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Research Paper

EXPERIMENTAL AND T-TEST (TESTING HYPOTHESIS) APPROACH IN VIBRATION REDUCTION

Nikhil S Kulkarni[1]* and Eknath R Deore[1]

*Corresponding Author: **Nikhil S Kulkarni** ✉ nikhilkulkarni20@gmail.com

Producing a noiseless and vibration free devices is a need of the day. The vibration causes rapid wear of machine parts such as bearings and gears. Unwanted vibrations may cause loosening of parts from the machine. Because of improper design or material distribution, the wheels of locomotive can leave the track due to excessive vibration which results in accident or heavy loss. Sometimes because of heavy vibrations proper readings of instrument cannot be taken. Vibration can be used for useful purposes such as vibration testing equipment's, vibratory conveyors, hoppers, and comparators. Vibration is found to be very fruitful in mechanical workshops such as improving the efficiency of machining, casting, forging and welding techniques. 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 hypothesis) will show us that vibrations are really reduced or not.

Keywords: Viscoelastic material, T-test, FFT analyser, Vibration reduction

INTRODUCTION

In our day today life we all use different appliances such as air-conditioners; flour mills, grinders, and many more all these appliances are designed to give a peaceful life, but the noise created by these appliances may have an adverse effect on the life of human being if a person is in this environment for long time. More prone to such environment may lead to reduce in hearing strength and also lead permanent deafness. So creating the noiseless and vibration free instruments is a need of the day, because noise and vibration are the two sides of same coin. Here in our present study I am going to reduce vibration by using viscoelastic material and then I am

[1] Mechanical Engineering Department SSVPS COE Dhule, SSVPS COE DHULE-424001

going to implement t-test which will tell me whether vibration has reduced or not. The test rig is specially designed for the study.

VIBRATION ISOLATION

The high speed engines and machines when mounted on foundations and supports cause vibrations of excessive amplitude because of unbalanced forces set up during their working. These are the disturbing forces which damage the foundation on which the machines are mounted. So the vibrations transmitted to the foundation should be eliminated or reduced considerably by using some devices such as dampers, springs, etc., between the foundation and machine. These devices isolate the vibrations by absorbing some disturbing energy themselves and allow only a fraction of it to pass through the foundation. Thus the amplitude of vibration is minimised and the adjoining structure or foundation is not put to heavy disturbances. There are two basic requirements of isolator: firstly, there should be no rigid connection between the unit and the base otherwise the undesired vibration will be completely transmitted from the unit to base. It may damage the supporting structure. Secondly, it should be ensured that the isolators remain together in case of material fails. It should be just to keep the machine or unit in the safe position with respect to the support. The materials normally used for vibration isolation are rubber, felt, cork, metallic spring, etc. these are put between the foundation and the vibrating body.

The viscoelastic layers can be added between the external layer of the roller bearing and the bearing housing or underneath the bearing housing, as shown in Figures 1 and 2. In the former case, the inertia of the bearing can be neglected while, in the latter, it must be considered. In the current work, it was used the second alternative (Figure 2) only, with and without layers of viscoelastic material.

Figure 1: A Viscoelastic Layer Mounted Between The Bearing Outer Ring and The Housing

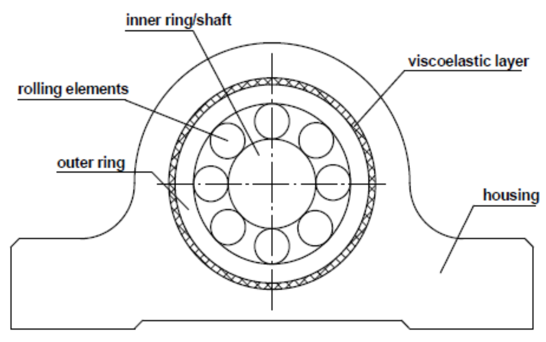
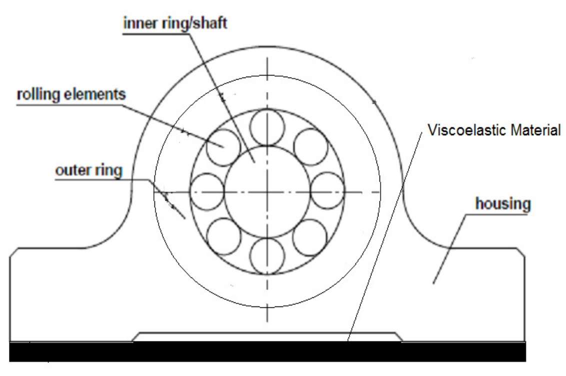


