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Experimental Verification of Damping Coefficient by Half Power Band Width Method

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Abstract

Modal analysis is a worldwide used methodology that allows fast and reliable identification of system dynamics in complex structures. In the last decades several methods have been developed in quest to improve accuracy of modal models extracted from test data and to enlarge the applicability of modal analysis in industrial context. Damping in composite materials is an important parameter affecting the dynamic behavior of structures, controlling the resonant and near-resonant vibration levels.

In this paper vibration characteristics of a cantilever beam made with different materials such as Steel, Spring Steel, Wood, Rubber, Fiber Reinforced Plastic (FRP) are studied experimentally.

Keywords*:* Fibre Reinforced Plastic (FRP), Half Power Band Width, Modal Analysis, Resonant.

1. Introduction

Damping properties are of significant importance in determining the dynamic response of structures, and accurate prediction of them at the design stage, especially in the case of light-weight structures [1]. Damping in composite materials is an important parameter affecting the dynamic behavior of structures, controlling the resonant and near-resonant vibration levels. For the solution of variety of noise and vibration problems, especially those associated with vibrations of structures made of sheet metal, surface damping treatments are often used [2]. Hence in order to design composite structure determination of damping coefficients is necessary.

2. Theoretical Background

Structures vibrate in special shapes called mode shapes when excited at their resonant frequencies. A mode shape is the characteristics deformation shape defined by relative amplitudes of the extreme positions of vibration of a system at a single natural frequency. The modal parameters are the natural frequencies, damping ratios and modal masses associated with each of the mode shapes.

Experimental modal analysis is a supportive tools to study the various vibration problems. In addition to verifying the theoretical results, it helps to study the actual dynamic behavior of a structure away from idealization. Modal analysis is the representation of the dynamic properties of an elastic structure in terms of its modes of vibration. The elastic structure tends to bend, twist and vibrate when subjected to an external dynamic force. The dynamic properties are also known as the modal parameters which are unique for the structure [3]. The modal parameters are:

Natural Frequency

Damping Factor

The damping in a system can be obtained from free vibration decay curve. Where the free vibration test is not practical, the damping may be obtained from the frequency response curve of forced vibration test. The damping ratio determination method comes originally from the electrical engineering domain and is called half power bandwidth method. On the response curve at the harmonic forced vibrations shown in Fig.2.1 one identifies the points A and B, corresponding to the maximum response, multiplie by 1/√2 (in electrical engineering this value matches to a point where the electric power amplifier is at half of the maximum value).

The damping ratio is given by the equation [4]:

$$2\xi = \frac{\omega_2 - \omega_1}{\omega_n} \quad (1)$$

$$C = \zeta * C \quad (2)$$

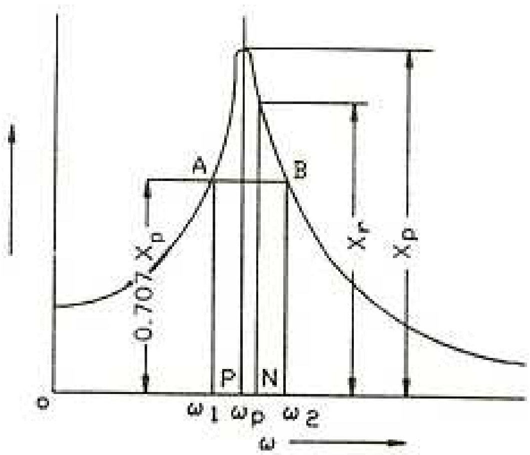


Fig. 1. Determination of Equivalent Viscous Damping from Resonant Amplitude.

Hence an accurate value of ξ and C can be found by construction and measurements.

3. Design and Experimentation

3.1Elements of Experimental Setup:

1. FFT (Fast Fourier Transform) Analyzer.
2. Magnetic Exciter
3. Impact Hammer
4. Accelerometer
5. Apparatus

Fig. 2 shows the developed experimental setup used for determination of damping coefficients and Fig.3 shows different types of composite beams used for determination of damping coefficient.

