STRESS REDUCTION USING SEMI ELLIPTICAL SLOTS IN AXIALLY LOADED PLATE HAVING CIRCULAR HOLE

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ABSTRACT

When a plate with circular hole is subjected to axial loading, the region in the vicinity of hole is under high stress. To reduce this stress, normally one auxiliary hole is introduced on either side of the main hole. The present work studies how a semi-elliptical slot on each side of the hole effects the maximum stress induced in a isotropic plate with circular hole. Using finite element analysis method, stress calculation is carried out in ANSYS. The effect of variation in the geometric parameters of ellipse on ‘maximum stress’ is presented in graphical form. Stress reduction of 42% is achieved for a particular combination of geometric parameters. A relation for these optimum geometric parameters is obtained with respect to the hole diameter.

Keywords: Slot, Stress Reduction, Semi-Elliptical, Optimization.

1. INTRODUCTION

As a general practice, in order to reduce the stress concentration around a circular hole, auxiliary holes of smaller dimensions are drilled on either side. But this method has certain limitations. Different approaches for stress reduction are examined and analysed in the literature.

H Acharya [1] obtained a relation for the optimum diameter and centre distance of auxiliary hole for 21% stress reduction and showed that thickness and width of the plate does not affect the optimum hole dimensions. N. K. Jain [2] carried out finite element study for reducing SCF by four coaxial holes on either side of the main hole. Using this he revealed that holes helps to smooth flow of the tensile stresses through the main hole. He also studied the effect of length and diameter of two auxiliary holes on each side of the main hole in isotropic and orthotropic plates. V Manur [3] studied the optimum location and diameter of auxiliary holes with respect to different diameter to plate width ratios. Plotting the graph of stress concentration factor (SCF) v/s Central hole diameter-to-plate width ratio, he found that SCF can be relieved by a factor of 19 to 21 percentage. Z Yang [4]
observed the sensitivity of the stress and strain concentration factor with respect to plate thickness as well as the Poisson’s ratio. While the structural dimensions like hole diameter and plate thickness were varied to examine their effect directional stress concentration factor and net deflection of the plate by S. Nagpal [5]. Studying the effect of fiber orientation of composite materials on stress concentration, B Endigeri [6] found that fibre oriented at 45° and 135° results in minimum stress concentration. While N.K. Jain [7] analysed the distributions of stresses and deflection in simply supported rectangular isotropic and orthotropic composite plates with central circular hole subjected to transverse static loading using 3-D finite element method. Using numerical analysis, in order to minimise the stress concentration factor, Mansfield [8] determined optimum distributions of compact edge reinforcement around a circular hole in a flat sheet subjected to uniaxial tension. P. K. Mallick [9] presented a method in which transverse normal pressure created by bolt clamping at open holes can be used to mitigate the hole stress concentration and increase the fatigue life of the plate. D Gunwant [10] studied stress in a plate with elliptical hole for different aspect ratios and compared the results of ANSYS with the analytical method.

As per these literatures, introducing circular holes, maximum stress reduction of only 21% can be achieved. Also in order to achieve this reduction, auxiliary holes are to be drilled very near the main hole making it weak.

Elliptical holes can be used instead of circular ones but very large elliptical holes on both side of main hole will increase the machining cost. Hence a semi-elliptical slot is studied in this paper.

2. DESCRIPTION OF PROBLEM

As shown in fig. 1 a plate of width 100 mm and thickness 10 mm is taken. In order to study an infinitely long plate, length 2000 mm is taken. While the main hole diameter is D = 40 mm and slot width is kept 5mm. Keeping these dimensions constant, the values of ‘a’, ‘b’ and ‘l’ are varied. A tensile force of 1000N is applied on one end of the plate while keeping the other end fixed.
3. FINITE ELEMENT ANALYSIS

A quadrilateral element is selected with maximum face length of 2mm. The element has eight nodes with each node having two degree of freedom, giving a total of sixteen degree of freedom per element. Proximity and curvature function is used in meshing to give fine meshing near the holes. The study is done for isotropic material. So the material taken is structural steel with Young's modulus 2E+11 Pa and Poisson's ratio 0.3.

4. RESULTS AND DISCUSSION

To observe the effect of change in the geometric parameters, a total of 185 design points with different combination of major axis, minor axis and centre distance are calculated for maximum stress in the plate. Using the optimization module of ANSYS, it is found that minimum value of ‘Equivalent maximum stress’ is 2.1516 MPa at a= 100mm, b= 20mm, l= 20mm. When the same plate without semi-elliptical slots is used under the same force the ‘Equivalent maximum stress’ is 3.7698 Mpa. Hence by introducing the slots of optimized geometric parameters, a stress reduction of 42.92% can be achieved.

As there are three input and one output parameters, it is not possible to show the relation of all the four parameters in one graph. Hence a graph of variation in maximum stress with respect to ‘a’ is shown in fig 2. In graph (i), the curved lines represent corresponding values of ‘b’ while for l= 20mm in graph (ii) the curved lines represent corresponding ‘l’ values for b= 20mm. From both the graphs, it can be seen that stress is minimum with increasing ‘a’ and for any value of ‘b’ or ‘l’, increasing ‘a’ beyond 100mm does not yield appreciable decrease in stress value hence optimum value of a= 100mm (2.5 D) is taken.

The variation in maximum stress with respect to ‘b’ is shown in fig 3. In graph (i), the curved lines represent corresponding values of ‘a’ for l= 20mm while graph (ii) the curved lines represent corresponding ‘l’ values for a= 100mm. From both the graphs, it can be seen that stress is minimum for b= 20 – 21mm thus a relation b = 0.5 D is obtained.
The variation in maximum stress with respect to ‘l’ is shown in fig 4. In graph (i), the curved lines represent corresponding values of ‘a’ for b=20mm while graph (ii) the curved lines represent corresponding ‘b’ values for a=100mm. From both the graphs, it can be seen that stress is minimum for l= 20 – 22mm thus a relation l = 0.5 D is obtained.

(i) With respect to ‘a’

(ii) With respect to ‘l’

Fig 3: Stress Vs ‘b’

The variation in maximum stress with respect to ‘l’ is shown in fig 4. In graph (i), the curved lines represent corresponding values of ‘a’ for b=20mm while graph (ii) the curved lines represent corresponding ‘b’ values for a=100mm. From both the graphs, it can be seen that stress is minimum for l= 20 – 22mm thus a relation l = 0.5 D is obtained.

(i) With respect to ‘a’

(ii) With respect to ‘l’

Fig 4: Stress Vs ‘l’

5. CONCLUSION

In this study, by using semi-elliptical slots it is seen that maximum possible stress reduction of 42% can be achieved which is double of what can be achieved using auxiliary circular holes (21%). The relation of optimum geometric parameters for stress minimization with respect to main hole diameter is: a= 2.5D, b= 0.5D and l= 0.5D.
REFERENCES


