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EXPERIMENTAL FREQUENCY RESPONSE FUNCTIONS AND THEIR USE IN DEVELOPING UPDATED FINITE ELEMENT MODEL

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ABSTRACT

The dynamic characteristics of a system include its modal parameters (natural frequencies, damping factors, mode shapes) as well as frequency response functions (FRFs). The important characteristics of the frequency response are its magnitude and phase. The magnitude provides the information about the resonance and anti-resonance frequencies of system, while the phase shows the lag in response and stimulus signal. Determining frequency response function of dynamic system is of great interest in recent years. This can be achieved through conducting some experiments as well as using theoretically/finite element method. This work reports the work involving estimation of both experimental FRFs and theoretical FRFs and the co-relation between the two. Finite element analysis is now a days widely used tool to carry out numerical analysis and the same has also been used in this work. In the process of correlation of experimental and finite element results, the issue of modelling inaccuracies of structures especially joint parameters has been addressed. The issue of coupling between bending and torsional mode has also been discussed.

KEYWORDS: Frequency response function, resonance and anti-resonance frequency, mode shapes, signal processing, Lab VIEW, ANSYS, point receptance, cross receptance.

INTRODUCTION

Vibratory motion in machines and structures are of frequent concern in engineering practices. In general, vibrations are undesirable in machines and structures as they are responsible for producing excessive stresses, wear, unwanted noise and premature failure of the components by way of looseness or due to fatigue.

Modal analysis is used to find out the dynamic characteristics of structures. These include natural frequencies, damping factors and mode shapes. These properties help in understanding the dynamic behaviour of structures. The conditions of resonance can be prevented by the knowledge of natural frequencies.

Modal analysis is a tool to determine the dynamic characteristics of structures. It can be performed both theoretically and experimentally (Ewins (2000b)). Experimental modal analysis consists of exciting the structure with a force transducer and sensors are used to measure the resulting response. The work by Ewins (2000a) can be referred to for details of procedures of modal testing. Structures can be non-spinning like stationary structures or spinning like in case of rotating machines. Chouksey, Dutt et al. (2012) carried out modal testing of spinning structures.

In recent years, various research studies are going to actively control the unwanted vibration of flexible structures by utilizing the piezoelectric actuators. Pradhanand Modak (2012). Proposed improved FRF based FE model updating method for updating mass and stiffness matrices. Gillich and Praisach (2014) proposed a new method based on natural frequency to detect and locate the damage in beam like structure. Arora(2014) proposed the new structural damping identification method using normal frequency response function.Friswell and Mottershead (1999b) proposed a method for replacement of unknown stiffness with rigid connections in two systems of equations from a finite element model. Besides the above mentioned work, numerous works has been carried on finding the frequency response of the system.

Merkel, Gatzwiller et al. (1998) performed experimental modal analysis for more accurate estimation of modal parameters anddeveloped mechanical impedance head sensors to more accurately determine driving point FRF measurements.Gillich and Praisach (2014) introduced a method to detect the damages in the beam like structure and to assess their location and severity.Lien and Yao (2000) developed a method based on modal analysis for locating the

Anti-Resonance frequency (ARF) of the building structure during the earthquake condition.Chouksey, Dutt et al. (2010) obtained the complete model and more accurate modal analysis of rotor shaft systems by taking into account the rotating shaft material damping force and the influence of the damping forces on the mode-shapes and directional frequency response.Friswell and Mottershead (1999a) proposed a method for the replacement of unknown stiffness with rigid connections in two systems of equation from a finite element model and from measured response functions.

In the literature surveyed as available so far, the studies involving the correlation of experimental results with theoretical results are found to be limited. Moreover, in the existing literature the studies showing the coupling in torsional and lateral degrees of freedom are not found.

Based on the literature review, it was decided to carry out experimental and numerical studies on modal analysis. The issue of developing the accurate finite element model is also addressed. In the Present work correlation of experimental and finite element results, the issue of modelling inaccuracies of structures especially joint parameters has been addressed. The issue of coupling between bending and torsional mode has also been discussed.

METHODOLOGY

By studying the various research works and literature, we identify the problem and for this the experimental modal analysis of cantilever beam is carried out in Lab VIEW to determine its frequency response experimentally. Modelling and simulation of the cantilever beam is carried out in ANSYS APDL to find its FRF and mode shapes. Updating the simulation model and comparing its result with experimental FRF.

RESULTS

The Figure 0.1 shows the initial and updated FE model. The initial FE model refers to the cantilever beam with fixed support. While the updated FE model is modelled on the basis of observation that the cantilever beam used in experiment is not rigidly fixed at support and thus FE model is updated by changing the boundary conditions (support).

