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VIBRATIONAL ANALYSIS OF BEAMS

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Abstract

This paper discusses the vibrational tolerances of structures and beams of different cross sections and how they behave when subjected to loads at different position. The configurations studied were cantilever and simply supported beams.

INTRODUCTION

Structures are primarily combination of different sets of beams and members to provide rigidity and safety. These purposes must be served throughout its service life. But structures are regularly subjected to cracks and deformations which shortens their lifespan. These cracks are induced due to multiple reasons i.e. manufacturing defects, transportation damages, poor installation etc. The main factors being vibrations. Vibrations occur when there are moving or rotational parts in machinery, or due to the existence of a loosened component. These vibrations cause stress accumulations, crack propagation and loosening of parts. The effects of these vibrations are large scale and visible when the structure is oscillating at natural frequency. Natural frequency is the tendency of any material to oscillate with maximum amplitude when the vibrations in the material harmonises with external forces. This increases the chances of failure and raises serious safety concerns. This paper discusses the different methodology and approach towards the problem of natural frequencies of different beams in different configurations such that a more suitable material and a preferable cross section and configuration can be selected as per application.

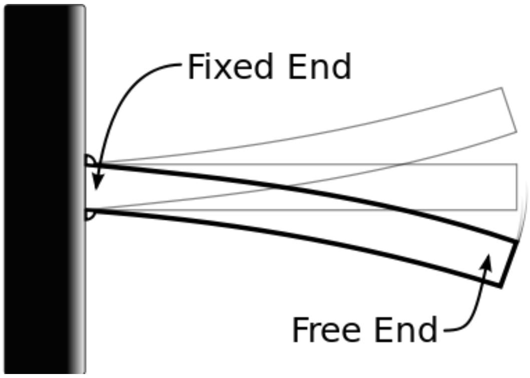

Figure 1 Free vibrations of a cantilever beam [1]

LITERATURE SURVEY

An ocean of literature exists in the fields of vibrational analysis. Majority of the work exists towards predicting the shape of deformation and calculating the natural frequency of beams. That too for limited configurations of beams and load distributions. These studies are also to be conducted on newer sets of material. It is obvious that still a lot of work has to be done in the fields of damage reduction, prediction of damage sites and damping of the vibrations. Precautions and cures have not been paid much attention. Below are some such literatures

PATEL VARSHA B [2] The effects of vibrations on I section cantilever beam was highlighted with consecutive changes in frequency, mode shape, stiffness etc. ANSYS was used to run simulation and generate result for beam with and without crack. Aluminium and steel were selected as the materials. The results are later analytically verified.

EMA technique is used and implemented using OROS FFT analyser.

Dimension	Steel
Length (mm)	425
Width (mm)	46
Height (mm)	92
Flange thickness (mm)	3
Web thickness (mm)	3
Young's modulus (MPa)	$2*10^5$
Density (kg/m^3)	7850

For cantilever solution, the ANSYS model is fixed from one side and subjected to load on the other. This is done for models with no crack, with centre crack and support crack.

The simulation yielded the following results-

Table 1 Uncracked Beam Frequency

ANSYS	EXPERIMENTAL	% ERROR
145.43	148.92	2.34
209.73	213.62	1.82
519.17	518.79	0.07
758.63	756.84	0.23
917.83	960.69	4.46
1065.7	1085.2	1.79

Table 2 Support Cracked Beam Frequency

ANSYS	EXPERIMENTAL	%ERROR
4.334	70.8	4.7
185.82	183.4	1.46
484.24	485.84	0.36
662.98	671.38	1.25
893.44	906.98	1.49
965.66	970.45	0.49

Table 3 Centre Cracked Beam Frequency

ANSYS	EXPERIMENTAL	%ERROR
120.2	108.64	9.6
199.68	203.85	2.04
511.97	482.17	5.82
529.27	540.77	2.09
893.43	833.74	6.6
933.12	939.94	0.72

The above table concluded that the higher the mode shape, higher is the natural frequency.

Frequency of beam decreases because of crack.

And centre crack is more reliable than support crack.

In the paper "Vibrational analysis of beams" written by Vaibhav Ghodge and others, they studied the natural frequencies of two different types of beams of four different materials under two different loading conditions. The types of beams that they used in their study were 1- Cantilever beam 2- Simply supported beam and the four different materials were 1- Structural steel 2- Aluminium alloy 3- Copper alloy 4- Gray cast iron and the different loading conditions were 1- Unloaded 2- Loaded. They have done the analysis using ANSYS and verified the results by analytical formulae. The platform on which the software runs is FEA (Finite Element Analysis).

