International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 02 Issue: 09 | Dec-2015 www.irjet.net p-ISSN: 2395-0072

VIBRATION DAMPING OF SHAFT BY MAGNETIC PIEZOELECTRIC CONTROL MOUNT: EXPERIMENTAL ANALYSIS

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Abstract: Vibration analysis is necessary for proper working of the system for getting maximum economy and efficiency. There are various techniques used to damp the vibration and vibration monitoring of the system. In this work magnetic-piezoelectric control mounts are used for vibration damping. Piezoelectric elements are bonded to permanent magnets, termed here as a control mounts which are attached to the surface of steel shaft through their magnetic attraction. It is one damping method for controlling vibrations generated in the system. Instead of epoxy attachment to piezoelectric control mount, the magnets are effectively used for vibration control mounts. Experimental investigation is done by using FFT Analyzer.

Keywords: control mount, shaft system, vibration damping, FFT Analyzer etc.

1. INTRODUCTION

Rotating machinery is commonly used in mechanical systems, including machining tools, industrial turbo machinery and aircraft gas turbine engines. Vibration caused by mass imbalance is a common problem in rotating machinery. Imbalance occurs if the principal axis of inertia of the rotor is not coincident with it's geometric axis. Higher speeds cause much greater centrifugal imbalance forces and the current trend of rotating equipment toward higher power density clearly leads to higher operational speeds. Therefore vibration control is essential in improving machine surface finish; achieving longer bearing, spindle, and tool life in high-speed machining; and reducing the number of unscheduled shutdowns also in space truss interferometer [1].

Shaft is the most important power transmission element. Transmission shafts transmit torque from one location to another. During power transmission, shaft subjected to torsion due to transmitted torque and bending from transverse loads (gears, pulleys, rotors, sprockets etc.) which creates vibration in the system which highly affects the system performance. So it is necessary to control the vibration there are different techniques used. But in this thesis magnetic-piezoelectric control mounts are used.

Traditional approaches to passive vibration control include the attachment of viscoelastic materials and mechanical vibration absorbers [2]. Piezoelectric materials, which have the ability to convert mechanical energy into electrical energy and vice versa, are often used in active and passive vibration control applications. When the piezoelectric material is strained, a charge develops across the element and energy is dissipated as current flows through an external electrical network or shunt.

2. PROBLEM STATEMENT

There are various active as well as passive methods of vibration damping used. That are effective and costlier and fails due to heat generation at high number of load cycles. Hence to avoid failure due to heat generation and vibration, the control mount is investigated for the shaft system which is rotating at 700 rpm conditions having 200 mm length supported by two bearing attached at left and right end of the shaft which is having 0.2 mm misalignment as shown in following experimental set-up fig.1 with control mount.

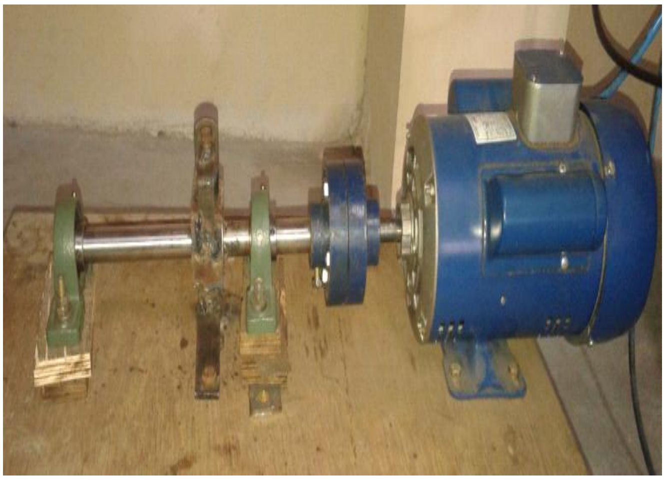

Fig-1: Experimental Set-up with control mounts.

In this work the system is analyzed with and without control mounts by experimental technique.