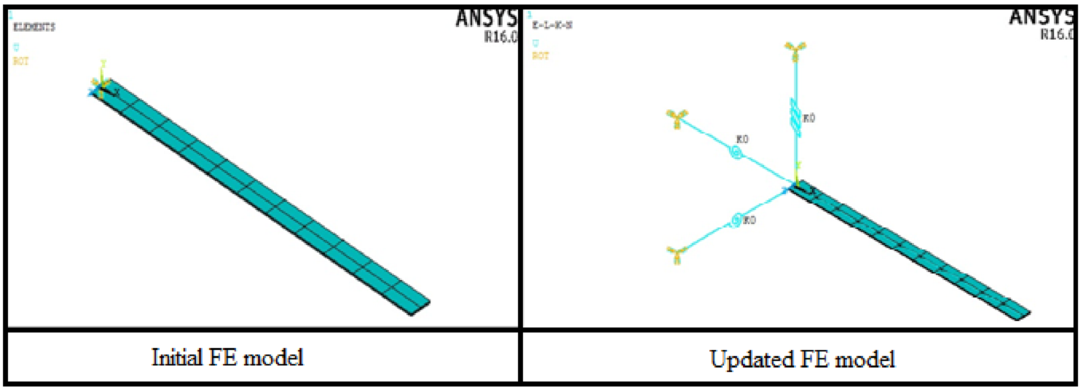

Figure 0.1: Initial and updated FE model.

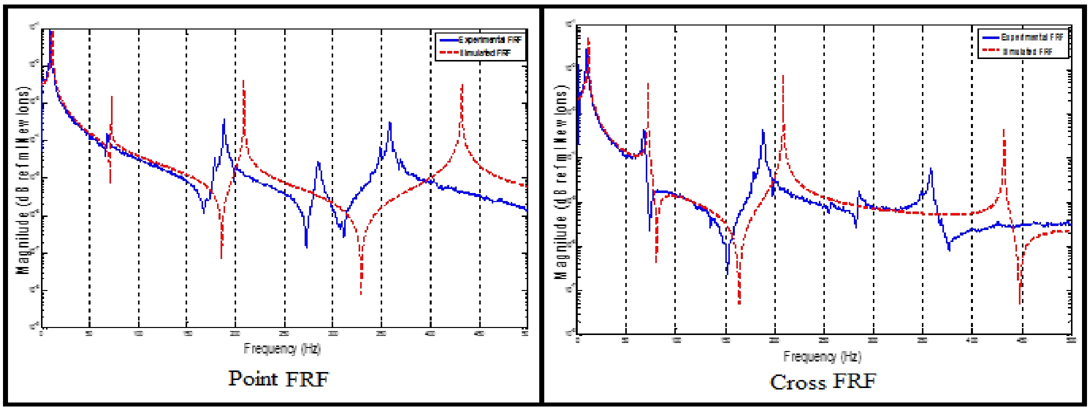

Figure 0.2: Comparison of experimental FRF andinitial FE model FRF.

Initial FE model has certainly some inaccuracies, as is reflected through comparison of FRFs shown in Figure 0.2. These inaccuracies as such may be either in inertial or stiffnesses. However, inertia is generally modelled correctly, as we have fair idea of density of the material. Further, with good idea of material properties like modulus of elasticity, Poisson's ratio the chances of inaccuracies of bending stiffness of beam are also not there. However, support/joint stiffnesses are generally not known and this forms the inaccuracies in the model. Estimation of the same is further addressed in the work. Regarding this, an updated finite element model has been modelled in the ANSYS APDL. The updated model is modelled by an observation that the cantilever beam used for experiment is not rigidly fixed at its end and thus the finite element model is updated by changing its boundary condition (support).

The cantilever beam is supported by the spring along the x, y, and z-directions. To provide the spring support in ansys COMBIN 14 element is taken. The stiffness is taken in such a way that the torsional stiffness is along the x-direction, radial stiffness is along the y-direction, and rotational stiffness is along the z-direction. The value of the stiffnesses of the springs are shown inTable 0-1.

Table 0-1: Spring stiffness value.

Type of stiffness	Value (in N/m)
Torsional stiffness	43.5
Radial stiffness	160
Rotational stiffness	150000