Figure 2: A Viscoelastic Layer Mounted Beneath The Bearing Housing



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.

Properties of viscoelastic materials:

1. Creep (if the stress is held constant, the strain increases with time) and Recovery
2. Stress Relaxation (if the strain is held constant, the stress decreases with time)
3. Energy Absorption.

List of Common Viscoelastic Polymeric Materials

Acrylic Rubber, Butadiene Rubber, Butyl Rubber, Chloroprene, Chlorinated Polyethylene, Ethylene-Propylene-Dyne, Fluor silicone Rubber, Fluorocarbon Rubber, Nitrile Rubber, Natural Rubber, Polyethylene, Polystyrene, Polyvinyl chloride (PVC), Polymethyl Methacrylate (PMMA), Polybutadiene, Polypropylene, Polyisobutylene, Polyurethane, Polyvinyl acetate, Polyisoprene, Styrene-butadiene (SBR), Silicon Rubber, Urethane Rubber.

Common Viscoelastic Materials Application

Grommets or Bushings, Component Vibration Isolation, Aircraft fuselage Panels, Submarine Hull Separators, Mass Storage Disk Drive Component, Automobile Tires, Stereo Speakers, Bridge Supports, Caulks and Sealants, Lubricants, Fibre Optics Compounds.

LITERATURE REVIEW

Espindola J J, Silva Neto J M and Lopes E M O, Carlos Alberto Bavastri (Panda and Dutt, 1999) introduced a new approach for characterization of viscoelastic materials via generalized derivatives. It is shown that, as derived by modelling generalized various functions transmissibility, obtained at various test temperatures, can be used simultaneously for the characterization of integrated material interest. Results with butyl rubber and silicone were presented and discussed. Espindola J J, Silva Neto J M and Lopes E M O (Shabaneh and Jean, 1999) attempted a new approach for the identification of the dynamic properties of viscoelastic materials, based on the fractional derivative model in their paper. Numerical and experimental results are produced and discussed.

Venugopal N, Chaudhari C M, Nitesh P Yelve (Dutt and Toi, 2003) applied Taguchi's concept of Orthogonal arrays for designing experiments to study the transmissibility ratio of viscoelastic materials and factors affecting it. Experiments are carried out with different process parameters like material, thickness, frequency. They used three viscoelastic materials namely Natural rubber, Neoprene rubber1, Neoprene rubber2. The results obtained are then analysed using ANOVA (Analysis of Variance). Thus the factors to be given importance while choosing the viscoelastic material as damping media are identified and also laid down the procedure for the same by making use of Taguchi's Orthogonal array technique for Design of experiments and ANOVA

Friswell M I, Sawicki J T, Inman D J, Lee A W (Eduardo Marcio de Oliveira Lopes *et al*., 2004) in their paper used internal variable approach to model the viscoelastic material for the transient dynamic responses, and includes an energy dissipation model. They gave an example of a turbo molecular pump, and the difficulty in balancing such machines is demonstrated. This paper has investigated the effect of an elastomer support on the dynamics of a rotating machine. In particular the effect of the frequency and temperature dependent modulus has been demonstrated. Although the example was relatively simple a number of conclusions may be drawn. It was shown that the dynamic characteristics of a machine change significantly with temperature because of the changes in stiffness and damping characteristics of the elastomer.

