ESTIMATION OF MODAL PARAMETERS FROM FREQUENCY RESPONSE FUNCTION THROUGH GLOBAL RATIONAL FRACTION POLYNOMIAL METHOD (GRFP)

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Abstract:* Modal analysis/ testing is an experimental technique used to derive the modal model of a linear time-invariant vibratory system. The theoretical basis of the technique is establishing a relationship between the vibration response at one location and excitation at the same or another location as a function of excitation frequency. This relation is known as frequency response function (FRF). A frequency response function (FRF) captures the unique dynamic characteristics of the structure between two degrees of freedom (DOFs); the response DOF and the excitation DOF. The modal properties of structures are extracted from resultant FRF's through Global Rational Fraction Polynomial method (GRFP) or curve fitting. Modal parameters are global properties of the structure. The changes in modal parameters may be used to locate structural faults. The structure faults occurred locally, but the modal parameters changes all over the structure. A case study of a cantilever beam is presented in order to evaluate its modal properties and detect failure zone. The experimental modal analysis of a cantilever beam has been carried out using vibration analyzer OROS®. The frequency response functions (FRFs) of the cantilever beam are obtained as output results, and its modal properties are determined by applying Global Rational Fraction Polynomial method (GRFP) on resultant FRFs.

Key words – Modal analysis, Mild steel cantilever beam, Global Rational Fraction Method (GRFP), Modal properties, Frequency Response Function (FRF).

I. INTRODUCTION

In order to understand structural dynamics of structures in real time, the modal and harmonic analysis are used to obtain the dynamic characteristics of structures. Structure frequency response testing i.e. modal analysis is an integral part of the development and testing of structures. The usefulness of this technique lies in the fact that the energy in an impulse, which is distributed continuously in the frequency domain. Thus, an impulse force will excite all resonances within given frequency range.

The frequency response functions (FRFs) of structures are obtained as output results by applying the system input artificially through some type of exciter, i.e. either impact hammer or magnetic shaker (Schwarz B.J. and Richardson M. H. [1], Mannan M. A. and Richardson M. H. [2]). The modal properties of structures i.e. natural frequency, damping and mode shape are extracted from resultant FRF's through Global Rational Fraction Polynomial method (GRFP) or curve fitting (Formenti, D. L. and Richardson M. H. [3], Richardson M. H. and Mannan M. A. [4]).

Singh B. and Nanda B.K. [5, 6] analyzed a layered and tack- welded mild steel cantilever beam through experimental modal analysis. Frequency response functions are collected as output results and modal parameters of the structure are evaluated from resultant FRFs through vibration analyzer software. Letícia F. and Fadel M. [7] analyzed a cantilever beam having tip mass through experimental modal analysis. They have concluded that GRFP method is reliable for evaluating modal parameters of structures. Boudjemai A.; Amri R.; and Mankour A.[8] analyzed a hexagonal honeycomb plate through impact hammer test. The experimental set up consisted of two accelerometers; these are placed on the top and on the core of beam to measure the bending and lateral modes respectively. The modal parameters are evaluated through resultant FRFs. In this research work a mild steel cantilever beam has been investigated through Structure frequency response testing i.e. modal analysis to evaluate its modal properties i.e. natural frequency, damping and mode shapes from resultant FRF's through Global Rational Fraction Polynomial method (GRFP) or curve fitting.

II. EXPERIMENTAL MODAL ANALYSIS

The experimental set up for experimental modal analysis is shown in Fig. 1. It consists of a mild steel cantilever beam, a *PCB-78534* accelerometer, a C-clamp, a *PCB-086C03* impact hammer and a vibration analyzer *OROS*®. Firstly, hammer tip (plastic), inputs (force and acceleration), the frequency range (*0-5 KHz*), triggering (start delay: *10ms*), windows (force: hamming and acceleration: response), sampling rate (*51.2kilo samples / sec*) and the number of FFT lines *(401)* are selected. The accelerometer is placed at the top of free end of cantilever beam. The boundary condition of the beam (cantilever beam) is obtained by having one end of beam fully built-in using a C-clamp as shown in Fig. 1.

2.1. MEASUREMENTS POINTS

For modal analysis of cantilever beam, four measurement points are taken distributed along the length of the beam. These four measurement location points are equally spaced at a distance of 7cm and marked as 1, 2, 3, and 4from free end to fixed end as shown in Fig. 3.The accelerometer is placed at location point 1 on the tip of cantilever beam.

