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Optimization Of Rectangular Plate With Two Holes Subjected to In-Plane Static Loading

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Abstract— Any discontinuity in structure penetrates the strength of the structure. The stress starts concentrating near the discontinuity. The study of stress distribution for the rectangular plate with two holes under in-plane load is analysed numerically with the help of Finite Element Method. The material used for the plate is isotropic in nature. In this paper a method is attempted to reduce the intensity of stress in the vicinity of holes by relocating the position of one of the holes. A rectangular plate with holes having negligible thickness is analysed. From this analysis author has found the variation in the intensity of stress in the plate for different W/CD ratios. The W/CD ratio considered are1.67, 2.0 and 2.5. Variation in stresses with respect to different hole locations is studied and plotted by graph. The results of reduction in intensity of stresses for different W/CD ratios are tabulated. The finite element formulation is carried out by using the software ANSYS

Keywords— Finite Element Analysis, Center distance, Discontinuity, Relocation, Stress, Position, Variation

Nomenclature— *W—Width of rectangular plate, mm; d—Diameter of hole, mm ;CD —Centre Distance of holes, mm; P—Load on the plate,N; σnom —Maximum stress at discontinuity, MPa ; σmax —Maximum stress at discontinuity, MPa; Kt—Stress concentration factor*

1 INTRODUCTION

Most of the members in the automobile body structure are made of sheet metal components. These sheet metals are of very less thickness in the range of 2 to 5mm.Out of these sheet metal members, many are having discontinuities like holes of different shape and size. Location of the holes at right place is a constrain in these cases.

In such cases there will be possibility of concentration of stresses around the discontinuities. Any small reduction in these Stresses is accountable.

In this study an attempt has been done to shift the location of holes by very negligible amount so that it will not hamper the functional ability of the component.

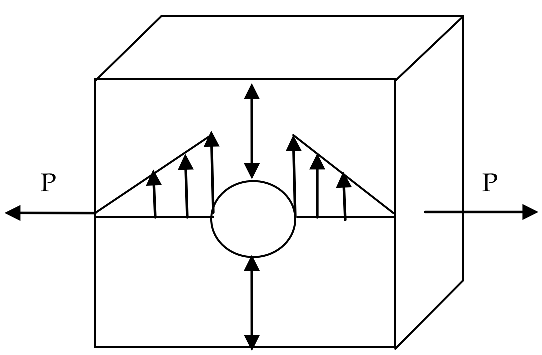

Fig.1 Plate under tensile stress.

Any discontinuity in structure penetrates the strength of the structure. The flow of stress is altered due to discontinuity. The stress starts concentrating near the discontinuity.

These stress concentrations are of concern during both the preliminary and detail design of any structure.

Through theory and experimentation, it has been shown that some of the stress concentration areas will have a stress value several times that of P/A. The ratio of these increased stress values as compared to the P/A value is termed the stress concentration factor.

Consider a plate under tensile stress as shown if fig1, a K value greater than one signifies that the local stress exceeds the average stress in the smaller cross sectional area, 2a. Value of K less than one but greater than zero indicates that the local stresses are reduced. Value of K is less than zero means that the structure is in compression.

Of particular interest to designers are the maximum values of the local and far field stress

The location and magnitude of this maximum stress will vary depending on a number of factors. These factors include the size of discontinuity, shape of the discontinuity, number of discontinuity, location of discontinuity and the relative size of discontinuity. It is desirable to apply techniques to reduce the stress concentration around the holes.

2 PROBLEM DEFINITION

The geometry of the problem considered in this study is as shown in below figure.

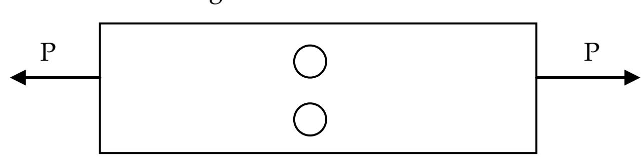

Fig.2 Plate with hole subjected to tensile load.

