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Modal analysis of cantilever beam with hole by solid works simulation

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***Abstract**:* Vibration analysis is very significant from the design point of view. It gives an idea about the dynamic behaviour of the structural elements in the actual working conditions. For that EMA i.e. Experimental Modal Analysis (EMA) is used which is a method to predict the behaviour of a system by effectively using the modal or vibration data. It helps in understanding and evaluating the dynamic behaviour of a system in actual scenario. In this paper, an attempt is made to study the free vibration analysis of the cantilever beam of ductile iron (taken as a material) with different hole sizes along the length at the centre of beam. The results obtained theoretically are cross checked using the solid works simulation package 2014.

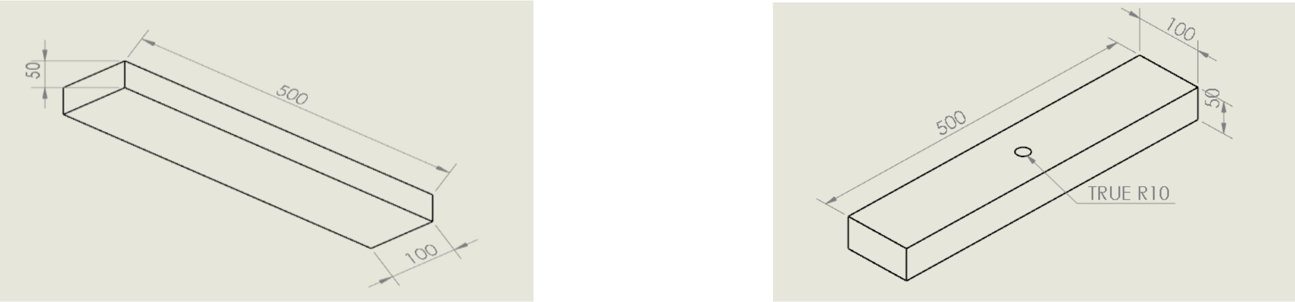
***Key Words*:** Simulation, solid works, modal analysis, free vibrations, cantilever beam.

I. INTRODUCTION

Modal analysis

The goal of modal analysis in structural mechanics is to determine the natural mode shapes and frequencies of an object or structure during free vibration. It is common to use the finite element method (FEM) to perform this analysis because, like other calculations using the FEM, the object being analyzed can have arbitrary shape and the results of the calculations are acceptable. In the presence of discontinuities, it is difficult to perform modal analysis of cantilever beam through analytical approach. The information collected from the vibration data helps the designer to make the necessary changes in the design to avoid the resonance condition of extreme amplitude of vibration, thereby increasing the reliability of the system. So, it is imperative to design the system prior to installation to avoid its vibration born failures. Beam structures find widespread applications. They are found in various configurations like fixed-fixed, fixed-free, overhang, continuous etc. as per the application [1].

Cantilever beam is one of the most commonly used structural members in ships and offshore platforms. Moreover, this structural mechanism is also found in construction of stadium, bridge, buildings, high rise towers and many more structures. So, presence of hole or crack in a single cantilever beam may cause the failure of a vast structure [2].



(a) (b)

Fig 1: (a) and (b) Cantilever beam with dimensions and with hole dimensions.

II. THEORY

The frequency of a simple uniform cantilever beam with rectangular cross section can be obtained from the following equation:

$$\omega_n = \frac{1}{2\pi}(\beta l)^2\sqrt{\frac{EI}{\rho AL^4}}$$

Where,
A = area of cross section of beam
L = length of the beam
ρ = density of material
EI = equivalent bending stiffness and is the constant relative to the vibration bound condition.

Using the formula, we can derive the fundamental mode shape frequencies of the beam specimens of different materials [1]. Here the effects of the hole will be added in the calculation of natural frequency or mode shapes.

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III. Designing of cantilever beam with hole

The cantilever beam is design with hole using Solidworks 2014.

Fig. 2 Design of cantilever beam with hole

IV. CONSTRAINTS

IV.I. MODEL INFORMATION

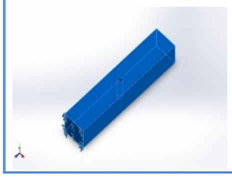
Solid Bodies		
Document Name and Reference	Treated As	Volumetric Properties
	Solid Body	Mass:17.6385 kg Volume:0.00248429 m^3 Density:7100 kg/m^3 Weight:172.857 N

Table 1: Mesh information

IV.II. MATERIAL PROPERTIES

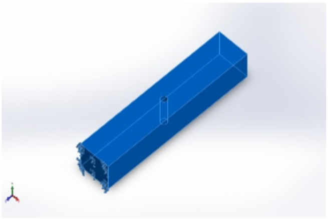
Model Reference	Properties	
	Name:	**Ductile Iron**
	Model type:	**Linear Elastic Isotropic**
	Failure criterion:	**Max von Mises Stress**
	Yield strength:	**5.51485e+008 N/m^2**
	Tensile strength:	**8.61695e+008 N/m^2**
	Mass density:	**7100 kg/m^3**
	Elastic modulus:	**1.2e+011 N/m^2**
	Poisson's ratio:	**0.31**

