Stress Concentration Analysis of Cut out Orientation of Plates by Finite Element Analysis

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ABSTRACT

Stress concentration factor is the significant parameter in the design of any structural component. The structural elements, panels and pressure vessel shells contain different types of cut-outs or openings for their functional requirements. Generally, failure of mechanical components occurs due to high concentration stress. Stress concentration is high near to the discontinuities in continuum, abrupt changes in cross section and due to contact stresses. In this study a rectangular plate is taken with square, triangular and elliptical cutouts for experimentation. Generally, stress concentration is extremely near the cutouts. The main objective of this study is to demonstrate the accuracy and simplicity of presented analytical solution for stress analysis of plates with central cutout and validating the results by electrical strain gauge method. The varying parameters such as cutout shape, bluntness and cutout orientations which affect the stress distributions and SCF in the plates are considered. The results presented herein indicate that the stress concentration factor of perforated plates can be significantly changed by using proper cutout shape, bluntness and orientation.

Keyword: - *Bluntness, Different cutouts, FEA, SCF, strain Gauge, etc.*

1. INTRODUCTION:

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), denoted as K_t.

$$K_t = \frac{\sigma \max}{\sigma \text{ nom}}$$

Where, σ_{max} is maximum stress at the discontinuity and σ_{nom} is nominal or background stress. The stress concentration factor can be determined analytically by applying elasticity theory. Stress analysis of the critical elements under various loading conditions is carried out by the researchers for safe design of the element. Stress is measured by experimental methods or analytical/numerical methods.

1.1 Problem Definition:

Plates and shells of various constructions find wide uses as primary structural elements in aerospace, mechanical and civil engineering structures. In recent years, the increasing need for lightweight efficient structures has led to structural shape optimization. Different cut-out shapes in structural elements are needed to reduce the weight of the system and provide access to other parts of the structure. It is well known that the presence of a cut-out or hole in a stressed member creates highly localized stresses at the vicinity of the cut-out. The ratio of the maximum stress at the cut-out edge to the nominal stress is called the stress concentration factor (SCF). The understanding of the effects of cut-out on the load bearing capacity and stress concentration of such plates is very important in designing of structures.

1.2 Objectives:
1.To find out the SCF for different shaped cutouts by FEA analysis method.
2. To find out the SCF for different shaped cutouts by strain gauge method.
3.To find the maximum stress concentration localization area for different shaped cutouts.
4.To analyses the effect of bluntness and orientation of cutout on SCF.
5.To compare the SCF results of analytical and experimental methods

2. Literature Review:

M Mohan Kumar, Rajesh S, Yogesh H and Yeshaswini B R: This paper describes that the plates with variously shaped cut-out are often used in engineering structures and the understanding of the effect of cut-out on the load bearing capacity and stress concentration of panels is very important in designing of structures. Allowable stress design is a design format extensively used in structural design. In allowable stress (or working stress) design, member stresses computed under service (or working) loads are compared to some predesignated stresses called allowable stresses.

Murilo Augusto Vaz, Julio Cesar Ramalho Cyrino and Gilson Gomes da Silva: In this paper the three-dimensional stress concentration factor (SCF) at the edge of elliptical and circular holes in infinite plates under remote tension has been extensively investigated considering the variations of plate thickness, hole dimensions and material properties, such as Poisson's coefficient.

Vanam B. C. L, Rajyalakshmi M. and Inala R: This paper describes the static analysis of an isotropic rectangular plate with various boundary conditions and various types of load applications. In this paper, finite element analysis has been carried out for an isotropic rectangular plate by considering the master element as a four noded quadrilateral element. Numerical analysis (finite element analysis, FEA) has been carried out by developing programming in mathematical software MATLAB and the results obtained from MATLAB are giving good agreement with the results obtained by classical method - exact solutions.