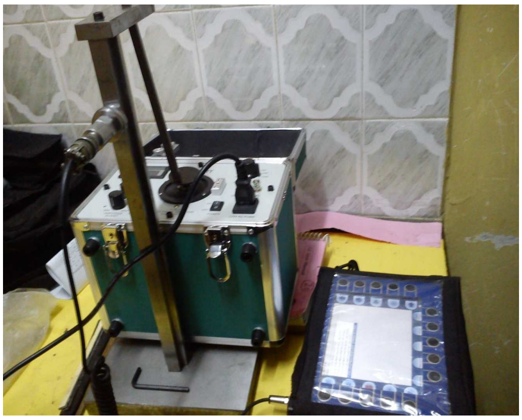


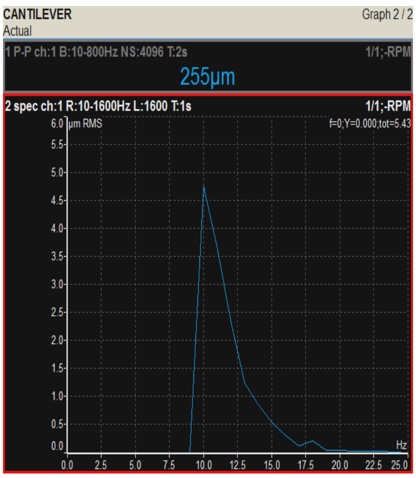
Fig.2 Experimental Setup

Fig. 3 Beams of Different Materials

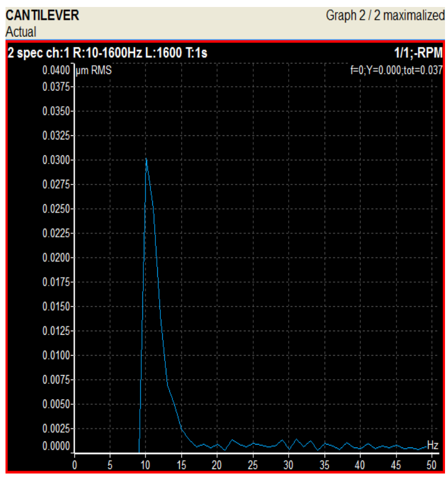
The procedure used for the determination for damping coefficient by this method is given below

1. Fix the beam with the help of clamp fixed on the table.
2. Make proper connections of the vibscanner and accelerometers.
3. Place accelerometer at the free end of the cantilever beamt to measure the vibration response.
4. Struck the free end of a cantilever beam with a wooden mallet.
5. Record all the data obtained from the vibrating beam with the help of vibscanner as accelerometer is attached to it.
6. Repeat the whole experiment for different material by changing the parameters like length & thickness.
7. Record the whole set of data and then import it into the PC.

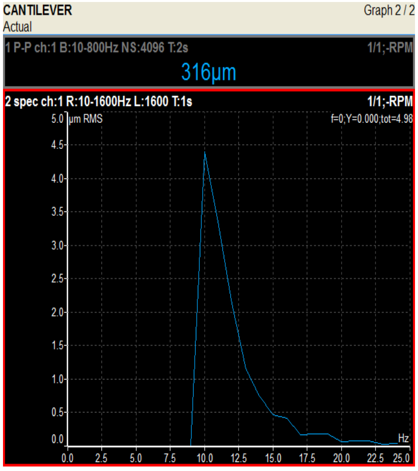
4. Results and Discussions



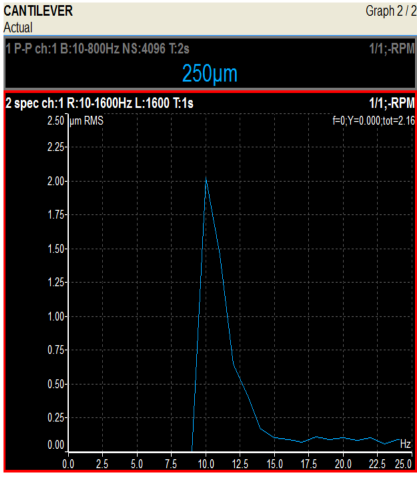
Graph 1Displacement Vs Frequency for Steel.



