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MODAL ANALYSIS OF FIXED-FIXED BEAM USING MATLAB

Engineering

KEYWORDS: Modal analysis; finite element method; fixed-fixed beam; vibration behaviour.

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ABSTRACT

The aim of this paper is to study heat transfer characteristics in a microchannel as it is an emerging trend from research point of view. With change in cross-section of the microchannel heat transfer characteristics varies and consequently there is change in pressure drop. Further the range of coolants used for microchannel heat transfer can vary from water ,ethyleneglycol,liquid metal to nanofluids. Heat transfer in microchannel with nanofluid is highly efficient wherasmicrochannel with liquid metal as coolant has higher heat dissipation capacity than water used as coolant. Microchannel cooling with liquid metal poses tough challenge with regard to corrosion and blocking problems in the cooling systems so better control methods have to be devised to prevent deterioration of the cooling system using liquid metal.

1. INTRODUCTION

Structural design of a number of products like automobiles, bearings, drilling machines, bridges, dams, multi-storey buildings, turbine-blades, etc. requires the evaluation of dynamic characteristics such as natural frequencies, mode-shapes and modal assurance criterion (MAC) values . Such dynamic characteristics can be predicted either through classical method or through the use of finite element (FE) method . Application of classical method is limited to simple shapes only. FE method is generally used in research as well as industrial environments for prediction of the dynamic characteristics. In FE method, complex continuous region of a structure is discretized into simple geometric shapes called finite elements. Each element is expressed in the form of elemental mass, stiffness and damping matrices. Subsequently, individual elements are assembled to form their global counterparts, which are jointly known as system matrices. These system matrices along with certain boundary conditions are used to produce a set of governing equations, which are then processed to evaluate dynamic behavior predicted by the FE model of the system. Thus FE method can help in predicting the dynamic behavior well in advance of manufacturing of actual product. Better modal testing and analysis tools are becoming the need of the day with the ever increasing demands for better performance and the use of lighter materials in modern day machines and structures. With the modern high performance engines, one can achieve very high speeds in no time, which results in increased vibration and noise problems. Further in the automotive, aircraft and spaceship industries, there is an ever existing demand of attaining better fuel economy; which can be met to a good extent by using thin products as well as with the use of light weight materials such as aluminium and plastics composites instead of the conventionally used heavy weight materials such as steels. Thin and light weight products have lot more tendencies to vibrate than their thick and heavy weight counterparts. Excessive vibrations can even result in pre-mature failure of products, whether it is the suspension of an automobile, wing of an aircraft, the printed-circuit-board installed in a spaceship, blades of an air-cooler, or the compact-disc of a computer etc. On the other hand, consumers of today's world desire for non-vibrating and silent functioning of such products. Thus it becomes very important for engineers to understand the vibration behavior of structures through their modal analysis. Modal analysis aims at understanding, evaluating and modifying the structural dynamic behavior which involves many terms such as natural frequencies, mode-shapes, damping ratios, MAC values etc. Modal analysis forms a pre-requirement for updating the FE model of structures also – . It is also useful in non-destructive testing of structures in order to identify the damage occurred to the structure . Modal analysis is also the backbone of dynamic design of structures

In this paper, theoretical results of modal analysis of a fixed-fixed beam have been presented with the purpose of providing the necessary understanding for beginning engineers so that they can understand the dynamic behaviour of fixed-fixed beam. FE model of the beam has been developed and processed using MATLAB software .

2. Modal Analysis of Fixed-Fixed Beam

First step in modal analysis is to develop the FE model of the structure under consideration. For this purpose, the structure is supposed to be made up of a large but finite number of sufficiently small sized elements. These elements are known as the finite elements. Such finite elements can be axial, torque, or, bending elements or some other form depending upon the shape and size of the structure under consideration, type of loading and the computational accuracy required. Boundary points of these finite elements are termed as nodal points or nodes.

Figure 1. FE model of a fixed-fixed beam.

In this paper, FE model of a fixed-fixed beam structure, as shown in Fig. 1, has been developed in MATLAB environment. Dimensions of the fixed-fixed beam structure of mild steel material are 1000 x 40 x 5 mm3, having a density of 8000 kg/m3. FE model of the beam has been developed using 100 finite elements. Each FE is having two nodes. There are 101 nodes in the FE model. Two degrees of freedom are measured at each node. One degree of freedom is the displacement in vertical direction and the other degree of freedom is the rotation about the lateral axis. Both the degrees of freedom of the end nodes have been reduced to zero so as to simulate fully constrained ends. FE model has been developed by assembling the elemental mass and stiffness matrices obtained using (1) and (2).