3. RESULT AND DISCUSSION:
3.1 Square Cutout:
For square cutout the following parameters are considered for experimentation
Parameters: -
Bluntness (w) - 0.1, 0.25, 0.3, 0.5, 0.75, 0.9 and 1.0
Orientation - 0˚, 15˚, 30˚, 45˚, 60˚, 75˚, and 90˚
The square cutout and ϕ is the angle of rotation with respect to x axis the square cutout is rotated counterclockwise like 0˚, 15˚, 30˚, 45˚, 60˚, 75˚ and 90˚, for different values of bluntness like 0.1, 0.25, 0.3, 0.5, 0.75, 0.9 and 1.0.

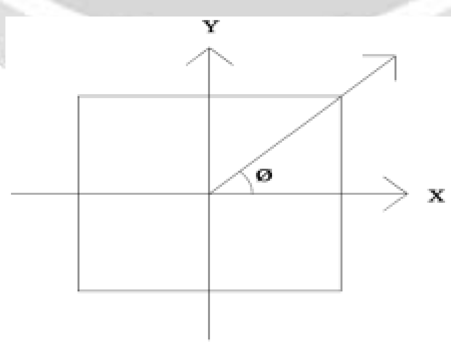

Fig-1 Rotation of square cutout

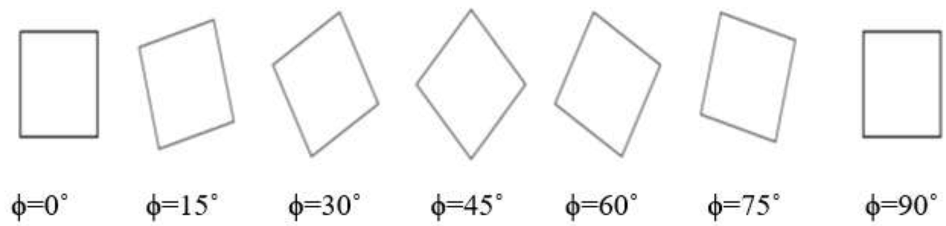

Fig-2 Rotated cutouts for

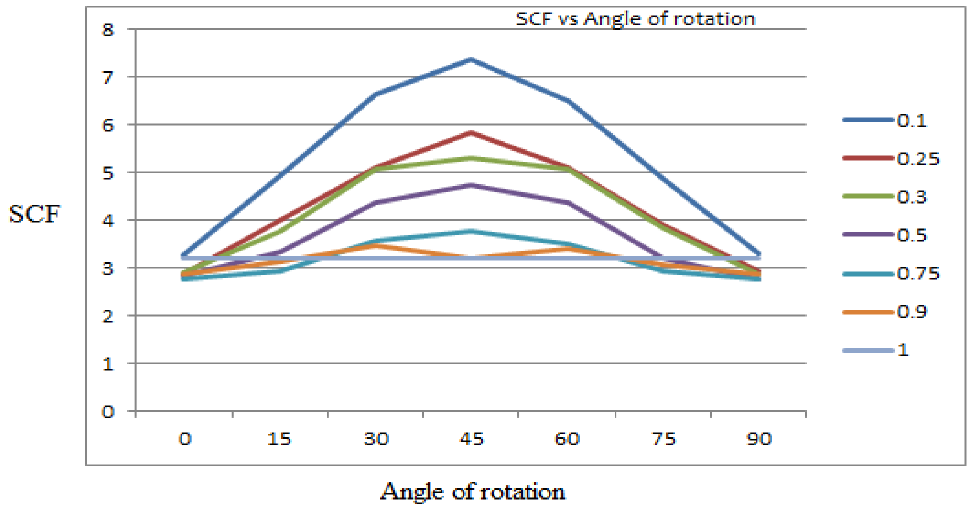

Chart -1: SCF vs Angle of rotation for square cutout

3.2 Triangular Cutout

For triangular cutout the following parameters are consider for experimentation

Parameters:-

Bluntness (w) - 0.1, 0.25, 0.3, 0.5, 0.75, 0.9 and 1.0

Orientation - 0˚, 15˚, 30˚, 45˚ and 60˚

Following Fig 3.3 shows the triangular cutout and ϕ is the angle of rotation with respect to x axis the triangular cutout is rotated counterclockwise like 0˚, 15˚, 30˚, 45˚and 60˚, for different values of bluntness like 0.1, 0.25, 0.3, 0.5, 0.75, 0.9 and 1.0. Fig 3.4 shows the different rotational conditions of the cutouts