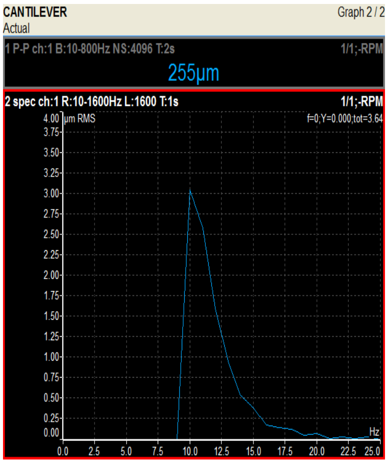
Graph 2 Displacement Vs Frequency for Steel on Steel.



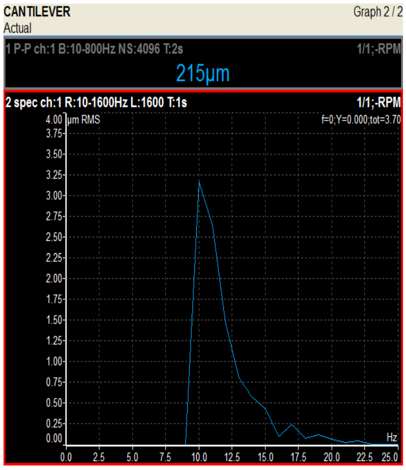
Graph 3 Displacement Vs Frequency for Wood on Steel.



Graph 4 Displacement Vs Frequency for Rubber on Steel.



Graph 5 Displacement Vs Frequency Spring Steel on Steel



Graph 6 Displacement Vs Frequency for for FRP on Steel

The variation in Displacement with respect to Frequency is tabulated in Table 4.1

Table 4.1 Variation of Displacement with respect to Frequency for Steel Beam.

Sr. No.	Beam	Peak Amplitude (Xp)	Half Power Amplitude (X)
1	Steel	4.7083	3.3287
2	Steel on Steel Beam	0.03	0.2121
1	Wood on steel	4.3666	3.087
2	Rubber on steel	2	1.41
3	Spring steel on steel	2	2.16027
4	FRP on steel	3.1388	2.2191

The variation in damping coefficient with respect to c/s area is tabulated in Table 4.2

Table 4.2: Variation in Damping Coefficient with Respect to c/s Area

Sr. No.	Damping coefficient Ns/m		Percentage Variation
	Steel	Steel on Steel	
1	39.089	167.74	76.69 %

The variation in Equivalent Damping Coefficient of bonded beams with Respect to Steel on Steel is tabulated in Table 4.3.

Table 4.3 Variation in Equivalent Damping Coefficient of Bonded Beams with Respect to Steel on Steel

Sr. No.	Beam	Damping Coefficient N-s/m	Percentage Variation
1	Wood on Steel	108.99	35.024 %
2	Rubber on Steel	253.61	33.859 %
3	Spring steel on Steel	171.83	2.83 %
4	FRP on Steel	197.25	14.96 %

From Table 4.3 it is observed that

The Percentage Variation of Damping Coefficient of Wood on Steel with respect to Steel on Steel is 35.024 %

The Percentage Variation of Damping Coefficient of Rubber on Steel with respect to Steel on Steel is 33.859 %

The Percentage Variation of Damping Coefficient of Spring Steel on Steel with respect to Steel on Steel is 2.83 %

The Percentage Variation of Damping Coefficient of FRP on Steel with respect to Steel on Steel is 14.96 %

From above result it can be concluded that,
Equivalent damping behavior of spring steel is nearly equal to that of steel

As the variation of equivalent damping coefficient is maximum for wood on steel, wood has more damping property as compared to rubber and FRP.

From Table 4.1 it is observed that when c/s of beam doubled, the damping coefficient for steel varies by 76.69%.

The variation in equivalent damping coefficient of bonded beams with respect to steel on steel is tabulated in Table 4.3.

5. Conclusion

Half Power Band Width method is useful for determination of damping coefficient in case of solid damping and equivalent damping coefficient in case of solid and slip damping of various materials. The damping coefficient of Fiber Reinforced Plastic (FRP) is more than Spring Steel (Spring Steel is a Steel used to make leaf spring in a 3 wheeler automobile, which are used to dampen the vibrations generated in an automobile) So we can make the leaf spring of a 3 wheeler automobile with Fiber Reinforced Plastic (FRP).

References

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