$$[m] = \frac{\rho A a}{105}\begin{bmatrix} 78 & 22a & 27 & -13 \\ 22a & 8a^2 & 13a & -6a^2 \\ 27 & 13a & 78 & -22a \\ -13a & -6a^2 & -22a & 8a^2 \end{bmatrix} \quad (1)$$

$$[k] = \frac{EI}{2a^3}\begin{bmatrix} 3 & 3a & -3 & 3a \\ 3a & 4a^2 & -3a & 2a^2 \\ -3 & -3a & 3 & -3a \\ 3a & 2a^2 & -3a & 4a^2 \end{bmatrix} \quad (2)$$

Where m, ρ, A, a, k, E and I are respectively the element mass matrix, density, area of cross-section of element, half-length of element, element stiffness matrix, Young's modulus of elasticity and moment of inertia of cross-section of beam element.

FE model of the fixed-fixed beam has been simulated in MATLAB environment to obtain first ten natural frequencies as 26.95, 74.30, 145.65, 240.76, 359.66, 502.33, 668.79, 859.02, 1073.04 and 1310.83 Hz. Mode-shapes of the first ten modes have also been evaluated through simulation. Mode-shapes for first five modes have been drawn in Fig. 2; while the mode shapes for next five modes have been presented in Fig. 3. MAC plot for the ten modes has been drawn in Fig. 4, which shows that the mode-shapes are very well predicted by the proposed FE model. MAC plot, as drawn in Fig. 4, helps in cross-checking the prediction accuracy of the FE model. All diagonal elements of the MAC plot are equal to unity and the off-diagonal elements are lying very close to zero; thereby showing that the modes are orthogonal to each other. Classically the off-diagonal elements should have been exact zeroes. But in this paper, FE method is being used, which is an approximate method. Hence the off-diagonal terms are not exact zeroes but very close to the null value.

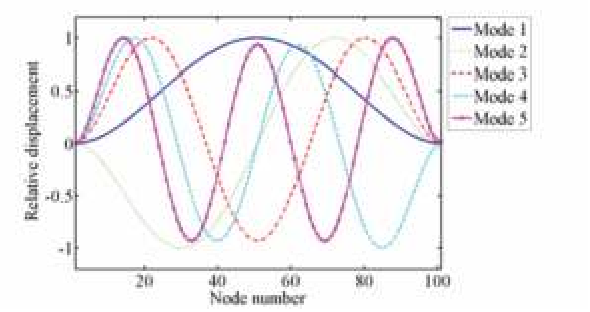

Figure 2. Mode-shapes for first to fifth mode.

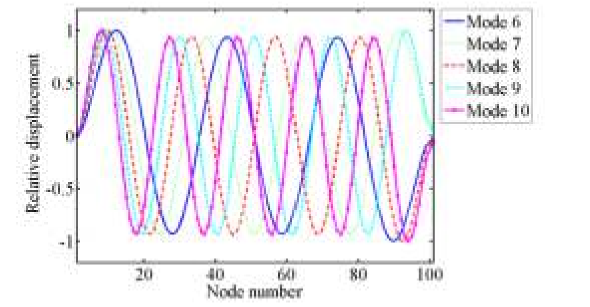

Figure 3. Mode-shapes for sixth to tenth mode.

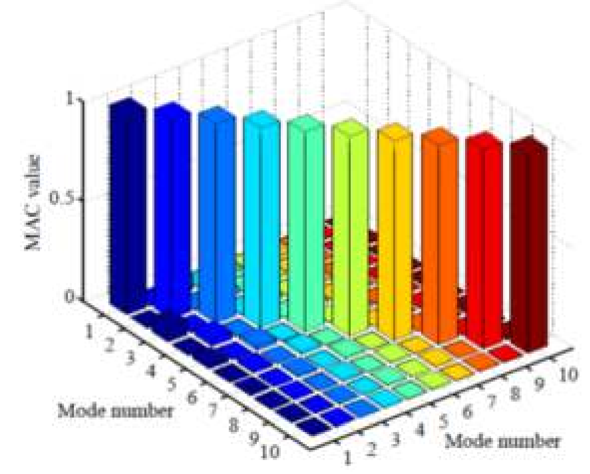

Figure 4. MAC plot for first ten modes.

3. CONCLUSION

Modal analysis of a fixed-fixed beam structure has been performed by using the FE method. Its natural frequencies, mode-shapes and MAC values have been evaluated through simulation of the FE model. MAC plots have been used to check the validity of the mode-shapes predicted by the FE model. MAC results show that the mode-shapes are orthogonal to each other and are accurate. Thus the FE model developed is ready to be used for further work in the field of vibration and control.

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