Design and Modeling of Magnetically Tuned Mass Damper for Vibration Suppression

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Abstract - *Any elastic body such as spring, shaft or beam when displaced from its equilibrium position by application of external forces and then released commences cyclic motion known as vibrations. A TMD (Tuned Mass Damper) is a device consisting of a mass, a spring and a damper that is attached to a structure in order to reduce the dynamic response of the structure. The frequency of damper is tuned to a particular structural frequency so that when that frequency is excited, the damper will resonate out of phase with the structural motion. Vibration suppression with Tuned Mass Damper (TMD) is effective only for certain natural frequency. The purpose of this study is design and modeling of Magnetically Tuned Mass Damper (MTMD). The performance evaluation of proposed MTMD in vibration suppression of dynamic vibration absorber is carried out using experimental setup. The experimental set up is designed to perform experimental test to validate the simulation results.*

***Key Words*: Tuned Mass Damper, Magnetically Tuned Mass Damper, Dynamic Response, Dynamic Vibration Absorber.**

1.INTRODUCTION

Magnetically tuned mass damper is a passive type of damper used in civil structures to damp the vibrations. MTMD works on the principle of formation of eddy currents. Eddy currents are generated when a moving conductor intersects a stationary magnetic field, or vice versa. The relative motion between the conductor and the magnetic field induces the circulation of the eddy current within the conductor. These circulating eddy currents induce their own magnetic field with the opposite polarity of the applied field that causes a resistive force. This resistive force suppresses the vibrations of the structure. A traditional tuned mass damper system is effective only for tuned natural frequency. MTMD works also on frequencies other than natural frequency of the structure. One of the most useful properties of an eddy current damper is that it forms a means of removing energy from the system without ever contacting the structure. This means that unlike other methods of damping, such as constrained layer damping, the dynamic response and material properties are unaffected by its addition into the system.

1.1 Literature Review.

Jae-Sung Bae [1] have proposed an effective method to suppress the vibration of a large and heavy beam structure with a minimum increase in mass or volume of material. They proposed method in which they apply relatively light-weight TMD to attenuate the vibration of a large beam structure and increase its performance by applying eddy current damping to a TMD. The results of experiment show that the present method is simple and effective in suppressing the vibration of a large beam structure without a substantial weight increase. Junda Chen [2] they have used an eddy current tuned mass damper (ECTMD) to control the vibration of a cantilever beam. The robustness of the ECTMD against frequency detuning is experimentally studied in cases of both free vibration and forced vibration. For purposes of comparison with the ECTMD, the robustness of a tuned mass damper (TMD) is also studied. Rahul Sharma [3] the goal of their study was to measure the damping of the beam as a function of the gap between the copper conducting plate and the surface of the permanent magnet. The density of the eddy current is directly related to velocity of conductor in magnetic field. Jaehyeong Lee [4] proposed an effective method to suppress the vibration of cantilever plates like the solar panels of a satellite. Magnetically Tuned Mass Damper (MTMD) is a Tuned Mass Damper (TMD) with Eddy Current Damping (ECD). Furthermore, they used magnetically tuned mass dampers to suppress the vibration of the plate.

Wang Zhihao [5] have discussed the design, analysis, manufacture and testing of a large-scale horizontal TMD based on ECD. First, the theoretical model of ECD was formulated, then one large-scale horizontal TMD using ECD is constructed, and finally performance tests of the TMD are conducted. Moreover, it is demonstrated that the damping ratio in the proposed

TMD can be easily adjusted by varying the air gap between permanent magnets and conductive plates

1.2 Problem Statement.

Although TMD is known as one of the effective methods for suppressing structural vibrations by mounting an additive mass on primary structure it has a couple of disadvantages for example it can perfectly suppress the vibrations in particular range of frequency but it may encourage vibrations in other range of frequency. Besides if the primary structure has structural variations such as change in mass or shape then effectiveness of TMD may decrease considerably.

