Experimentation and *t*-Test of Viscoelastic Vibration Damping

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Abstract — *Viscoelastic materials are largely used as a means to provide damping to structures, thus mitigating resonant vibration responses. The demand for silent machine operation in any of the organization is prime need in today's environmentally conscious world. The legal aspects of noise control requires a silent and noise free operation of the machine. The vibration causes rapid wear of machine parts such as bearings and gears. Unwanted vibrations may cause loosening of parts from the machine. In this paper an attempt has been made to found a suitable Viscoelastic material which can minimize the vibration and results into less noise and efficient operation. Devices made with viscoelastic materials such as isolators, dynamic vibration neutralizers (also called dynamic vibration absorbers), sandwich panels and structural links can be designed for highly efficient vibration control. The transfer of noise can also be reduced by decoupling the components in such a way that the noise path is interrupted. This can be achieved by adding noise reducing treatments to the structure such as elastic elements, masses, local shielding or damping layers. In the present investigation, the use of viscoelastic damping layers as a noise reducing measure in rotating machinery is considered. Here in this investigation the result obtained will give frequency value in random manner and the use of t-test (testing of hypothesis) will show us that vibrations are really reduced or not.*

Keywords — *Viscoelastic material, Vibration, FFT analyzer, t-test.*

I. INTRODUCTION

Viscoelastic materials are largely used as a means to provide damping to structures, thus mitigating resonant vibration responses. Devices made with Viscoelastic materials such as isolators, dynamic vibration neutralizers, sandwich panels and structural links can be designed for highly efficient vibration control. Viscoelastic materials are elastomers with long chain molecules enabling them to convert mechanical energy to heat when subjected to strain. This energy dissipation can provide effective passive damping in structures.

Here in our present study I am going to reduce vibration by using Viscoelastic material and then I am going to implement t-test which will tell me whether vibration has reduced or not. The test rig is specially designed for the study.

A. Vibration Isolation and Damping

Vibration isolation is the process of isolating an object, such as a piece of equipment, from the source of vibrations. Passive vibration isolation makes use of materials and mechanical linkages that absorb and damp these mechanical waves. Active vibration isolation involves sensors and actuators that produce destructive interference that cancels-out incoming vibration.

B. Viscoelastic Material

Viscoelasticity is the property of materials that exhibit both viscous and elastic characteristics when undergoing deformation. Viscous materials, like honey, resist shear flow and strain linearly with time when a stress is applied. Elastic materials strain instantaneously when stretched and just as quickly return to their original state once the stress is removed. Viscoelastic materials have elements of both of these properties and, as such, exhibit time dependent strain. Whereas elasticity is usually the result of bond stretching along crystallographic planes in an ordered solid, viscosity is the result of the diffusion of atoms or molecules inside an amorphous material.

List of common Viscoelastic polymeric materials.

1. Acrylic Rubber
2. Butadiene Rubber
3. **Butyl Rubber**
4. Chloroprene
5. Chlorinated Polyethylene
6. Ethylene-Propylene-Diene
7. Fluor silicone Rubber
8. Fluorocarbon Rubber
9. Nitrile Rubber
10. Natural Rubber

11. Polyethylene
12. Polystyrene
13. Polyvinyl chloride (PVC)
14. Polymethyl Methacrylate (PMMA)
15. Polybutadiene
16. Polypropylene
17. Polyisobutylene
18. Polyurethane
19. Polyvinyl acetate
20. Polyisoprene
21. Styrene-butadiene (SBR)
22. Silicon Rubber
23. Urethane Rubber

II. EXPERIMENTAL METHODOLOGY

Based on the literature survey and information received from the various sources the problem has been carefully defined. To resolve the issues rose in the problem definition, it is required either to formulate a mathematical model (or analytically solved the previously available one) or conduct number of experiments to make fruitful conclusions. To conduct the successful experiments, it has to plan carefully with available standard procedures. The following sections of this chapter will elaborate the procedures for conducting the experiments of vibration analysis using Viscoelastic material as damping media.

A. *Viscoelastic Materials for Comparative Analysis*

The selection of viscoelastic material is based on the ease of availability, installation, replacement and cost. Following viscoelastic materials were used for evaluating their effectiveness in minimizing the effect of vibration.