3. ANALYSIS WORK

3.1 Optimization Of Shape Of Control Mount

First control mount shape is optimized for 3 different shapes by structural analysis. It is based on the material saving for getting good economy and efficiency.

- Semi-circular shape of control mount
- Square but circular based control mount
- Circular shaped control mount

3.1.1 Semi-circular shape of control mount

For material and cost saving purpose this control mount shape is selected as shown in fig.2 bellow. For this shape maximum deformation is 0.12395 m and minimum is 0 m.

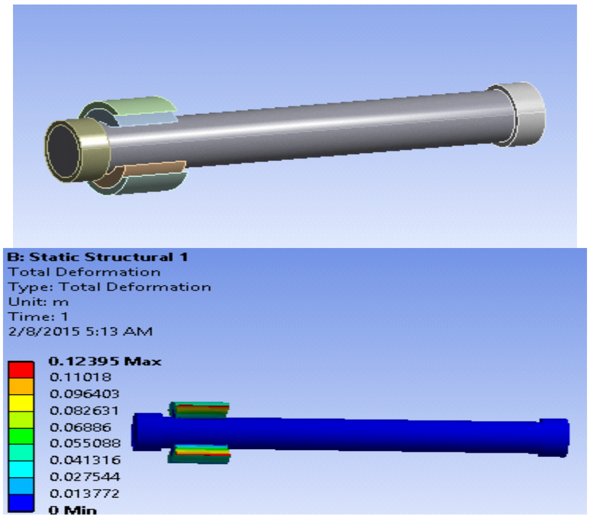

Fig.2 Semi-circular shape of control mount analysis

3.1.2 Square but circular based control mount

In this flat plate of piezoelectric element and square but circular based magnet is used here in fig.3. For this shape maximum deformation is 0.060591 m and minimum is 0 m. Here stress concentration occurs at inner circular base of magnet which can be produced the failure of the control mount. So it is not good for the system.

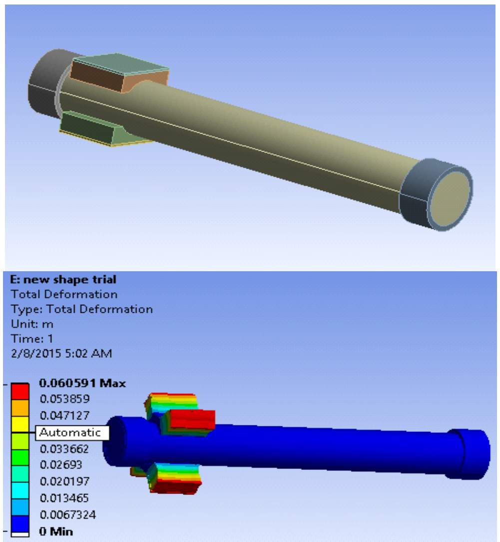

Fig.3 Square but circular based control mount analysis

3.1.3 Circular shaped control mount

It is having small thickness as compared to other control mounts. For this shape maximum deformation is 0.012434 m and minimum is 0 m as shown in fig.4. By applying two control mounts as shown in fig.5 bellow which shows similar results of that single control mount. In this way circular shaped control mount is selected.