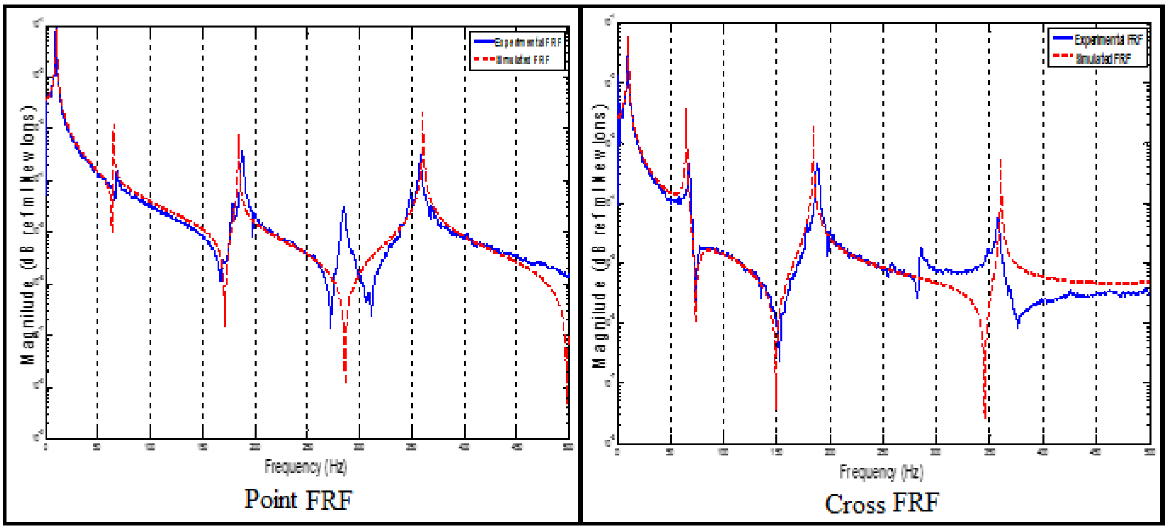

Figure 0. 3: Comparison of experimental FRF and updated FE model FRF.

From the Figure 0. ***3***it has been observed that the experimentally measured FRF matches with the updated finite element model FRF. Although, it has been observed that there is a mode observed in the experimental result and is not observed in the simulation result this is due to the presence of coupling between bending and torsion in the real- system and thus due to uncoupling in the simulation the torsion mode is not observed in the frequency response of the cantilever beam. To justify this, the torsion mode corresponding to natural frequency 279.387 is shown in Figure 0.4.

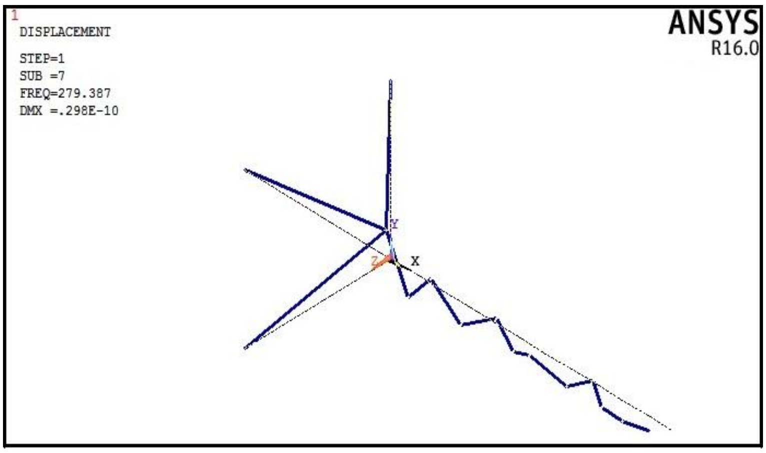

Figure 0.4: Fourth mode shape of the cantilever beam (First torsional mode).

Table 0-2 Comparison of natural frequencies.

Experimental Data	Simulation Data		Percentage Error	
	Before update	After update	Before Update	After Update
10.24	11.5	10.24	10.95	00.00
66.56	72	65.13	07.55	02.19
186.36	208.5	184.32	10.61	01.10
359.50	432	360.65	16.78	00.31

It can be seen from the Table 0-2 that the percentage error after updating FE model is considerably reduced.

CONCLUSIONS

In this work, experimental and finite element analysis of the cantilever beam has been carried out. The objective of the work is to obtain the frequency response of the cantilever beam experimentally and using numerical simulation. An updated finite element model is shown by changing the boundary condition (support) of cantilever beam and the effectiveness of the updated model is demonstrated by comparing with the experimentally measured frequency response. It can be concluded from the work that there is remarkable change in the frequency response by changing the boundary conditions of the beam.

The importance of various terms related to signal processing are also discussed. The point FRF and cross FRF measured are plotted and the experimental natural frequencies are measured through the FRFs. The plots of coherence showed the accuracy of the FRFs measured.

The issues of modelling inaccuracies are discussed in the work. The joint parameters may be the main sources of inaccuracies in a finite element model

The work also included comparison of experimental FRFs and finite element model FRFs.

The comparison of measured FRFs and initial FE model FRFs results showed large variation.

However, with updating the FE model the variations are minimized considerably.

Measured FRFs showed presence of torsion mode, which is absent in the FE model FRFs. This is attributed to the fact that coupling is not there in the FE model, which in actual may be present in an actual system.

The comparison of measured natural frequencies has been made with the initial as well as updated FE model. This comparison in case of initial FE model showed large variation, which is reduced considerably in case of updated model

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