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Modal Analysis of Rectangular Plate with Circular Cut out Subjected to Different Boundary Conditions.

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Abstract - *The aim of this paper is to perform a modal analysis to determine the natural frequencies and mode shapes for the mild steel specimen. This research presents an experimental of the Model analysis of Square Mild steel plate with circular cut out. The Various sizes of square mild steel plate with circular cut outs are considered in order to examine the effect of cut out size and boundary condition on the fundamental natural frequency of the square plate. The Natural frequencies of the finite element (FE) were analyzed by the Optistuct software, which was found by analysis.*

Key Words: *Circular Cut out; Model Analysis; Boundary Condition; Square plate; FEM.*

1. INTRODUCTION

The paper aims to calculate the natural frequencies and accompanying mode shapes of the plate which are the key parameters when considering noise and acoustic parameters. To determine these parameters modal analysis will be used.

Vibration problems are often occurred in mechanical structure. It is important to prevent such problems because it can cause structures damage by fatigue. The structure itself has a certain properties so it is necessary to understand its characteristics. In this work a modal analysis by finite element method is used.

The main purpose of modal analysis is to study the dynamic properties of structures like natural frequency and mode shapes. This can also be used for some purposes such as, troubleshooting i.e. direct insight into the root cause of vibration problems, find structural flexibility properties quickly to monitor incremental structural changes, design optimization-design according to noise and vibration targets, enhance performance and reduce component and overall vibration & fast, test based evaluation of redesign for dynamics etc.

So it is important to determine dynamic properties of a square plate of mild steel material. First the modal analysis of a square plate is done by finite element analysis software method.

Modal analysis is a method of determining the natural acoustic characteristics or dynamic response of materials. The analysis involves imposing an excitation into the structure and finding the frequencies at which the structure resonates (when the excitation and vibration response match). A typical modal analysis will return multiple frequencies each with an accompanying displacement field which the structure experiencing at that frequency. Each frequency is known as mode and displacement field is known as mode shape.

In this work the free vibration responses of a square mild steel plate with different circular cut outs at the centre and subjected to different boundary conditions is tabulated and analyzed.

2. PROBLEM MODELING

Square plate with circular cut out Various sizes of centrally located circular cut outs are considered in order to examine the effect of cut out size on the natural frequency of the square plate. The plate has thickness of 5mm. The material properties of the plate are given in Table 1.

The cut out ratio (i.e. d/a) along x-axis and y-axis is varied from 0.0 to 0.6 in steps of 0.25. Plate geometries for plates with cut out ratio 0.0, 0.125, 0.375, 0.625 are shown in Fig 1

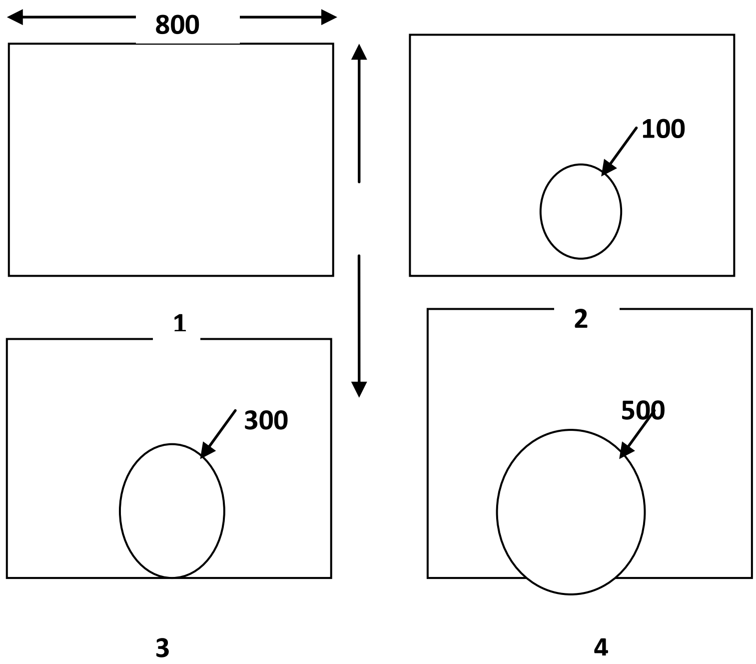

Figure 1: Geometry of the plate

1) Plate geometry with cut out ratio 0.

2) Plate geometry with cut out ratio 0.125.

3) Plate geometry with cut out ratio 0.375.

4) Plate geometry with cut out ratio 0.625.

Four types of boundary condition namely FFFS, FFSS, FSSS and SSSS (where F and S stand for a free, a simply supported) are considered in order to examine the effect of boundary condition on the fundamental natural frequency of a square mild steel plate with a centrally located circular cut out. The FFFS, FFSS, FSSS, SSSS stand for four types of boundary conditions.

Table 1: Material properties of the Plate.

