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Vibration control of structures using piezoelectric material

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ABSTRACT: Structural elements and systems used in spacecraft and antenna structures are flexible and light in weight. Vibration in flexible structures may produce secondary effects in it and affect the performance. Therefore, it is important to control structural response of flexible structures. This can be achieved by either Passive control or Active control. It has been found that active control of flexible structures may lead to instability, if there is an error in feedback control. In such situations passive control of flexible structures coated with thin viscoelastic material offers promise. Apart, smart materials like Piezoelectric Ceramic Powder, Magneto-rheological Fluids etc. are potential alternatives. In present study cantilever structure made up of aluminum material is considered. Bare specimen is coated with Piezoelectric Ceramic Powder. Acceleration is captured using Data Acquisition System and LabVIEW through Free vibration test. Results shows piezoelectric powder coating increases damping into the system.

1 INTRODUCTION

Mechanical Vibrations have harmful effects on structures. Vibration of a structure can be controlled by either active method or passive method of controlling response. Active method includes a sensor, a processor and an actuator. Passive method is simple and it don't use a processor. Examples of passive method are Base Isolation, Tune Mass Damper, Viscoelastic damper, Frictional Damper, Viscous Damper etc.

Many researchers are working to access the potential of new generation smart material for the response control of structures. Ferroelectrically soft piezoelectric ceramic has the potential to control the vibrations passively but it can be used for thin flexible structures. Thin layers of highly sensitive ferroelectrically soft piezoelectric ceramic and piezo ceramic powder coating shows vibration damping effects (Munjal, B.S et al.).

In the present study Piezoelectric Ceramic SP-4 and SP-5 A are surface coated on aluminum cantilever beam in the form of thin layers with the help of Araldite Epoxy Hardener and Resin (HV 953 & AW106). Bare (un-coated) and coated specimens are tested under time domain for calculating vibration damping. Log decrement method is used to calculate damping coefficient.

2 PIEZOELECTRIC MATERIAL AND PROPERTIES

Piezoelectricity originated from the Greek word "piezo" which means pressure electricity. It is the property of certain crystalline substances that on the application of mechanical stress they generate electrical charges. Piezoelectric Ceramic SP-4 and SP-5 A are considered for the present study has following properties.

3 EXPERIMENTAL WORK

Dynamic properties of coated and un-coated aluminum cantilever beam are determined. SP-4 and SP-5 A are procured from Sparkler Ceramics Pvt. Ltd. Cantilever structural system

Table 1. Properties of piezoelectric powder SP-4 and SP-5 A.

Property	SP-4	SP-5 A
Particle Size	0.9 micron	0.9 micron
Density	7600 kg/m^3	7650 kg/m^3

Table 2. Physical and mechanical properties of aluminum cantilever beam.

Length	600 mm
Width	25 mm
Thickness	3 mm
Modulus of Elasticity	60000 MPa

Figure 1. Bare aluminum cantilever beam.

Table 3. Natural frequency of bare aluminum cantilever beam.

Method	Frequency (Hz)
Experimental	5.70
Numerical (Ansys)	5.73
Beam Theory	5.76

is used for determination of natural frequency and damping ratio. Damping ratio is determined by using free vibration.

3.1 *Bare aluminum cantilever beam*

Un-coated aluminum cantilever beam is tested for mechanical and dynamic properties. Physical, Mechanical and Dynamics properties obtained for bare aluminum cantilever beam are described in the present section. Table 2 shows physical and mechanical properties of aluminum cantilever beam.

Natural frequency of aluminum cantilever beam is calculated by two different methods, Analytical approach and Experimental approach. Beam Theory is used for calculating frequency analytically. Experimentally frequency of cantilever beam is obtained by capturing acceleration response of beam using Accelerometer and Data Acquisition System. Natural frequency determined using different approaches are described in Table 3. Results shows natural frequency is determined from different methods shows good agreement. There is not much difference in natural frequencies. Figure 1 shows bare aluminum cantilever beam used as host material on which coating of SP-4 and SP-5 A piezoelectric powder is applied and tested.