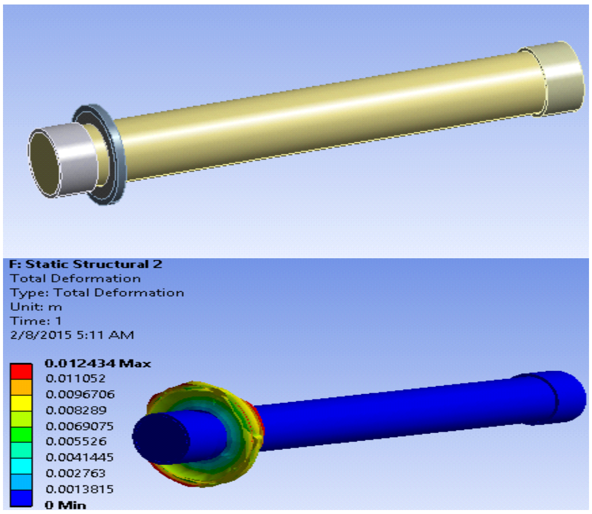

Fig.4 Circular shaped control mount analysis

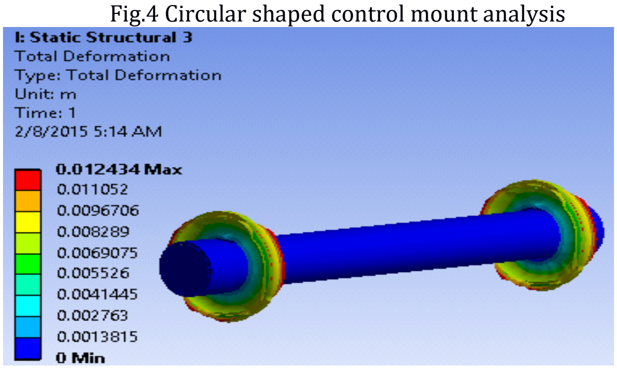

Fig.5 Two circular shaped control mount attached at the ends

3.2. Experimental Analysis:

In this vibration analysis of system is carried by using FFT Analyzer. In this frequency of the system and displacement of frequency waves is analyzed experimentally by using experimental setup. It consist of motor, coupling, shaft, bearing and control mount for analyzing system with and without control mount as shown in fig.1.

Table 1: Design details

SHAFT	
Diameter , d	25 mm
Length, L	200 mm
Density of material	7850 kg/mm^3
BEARING	6005, single row deep groove ball bearing.
HUB	
Outside diameter, D	50 mm
Length of hub, l	37.5 mm

3.2.1 Control Mount Design:

As per optimization for less thick control mount gives good economy as compared to others. Hence the selected control mount for experimental technique is as shown in fig.6 bellow.

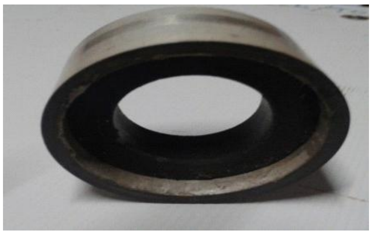

Fig.6 Magnetic- piezoelectric control mount for experimental work

Table 2: Dimensions of control mount

	Inner diameter	Outer diameter	Thickness
Magnet	24 mm	38 mm	11 mm
Piezo element	38 mm	44 mm	24 mm

3.2.2 Fast Fourier Transform Analysis

The vibration of a machine is a physical motion. Vibration transducers convert this motion into an electrical signal. The electrical signal is then passed on to data collectors or analyzers. The analyzers then process this signal to give the FFTs and other parameters.

3.2.3 Multi-Channel FFT Analyzer

Fig.7 shows the multichannel FFT analyzer consisting of 4 channels. When it is necessary to measure the data from more than two points from a machine or structure, this FFT analyzer is used. It can be used in combination with all relevant vibration and sound transducers.

Fig.7 FFT Analyzer

3.2.4 Accelerometer Probe And Analyzer Box

Accelerometers are the most popular transducers used for rotating machinery applications. They are rugged, compact, lightweight transducers with a wide frequency response range. Accelerometers are extensively used in many condition-monitoring applications.

3.2.5 Analysis Without Magnetic-Piezoelectric Control Mount

In this shaft is rotated by using motor having 1425 rpm standard rating and is transferred through coupling. In this work shaft is subjected to varying rpm condition from 700 to 1200 rpm by voltage control technique. Here for experimental analysis purpose the system has not applied external load through hammer. The fig. 8 shows system without control mount.