Material Constant	Young's modulus	Density	Poissons ratio
Values	2E5N/mm2	7800Kg/m3	0.3

The meshed model of square plate with cut out ratio of 0.375 is as shown in figure2

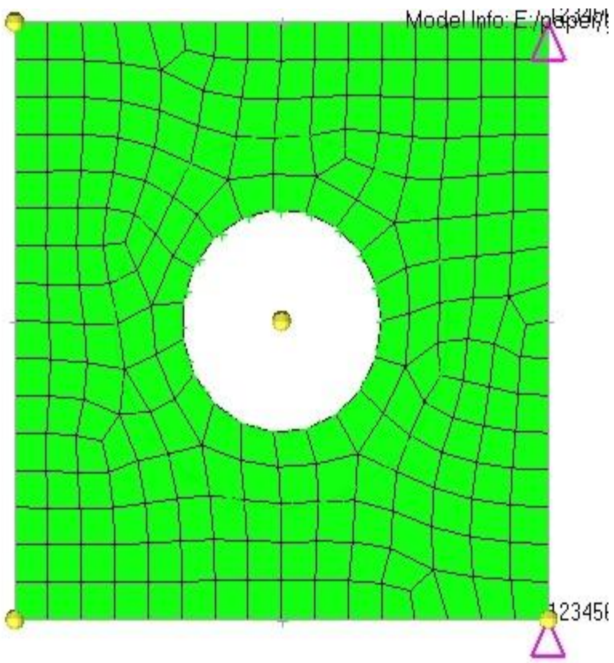

Figure 2: Square plate with cut out ratio of 0.375

Cut out ratio is varied from 0.0 to 0.625 in steps of 0.25.Plate geometries for plates with cut out ratio 0.0, 0.125, 0.375, 0.625, are shown in Figure 1.
The Results of Natural frequencies for various d/a ratios with different boundary conditions are summarized in Table 2.

Table2: Natural frequencies for various d/a ratios with different boundary conditions

Conditions	Modes	d/a ratio			
FFFS		0	0.125	0.375	0.625
	1	1.64	1.65	3.96E-05	2.75E-05
	2	4.28	4.27	6.69E-05	5.78E-05
	3	10.55	10.6	7.68E-05	8.89E-05
	4	17.06	16.9	3.27E-04	3.26E-04
FFSS	1	3.11	8.65E-05	3.71E-05	7.37E-05
	2	14.43	9.18E-05	5.46E-05	8.11E-05
	3	25.79	9.48E-05	7.51E-05	8.28E-05
	4	41.58	4.11E-05	3.29E-04	3.11E-04
FSSS	1	8.84	8.88E-05	3.71E-05	1.854
	2	23.89	9.21E-05	5.46E-05	4.281
	3	36.38	9.54E-05	7.51E-05	12.18
	4	44.05	4.10E-04	3.29E-04	14.37
SSSS	1	18.68	8.52E-05	3.71E-05	7.38E-05
	2	37.76	9.48E-05	5.46E-05	8.11E-05
	3	37.76	9.94E-05	7.51E-05	8.28E-05
	4	45.89	3.93E-04	3.30E-04	3.11E-04

3. RESULT ANALYSIS:

Below table shows the first 4 Natural frequencies for the steel plate with cut outs and for various boundary conditions.

Case1: Plate with No hole.

Table3: Natural frequencies for Plate with No hole condition

	SSSS	SSSF	SSFF	SFFF
F1	18.68	8.84	3.11	1.64
F2	37.76	23.89	14.43	4.28
F3	37.76	36.38	25.79	10.55
F4	45.89	44.05	41.58	17.06

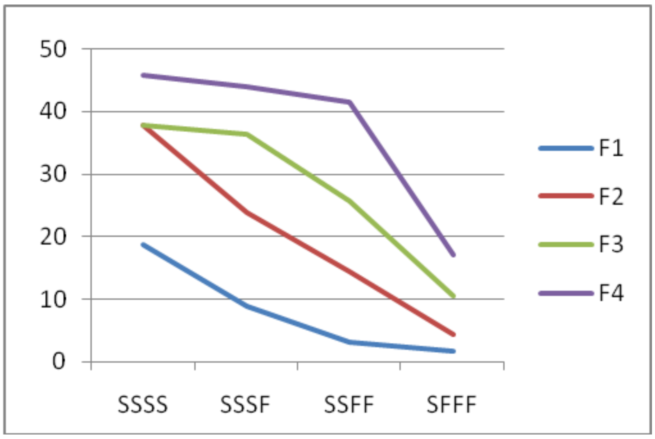

Figure3 Graph variation of frequencies for plate with no hole condition.

We can observe that all the frequencies are decreasing as we go on freeing up the corners of the plate. Hence we can conclude that the natural frequency will decrease as we go on freeing up the boundaries.

Case2: Plate with cut out (d/a) ratio of 0.125.

