International Engineering Research Journal Page No 1881-1887

Experimental Evaluation of Semi-Active Particle-Based Damping Systems Controlled By Magnetic Field

Chaitali S. Mahajan[1], Avinash K. Mahale[2]
Dept. of Mechanical Engineering
TSSM's BSCOER, Narhe, Pune
chaitalimahajan26@gmail.com
akmahale@gmail.com

***Abstract*- The concepts of structural control including both passive and active control systems, have been growing in acceptance and may preclude the necessity of allowing for inelastic deformations in the structural system. A compromise between passive and active control systems has been developed recently in the form of semi-active control systems. Semi-active control systems maintain the reliability of passive control systems while taking advantage of the adjustable parameter characteristics of an active control system.**

In this experimentation , the designed and fabrication of semi-active particle-based damping system and we measure the particle impact damping for simply supported beam in which a dry magnetic particle bed is used to dissipate the energy of a vibrating piston. The system is magnetized by a magnetic field generated by an electromagnetic coil. Hysteresis-free, ferromagnetic materials are selected for both the piston and particles. The damping efficiency increases as the magnetization of the piston and particles increases up to saturation. Semi-active control is achieved by varying the electric current supplied to the coil. The performance of semi active particle based damping will be compared with conventional damper. It is expected to minimize the vibration up to 20% and to study the performance parameters.

Keywords: Structural control, Semi-active control, magnetization, electric current

INTRODUCTION

In recent years, considerable attention has been paid to research and development of structural control devices, with particular emphasis on alleviation of wind and seismic response of buildings and bridges. In both areas, serious efforts have been undertaken in the last two decades to develop the structural control concept into a workable technology. Full-scale implementation of active control systems have been accomplished in several structures, mainly in Japan; however, cost effectiveness and reliability considerations have limited their wide spread acceptance. Because of their mechanical simplicity, low power requirements, and large, controllable force capacity, semi-active systems provide an attractive alternative to active and hybrid control systems for structural vibration reduction. Passive, active and semi-active vibration control methods are used to provide external damping for aerospace, automotive and civil engineering applications. Passive systems use viscous fluids, visco-elastic materials or tuned masses as dampers to dissipate energy without the use of actuators and external power supply[1]. However, such systems are most effective only in a narrow frequency range. Moreover, their performance is hampered by a detuning effect because of which, over time, they are unable to provide the level of vibration suppression originally designed for. Detuning can occur either as a result of deterioration of the damper or due to changes in the excitation or natural frequency of the vibrating structure. Active damping systems can produce desired response characteristics for a variety of disturbances by using actuators to provide an active force to the vibrating structure. However, active systems are often limited in their use because their actuators require a large external source of power[4]. A semi-active damping system addresses the limitations of the passive and the active system by integrating tunable control into a passive device, by replacing force actuators with continually adjustable control elements which are capable of modifying a damper's energy dissipation rate in response to excitation conditions. Therefore, semi-active devices are also referred to as variable-rate or adaptive-passive dampers. This damping method is attractive because it requires a significantly lower amount of external power supply, as compared to the active system. Since semi-active devices do not employ force actuators, they do not produce excessive mechanical energy which can destabilize a structure. Furthermore, a semi-active system is considered fail-safe because in the even to power-failure it can still function as a passive damping system. Examples of semi active systems include controllable fluid dampers, variable orifice fluid dampers, controllable friction devices, variable-stiffness devices and smart tuned mass dampers[4].

In this research, a new concept for a semi-active thrust damping system is proposed, in which a piston oscillates vertically in a dry magnetic particle bed. The particles serve as the damping medium, and the particle-particle and particle-piston interactions serve as the damping mechanisms. The strength of the interactions is controlled by an external magnetic field to provide tunable damping. This system benefits from the dual solid and liquid-like nature of the particle medium. The solid-like nature allows the particles to have a significantly wider operating temperature range, avoid fluid- like leakage issues and operate in vacuum environments. The liquid-like nature enables the particles to flow and re-organize, thereby preventing settling or fatigue in the system. A particle medium is also chemically and physically stable, low in cost, commercially available and easy to use[1].