Table. 1: Viscoelastic Materials used for experiments

Sr.No.	DESCRIPTION	PICTURE
1	Butyl rubber sheet 12 mm thick	
2	Silcone rubber sheet 12 mm thick	
3	PVC sheet 12 mm thick	

The above selected materials are used as vibration isolators (damping agent to absorb the vibrations). The other parameters for vibration analysis were rpm of rotating shaft, location of disc on which unbalanced mass is attached and distance between bearing supports.

B. *Experimental Setup*

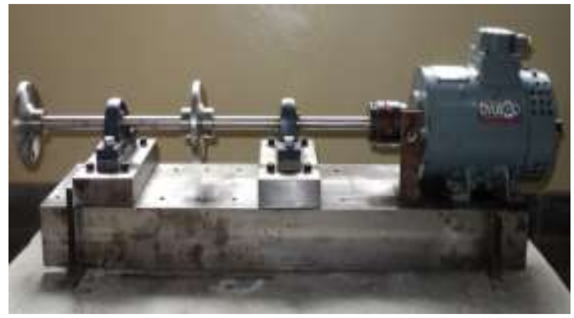

Figure 1: Experimental Setup

Figure 2: Experimental Setup Instrumentation

Experimental setup consists of electric motor (0.37 kW), shaft (material stainless steel of Φ 15 mm diameter of full length 630), two bearings, two discs, bearing's base plate, bearing's support plate, base plate and jaw coupling. The major part of this test setup is base plate which is made up from C – Channel having dimensions 200x100x25mm. The base plate also facilitated with number of holes to change the bearing support positions according to the requirement at various locations. The main objective of bearings support plate is to give rigid and firm support to the bearings of the test setup. The dimensions of plate are 200 mm x 100 mm x 33 mm.

Experimental Setup Instrumentation consists of

- Accelerometer (for sensing vibrations at the bearing locations)
- Inductive pickup sensor (for measuring speed (frequency) rpm of shaft)
- FFT analyser (to record the vibration signal)
- Speed regulator (to control speed of motor)
- Speed display unit (to display speed (frequency) rpm of shaft)
- PC (to record vibration spectrum).

The accelerometer is mounted on bearing senses vibration signal sends it to FFT analyser, FFT analyser processes it and converts it into signal form compatible with PC. These vibration signal values are shown in the form of vibration spectrum on the screen of PC.

Experiments were carried out on specially developed vibration test rig as shown in figure 1. Which can facilitate the change of bearing support location, change in operating frequency (i.e. speed can be varied) etc. Following test plan is decided to conduct the experiments for the bearing locations shown in figure 1.

The distance between two bearings is 300 mm with speed range 500/1000/1500 rpm

- *Case 1:* Butyl rubber sheet with 12 mm thickness
- *Case 2:* Silcon rubber sheet with 12 mm thickness
- *Case 3:* PVC sheet with 12 mm thickness

For each case 20 no. of readings were taken. The speed (frequency) is measured using non-contacting type speed sensor with digital display, an accelerometer attached to FFT analyzer is mounted on both bearing support (i.e. near to the drive and away from the drive), the signal received from the accelerometer with the help of FFT analyzer is acquire and displayed on PC using NV Gate software.

Table 2: Arrangement of Viscoelastic support beneath bearing housing for different cases

CASE NO.	DESCRIPTION	PHOTO IMAGE
Case 1	Butyl rubber sheet with 12 mm thickness	
Case 2	Silcone rubber sheet with 12 mm thickness	
Case 3	PVC sheet with 6 mm thickness	

III. RESULTS

Table 3: Result Table

Case 1		Case 2		Case 3	
Sr No	Vibra. Magni. (RMS Value)	Sr No	Vibra. Magni. (RMS Value)	Sr No	Vibra. Magni. (RMS Value)
1	388.07	1	247.57	1	288.10
2	387.07	2	245.70	2	286.80
3	389.13	3	246.53	3	287.43
4	388.77	4	248.63	4	288.53
5	388.53	5	249.90	5	287.77
6	386.97	6	247.40	6	288.50
7	389.20	7	250.27	7	287.77
8	389.57	8	249.53	8	287.43
9	390.17	9	247.00	9	286.50
10	388.40	10	247.47	10	285.50
11	388.37	11	245.77	11	286.97
12	389.27	12	247.43	12	284.40
13	389.40	13	247.97	13	287.07
14	389.13	14	247.60	14	287.13
15	389.77	15	246.43	15	288.83
16	388.17	16	247.50	16	291.33
17	389.27	17	248.30	17	287.30
18	389.33	18	247.30	18	288.97
19	390.23	19	245.67	19	286.70
20	388.03	20	248.07	20	288.40

As per the test plan discussed in previous chapter, the experiments were conducted and result tables were prepared. Above result tables referred to the different case and conditions discussed previously.

