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Topology optimization of rectangular plate having central circular hole & provision of auxiliary holes to reduce SCF

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Abstract - *The rectangular plate having central circular hole is generally used as a connecting member in many of the assemblies. Because of the central hole the stress concentration factor of the plate increases and that results in reduced life of the component. In this paper to improve the life of component and to reduce value of its stress concentration factor the provision of auxiliary hole has made. These auxiliary holes make the flow of stresses smooth and improve life of component. In this to find the exact location for the provision of the auxiliary holes Topology optimization has been conducted which gives us idea about the exact location as well as the optimum material layout of the of the rectangular plate.*

Key Words: Rectangular plate, Topology optimization, Auxiliary holes

1. INTRODUCTION

Many of the structures use rectangular plate having central circular hole for connection purpose in the assemblies. The hole at the centre of the rectangular plate satisfies the functional requirement of bolting or riveting. But that hole while satisfying functional requirement also leads to increment of stress concentration factor of the plate. This paper work focuses on the reduction of stress concentration factor by provision of the auxiliary holes at the various distances from the centre of main hole. Here topology optimization of the plate and the analysis of each plate model has been conducted in Finite Element Analysis software Hypermesh.

1.1 Problem Definition

Reduction of stress concentration factor of the plate of length 200mm, width 100mm, thickness 1mm and having central circular hole of 10mm to improve its life.

1.2. Literature Review

Zheng Yang et al. in "The concentration of stress and strain in finite thickness elastic plate containing circular hole" investigated the elastic stress and strain fields of finite thickness plate containing a hole subjected to uniaxial tension by finite element method. [1]

Shubhrata Nagpal et al. in "Analysis and mitigation of stress concentration factor of a rectangular isotropic and orthotropic plate with central circular hole subjected to in plane static loading by design optimization" studied the effect of structural dimension ratio upon stress concentration factor for different cases. [2]

Nagpal S., et al. in "Mitigation Curves for Determination of Relief Holes to Mitigate Stress Concentration Factor in Thin Plates Loaded Axially for Different Discontinuities" described mitigation curves for the relief of stress concentration factor. [3]

Shubhrata Nagpal in "Optimization of rectangular plate with central square hole subjected to in plane static loading for mitigation of SCF" studied the SCF for rectangular plate with central square hole by finite element method. [4]

2. METHODOLOGY

Following flow chart shows the methodology followed for the work

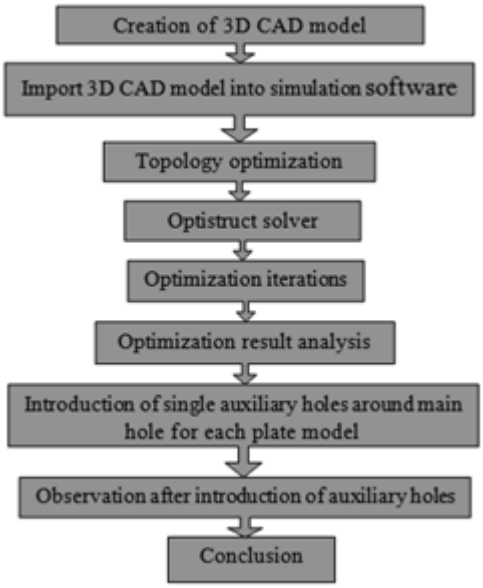


Fig.-1: Flow chart of methodology

In this work the 3D model of plate having central circular hole prepared and the topology optimization of the plate has conducted in Hypermesh using optistruct solver. After getting the exact location for the provision of auxiliary holes

trials of the provision of auxiliary holes have conducted to find minimum and maximum reduction in stress concentration factor of the rectangular plate.
Material: Galvanized steel 550 (G550) is material used for the rectangular plate. Young modulus (E) = 240 GPa, Poisson's Ratio = 0.3, Material density = 7900 Kg/ m^3

3. DESCRIPTION

3.1 Topology Optimization

Topology Optimization is the technique that is used to produce an optimized material layout of the component. With this technique we can get optimized shape and material distribution for a component within a given space. Optistruct solver of Hypermesh has used for that optimization. Optistruct calculates material properties for each element of the component and it also changes the distribution of material to get optimum material layout. In topology optimization, the material density of each element will be either 0 or 1, that means it is either void or solid, respectively. The steps carried out in optimization process using optistruct solver of HYPERMESH software are as shown in figure 2.