Table 2: Material properties

IV.III. LOADS AND FIXTURES

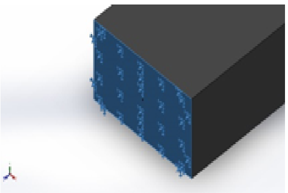
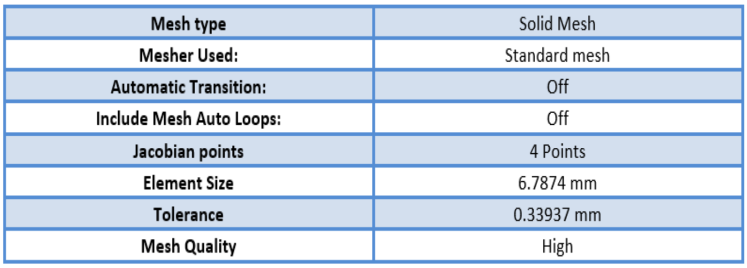
Fixture name	Fixture Image	Fixture Details
Fixed-1		**Entities:** 1 face(s) **Type:** Fixed Geometry Since it is free vibration that's why the load taken is zero newton.

Table 3: Load and fixtures

V. Modeling and simulation:

The modeling and simulation are performed by solid works simulation 2014.

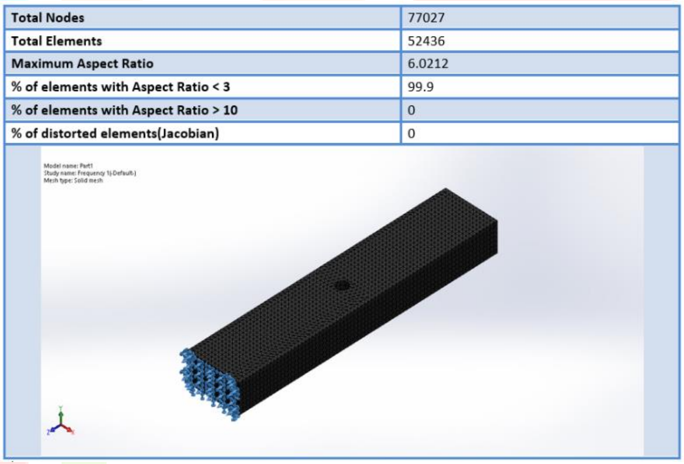
V.I. Mesh information



Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points	4 Points
Element Size	6.7874 mm
Tolerance	0.33937 mm
Mesh Quality	High

Table 4: Mesh information

V.II. Mesh details

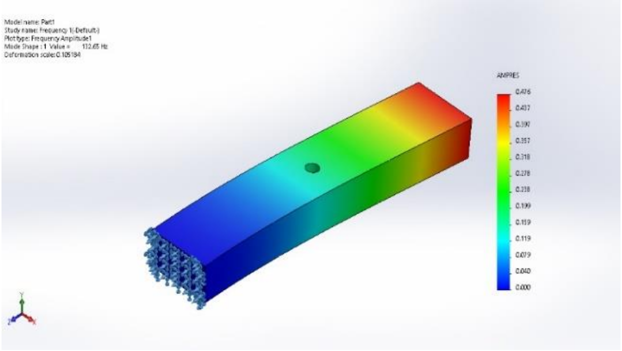


Total Nodes	77027
Total Elements	52436
Maximum Aspect Ratio	6.0212
% of elements with Aspect Ratio < 3	99.9
% of elements with Aspect Ratio > 10	0
% of distorted elements(Jacobian)	0

Model name: Part1
Study name: Frequency 1(-Default-)
Mesh type: Solid mesh

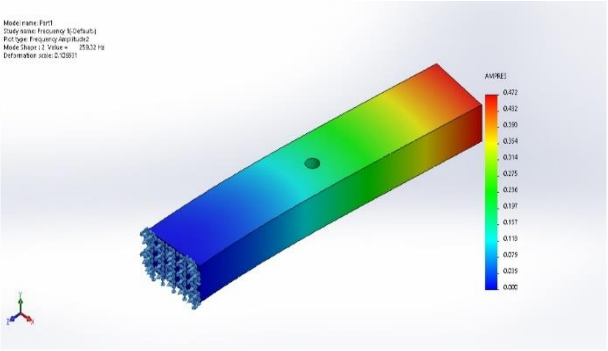
Table 5: Mesh details

V.III. Simulation



Model name: Part1
Study name: Frequency 1(-Default-)
Plot type: Frequency Amplitude1
Mode Shape : 1 Value = 132.65 Hz
Deformation scale: 0.105184