2. Experimental Setup

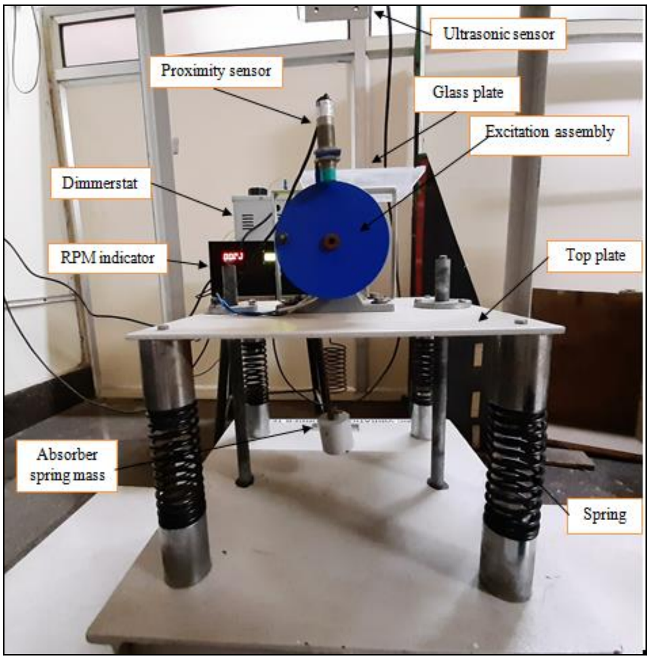

Fig -1: Experimental setup.

i. The apparatus consists of four compression springs along with a top plate.
ii. On which exciter assembly is mounted, in order to create vibration in plate.
iii. A proximity sensor is fitted on motor for RPM indication.
iv. A glass plate is fitted parallel to the top plate, in order to measure vibration in the top plate.
v. An ultrasonic sensor is fitted perfectly above the glass plate, so that it senses the movement of the glass plate and hence the top plate.
vi. A dimmerstat is used to control the speed of exciter assembly.
vii. RPM indicator & Digital displacement indicator is used to show speed of motor and displacement of top plate respectively.

3. Experimental Procedure

Part A:-

Selection of speeds for reading.

i. Check that dimmerstat is on zero.
ii. Switch ON panel.
iii. Now increase the speed of exciter with very small increment of dimmerstat knob.
iv. During this observe the displacement of top plate in digital displacement indicator.
v. With increase in excitor speed, displacement fist increases up to resonance condition, then it decreases up to zero.
vi. Note down the RPM at which the maximum displacement of top plate occurs.
vii. Set dimmerstat knob at zero position.
viii. Switch off panel.

- In order to check effectivity of MTMD over TMD, from above procedure we select three speeds at which reading is to be taken. i.e. resonance condition speed, one above the resonance condition speed and one below the resonance condition speed.

The speeds are:-

1. 290 RPM (below the resonance condition)
2. 312 RPM (resonance condition)
3. 330 RPM (above the resonance condition)

Part B :-Analysis with TMD

i. Fix absorber mass of 0.8 Kg found from calculation, at the spring which is fixed at the bottom of plate precisely.
ii. Check that dimmerstat is on zero.
iii. Switch ON panel.
iv. Run the experimental setup at 3 predefined speeds.
v. Simultaneously, note the displacement reading in displacement indicator at those three predefined speeds.
vi. Set dimmerstat knob at zero position.
vii. Switch off panel.

3. RESULTS
3.1 Parametric Study of TMD and MTMD:-

- The resonant frequency or natural frequency of the setup was at 312 rpm at which maximum displacement occurs for the plate.
- When TMD is attached to the setup it effectively damps the vibration of the plate to zero at 312 rpm but still gives some amount of displacement at 290 rpm and 330 rpm which is below and above resonant frequency.
- However, MTMD when attached to setup, because of the reaction between neodymium magnet and copper plate setup gives damping wider band of 290 to 330 rpm including 312 rpm. With effective damping and zero displacement of plate.

Various readings of "displacement" of top plate are as follows:-

RPM / Type	290	312	330
TMD	9	0	15
MTMD	5	0	7

Table 6.1.1: Displacement reading of top plate

*Here MTMD reading taken at optimum gap and thickness.

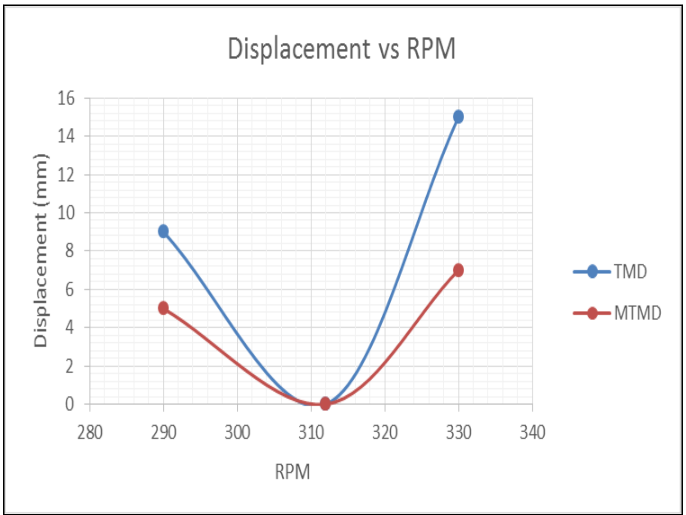

Fig.-2: Graph: displacement vs. rpm.