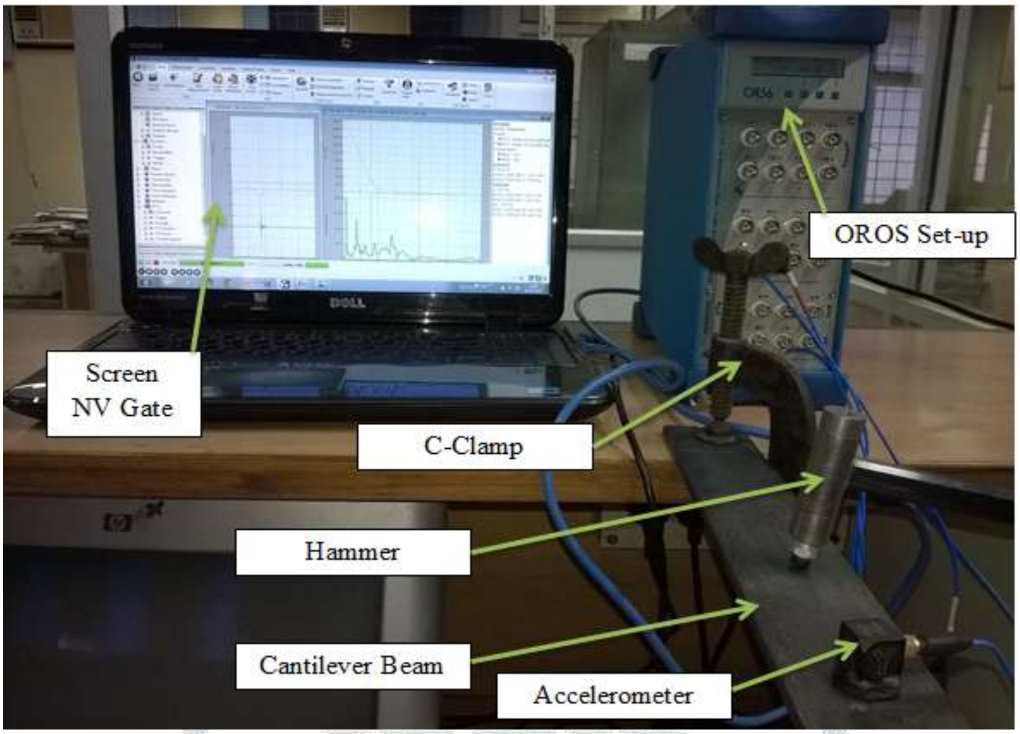


Fig. 1: Experimental set up for modal analysis of cantilever beam

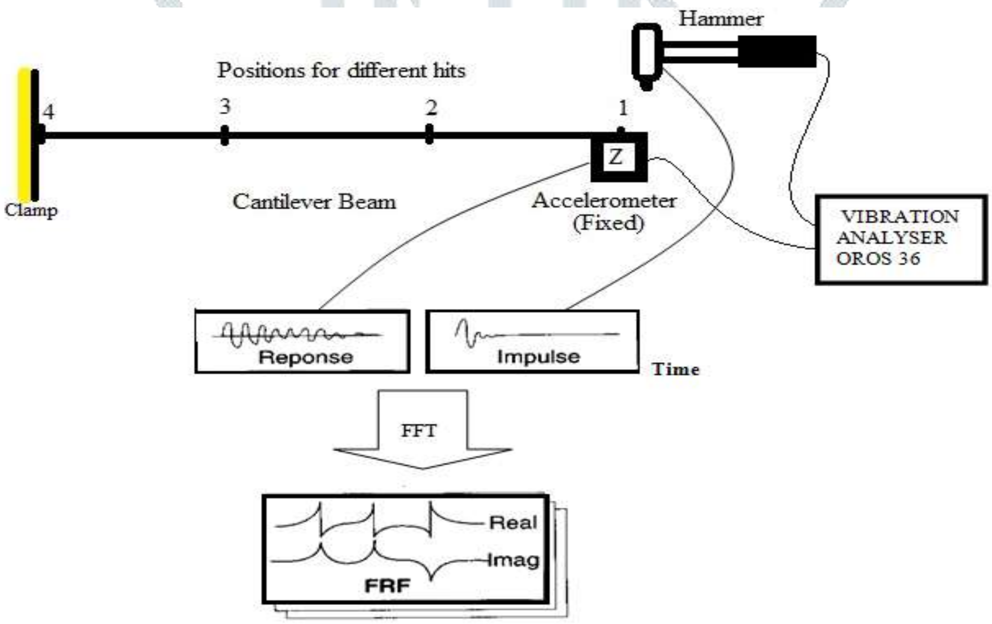


Fig. 2: The frequency response function (FRF) measurement

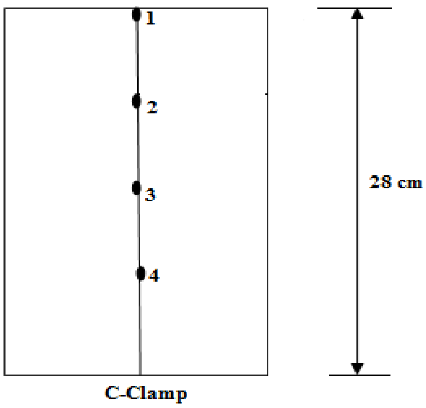


Fig. 3: Measurement points on cantilever beam

III. ESTIMATION OF MODAL PARAMETERS

The natural frequency and damping of beam are evaluated from resultant FRF obtained at location 1 as shown in Fig.4 through GRFP method. The resultant FRFs at four measured locations are shown in Fig. 5.