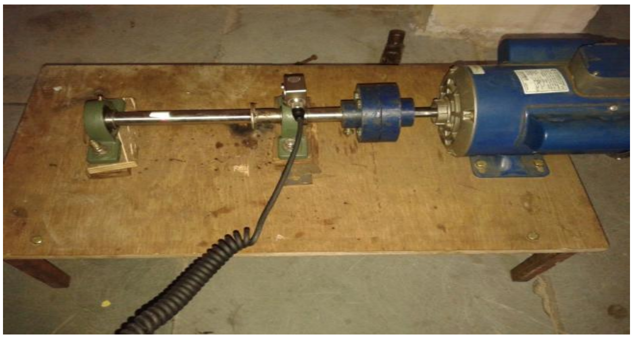

Fig.8 : System without control mount

3.2.5.1 Results Without Control Mount

Displacement Result: Due to misalignment and rotary motion it is subjected to vibration which produces maximum displacement in rotating direction.

- At 897 rpm condition the system is subjected to maximum displacement in rotating direction i.e. 218 µm. and 45.8 µm as shown in fig.10

Fig 9: Displacement of system at 897 rpm without control mount

3.2.5.2 Tabulated Result of Analysis:

Table 3: Result of analysis

Sr. No.	RPM	Rotating Direction Dispt. (µm) (Z)	(Y)
1	708	165	39.1
2	897	218	45.8
3	1100	287	55
4	1200	396	101

3.2.6 Analysis With Magnetic-Piezoelectric Control Mount

The shape of control mount is optimized by using analysis software ANSYS 14.0 which gives optimized and good results for circular shaped control mount. It is attached 20 mm distance from first Bearing Centre. The control mount used is having standard dimensions which is available in market. Due to misalignment at the coupling shaft it produces vibration and are controlled by using this control mount as a damper. Magnetic piezoelectric control mount is used for vibration control which has become very effective and successful, having dimensions,PZT=(44*38*24) mm and Magnet=(38*24*11) mm.

Fig.11: Experimental system with control mount

3.2.6.1 Displacement Results

1. The shaft results are recorded for 894 rpm of shaft. It produces less displacement in rotating direction 116 µm as compared to the system without control mount. It is the maximum displacement for system with control mount as shown by fig.12

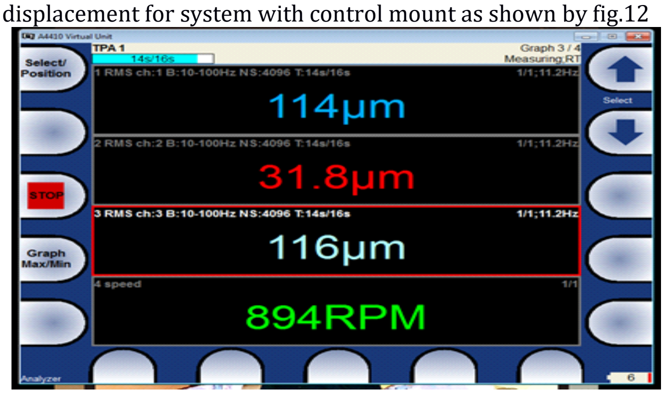

Fig.12: FFT displacement result of system with control mount for 894 rpm.

3.2.6.2 Tabulated Result of Analysis:

Table 4: Result of analysis with control mount

Sr. No.	RPM	Rotating Direction Dispt. (µm) (Z)	(Y)
1	708	31.8	10
2	894	116	31.8
3	1100	205	41
4	1200	280	80

4. RESULT DISCUSSION

From the experimental analysis it is observed that the Magnetic-Piezoelectric control mount effectively controlled the vibration and reduced deformation produced in the system**.** For without control mount system is having more displacement as compared to the system with control mount as shown in following graph 1.Graph 1: RPM Vs Displacement

5. CONCLUSIONS

Thus the focused work for safe working of the system by controlling the vibrations has successfully completed with Magnetic-piezoelectric control mount by efficient way as compared to other vibration damping units. In this the control mount has damped vibrations successfully. It is very good and economical vibration controller and damper. It can be used at lower or higher temperature conditions. It has successfully controlled the deformation produced due to vibration in the system.

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