This paper describes the design of a particle-based semi-active damping system and the experimental analysis of its performance.

the objective of this study is expected to minimize the vibration up to 20% and to study the performance parameters.

I. DESIGN OF THE DAMPING SYSTEM

. The designed damping system (Fig.1) contains three essential components:

(1) An oscillating thrust piston to transfer energy from a vibrating mass to the damping medium.

(2) Magnetic particles to dissipate energy and serve as tunable damping medium, and

(3) An electromagnet to generate a magnetic field of desired strength.

The thrust piston is a cylindrical metal rod with flat ends and 20mm diameter. It is made from either steel (12L14 carbon steel) to produce a magnetic piston or aluminum to produce a non-magnetic one. The properties of the magnetic particles and the electromagnet are presented in detail hereafter.

II PROPERTIES OF THE MAGNETIC PARTICLES

The damping medium must be selected based on its magnetic, thermal and mechanical properties. Particles made of AISI 52100 chrome steel (Fox Industries) were selected because of their large magnetic susceptibility, resistance to high temperatures, and high strength to endure repeated loadings. These particles are spherical with diameter d=4mm and 5mm, density r=7800 kg/m3, melting point temperature of 1500°C and Young's modulus of 193 GPa.

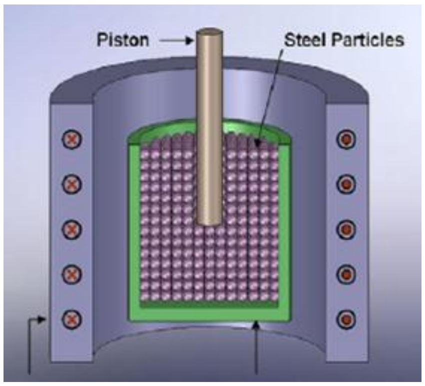


Fig.1 Components in the design of a particle based semi-active thrust damping system

LITERATURE REVIEW

Binoy M. Shah, et al. "Semi active particle based damping Systems controlled by magnetic fields".

This paper reports the design of a semi-active particle-based damping system in which a dry magnetic particle bed is used to dissipate the energy of a vibrating piston. The system is magnetized by a magnetic field generated by an electromagnetic coil. Semi-active control is achieved by varying the electric current supplied to the coil, which changes the magnetization and allows for real-time tunability of the damping rate. During the process of magnetization and demagnetization, the damping is reversible and temperature-independent over a wide temperature range. This paper is also concluded that for the design of semi active based damping systems, the particle and the piston must be ferromagnetic to achieve high damping efficiency and free of magnetic hysteresis to obtain a predictable damping rate. For use in high temperature applications, magnetic material must be selected based on their melting point and Curie temperatures. This system can be useful in aerospace, automobile and structural engineering applications, particularly in harsh environments.[1]

Michael D. Symans and Michael C. Constantinou, "Semi-active control systems for seismic protection of structures: a state-of-the-art review".

In this paper, A brief comparison of passive, active, and semi-active structural control systems revealed that semi-active control systems provide an attractive approach to seismic protection without the limitations associated with passive and active systems. As passive structural control systems begin to see an increased acceptance within the earthquake engineering community, strong research efforts have been shifted towards the development of semi-active structural control systems.

Binoy M. Shah, et al. "Construction and characterization of a particle-based thrust damping system".

This paper presented experimental demonstration and performance characteristics of an innovative particle-based thrust damping system for extreme temperature applications. Experiments show that damping is temperature independent, repeatable over consecutive tests, and effective even at low excitation levels where particle-based impact damping fails. The displacement decay is non-linear and the damped frequency is greater than the undamped. Due to these two conditions, the damping behavior cannot be described by either a viscous or a frictional damping model.

PROBLEM STATEMENT

To evaluate the performance of a semi active particle based damping system by varying the parameters such as Size of particles, Material of piston Temperature effect, Demagnetization effect.This work is evaluated for forced and free vibration.