3.1 MODAL FREQUENCY

The four dominant resonance peaks appear clearly in FRF at frequencies around *49 Hz*, *302 Hz*, *467 Hz* and *850Hz*. Therefore, the first four natural/ resonant frequencies of cantilever beam are *49 Hz*, *302 Hz*, *467 Hz* and *850Hz*. The peaks are also seen at around *270Hz* but this peak is not identity as resonance peak.

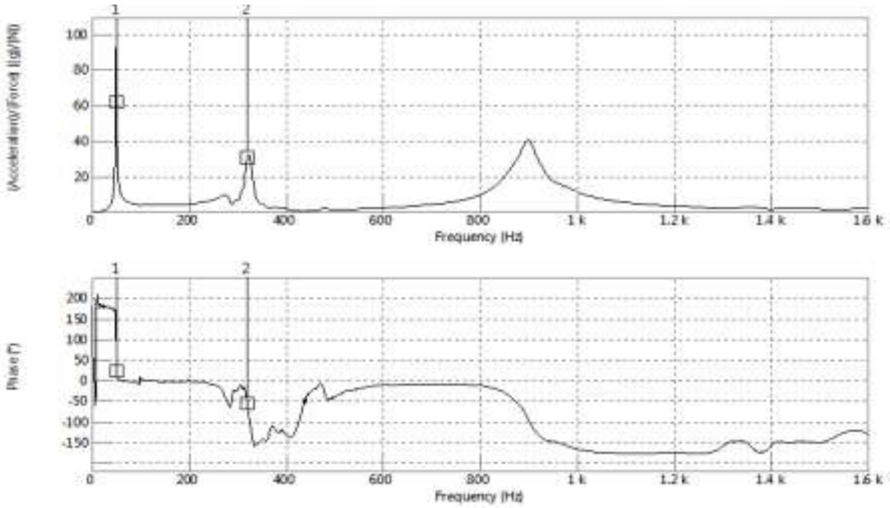
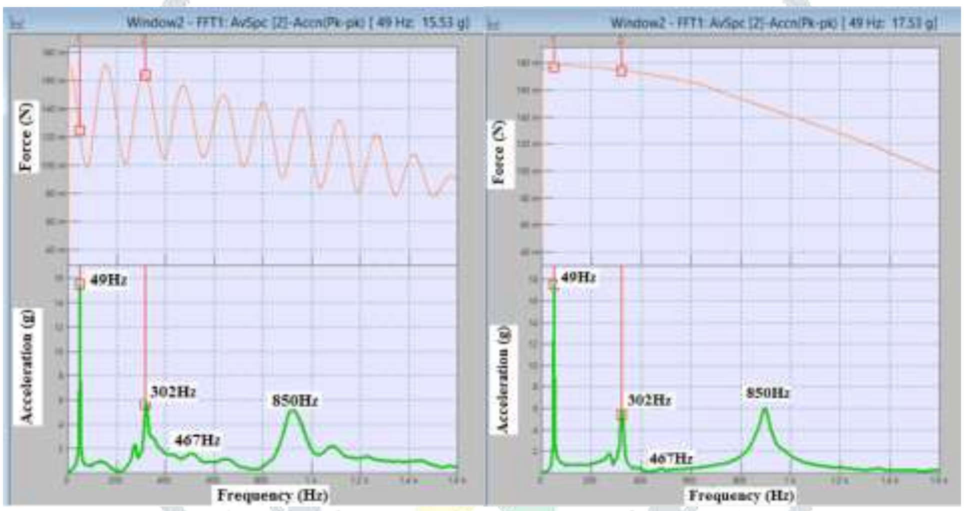
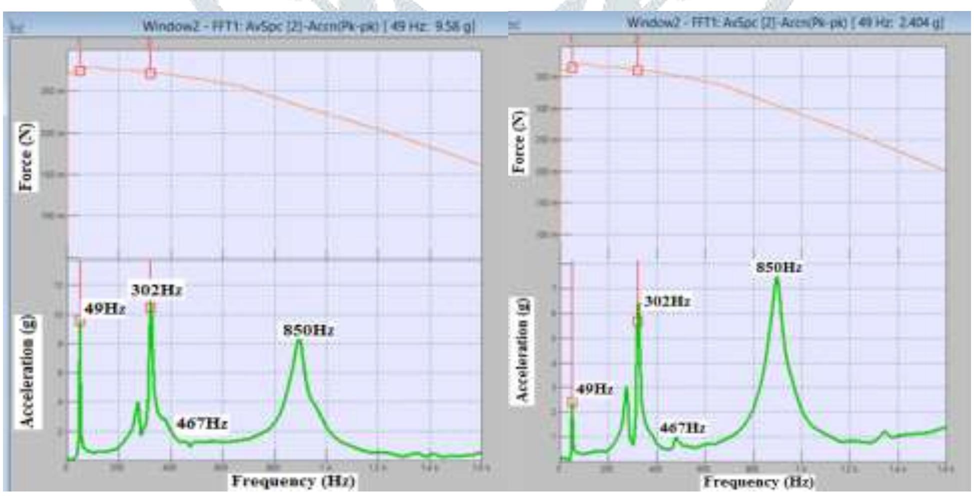