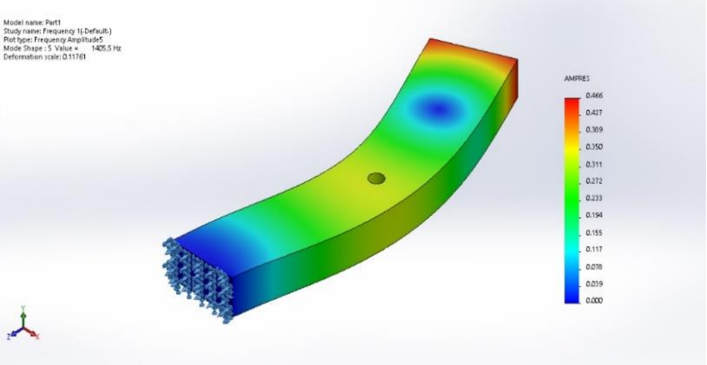
(a) Mode shape :1



Model name: Part1
Study name: Frequency 1(-Default-)
Plot type: Frequency Amplitude2
Mode Shape : 2 Value = 259.32 Hz
Deformation scale: 0.106831

(b) Mode shape :2

(c) Mode shape: 3 (d) Mode shape: 4



(e) Mode shape: 5

Fig. 3 (a, b, c, d, e) Mode shapes obtained respectively.

V.IV. Mode List

Frequency Number	Rad/sec	Hertz	Seconds
1	**833.48**	**132.65**	**0.0075385**
2	**1629.3**	**259.32**	**0.0038563**
3	**4961.1**	**789.59**	**0.0012665**
4	**5973.8**	**950.75**	**0.0010518**
5	**8830.9**	**1405.5**	**0.0007115**

Table 6: Different frequency modes obtained.

VI. Results:

The following results were obtaining for a single mode functions by varying the size of the hole from 1mm to 20 mm at the center of cantilever beam. The changes in the amplitude caused due to the holes are shown in table 7.

size of hole (mm)	amplitude (mm)	without hole (mm)
1	0.475	0.475
2	0.475	0.475
3	0.475	0.475
4	0.475	0.475
5	0.475	0.475
6	0.475	0.475
7	0.476	0.475
8	0.476	0.475
9	0.476	0.475
10	0.476	0.475
11	0.477	0.475
12	0.477	0.475
13	0.478	0.475
14	0.478	0.475
15	0.479	0.475
16	0.479	0.475
17	0.48	0.475
18	0.481	0.475
19	0.481	0.475
20	0.482	0.475

Table 7: Amplitude obtained at different hole sizes.

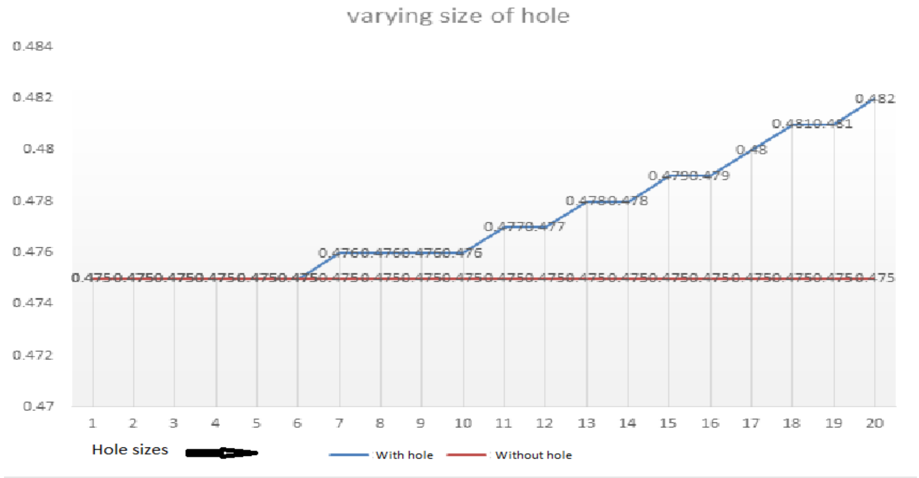


Fig. 4 Effect of hole on the amplitude of the beam.

VII. Conclusion:

1) From the above results it is seen that up to 6 mm the effect of hole is negligible and from 7mm to 10mm the hole causes minimum effect in the amplitude of the cantilever beam.
2) Therefore, 10mm is considered as the standard dimension of hole for further calculation. As most of the engineering applications are having up to 10 mm hole requirement only.

VIII. Future work:

By keeping the hole dimension constant, the effect caused on the amplitude on frequency of the cantilever beam by changing the location of hole along the length can be studied.

IX. Reference:

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