IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 13, Issue 3, Ver. I (May- Jun. 2016), PP 90-93
www.iosrjournals.org

Strengthening Of Structures Using Smart Dampers

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Abstract: *This paper disuses the use of magnetorheological smart dampers for strengthening the structures. Magnetorheological damper fabricated using magnetorheological fluid and a magnetic coil was tested using an exciter. It was observed that the damper attenuates vibration amplitudes effectively and is capable of generating large damping forces as the current input is varied. Such smart devices can be used to strengthen tall buildings, towers, historical buildings or similar man-made structures against wind or seismic loads using semi-active control. Thus, the stability of the structures can be ensured and the catastrophic failures can be prevented by installing these dampers at the appropriate locations.*

Keywords:*magnetorheological (MR) fluid, seismic loads, semi-active control, smart damper, vibration amplitude.*

I. Introduction

Now-a-days, there is an increasing trend to construct tall structures [1, 2], to minimize space problems in urban areas. Similarly, radio masts, towers etc. are the tallest man-made structures. These structures are often made relatively light and comparatively flexible, possessing low damping [3]. This makes structures more vibration prone due to wind load, mechanical load and seismic load. Hence, it is important to keep the frequency of vibration to a level below threshold to prevent catastrophic failure. Also, in case of special structures like historical monuments, museums, libraries etc., it is important to save the interior of the structure. This may not be achievable by increasing structural rigidity. Strengthening methods like addition of reinforced walls and enlarging existing beams and columns may not be feasible in all cases. To avoid all such damages, use of dampers is a common practice. Earlier friction dampers, metallic dampers were extensively used. These served as passive dampers [4] without having concern to variations in seismic vibrations.

Magnetorheological damper is one of the most promising new devices which are being used to provide controllable damping [5, 6]. These are semi-active devices having minimum power [7] requirements and instantaneous response. Hence, a semi-active damper was fabricated using magnetorheological fluid and a magnetic coil and the suitability of the damper was tested for vibration control.

II. Fabrication of the Smart Damper

This section explains the details of fabrication of the complete damper. A conventional damper was selected, and a few modifications were done to fabricate the smart damper.

2.1 Fabrication Process

As shown in Fig. 1, the outer tube **1** of the conventional damper body was cut at the top and a sleeve **5** having 4 holes of 8 mm diameter along a pitch circle diameter was brazed to it, which has arrangement for fastening with another similar sleeve **8** thereby sealing the damper assembly. A rubber gasket having very small thickness of about 1mm placed between the two sleeves makes the joint tight and leak proof. The upper sleeve is having an eye hole **6** fitted with a bush. The diameter of the outer body is 30 mm and thickness 1.5 mm with overall length of 150 mm. The inner tube **2** with thickness of 1mm contains a reciprocating piston **3** of 25 mm diameter and 5 mm thickness, connected to a rod **7** of 8 mm diameter. The piston is having annular orifices of very small diameter through which the MR fluid is forced in upward or downward direction depending upon the forward and rebound stroke. A foot valve is attached at the end of inner tube for regulating the fluid flow

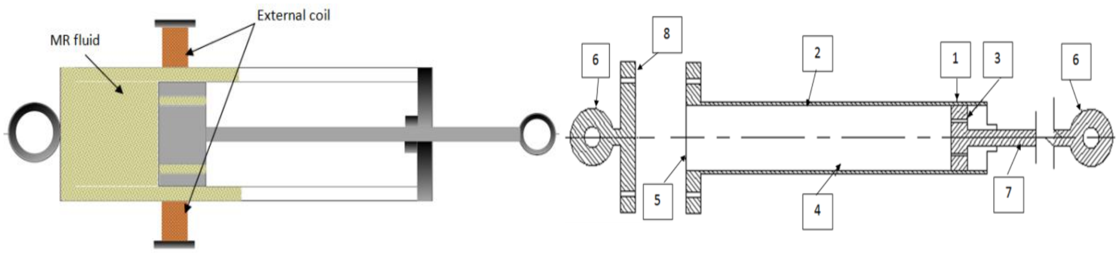

Fig. 1 Constructional details of Smart Damper

Between inner and the outer tube. The inner tube has to be filled completely with MR fluid **4** in order to remove the air gaps. The outer tube is filled partly to accommodate changes in volume of the fluid. Approximately, 105 ml quantity of MR fluid can be accommodated in the damper tube.

2.2 MR Fluid Preparation

MR fluid consists of a carrier liquid to provide a base for suspension of magnetizable particles. Paraffin oil of low viscosity, 50 mPa.s was selected. Carbonyl iron powder with high purity and super electromagnetic properties was selected. The powder is having uniform microscopic spheres with average size of 3µm and apparent density 7.87g/cm^3. After many trials, concentration of carbonyl iron particles was fixed as 40% of the total volume [8]. Fumed silica was used as a stabilizing agent with 2% volume weight of the iron particles. This combination exhibited better response to the external magnetic field and also showed better sedimentation stability.