3.2 Effect of gap between copper plate and magnet:-

- The change in air gap also has effect on the eddy current generation and the damping.
- Optimum air gap from three gaps selected is to be studied.
- The selected gap are 5 mm, 7 mm, and 9 mm.
  - **Gap between copper plate and magnet = 5 mm**

RPM / Thickness	290	312	330
4 mm	5	0	7
6 mm	3.5	0	5.5
10 mm	1.5	0	3

Table 6.2.1: Displacement reading for 5 mm gap

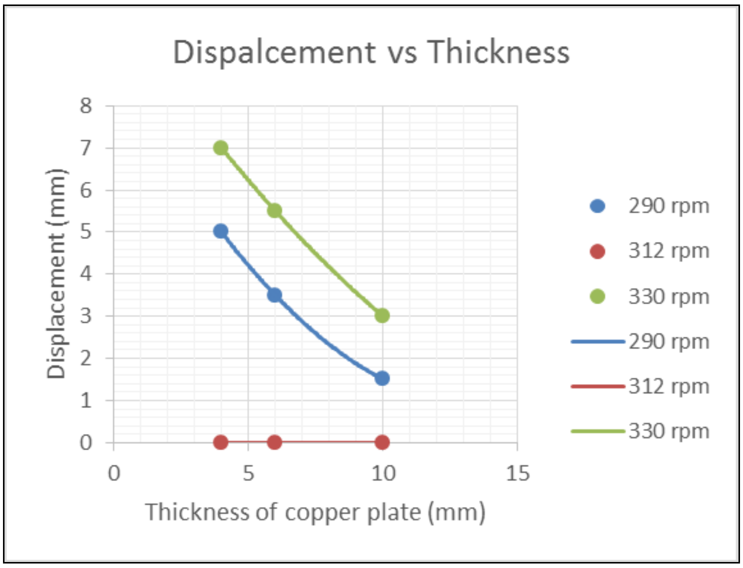

Fig.-3: Graph**:** displacement vs. thickness.

6.3 Effect of change of copper plate thickness:-

- As the thickness of copper plate, eddy currents generated also get changed. To study this, copper plate with three different thicknesses were selected.
- The change in thickness and its effect on damping is studied.

- **Thickness of copper plate = 10 mm**

RPM Gap	290	312	330
5 mm	2	0	5
7 mm	3.3	0	5.5
9 mm	5	0	7

Table 6.3.3: Displacement reading for 10mm thickness

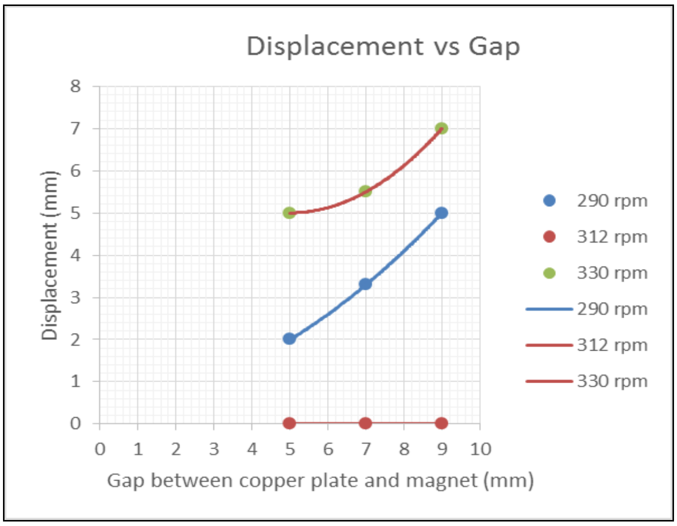

Fig.-4: Graph: displacement vs thickness. (290 rpm)

4. CONCLUSIONS

- TMD gives maximum damping only for the tuning frequency and is ineffective in damping the vibration in other range of frequencies MTMD overcomes the disadvantage of TMD and gives damping in other frequencies with the tuning frequency increasing the bandwidth for different values. The damping by MTMD is 2 times that of TMD.
- The effect of air gap also has an effect on the displacement or vibrations in structure at air gap of 5mm, the displacement is minimum. Hence as air gap decreases eddy current induced increases and damping increases.
- The thickness of copper plate when increases also increases the amount of eddy current. So the vibration of structure reduces drastically.
- The MTMD can also be made in closed loop system for damping the vibrations. The system can be applied in various applications, like huge solar panels, submerged pipelines, robotic arms, etc.

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