Rectangular plate of 500mm length, 100mm width and 2mm thickness is considered for analysis. Two holes of 20mm diameter at equidistant from center are considered as discontinuities in the rectangular bar.

The isotropic material of the plate is structural steel with Poisson s ratio=0.3, Young s modulus E=200 GPa.

Uniform tensile load of P=20KN is applied to the plate in axial direction. The model has been analysed for different hole locations along the length.

The maximum relocation of hole position from is kept within 1mm from its actual position. The hole is shifted to the next location in steps of 0.1mm. A four noded structural Plane42 element type with free meshing is used for the discretization of the plate with holes.

The fig.3 shows rectangular plate with the element mesh. Each node has two degrees of freedom. The whole model is considered for discretization and analysis.

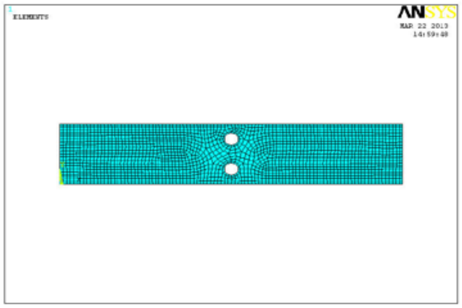

Fig.3 Plate with hole meshed

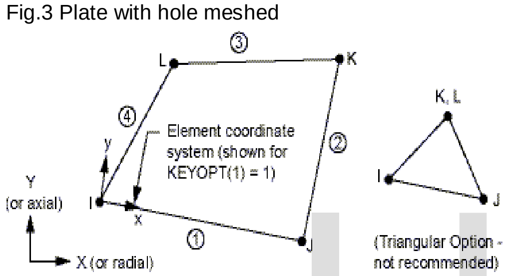

Fig.4 4noded Plane 42 element geometry.

3 Analysis of Rectangular Plate with Two Holes

The problem is identified as a plane stress problem as the sheet metal thickness is less i.e 2mm.

3.1Theoretical Results

d/w=20/100=0.2
Kt=2.5
σnom= F/A=2000/(100-20)*2
σnom =12.5MPa
σmax = σnom*Kt
=12.5*2.5
σmax =31.25MP

3.2. ANSYS Analysis

Finite element analysis software ANSYS is a capable way to analyse a wide range of different problems. ANSYS has the following steps to for problem solving.

3.2.1. Modeling

It includes the system geometry definition and material property selection. In this step user can draw either 2D or 3D representation of the problem. For the problem described a sheet metal plate with 2mm thickness is modeled.

3.2.2. Meshing

This step involves discretization of the model according to predefined geometric model. Plane 42 element is chosen for meshing the given model.

3.2.3. Solution

In this step, we apply boundary conditions and loads to the system that solves the problem.

3.1.4. Post Processing

This step involves plotting/listing the nodal solutions, which may be displacements in different directions, stresses in different directions etc.

The plate has been analysed for different locations of one of the holes in the rectangular plate. The results are tabulated in the Table. The study of intensity of stresses has been made.

TABLE.1 Variation of stress with W/D ratio while shifting the hole location along positive X-axis

W/CD	Max Intensity of stress	Min Intensity of stress
100/40	32.043	31.081
100/50	32.299	32.093
100/60	32.633	32.57

TABLE.2 Variation of stress with W/D ratio while shifting the hole location along negative X-axis

W/CD	Max Intensity of stress	Min Intensity of stress
100/40	32.043	31.152
100/50	32.299	32.124
100/60	32.633	32.578

We can see from table I and II that the intensity of stress will decrease with change in location of holes.

One basic model of rectangular plate with two holes is generated for different W/CD ratios in ANSYS.

In the literature it has been already mentioned more the discontinuities more the chances of failure.

Here the study of effect of changing one of the hole locations for different W/D ratios is made. The hole location is changed such that it should not affect the functional requirement of the recess.

In this study the maximum distance of relocation of hole is considered as 1mm.One of the hole is relocated from its previous position in steps of 0.1mm.The observed results of the stress variation are tabulated in the following figures.