Damping ratio of aluminum cantilever beam is calculated using free vibration test. Displacement and velocity are provided as initial conditions to the structure and response of the structure is recorded using an Accelerometer which is attached at the top of aluminum cantilever beam. LabVIEW software is used for analyzing the recorded signal. Figure 2 shows response of aluminum cantilever beam under free vibration in LabVIEW.

Damping ratio is determined from the free vibration plot of aluminum cantilever beam, some portion of waveform is extracted and peaks are detected from the extracted waveform using LabVIEW software. Logarithmic decrement method is used to determine damping ratio. Apart, a log curve is developed compiling peak acceleration through MATLAB Curve Fitting Tool. An Average damping value obtained for bare aluminum specimen is 1.52%.

3.2 *Piezoelectric ceramic coated aluminum cantilever beam*

Piezoelectric Ceramic coated aluminum cantilever beam is tested for mechanical and dynamic properties. SP-4 and SP-5 A Piezoelectric Ceramic are used for surface coating. Physical and Dynamic properties determined and described in Table 4. Figure 3 and Figure 4 shows SP-4 and SP-5 A coated aluminum cantilever beam respectively.

Damping ratio of coated aluminum cantilever beam is calculated similar to bare aluminum cantilever beam. Figure 4 (a), (b) and (c) shows response of aluminum cantilever beam under

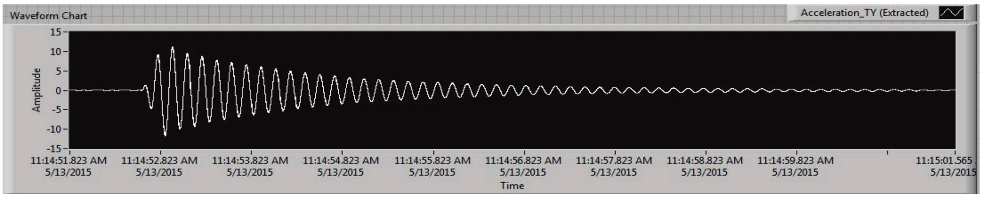

Figure 2. Response of aluminum cantilever beam under free vibration.

Table 4. Physical and dynamic properties of coated aluminum cantilever beam.

Property	SP-4	SP-5 A	SP-4+SP-5 A
Thickness of Coating	340 microns	170 microns	260 microns
Frequency (Hz)	5.64	5.81	5.70

Figure 3. SP-4 Coated aluminum cantilever beam.

Figure 4. SP-5 A Coated aluminum cantilever beam.

free vibration in LabVIEW. It is clearly visible on comparing Figure 1 and Figure 4 (a), (b) and (c) the damping increases for coated cantilever aluminum beam as compared to bare aluminum cantilever beam with very less mass penalty.

Damping ratio of coated aluminum cantilever beam is determined from the free vibration plot using logarithmic decrement method. Table 5 shows damping ratio of bare and coated aluminum cantilever beam. SP-4 coated beam shows significant increase in damping whereas SP-5 A alone and mixture of SP-4 and SP-5 A coating shows marginal increase in damping with very less mass penalty.

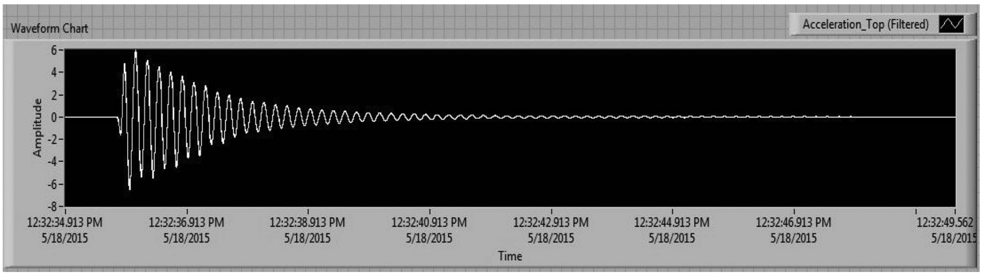

Figure 4 (a). Free vibration response of SP-4 coated aluminum cantilever beam.

