Material of Structure affecting the Frequency Analysis using FEM Package

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Abstract--In the present investigation, efforts have been made to find effect material on cantilever beam under vibration. Specimens were modelled and analysed using FEM package (Abacus). Analysis was done by setting maximum frequency value as 60 Hz. It was found that a cantilever beam attains different modes of vibration. For mode-I of vibration the value of 'strain energy' and 'deflection of beam' along the cantilever beam from fixed end towards free end were obtained and tabulated. Aluminium, Copper and Steel were selected as three different materials for analysis. Numerical data obtained from FEM analysis were further tabulated and plotted for further useful analysis. Using numerical techniques, polynomial equations were also developed so that intermediate data can be determined.

Keywords--Frequency Analysis, FEM Package, Structural Analysis, Mode-I Vibration, deflection of beam.

I. Introduction

Materials experiences vibration should be observed and monitored very carefully because those materials may fail without any prior information of failure. In order to finalize the material for experimentation, structure can be simulated using FEM package. Through FEM package it becomes easy to know materials when vibrating.

It is very important if an equation can replace any set of data obtained to characterize behavior of any dynamic system. Modal parameters such as natural frequencies, mode shapes, are key information in determining the dynamic performance of a structure. This information can also be useful in a modal analysis to determine effect of material change in the behaviour of structure under cyclic load. Also, stress, strain energy, displacement can be greatly affected if property of material changes. However, the accuracy of these quantities depends on the accuracy of the modal parameters used in the analysis. FEM packages are adequately available to simulate a structure to know its frequency responce. The data obtained can be further analyzed in order to know behaviour of structure.

II. Literature Review

Frequency response of the vibration is very sensitive to the inhomogenity present in the structure and can be used to determine location of crack and crack growth rate in a structure under vibration [1, 2].

Frequency response of a material is not only utilized to know about construction materials, but it has also been utilized to develop sensors. A cantilever sensor can be operated in two different modes: the static mode, where the cantilever deflection is monitored, and the dynamic mode, where the cantilever resonance is monitored. The deflection of a cantilever can be due to number of processes such as molecular adsorption, thermal effects, electric and magnetic fields, and fluid flow. Cantilevers shorter than 10 μm in length with sub-attogram sensitivity were demonstrated in 2004 [3, 4, 5], enabling the detection of single virus particles of femtogram mass [6].

III. FEM Analysis

The three materials (i.e., steel, copper, aluminium) have different value of Young's Modulus (E). The value of Young's Modulus of the three materials are, E_{Steel}=210 GPa, E_{Cu}=117.2GPa, E_{Al}=68.95GPa. Density (ρ) and poison's ratio (υ) of the materials are ρ_{Steel}= 7800 kg/m^3, ρ_{Cu}= 8960 kg/m^3, ρ_{Al}= 2700 kg/m^3 and υ_{Steel}= 0.3, υ_{Cu}= 0.36, υ_{Al}= 0.33.

For the analysis of aluminium bar as a cantilever beam, a rectangular bar with dimensions 500m*50mm*12mm was modelled and material of model was defined as aluminium by taking value of Young's Modulus of Elasticity, density and poison's ratio of aluminium. The size of elements taken was 0.011, the number of elements as a result obtained was 225 and number of nodes so obtained was 552. The Lancos Eigen-solver was used to calculate structural and acoustic modes.

The maximum frequency value selected was 60 Hz with maximum steps within run as 35. The largest displacement entry in each vector was unity.

In case of aluminium, total mass of model calculated as 0.81 kg. The moment of inertia about the origin was found as I_{xx} = 7.47e-04 kg-m^2, I_{yy} = 6.82e-02 kg-m^2, I_{zz} = 6.76e-02 kg-m^2. The model under natural frequency experiences mode-I vibration at frequency of 4.0386Hz.

In case of the analysis of the rectangular bar of copper, it was observed that the total mass of model was 2.688 kg. The moment of inertia about the origin was found as I_{xx} = 2.4783361E-03 kg-m^2, I_{yy} = 8057.507 kg-m^2, I_{zz} = 8057.504 kg-m^2. The model under natural frequency experiences mode-I vibration at frequency of 2.8583 Hz.

While analysing rectangular bar of steel, it was observed that the total mass of model was 2.34 kg. The moment of inertia about the origin was I_{xx} = 2.1574801E-03 kg-m^2, I_{yy} = 5791.697 kg-m^2, I_{zz} = 5791.695 kg-m^2. The model under natural frequency experiences mode-I vibration at frequency of 4.1943 Hz.

IV. Results And Discussions

Nodal plots for the analysis of the three modal is as shown in the Fig.1, Fig.2 and Fig.3. It was observed that the strain energy at mode-I of vibration for the three models is different because of material change. The graphs were also