4 Case I

Results for change in stress values when one of the hole is relocated along the positive x-axis.

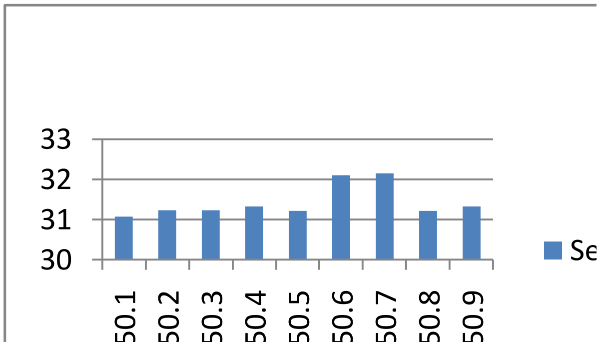

Fig.5 Graph for Hole with 40mm centre distance

The fig.5 shows the variation of maximum stress for different hole locations in steps of 0.1mm for W/D ratio of 2.5.

By performing the iterations for change in hole locations it is found that the maximum stress is 32.093MPa as compared to maximum stress of 32.299MPa in the actual case.

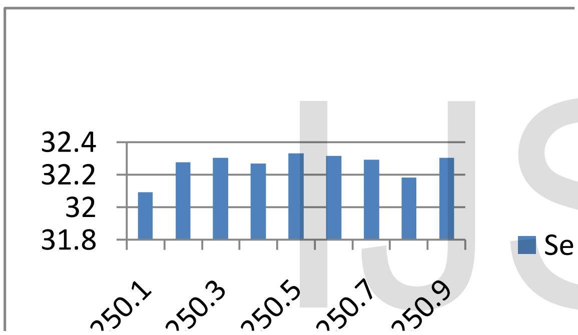

Fig.6 Graph for Hole with 50mm centre distance

The fig.6 shows the variation of maximum stress for different hole locations in steps of 0.1mm for W/D ratio of 2.0.

By performing the iterations for change in hole locations it is found that the maximum stress is 31.081MPa as compared to maximum stress of 32.299MPa in the actual case.

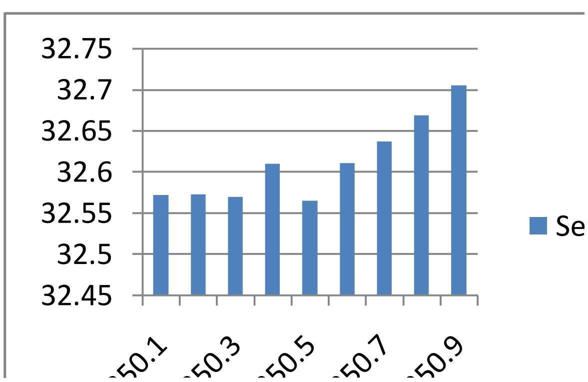

Fig.7 Graph for Hole with 60mm centre distance

The fig.7 shows the variation of maximum stress for different hole locations in steps of 0.1mm for W/D ratio of 1.667.

By performing the iterations for change in hole locations it is found that the maximum stress is 32.57MPa as compared to maximum stress of 32.299MPa in the actual case.

5 Case II

Results for change in stress values when one of the hole is relocated along the negative x-axis.

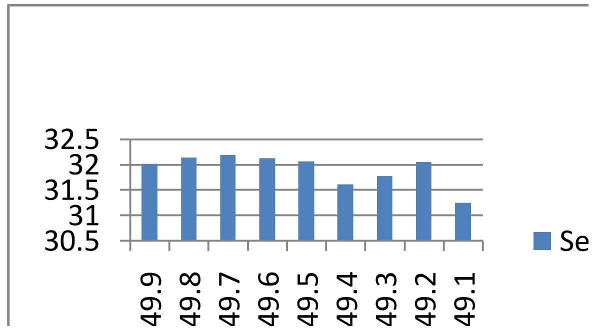

Fig.8 Graph for Hole with 40mm centre distance

The fig.8 shows the variation of maximum stress for different hole locations in steps of 0.1mm for W/D ratio of 2.5.