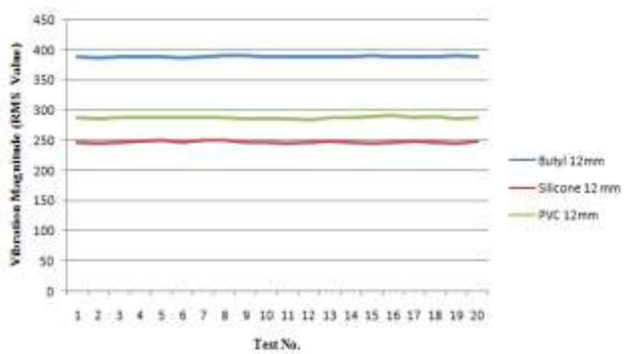

Figure 3: Vibration magnitude (RMS Value) mm/sec ^{2} Vs Test Number Plot for 12 mm Viscoelastic isolation.

IV. T-TEST FOR VIBRATION REDUCTION

t-test is based on t-distribution and is considered an appropriate test for judging the significance of a sample mean or for judging the significance of difference between the means of two samples in case of small sample(s) when population variance is not known (in which case we use variance of the sample as an estimate of the population variance). In case two samples are related, we use paired t-test(or what is known as difference test) for judging the significance of the mean of difference between the two related samples. It can also be used for judging the significance of the coefficients of simple and partial correlations. The relevant test statistic, t, is calculated from the sample data and then compared with its probable value based on t-distribution (to be read from the table that gives probable values of tfor different levels of significance for different degrees of freedom) at a specified level of significance for concerning degrees of freedom for accepting or rejecting the null hypothesis. It may be noted that t-test applies only in case of small sample(s) when population variance is unknown.

Formulas required for carrying t-test

$$\bar{X} = \frac{\sum X_i}{n}$$

$$\sigma_s = \frac{\sqrt{\sum (X_i - \bar{X})^2}}{\sqrt{n-1}}$$

$$t = \frac{\bar{X} - \mu_{H_o}}{\sigma_s / \sqrt{n}}$$

Implementation of t-test in project:

Case 3: 12 mm thick PVC sheet with plain profile beneath bearing housing

From the result analysis we have the readings for the above mentioned case let us consider those results.

By using above mentioned formulae we have calculations as follows.

$$\bar{X} = \frac{\sum X_i}{n} = \frac{5751.43}{20} = 287.57$$

$$\sigma_s = \frac{\sqrt{\sum (X_i - \bar{X})^2}}{\sqrt{n-1}} = \frac{\sqrt{38.29}}{\sqrt{19}} = 1.41$$

μ_{H_o} = Highest Value of X_i = 291.33

Table 4: Result table for case 3

Sr.No.	X_i	$(X_i - \bar{X})$	$(X_i - \bar{X})^2$
1	288.10	0.53	0.2809
2	286.80	-0.77	0.5929
3	287.43	-0.14	0.018687
4	288.53	0.96	0.927947
5	287.77	0.20	0.038691
6	288.50	0.93	0.8649
7	287.77	0.20	0.038691
8	287.43	-0.14	0.018687
9	286.50	-1.07	1.1449
10	285.50	-2.07	4.2849
11	286.97	-0.60	0.363971
12	284.40	-3.17	10.0489
13	287.07	-0.50	0.253311
14	287.13	-0.44	0.190707
15	288.83	1.26	1.595927
16	291.33	3.76	14.16243
17	287.30	-0.27	0.0729
18	288.97	1.40	1.950771
19	286.70	-0.87	0.7569
20	288.40	0.83	0.6889
TOTAL		0.0333	38.2959

$$t = \frac{\bar{X} - \mu_{H_o}}{\sigma_s / \sqrt{n}}$$

$$t = \frac{287.57 - 291.33}{1.41 / \sqrt{20}} = -11.84$$

From the table "critical values of student's t-Distribution"

Degree of freedom = n-1 = 20-1 = 19

At 5% significance level for 19 degree of freedom we have from the table of "Critical value of student's t-distribution"

R: t < 1.725

The observed value of t is -11.84 which is in the acceptance region and thus H_0 is accepted at 5% level of significance and thus we can conclude that the sample data indicate that vibrations have reduced by the use of 12 mm thick PVC sheet beneath bearing housing.