METHODOLOGY

1. Literature survey
2. To study and measure the vibration characteristics of the machine.
3. Determine vibration characteristic of the system with adjusted mass.
4. Mathematical model of the structure.
5. Analysis of magnetic field and flux density.
6. Preparing the experimental setup.
7. Testing and result analysis of the system.
8. Preparation of report.

EXPERIMENTAL SETUP AND PROCEDURE

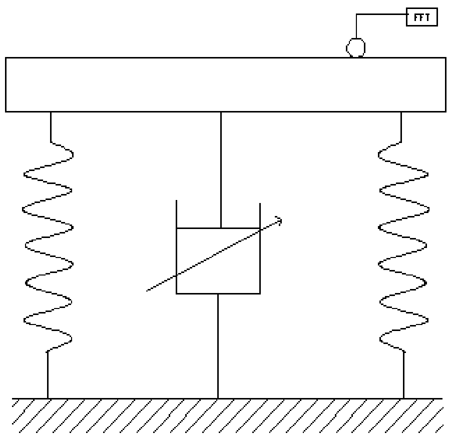


Fig. Experimental Setup

Setup is consist of;

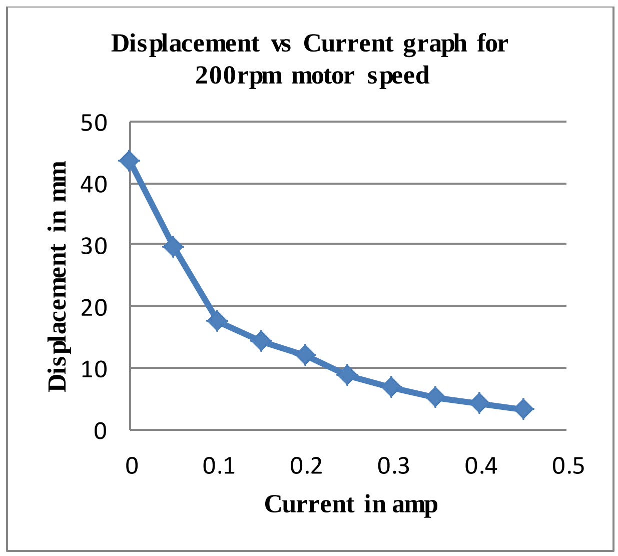
1. Frame structure
2. Helical springs
3. Exciter
4. Piston, Magnetic Particles and Electromagnet for design of damper.

PROCEDURE

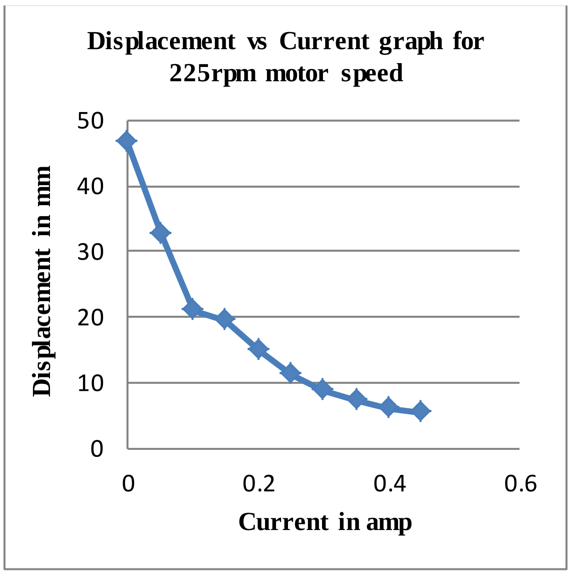
1. Arrange the equipment as shown in figure.
2. Attached the exciter at the center of simply supported beam.
3. Connect the damper unit to the system
4. Give the current supply to a damper winding having particles of diameter 4mm and 5mm respectively.
5. Start the motor and increase the speed gradually.
6. Record the amplitude of oscillation of damper having the magnetic piston (steel) and non magnetic piston with 4mm and 5mm diameter at a given constant speed.
7. Then readings are taken by varying current supply (0-2A) for different constant speed.
8. Repeat procedure for different constant speed reading by gradually varying current supply (0-2A) for each constant speed.
9. Plot the graph of Displacement vs. Current for each constant speed reading.