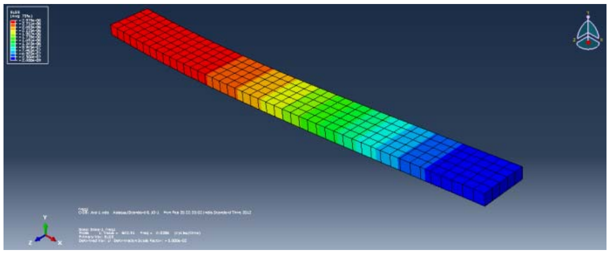

Fig.1. Strain Energy of Al Beam at Mode-I

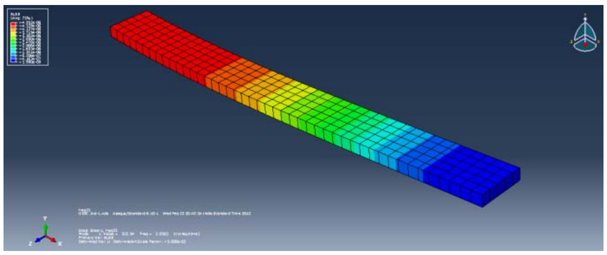

Fig.2. Strain Energy of Cu Beam at Mode-I

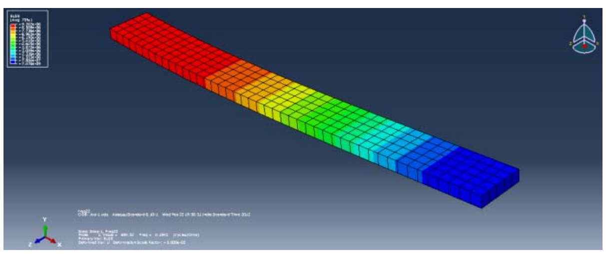

Fig.3. Strain Energy of Steel Beam at Mode-I

drawn with the data obtained using FEM package for strain energy is as shown in Fig.4. The polynomial equation obtained for the three curves generated. Here strain energy ($\square$) taken as dependent variable and position of strain energy (d) over the beam is taken as independent variable. The polynomial equation obtained are, $\square_{Steel} = 2\times10^{-12}d^4 - 7\times10^{-11}d^3 - 9\times10^{-09}d^2 + 1\times10^{-07}d + 9\times10^{-06}$ for steel, $\square_{Cu} = 2\times10^{-12}d^4 - 2\times10^{-10}d^3 + 7\times10^{-10}d^2 + 2\times10^{-09}d + 5\times10^{-06}$ for

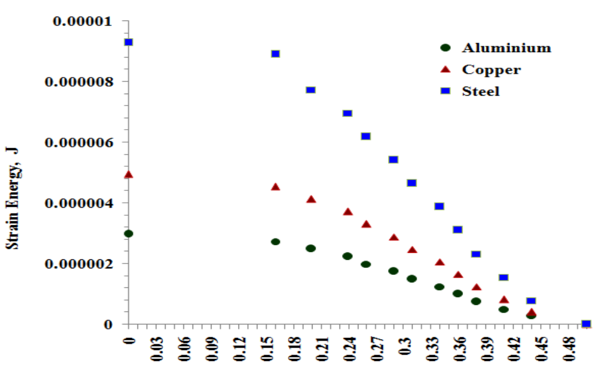

Fig.4. Strain Energy along the Beam from Fixed End to Free End at Mode-I under Natural Frequency

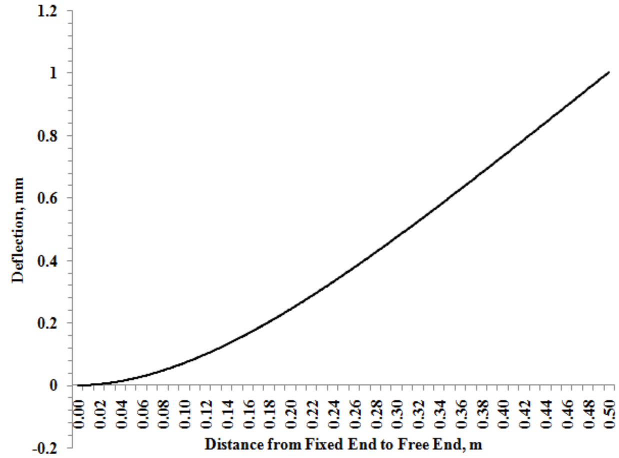

Fig. 5. Deflection along the Beam from Fixed End to Free End at Mode-I under Natural Frequency

copper, and $\square_{Al} = 1\times10^{-12}d^4 - 9\times10^{-11}d^3 - 1\times10^{-10}d^2 + 8\times10^{-09}d + 3\times10^{-06}$ for aluminium.

The deflection (δ) of beam at mode-I of vibration is as shown in Fig.5. Polynomial equation obtained to represent deflection of beam from fixed end to free end is, $\delta = 5\times10^{-08}d^4 - 1\times10^{-05}d^3 - 1\times10^{-03}d$ and is same for all the three materials.

V. Conclusions

From Fig.1, Fig.2 and Fig.3 it can be observed that strain energy of the rectangular bar under cantilever beam condition decreases from fixed end towards free end. Also the pattern of strain energy remains same for all three materials investigated. It can also be observed from Fig.4 that property of material has remarkable effect on the strain energy value of the cantilever beam under vibrating condition.

From Fig.5 it was found that for all the three materials the deflection of cantilever beam at mode –I of vibration is same with maximum deflection value of 1 mm at free end.

From Fig.6 it can be observed that value of poison’s ratio varies from 0.3 for steel to 0.36 for copper where as the value of frequency at mode-I of vibration varies from 4.1943 Hz for steel to 2.8583 Hz for copper.

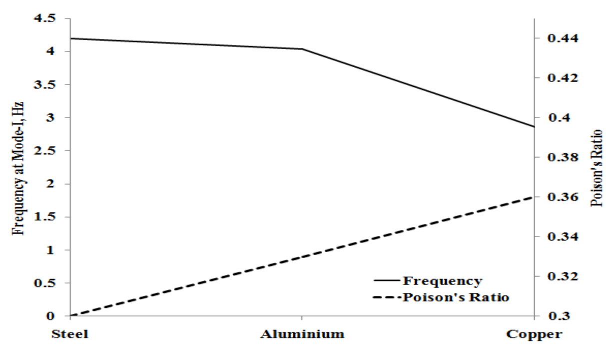

Fig. 6. Frequency Value of Materials at Mode-I

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