Similar can be done with other cases and results are found to be same that is vibrations are reduced by using viscoelastic materials.

V. Conclusions

From the experimental results recorded in the result tables as previously discussed and the corresponding plots based on these results following conclusions were made

1) Undoubtedly the Viscoelastic material shows its utility as a vibration damping material and can

be used as vibration isolators in variety of applications.

2) The conducted research will provide the comparative study between the different readily available Viscoelastic materials. It helps to evaluate the effectiveness of these materials under various circumstances.
3) The Silicone material with thickness (12 mm) gives best results i.e. showing less amplitude of vibrations at both the support locations and at all the frequency values.
4) The Butyl rubber material with maximum thickness (12 mm) indicates a less effective material for absorbing the vibrations. (There is a need of paying more attention towards the study of effect of geometry and thickness of the rubber as a viscoelastic material)
5) From the result obtained for the similar set of conditions the (12 mm) the average vibration magnitude (RMS Value) for silicone rubber is 247.60 mm/s^2, for butyl 388.84 mm/s^2 and for PVC 287.57 mm/s^2. This shows that silicone gives reduction in vibration magnitude by 36.32% and 13.89% over butyl and PVC viscoelastic support.
6) From the present study and based on above conclusions it is found that the use of Viscoelastic material is one of the best choice of passive vibration isolation technique. Further there is a scope to conduct some part of research in the area of optimized thickness and geometry profile of the PVC sheet as a Viscoelastic material.

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REFERENCES

[1] H.G. Tillema, "Thesis on Noise reduction of rotating machinery by viscoelastic bearing supports". University of Twente, Enschede, Netherlands, pp. 2-3, February 2003.

[2] Palash Dewangan, "Thesis on Passive Viscoelastic Constrained Layer Damping For Structural Application". National Institute of Technology Rourkela May, 2009.

[3] Panda K.C., Dutt J.K., "Design of Optimum Support Parameters for Minimum Rotor Response and Maximum Stability Limit", Journal of Sound and Vibration, 223 (1), pp. 1-21, May 1999.

[4] Dutt. J.K., Toi T., "Rotor Vibration Reduction with Polymeric Sectors", Journal of Sound and Vibration, Vol. 262(4), pp. 769-793,May 2003.

[5] Tai-Hong Cheng, Zhen-Zhe Li, and Yun-De Shen, "Vibration Analysis of Cylindrical Sandwich Aluminum Shell with Viscoelastic Damping Treatment" in Hindawi Publishing Corporation Advances in Materials Science and Engineering Volume 2013, Article ID 130438,7pages.

[6] Ali Khoshraftar, "The Evaluation of Steel Frame Structures with Viscoelastic Dampers" in IACSIT International Journal of Engineering and Technology, Vol. 8, No. 4, August 2015.

[7] Roman Lewandowski, Bartosz Chorążyczewski, "Remarks On Modelling Of Passive Viscoelastic Dampers".

[8] Snowdon, J.C., Rubberlike Materials, Their Internal Damping and Role in Vibration Isolation, Journal of Sound and Vibration, 2 (2), pp. 175-193,April 1965.

[9] Su Myat Aye, Dr. Kyaw Moe Aung, "Comparative Study on Seismic Response of RC Structure Using Viscous Dampers and Viscoelastic Dampers" in IJSETR, ISSN 2319-8885 Vol.03,Issue.08, May-2014, Pages:1468-1478.

[10] Jadhav Sainand M and Jadhav Dattatraya B. "Comparative Analysis of Viscoelastic Material Support for Rotating Machinery", International Journal of Applied Research, (2012), Vol. 2, No. 3, pp. 63-67.

[11] C. R. kothari, "*Research Methodology"*. New Delhi: new age publication, 2011