Sainand Jadhav, *et al.* has made use of viscoelastic materials for vibration reduction in a test rig. He had used natural rubber, corrugated rubber, and PVC material for reducing vibration.

EXPERIMENTAL SETUP

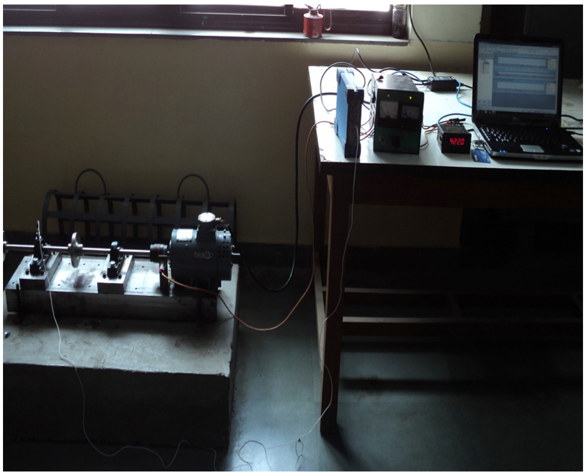
Various parameters like material, thickness, rpm of rotating shaft, location of flange on which unbalanced mass is attached, Distance between Bearing Supports are varied and experiments are conducted.

Figure 3: Experimental Setup

EXPERIMENTAL PROCEDURE

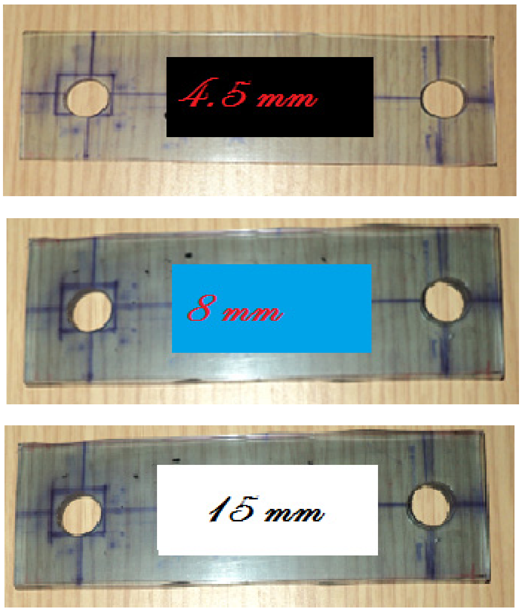
Experiments were carried out on specially developed vibration test rig which can facilitate the change of bearing support location, location of unbalanced mass, change in mass position, change in operating frequency (i.e. speed can be varied) etc. For each case 18 no. of readings were taken. The speed (frequency) is measured using non-contacting type speed

Figure 4: Experimental Setup Instrumentation



Variables	Levels		
	1	**2**	**3**
Material	**PVC Sheet**	**PVC Sheet**	**PVC plain Sheet**
Thickness	4.5 mm	8mm	15 mm
Rpm Of RotatingShaft	300	600	900
Location of Unbalanced Mass	I	II	-
Distance Between Bearing Supports	300	-	-

Figure 5: 4.5mm, 8mm, and 15mm PVC Material



sensor with digital display, an accelerometer attached to FFT analyser 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 analyser is acquire and displayed on PC using NV Gate software.