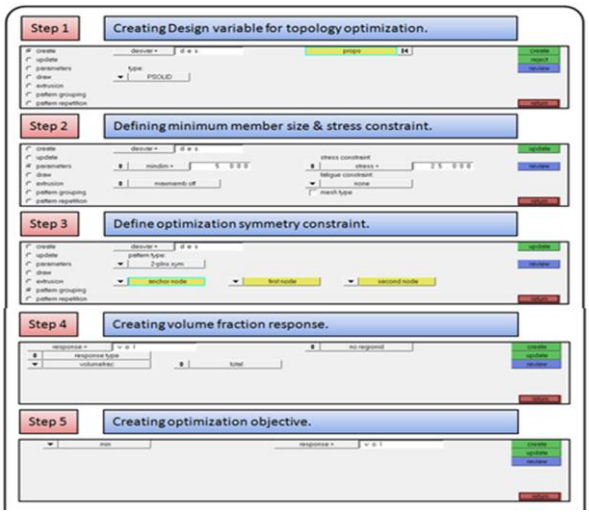


Fig.-2 Steps in optimization

3.2 Topology Optimization Results

The optistruct solver gives the results in the form of iterations of which the last iteration gives the optimized solution. Some iteration are shown in fig 3 to fig. 6

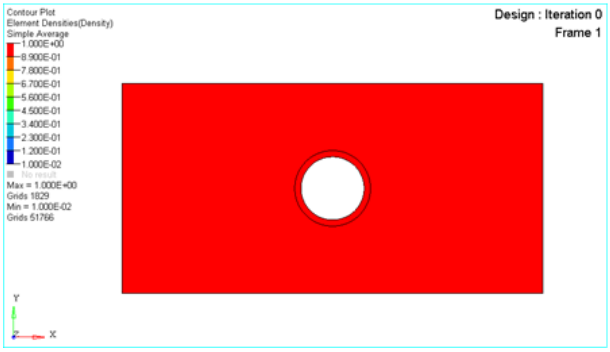
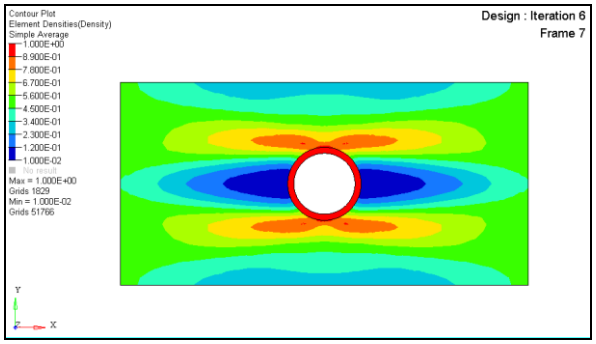


Fig.-3 Iteration 0



. **Fig.-4** Iteration 6

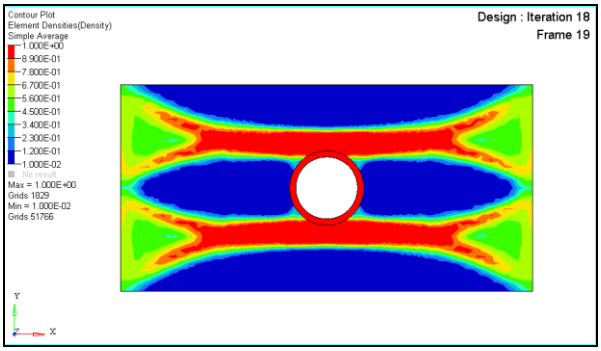


Fig.-5 Iteration 18

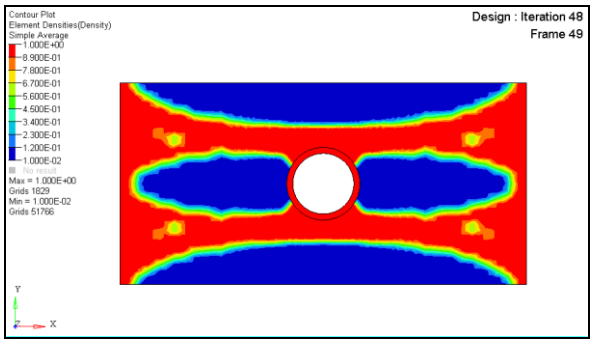


Fig.-6 Iteration 48

At 48th iteration of topology optimization optimized material layout of plate has obtained. It shows blue colored regions where we can place auxiliary holes for stress relief of plate. But the blue regions at the boundary of plate will change the shape of plate which is not desired. Hence auxiliary holes can be introduced at the blue ellipsoid region. That will not change shape of plate.

3.3 Trials with the Auxiliary holes

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.

Stress concentration can be reduced by placing auxiliary holes along with the main hole. The auxiliary holes can be placed in the ellipsoid region shown by last iteration of topology optimization. The minor diameter of that ellipsoidal shape is same as that of the diameter of the main hole at the centre of the plate and major axis is same as that of the t length of the rectangular plate. Hence the diameter of auxiliary hole depends on the ellipsoid shape obtained in the topology optimization. The size of auxiliary hole provided will be reduced as the distance between main hole and auxiliary hole increases. The distance of auxiliary hole from main hole is measured in the direction of length of plate along the circumference of circular hole. The plate models considered are having distances between main and auxiliary hole as 10mm, 20mm, 30mm, and 40mm. The trials are carried out for each plate model in the same manner of loading conditions.