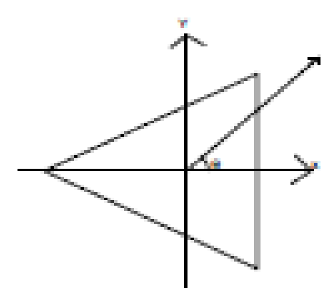

Fig-3 Rotation of triangular cutout

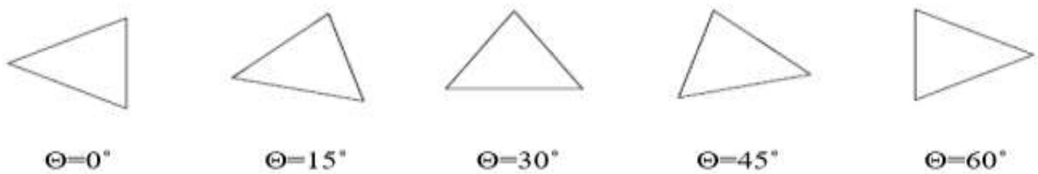

Fig-4 Rotated cutouts for triangle

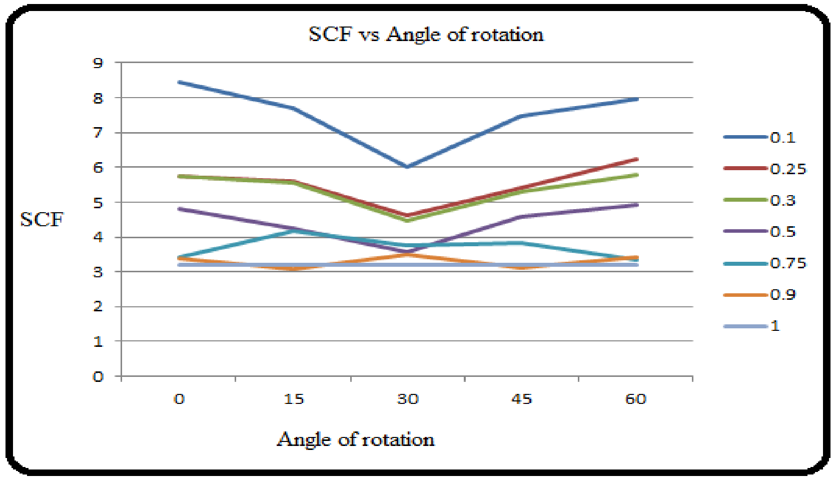

Chart-2 SCF Vs Angle of rotation for triangular cutout

3.3 Experimental Validation (Electrical Strain Gauge Method)

Vishay micro-measurement P3 strain indicator and recorder module Electrical strain gauge method is used for finding out the stress concentration factor for elliptical cutout; the experimental setup is shown in following Fig., P3 strain module (Strain indicator) is used for strain measurements.

Fig-5 Experimental setup for square cutout (Electrical strain gauge method)

4. CONCLUSIONS

From above experimentation is cleared that, we can control the SCF value by changing the parameters like bluntness, cutout shape and orientation of cutout with respect to applied force,

- For square cutout the maximum SCF value is 7.37(FEA), when bluntness is 0.1 and θ = 45˚. We know generally for circular cutout the SCF value is 3, from above experimentation it is noted that for square cutout SCF value can be reduced to 3 when bluntness value 0.25, 0.3, 0.5, 0.75 and 0.9 (and θ = 0˚ or 90˚) that means any two opposite sides of a square must be parallel to applied force at this condition SCF value is minimum for any bluntness value.
- For triangular cutout the maximum SCF value is 8.45, when bluntness is 0.1 and θ = 0˚. from experimentation it is noted that for triangular cutout SCF value cannot be reduced to 3 for any bluntness value but it can be nearly equal to 3 and the one side of a triangular must be perpendicular to the applied force at this condition SCF value is minimum for any bluntness value except (w= 0.75 and 0.9).

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