Fig. 4: FRF measured at location 1



Meaured Location 1 Meaured Location 2



Meaured Location 3 Meaured Location 4

Fig. 5: Resultant FRFs at four measured locations

3.2. MODAL DAMPING

Modal damping is evaluated by applying half power method, detailed in Fig. 6. The calculated value of damping coefficient at natural frequency*850 Hz* is *0.01352*.

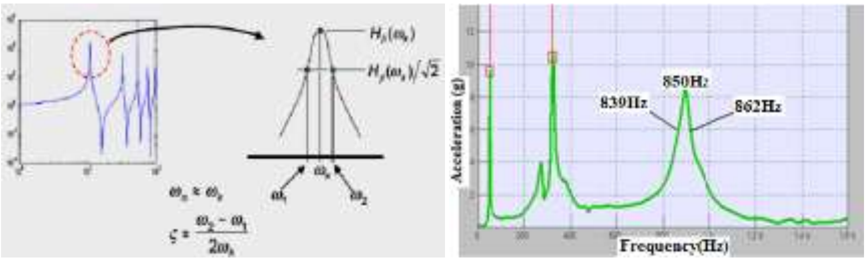
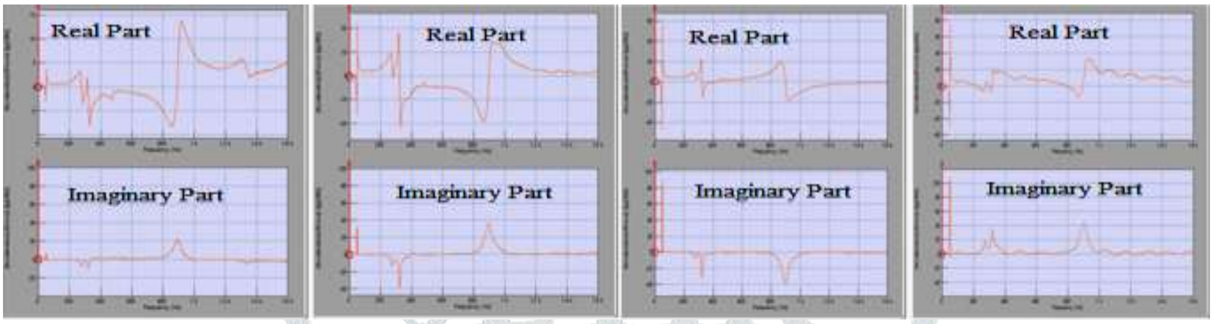