Trial for 10 mm distance for plate with D/A=0.1

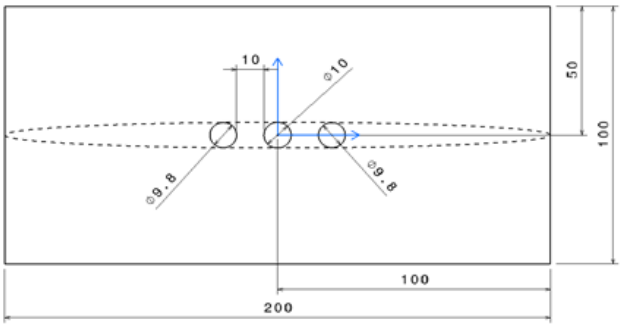
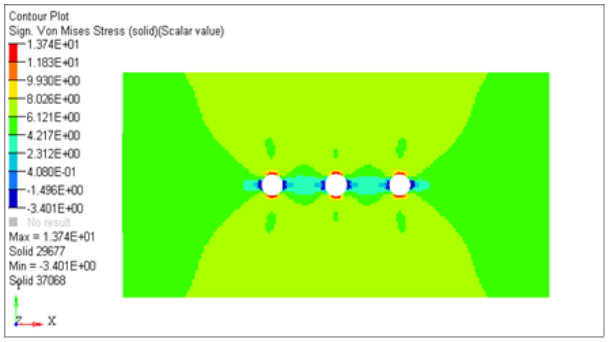


Fig.-7 Plate with D/A=0.1 and distance=10

Fig.-8 Zero setting of Digital strain Indicator



. **Fig.-8** Iteration 6

In the same manner analysis has been conducted and values of stress for all the models of the plate are collectively represented here in the table 1.

Table1. Results of trials taken on each plate model

D/A ⇨	0.1		0.2		0.3		0.4		0.5		0.6	
Distance of A.H from M. H. (mm) ⇩	Stress MPa	% Reduction in stress	Stress MPa	% Reduction in stress	Stress MPa	% Reduction in stress	Stress MPa	% Reduction in stress	Stress MPa	% Reduction in stress	Stress MPa	% Reduction in stress
10	13.13	17.21%	14.57	15.34%	16	13.51%	18.37	12.32%	22.02	10.31%	26.54	12.00%
20	13.74	13.37%	15.07	12.43%	16.56	10.49%	18.99	9.36%	22.28	9.25%	27.01	10.44%
30	13.82	12.86%	15.4	10.52%	17.12	7.46%	19.61	6.40%	22.79	7.17%	32.07	-6.33%
40	13.82	12.86%	15.98	15.98%	17.56	5.08%	20.1	4.06%	25.26	-2.89%	29.22	3.12%
Original Values of stress without A. H in MPa	15.86		17.21		18.5		20.95		24.55		30.16	

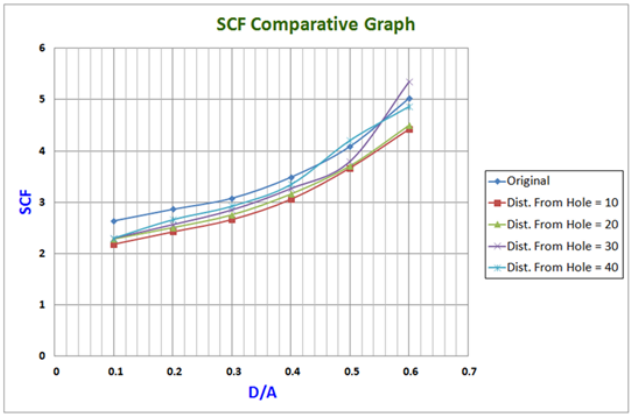


Fig.-9 SCF comparative graph for all trials

As per the values of stresses the stress concentration factor of each plate model calculated and plotted a graph which is shown in the figure 9. Graph shows behaviour plates having D/A ratio 0.1, 0.2, 0.3, 0.4, 0.5 and 0.6 when auxiliary holes are provided at 10mm, 20mm, 30mm and 40mm for each. It shows nature of graph shows the effect of distance of change in of auxiliary holes from the centre of the main hole on the stress concentration factor of the rectangular plate having central circular hole.

4. RESULT & DISCUSSION

From analysis the maximum reduction of stress (17.21%) observed in the plate having D/A ratio 0.1 with auxiliary holes at 10 mm on either sides of the main hole & minimum reduction of stress (-6.33%) observed in the plate having D/A ratio 0.6 with auxiliary holes at 30 mm on either sides of main hole. And also from graph it is concluded that the value of stress concentration factor of the plate having D/A ratio 0.1, when auxiliary holes are provided at 10 mm from the centre of main hole is considerably less than the original value of stress concentration factor without auxiliary holes.

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