RESULTS AND DISCUSSION

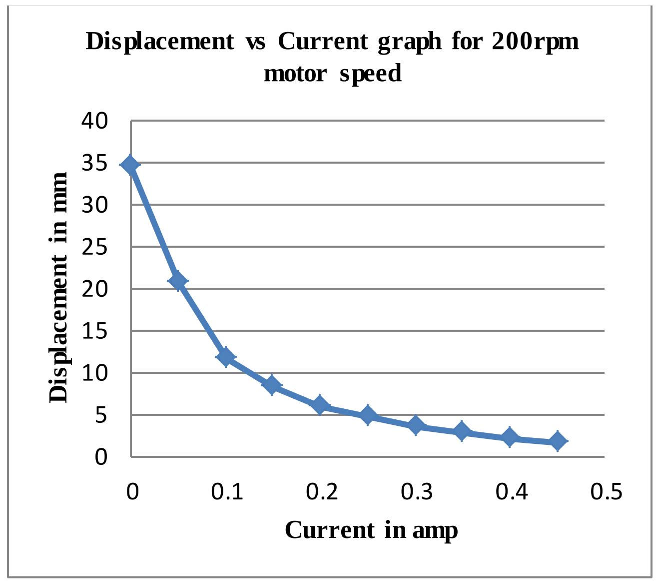
1. Result for the Semi Active Particle damper with the 5mm chrome steel particles and magnetic piston (steel)