2.3 External Magnetic Coil Design

An external magnetic coil was designed for activating the magnetorheological fluid filled inside the damper tube. Fig. 2, shows fabricated external coil with four flux pole pieces. The dimensions of the shell and core, gauge of wire, number of turns of wire were selected depending upon the magnetic field strength required and the dimensions of the damper. A piece of pipe having diameter 50 mm and thickness 1.5 mm was cut to a length of 25 mm along its periphery to form the shells. Another piece of pipe having diameter 30 mm and thickness 1mm was taken and cut to a length of 25 mm. Flat plates of 2 mm thickness, width 25 mm, and height 30 mm were cut to size to form the core part and were welded to the piece of pipe and the shell pieces. While selecting the dimensions, care was taken to maintain minimum radial distance between the adjacent poles and the ease of winding the wire around the core. A small hole is drilled in the inner circular piece of pipe and screw is provided to mount this external coil on the damper body. This type of arrangement provides ease of mounting, fitment at convenient location on the damper body and also demounting of the external coil. The wire of 24 SWG was wound and the number of windings used is 140. A Maximum current of 4 ampere can be passed through the wire for a period sufficient for short intermittent excitations without excessive heating.

The magnetic flux lines passes radially through the inner tube of the damper covering sufficiently large area. Also, as the direction of the magnetic flux lines is perpendicular to the flow direction of the MR fluid, maximum yield stress is produced. During the trials, for different values of currents, strength of magnetic field at various locations inside the damper was examined by using a Gauss meter. Damper tubes up to wall thickness of 3 mm were tested for observing the penetration of the magnetic field through walls of inner tubes.

III. Experimental Work

3.1 Test setup

Using exciter the smart damper was tested at various excitation frequencies and currents. setup for examining the effectiveness of the smart damper is as represented in the Fig. 3. Various devices used for conducting the experiment included a rigid frame for mounting the smart damper assembly, external coils, power supply, an amplifier, oscillator, exciter, accelerometer, data acquisition system and dynamic signal analyzer. For application of forced vibrations, an exciter (Model Id-230) with a capacity to produce 200 N peak sine force and maximum peak to peak displacement 12 mm along with function generator, supplied by Instrol Devices, was used. The exciter was driven by the power amplifier the oscillator which generates sinusoidal signals in the range of 1 Hz to 10 kHz. The setup also consists of a load cell and dial gauge for measurement of forces and displacements respectively. The accelerometer used was of make Piezotronics, USA PCB 353B34 with sensitivity 97.5 mV/g. The FFT analyzer used for finding out the amplitudes at various frequencies to understand vibration reduction performance is from OROS, France make OR-34 which is 4 channel integrated portable mobile analyzer with NV Gate software.

Fig. 2 External magnetic coil

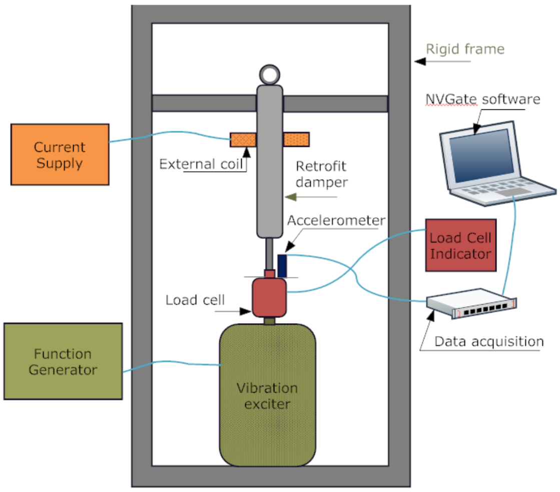

Fig. 3 Experimental setup for testing smart damper

3.2 Results

The damping force generated by the smart damper at different input currents supplied to the external coils was measured. Also, the amplitudes of vibration at different frequencies were obtained. Fig. 4 shows variation in damping force against the variation of input current of the magnetic coil at OFF and ON states and represents only the rebound force. When the DC power supply was OFF i.e. current supplied to the external coil was zero, the value of damping was taken from the corresponding curve on the plot. The best fit of this curve has the following equation

$$F = 7772V + 9.64 \quad (1)$$

From the above equation, the damping $C_{rebound}$ obtained is 7772 Nsm^{-1}. When the DC power supply was turned ON, the effect of the applied current on the damping was noticed. As the current was increased, the rebound damping also increased. The plot obtained is a curve with third degree polynomial damping increased from 7772 Nsm^{-1} to 16000 at current of 2 ampere and various current inputs.

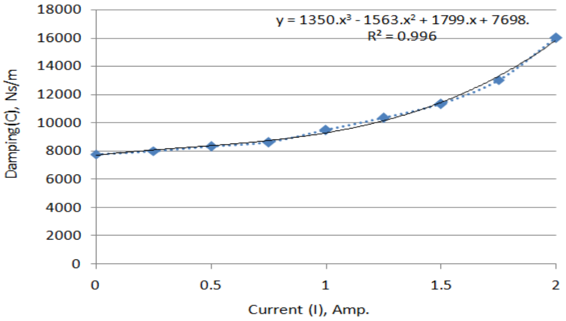

Fig. 4 Damping force against applied current

IV. Conclusion

The smart damper, thus, is capable of producing very large damping by varying the input current supplied to the magnetic coil. This semi-active control can be utilized to stabilize the tall structures, buildings or other man-made structures that are subjected varying loads such as seismic or wind loading. When applied at appropriate locations, the smart dampers can prevent the catastrophic failures and further damages.

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