By performing the iterations for change in hole locations it is found that the maximum stress is 32.57MPa as compared to maximum stress of 32.299MPa in the actual case.

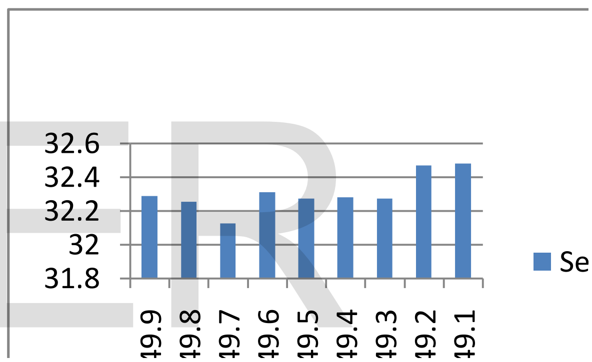

Fig.9 Graph for Hole with 50mm center distance

The fig.9 shows the variation of maximum stress for different hole locations in steps of 0.1mm for W/D ratio of 2.0.

By performing the iterations for change in hole locations it is found that maximum stress is 32.57MP as compared to maximum stress of 32.299MPa in the actual case.

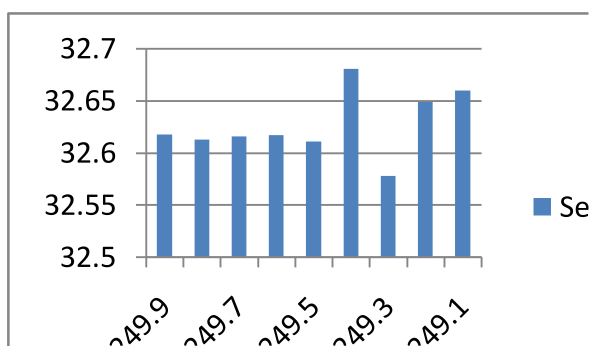

Fig.10 Graph for Hole with 60mm centre distance

The fig.10 shows the variation of maximum stress for different hole locations in steps of 0.1mm for W/D ratio of 1.667.

By performing the iterations for change in hole locations it is found that the maximum stress is 32.57MPa as compared to maximum stress of 32.299MPa in the actual case.

6. Reduction in Intensity of stress

In literature many methods are proposed for stress analysis around the discontinuity. Many methods are tried for reducing the stresses around discontinuity.

Three basic models of finite rectangular plate with two holes are generated for W/D ratios of 2.5,2 and 1.67 in ANSYS. We already know that by introducing auxiliary holes, fillets at square corners and by reinforcement on discontinuity, we get reduction in intensity of stresses.

We studied the effect of several position changes of hole on intensity of stress that are related to the geometry of discontinuity in the plate. In present analysis all the models are analysed by relocating the position of one of the holes with other.

7. Results and Discussion:

Numerical results obtained from 2D finite element analysis for different case studies of uniaxial loaded rectangular plate with two holes are presented with bar charts.

The intensity of stress will change as the relocation of one of the holes takes place along the positive x-axis as shown in figures 5,6and7.It is found that at some location(within range of 1mm) the maximum intensity of stress will reduce and will become minimum. The table1 shows the minimum stress values for different center distances.

Similarly the intensity of stress will change as the relocation of one of the holes takes place along the negative x-axis as shown in figures 8,9and10.It is found that at some location(within range of 1mm) the maximum intensity of stress will reduce and will become minimum. The table2 shows the minimum stress values for different centre distances.

Hence the above method can be used for reducing the maximum intensity of stress around the discontinuities without affecting the functional requirement of the component.

8. Conclusion:

Stresses will be higher at the discontinuities in the structure. As the discontinuities increase the stresses will increase near the discontinuity.

We can conclude from the above results that with changing the location of one of the holes the stresses can be reduced. The results also enable us to find the optimum hole location for a particular w/d ratio.

Another useful information is that variation of stresses will be different when we consider relocation of one of the holes along the positive and negative x-axis.

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