Table4: Natural frequencies for Plate with cut out (d/a) ratio of 0.125

	SSSS	SSSF	SSFF	SFFF
F1	8.52E-05	8.88E-05	8.65E-05	1.65
F2	9.48E-05	9.21E-05	9.18E-05	4.27
F3	9.94E-05	9.54E-05	9.48E-05	10.6
F4	3.93E-04	4.10E-04	4.11E-05	16.9

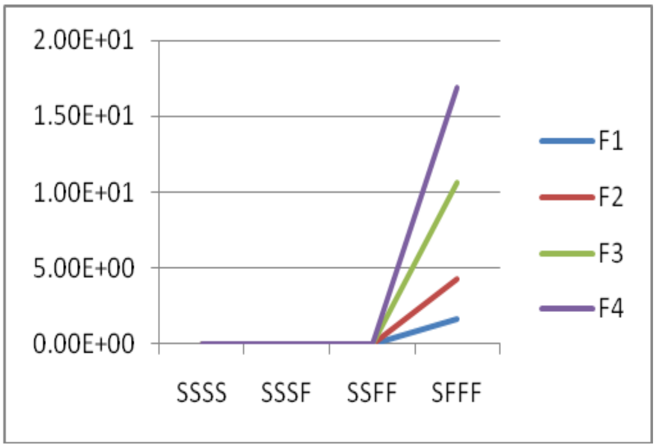

Figure4: Graph variation of frequencies for plate with cut out (d/a) ratio of 0.125

We can observe that all the frequencies are very less for SSSS, SSSF, SSFF as compared to SFFF boundary condition.

Case3: Plate with cut out (d/a) ratio of 0.375

Table5: Natural frequencies for Plate with cut out (d/a) ratio of 0.375

	SSSS	SSSF	SSFF	SFFF
F1	3.71E-05	3.71E-05	3.71E-05	3.96E-05
F2	5.46E-05	5.46E-05	5.46E-05	6.69E-05
F3	7.51E-05	7.51E-05	7.51E-05	7.68E-05
F4	3.30E-04	3.29E-04	3.29E-04	3.27E-04

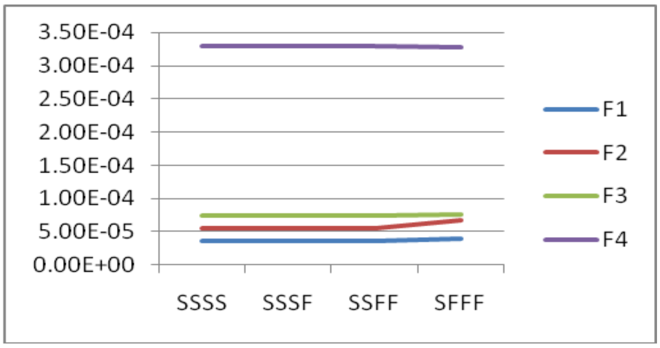

Figure5: Graph variation of frequencies for plate with cut out (d/a) ratio of 0.375

We can observe that all the frequencies are very negligible for all the conditions.

Case 4: Plate with cut out (d/a) ratio of 0.625

Table6: Natural frequencies for Plate with cut out (d/a) ratio of 0.625

	SSSS	SSSF	SSFF	SFFF
F1	7.38E-05	1.854	7.37E-05	2.75E-05
F2	8.11E-05	4.281	8.11E-05	5.78E-05
F3	8.28E-05	12.18	8.28E-05	8.89E-05
F4	3.11E-04	14.37	3.11E-04	3.26E-04

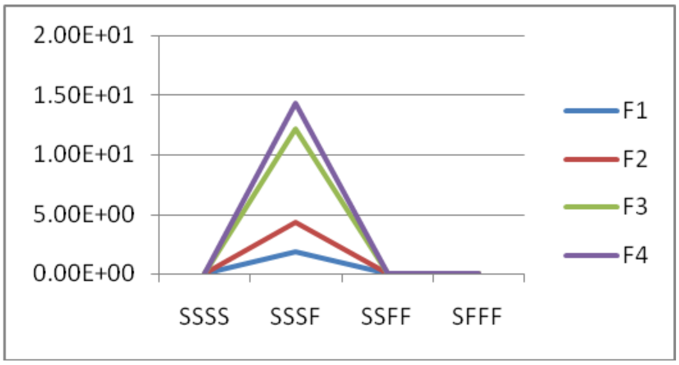

Figure6 : Graph variation of frequencies for plate with cut out (d/a) ratio of 0.625

Here we can observe that the natural frequencies are negligible for SSSS, SSFF, SFFF as compared to SSSF boundary condition.

CONCLUSION

The finite element formulation is used to study effect of cut out on the free vibration of Mild steel plate. The numerical results are presented and discussed in above. The broad conclusions that can be made from the present study are summarized as follows:

The fundamental natural frequency changes only marginally if a small cut out (either of the two cut out ratios being small) is made in the plate. However, for intermediate and large size cut outs, the fundamental natural frequency increases rapidly; the amount of increase depends on cut out ratios in two directions.

For square plate with circular cut out, the natural frequency increases with the increasing constraint at the boundary irrespective of the size of the cut out. However, this increase is not uniform; it is also dependent on the particular mode of vibration.

For square plate with circular cut out, an increase in cut out size does not always result in an increase in the natural frequency. Besides depending on the cut out size, the increase or decrease also depends on the boundary condition.

Hence depending upon the natural frequency required of the given component we can give the support to the system so that there will not be any resonance during the operating conditions.

Hence the required geometry of the component can be made use without causing resonance by making use of different boundary conditions.

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