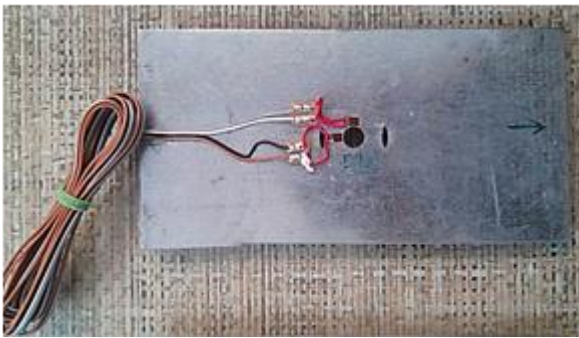The figure 5 and figure 6 shows the view of plates after application of strain gauge foils.

Fig.-6 Plate with Relief holes after application of strain gauges

3.3 Application of load

In this work tensile loading of 600 N on both the plates is required. This loading is applied here with universal testing machine. After application of the strain gauge on the plates the connections of strain gauges with the digital strain indicator are required. The connection s of strain gauges on the first plate without relief holes has done. After that the plate has clamped on the universal testing machine to apply uniformly distributed tensile loading of 600N. Then strain readings what displayed on the digital strain indicator have observed.

Plate without relief holes

Following figure 7 shows the view when the plate without relief hole is clamped on universal testing machine.

Fig.-7 Plate without Relief holes clamped on UTM

The connections of strain gauges on the second plate with relief holes have done. After that the plate has clamped on the universal testing machine to apply uniformly distributed tensile loading of 600N. After switching on the digital strain indicator, all values set to the zero. Then Applied load on plate and observed strain readings what displayed on the digital strain indicator have observed. Following figure 8 shows the view of digital strain indicator when zero setting has done and figure 9 shows the reading displayed by the digital indicator after application of the load.

Fig.-8 Zero setting of Digital strain Indicator

Fig.-9 Strain Reading on Digital strain Indicator for Plate without Relief hole

The value of strain displayed by the digital strain indicator for the Plate without relief hole is 68 microns ($68 * 10^{-6}$ = 0.000068). After getting the value of maximum strain in the plate following calculations conducted for the Stress Concentration Factor of the plate having no relief hole.

Calculations for SCF of Plate without relief hole:
Maximum Stress = Modulus of Elasticity * Maximum strain

$$\sigma_{Max} = E * e_{Max}$$
$$\sigma_{Max} = (240 * 10^9) * (0.000068)$$
$$\sigma_{Max} = 16320000 \text{ N}$$

Stress Concentration Factor = Maximum Stress / Nominal Stress

$$SCF = \sigma_{Max} / \sigma_{Nominal}$$
$$SCF = 16320000 / 6000000$$
$$SCF = 2.72$$

Plate with relief holes

Following figure 10 shows the view when the plate with relief hole is clamped on universal testing machine. Same procedure as that of the plate without hole has followed for the plate with relief hole. The connections of strain gauges on the second plate with relief holes have done. After that the plate has clamped on the universal testing machine to apply uniformly distributed tensile loading of 600N. After

switching on the digital strain indicator, all values set to the zero. Then Applied load on plate and observed strain readings what displayed on the digital strain indicator have observed. Following figure 11 shows the reading displayed by the digital indicator after application of the load.

Fig.-10 Plate with Relief holes clamped on UTM

Fig.-11 Strain Reading on Digital strain Indicator for Plate with Relief hole

The value of strain displayed by the digital strain indicator for the Plate with relief hole is 46 microns (46 * 10-6 = 0.000046). After getting the value of maximum strain in the plate following calculations conducted for the Stress Concentration Factor of the plate having relief hole.

Calculations for SCF of Plate with relief hole:

Maximum Stress = Modulus of Elasticity *
            Maximum strain

$\sigma_{Max} = E * e_{Max}$

$\sigma_{Max} = (240 * 109) * (0.000046)$

$\sigma_{Max} = 11040000$ N

Stress Concentration Factor = Maximum Stress /
            Nominal Stress

$SCF = \sigma_{Max} / \sigma_{Nominal}$

SCF = 11040000 / 6000000

SCF = 1.84

The per cent reduction in Stress Concentration Factor of the plate is calculated as follows.

According to Experimentation the per cent reduction in Stress Concentration Factor is,

% Reduction in Stress Concentration Factor =
            = (2.72 -1.84) / 2.72
            = 32.35 %

4. CONCLUSIONS

The Stress concentration factor of rectangular plate without relief holes is 2.72 and the Stress concentration factor of rectangular plate with relief holes is 1.84. There is considerable difference between two values of Stress concentration factor. The maximum reduction in SCF as per experimentation it is reported as 32.35%.

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