Fig. 6: Modal damping evaluated from FRF through GFRP Method

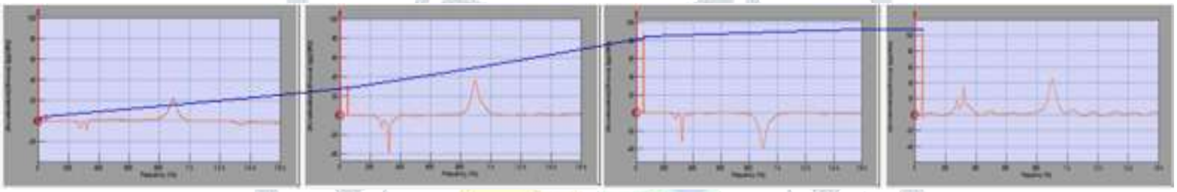
3.3. MODE SHAPE

The mode shapes of cantilever beam are obtained by considering the imaginary part of all the FRFs as shown in Fig. 7. The mode shapes of the cantilever beam are obtained by joining the peak of each of the resonance obtained at the same frequency in imaginary part of all the measured FRFs starting from location 4 to location 1. The mode shapes of cantilever beam at frequencies 49 Hz, 302 Hz, 467 Hz and 850 HZ are shown in Fig. 8.

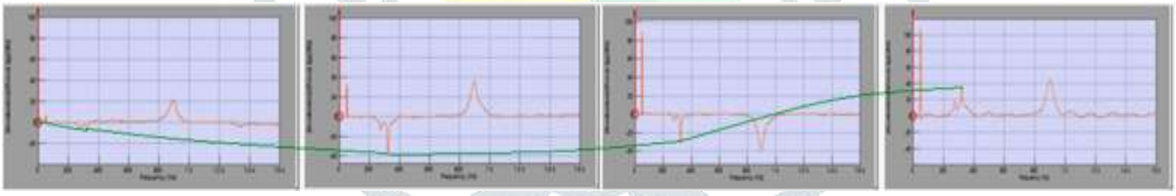


Measured Location 4 Measured Location 3 Measured Location 2 Measured Location 1

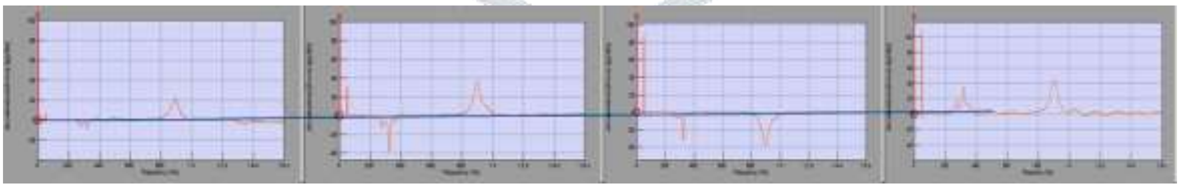
Fig. 7: Real and Imaginary parts of FRF's



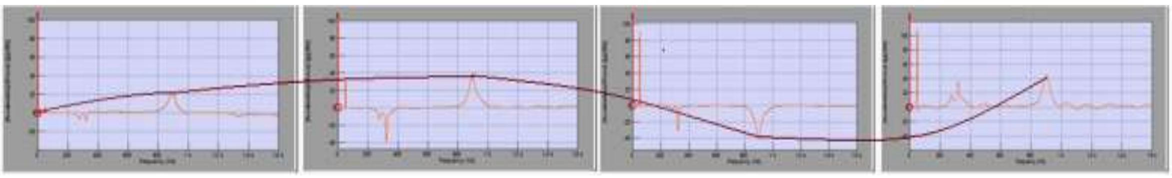
Mode 1 of cantilever beam at natural frequency49 Hz



Mode 2 of cantilever beam at natural frequency 302 Hz



Mode3 of cantilever beam at natural frequency 467 Hz



Mode 4 of cantilever beam at natural frequency 850 Hz

Fig. 8: Mode shapes of cantilever beam

IV CONCLUSIONS

In this research work a mild steel cantilever beam has been investigated through Structure frequency response testing i.e. modal analysis to estimate its modal parameters. The following conclusions have been drawn:

1. Modal analysis technique is establishing a relationship between the vibration response at one location and excitation at the same or another location as a function of excitation frequency.
2. The modal parameters of cantilever beam are evaluated from frequency response function (FRF) through Global Rational Fraction Polynomial method or curve fitting.

3. Modal parameters are global properties of a structure and any changes in these parameters can be used to detect and locate structural faults.

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