(I) distance between bearing supports = 300mm

Case 1: 4.5mm thick PVC sheet+7mm thick M.S. plate beneath bearing housing

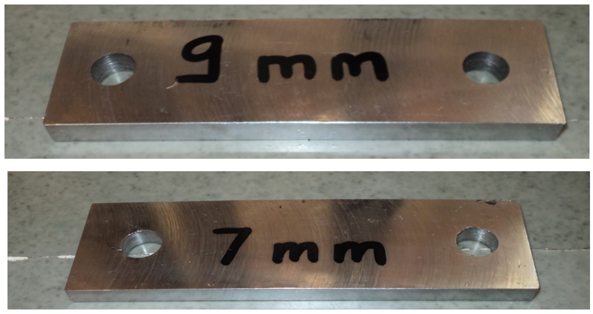
Case 2: 8mm thick PVC sheet + 7mm thick M.S. plate beneath bearing housing

Case 3: 4.5mm thick PVC sheet + 9mm thick M.S. plate beneath bearing housing

Case 4: 8 mm thick PVC sheet + 9mm thick M.S. plate beneath bearing housing

Case 5: 15mm thick PVC sheet beneath bearing housing

Figure 6: 7mm and 9mm Mild Steel Material



RESULTS

Distance between bearings is kept constant as 300 mm

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 samples when population variance is not known. The relevant test statistic, t, is calculated from the sample data and then compared with its probable value based on t-distribution at a specified level of significance.

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 samples when population variance is unknown.

Formulas required for carrying t-test:

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

$$\sigma_s = \frac{\sqrt{\sum\left(x_i - \bar{X}\right)^\wedge 2}}{\sqrt{n-1}}$$

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

Distance Between Bearings is Kept Constant as 300 mm									
Case 1		Case 2		Case 3		Case 4		Case 5	
Test No.	Vibration Magnitude (RMS Value)	Test No.	Vibration Magnitude (RMS Value)	Test No.	Vibration Magnitude (RMS Value)	Test No.	Vibration Magnitude (RMS Value)	Test No.	Vibration Magnitude (RMS Value)
1	23.33	1	28.41	1	9.45	1	11.11	1	13.28
2	12.17	2	26.55	2	10.26	2	12.11	2	19.87
3	25.45	3	32.28	3	19.87	3	35.01	3	10.5
4	22.24	4	18	4	18.75	4	22.77	4	33.25
5	40.25	5	46.88	5	38.75	5	60.44	5	22.45
6	58.78	6	73.2	6	39.88	6	35.87	6	41.35
7	19.25	7	25	7	11.25	7	10.75	7	12.32
8	18.77	8	17.88	8	12.55	8	9.78	8	12.28
9	16.88	9	22.22	9	14.99	9	11.68	9	17.9
10	10.26	10	30.22	10	19.22	10	14.75	10	11.09
11	17.47	11	42.22	11	22.22	11	25.75	11	27.25
12	15.66	12	37.07	12	18.99	12	15.65	12	24.25
13	19.88	13	36.61	13	17.56	13	18.57	13	13.25
14	24.45	14	31.01	14	26.45	14	20.89	14	15.68
15	44.44	15	73.61	15	50.31	15	40.07	15	48.2
16	29.54	16	65.55	16	38.56	16	47.48	16	36.45
17	40.12	17	56.65	17	45.45	17	61.25	17	16.75
18	31.56	18	55.55	18	36.96	18	32.22	18	19.85

For Case 5

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

$$\bar{X} = \frac{\sum x_i}{n} = 395.97/18 = 21.9983$$

$$\sigma_s = \frac{\sqrt{\sum\left(x_i - \bar{X}\right)^\wedge 2}}{\sqrt{n-1}} = 11.15292$$

Test No.	Vibration Magnitude (RMS Value)
1	13.28
2	19.87
3	10.5
4	33.25
5	22.45
6	41.35
7	12.32
8	12.28
9	17.9
10	11.09
11	27.25
12	24.25
13	13.25
14	15.68
15	48.2
16	36.45
17	16.75
18	19.85

μ_{H_o} = highest value of X_i = 48.2

$$t = \frac{\bar{X} - \mu_{H_0}}{\sigma_s \sqrt{n}} = -9.96666$$

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

Degree of freedom = n-1 = 18-1 =17

At 5% significance level for 17 degree of freedom we have from the table of "Critical value of student's t-distribution"