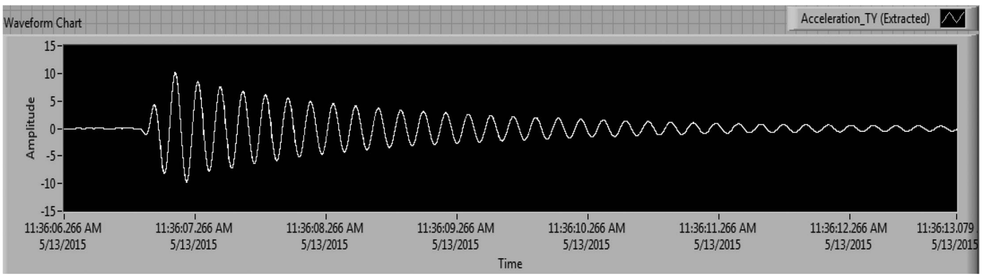

Figure 4 (b). Free vibration response of SP-5 A coated aluminum cantilever beam.

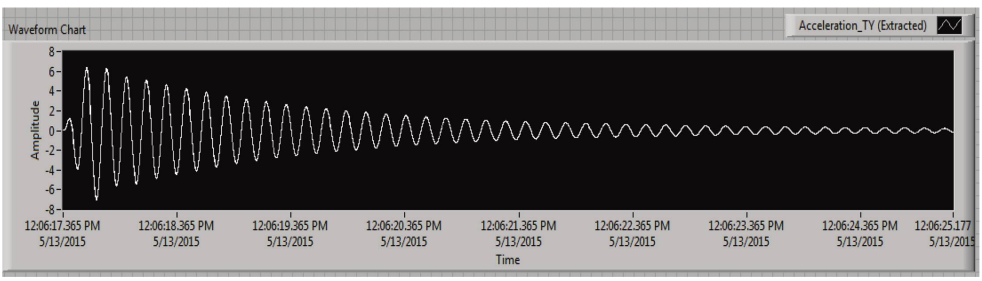

Figure 4 (c). Free vibration response of SP-4 and SP-5 A coated aluminum cantilever beam.

Table 5. Average damping of SP-4, SP-5 A and SP-4 + SP-5 A coated aluminum cantilever beam.

Coating	SP-5 A	SP-4	SP-4 & SP-5 A
Damping	1.622%	2.046%	1.642%
Increase in Damping	6.44%	34.27%	7.756%

4 CONCLUSION

Structural response of flexible structure can be controlled passively by many ways. Piezoelectric powder coating on structures helps in increasing damping of the structure. A bare and coated aluminum beams are considered for the present study. A free vibration test is carried out to determine damping ratio.

The study carried out indicates that

- Coating with smart materials on light flexible structures shows significant damping effects.
- As compared to bare specimen, specimen coated with piezoelectric powder SP-4, SP-5 A and mix of SP-4 and SP-5 A shows increment in damping.
- Maximum damping is achieved for aluminum specimen coated with SP-4 piezoelectric powder.

REFERENCES

Banerjee, S., Du, W., Wang, L. & Cook-Chennault, K.A. Fabrication of dome-shaped PZT- epoxy actuator using modified solvent and spin coating technique. *Journal of Electroceramics*. Publisher Springer US, Volume 31, Page 148–158.

Chopra, A.K. 3 edition, 2009. *Dynamics of structure*. Pearson Education, Inc.

Jordan, T.L. & Ounaies, Z. 2009. Piezoelectric Ceramics Characterization.

Munjal, B.S., Trivedi, H.V. and Sharma, P.V.B.A.S., Passive Damping Characterization of Parabolic Composite Reflectors with Hybrid PZT- Coated Layers. *Journal of Intelligent Materials Systems and Structure*. November 2008 19: Pages 1281–1294.

Panchal, D, Purohit, Sharad, Dynamic Response Control of a Building Model using Bracings, *Journal of Procedia Engineering, Chemical, Civil and Mechanical Engineering Tracks of the 3rd Nirma University International Conference on Engineering (NUiCONE-2012)*, Volume 51, 2013, Pages 266–273.