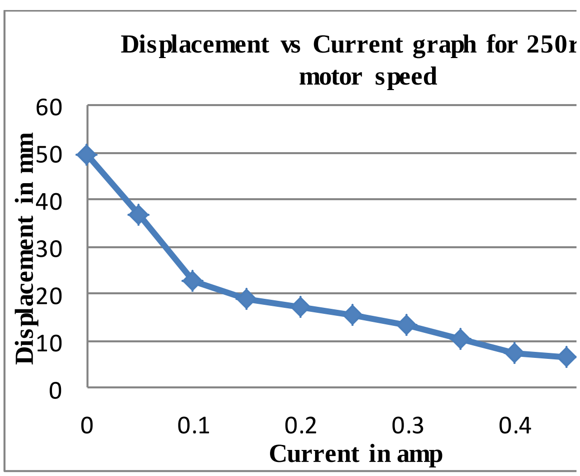
Graph 1: disp. Vs current for 200 rpm



Graph 2: disp. Vs current for 225 motor speed

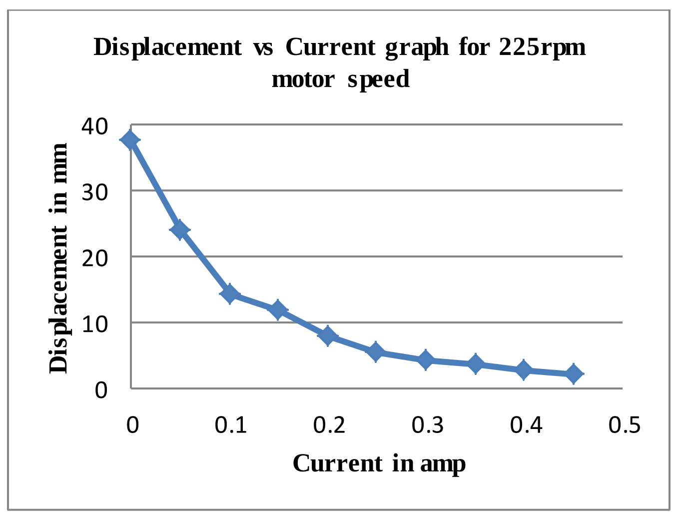


Graph 4: disp. Vs current for 200rpm motor speed

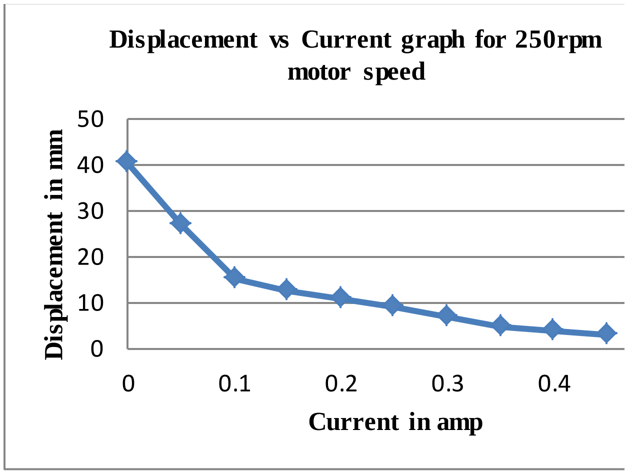


Graph 3: disp. Vs current for 250 motor speed

2 Results for the Semi Active Particle damper with the 4mm chrome steel particles and magnetic piston (steel).



Graph 5: disp. Vs current for 200rpm motor speed



Graph 6: disp. Vs current for 200rpm motor speed

From the graph, The test is carried out by keeping load constant and by varying supplied electric current in step size of 0.05A. The displacement readings are recorded for different current and graphs are plotted. It shows that as current goes on increasing displacement of piston goes on decreasing. Thus we get variable damping with the help of damper.

A set of test also conducted to investigate the effect of particle size for same particle material. The diameter of sphere were 4 and 5mm having quantity 800 and 1100 respectively. As graph shown for 5mm spheres, the damping is noticeable lower than 4mm sphere

CONCLUSION

In this study, for the case in which a magnetic piston is used, the magnetization of both particles and pistons can improve the damping efficiency until the magnetization saturates. If both the particles and pistons are free of magnetic hysteresis, their demagnetization can reverse the damping system to its original un- magnetized status; i.e. the entire system is reversible during the process of magnetization and demagnetization. As a result, the damping rate is predictable, which ensures well-characterized tunability. In contrast, for the case with a non- magnetic piston, the damping system achieves the highest efficiency when particles are not magnetized, and the efficiency decreases with increasing magnetization. Under the tip of the non-magnetic piston, a void forms whose size increases as magnetization increases and reduces the damping force and thus the efficiency.

From the graph, It shows that as current goes on increasing displacement of piston goes on decreasing. Thus we get variable damping with the help of damper. A set of test also conducted to investigate the effect of particle size for same particle material. The diameter of sphere were 4 and 5mm having quantity 800 and 1100 respectively. As graph shown for 5mm spheres, the damping is noticeable lower than 4mm sphere It is concluded that for the design of a semi-active particle-based damping system, the particles and the piston must be ferromagnetic to achieve high damping efficiency and free of magnetic hysteresis to obtain a predictable damping rate.

REFERENCES

1. Binoy M. Shah, Jeremy J.Nudell, et al. "**Semi active particle based damping Systems controlled by magnetic fields**" department of mechanical Engineering, Northwestern University, 2145 Sheridan Road, Evanston,IL 60208-3109,USA (2010) .
2. Michael D. Symans and Michael C. Constantinou, "Semi-active control systems for seismic protection of structures: a state-of-the-art review", Engineering Structures 21 (1999) 469–487.
3. B. F. Spencer Jr. and S. Nagarajaiah, "**state of the art of structural control**", journal of structural engineering © asce / july 2003.
4. Binoy M.Shah a, Davy Pillet, et al. "**Construction and characterization of a particle-based thrust damping system**", Department of Mechanical Engineering, Northwestern University, 2145 Sheridan Road, Evanston, IL 60208-3109, USA (2009).
5. M. N. Bannerman, et al. "**Movers and shakers: Granular damping in microgravity**", Dated: October 13, 2010.

6. G. Yang, B.F. Spencer, et al. "**Large-scale MR fluid dampers: modeling and dynamic performance considerations**", Department of Electrical Engineering, University of Notre Dame, Notre Dame, IN 46556, USA (2002).