R:t<1.74

S.No.	$(X_i - \bar{X})$	X_i	$(X_i - \bar{X})$
1	8.71833	13.28	76.00927799
2	2.12833	19.87	4.529788589
3	11.49833	10.5	132.2115928
4	-11.2517	33.25	126.6000778
5	-0.45167	22.45	0.204005789
6	-19.3517	41.35	374.4871318
7	9.67833	12.32	93.67007159
8	9.71833	12.28	94.44593799
9	4.09833	17.9	16.79630879
10	10.90833	11.09	118.9916634
11	-5.25167	27.25	27.58003779
12	-2.25167	24.25	5.070017789
13	8.74833	13.25	76.53327779
14	6.31833	15.68	39.92129399
15	-26.2017	48.2	686.5275108
16	-14.4517	36.45	208.8507658
17	5.24833	16.75	27.54496779
18	2.14833	19.85	4.615321789
	Total	**395.97**	**2114.58905**

The observed value of t is -9.96666 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 15mm thick PVC sheet.

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

CONCLUSION

Case 3: 4.5mm thick PVC sheet + 9mm thick M.S. plate beneath bearing housing

Case 4: 8 mm thick PVC sheet + 9mm thick M.S. plate beneath bearing housing

Case 5: 15mm thick PVC sheet beneath bearing housing

These three cases are best suited in vibration reduction and if we want to any one of the three cases then case 4 is the best suited in any condition 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.

REFERENCES

1. Carlos Alberto Bavastri, Euda Mara da S Ferreira, Jose Joao de Espindola, Eduardo Marcio de O Lopes (2008), "Modeling of Dynamic Rotors with Flexible Bearings due to the use of Viscoelastic Materials", *Journal of the Brazil, Soc. of Mech. Sci. & Eng*., Vol. 3, No. 1, pp. 23-29.
2. Dutt J K and Toi T (2003), "Rotor Vibration Reduction with Polymeric Sectors", *Journal of Sound and Vibration*, Vol. 262, VOL. 4, pp. 769-793.
3. Eduardo Marcio de Oliveira Lopes *et al*. (2004), "Characterization Dynamics in Integrated Elastomers Generalized Derivatives", *Proceedings of the IIIrd CONEM*, Belem, Brazil.
4. Espindola J J, Silva Neto J M and Lopes A (2005), "Generalized Fractional Derivative Approach to Viscoelastic Material Properties Measurement", *Applied Mathematics and Computation*, Vol. 164, No. 2, pp. 493-506.
5. Panda K C, Dutt J K (1999), "Design of Optimum Support Parameters for Minimum Rotor Response and Maximum Stability Limit", *Journal of Sound and Vibration*, Vol. 223, No. 1, pp. 1-21.
6. Severino P C Marques, Guillermo J Creus (2012), "Computational Viscoelasticity", *Springer Heidelberg Dordrecht London*, New York, p. 3.
7. Shabaneh N H and Jean W (1999), "Dynamic Analysis of Rotor-Shaft Systems with Viscoelastically Supported Bearings", *Mechanism and Machine Theory*, University of Toronto, Canada, Vol. 35, No. 1, pp. 1313-1330.
8. Snowdon J C (1965), "Rubberlike Materials, Their Internal Damping and Role in Vibration Isolation", *Journal of Sound and Vibration*, Vol. 2, No. 2, pp. 175-193.
9. Tillema H G (2003), Thesis Noise reduction of rotating machinery by viscoelastic bearing supports, University of Twente, Enschede, Netherlands, pp. 2-3, February.
10. Venugopal N, Chaudhari C M, Nitesh P Yelve (2006), "An Investigation on Vibration of Visco-elastic materials by Using Taguchi Method & ANOVA, NCRTM 2006".
12. Jadhav Sainand M and Jadhav Dattatraya B (2012), "Comparative Analysis of Viscoelastic Material Support for Rotating Machinery", *International Journal of Applied Research,* Vol. 2, No. 3, pp. 63-67.