The results of the experiment conducted can be deduced in the tabular format given below-

Table 4 Natural Frequencies Of Cantilever beam In Loaded And Unloaded Condition

Materials / Modes	Structural Steel		Al Alloy		Copper Alloy		Gray Cast Iron	
	Unloaded	Loaded	Unloaded	Loaded	Unloaded	Loaded	Unloaded	Loaded
1)	13.555	6.482	13.613	4.1805	9.7929	4.7837	10.489	4.849
2)	84.901	53.273	85.259	32.724	61.333	39.184	65.697	39.804
3)	134.1	58.726	134.53	51.23	96.746	42.694	103.83	45.009
4)	237.71	126.97	238.73	90.35	171.74	92.168	183.93	96.476
5)	280.35	162.2	278.15	132.98	199.29	118.47	218.72	123.78
6)	465.92	309.42	468.01	278.49	336.71	226.16	360.47	237.04

They have taken a load of 0.88 kg considering rough estimate of weight of motor its mounting and eccentric weight attached to the motor. From the above table they inferred that there was no particular trend of increasing or decreasing order. The analytical formulae for cantilever beam that they used to verify the results obtained from ANSYS are: -

1- $\omega_{nf} = a_n \sqrt{\frac{EI}{\rho A L^4}}$

Where n=1, 2, 3….

Denotes bending mode 1, 2...

ω_{nf} being natural angular frequency of bending (rad/sec).

2) The analytical formula for torsional modes is $\omega_{nt} = \frac{n\pi}{2L}\sqrt{\frac{G J_s}{J_0 \rho}}$

$$J_s = bh^3 \frac{1}{3}\left(1 - 0.63\frac{h}{b} + 0.052\left(\frac{h}{b}\right)^5\right).$$

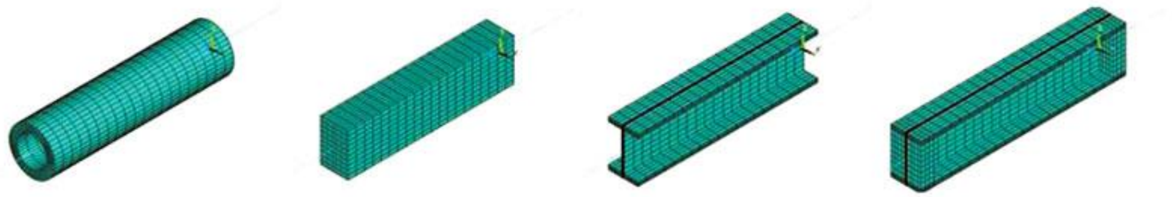

Figure 2 Different Cross section Beams with FEA [5]

Mehmet Avcar [4]

In the paper ”Free vibration analysis of beams considering different geometric characteristics and boundary conditions” written by Mehmet Avcar , he studied free vibrations of a square cross-sectioned beam. The material of the beam under study was aluminum. He studied the beam under four different boundary conditions i.e., 1) Clamped-Clamped (C-C) 2) Clamped-Free (C-F) 3) Clamped-Simply Supported (C-SS) 4) Simply Supported-Simply Supported. He conducted his study by two different methods which are: -1) Analytical solution and solving the equations by Newton Raphson method to find the approximate solution to the equation 2) Finite Element Method (FEM) using ANSYS Software.

In analytical method all the solutions are carried out by using Euler-Bernoulli beam theory and then obtaining the eigenvalues by using Newton-Raphson method. In his experiment only the natural frequencies of the first three modes are discussed and the answers to the effect of geometric characteristics like length, cross-sectional area. Different boundary conditions were obtained for different cases. Euler-Bernoulli equation is

$$EI\frac{\partial^4\omega}{\partial x^4}+\rho A\frac{\partial^2\omega}{\partial t^2}=0; 0<x<l$$

CONCLUSION

In this study of natural frequencies, it can be concluded that

1. frequency rises as the mode increases.
2. Frequency decreases as density increases and vice versa.
3. Frequency increases with increase in cross sectional area.

This can further be used to calculate the damping curve and crack locations.

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