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Analysis of a Structure with Magneto-rheological Fluid Damper

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Abstract:- *In the last three decades or so, there has been a great deal of interest in the use of control systems to mitigate the effects of dynamic vibrational hazards on both Mechanical and Civil Structures. Magnetorheological (MR) Fluids are controllable fluids that respond to an applied magnetic field with a dramatic change in rheological behaviour. An MR Fluid is a free-flowing liquid in the absence of magnetic field, but under a strong magnetic field its viscosity can be increased by more than two orders of magnitude in a very short time (milliseconds) and it exhibits solid-like characteristics. MR Fluid Dampers, based on MR Fluids, have been shown to be semi-active control devices that mesh well with application demands and constraints to offer an attractive means of controlling the intensity of vibrations in structures due to their mechanical simplicity, high dynamic range, low power requirements, large force capacity and robustness.The structures designed to support the high speed engines are subjected to inherent unbalance which causes vibrational problems. The focus of this work is to study the analysis of an aluminium structure using the Magnetorheological dampers with fluid MRF-132DGwithand without applying magnetic field. And it is observed that the MR Fluid dampers could able to effectively reduce the mechanical vibrations of structures.*

Keywords*:MR Fluids; Magnetic field; MR Fluid Damper; Structural vibrations,Frequency.*

I. INTRODUCTION

In recent years there has been a lot of research in the use of control systems to mitigate the effects of dynamic environmental and vibrational hazards such as earthquakes and strong winds on civil and mechanical engineering structures. A variety of control systems have been considered for these applications that can be classified as either passive, active, semi-active or hybrid (combinations of the previous types) [1]. A typical MR fluid contains 20-40% by volume of relatively pure, soft iron particles, e.g., carbonyl iron; these particles are suspended in mineral oil, synthetic oil, water or glycol. A variety of proprietary additives similar to those find in commercial lubricants are commonly added to discourage gravitational settling and promote particle suspension, enhance lubricity, modify viscosity, and inhibit wear [2]. The ultimate strength of an MR fluid depends on the square of the saturation magnetization of the suspended particles. Hence, materials with lowest coercivity and highest saturation magnetization are preferred because as soon as the magnetic field is taken off, the MR fluid should come to its demagnetized state in milliseconds [3]. Due to its low coercivity and high saturation magnetization, high purity carbonyl iron powder appears to be the main magnetic phase of most practical MR fluid compositions. The ultimate strength of an MR fluid depends on the square of the saturation magnetization of the suspended particle. The best available particles are alloys of iron and cobalt that have saturation magnetization of about 2.4T. Recent devastating earthquakes around the world have underscored the tremendous importance of understanding the way in which Civil engineering structures respond during such dynamic events. A magnitude of 7.7 during the Bhuj earthquake (India), death toll was 20,000 and more than 1, 00,000 people were injured, and more than 4,00,000 houses were destroyed due to the effects of the earthquake.In addition to earthquakes, strong winds can also result in unprecedented devastation along their path. The structures designed to support the high speed engines are subjected to inherent unbalance which causes vibrational problems. The unbalance may be due to faulty design or poor manufacture. Vibrations cause notable mechanical failures in turbines blade and disc vibrations are tough to control.

II. MAGNETO-RHEOLOGICAL FLUIDS

Magnetorheological (MR) fluids are the combination of micron sized, magnetizable particles (iron, iron oxide, iron nitride, iron carbide, carbonyl iron, chromium dioxide, low-carbon steel, silicon steel, nickel, cobalt, and combinations thereof [4]) in an appropriate carrier liquid (non-magnetizable) such as mineral oil, synthetic oil, water or ethylene glycol. The carrier liquid serves as a dispersed medium and ensures the homogeneity of particles in the fluid. A typical MR fluid consists of 20-40 per cent by volume of relatively pure, 3-10 micron diameter iron particles, suspended in a carrier liquid. They are field responsive in nature and the Magnetorheological response of these fluids lies in the fact that the polarization is induced in the suspended particles by the application of an external magnetic field. This allows the fluid to transform from freely flowing liquid state to solid-like state within milliseconds, because the magnetically dispersed particles attract each other to form fibril/chain-like structures along the direction of magnetic field. The chain-like structures resist the motion of the fluid and increase its viscous characteristics. Such a behavior of MR fluid is analogous to Bingham plastics (non-Newtonian fluids) capable of developing a yield stress. A favorable arrangement consists of particle chains aligned in the direction of the applied field and this, in turn, gives rise to a strong resistance to applied strains.The yield stress developed within the MR fluid is a function of the applied magnetic field. However, once this yield stress is exceeded, the behavior of the MR fluid deviates from that of a Bingham plastic [4]. This is attributable to the breakdown of the chains of particles under the forces of the fluid flow, and results in a shear-stress/shear-rate characteristic that is highly non-linear. When used in a damping device, the result is a damper whose force/velocity characteristic is non-linear, but can be changed by the way the magnetic field is applied. Typically, the diameter of magnetizable particles is 3 to 5 microns. Functional MR fluids may be made with larger particles; however particle suspension becomes increasingly more difficult as the size increases. Smaller particles that are easier to suspend could be used, but the manufacture of such particles is difficult. Commercial quantities of relatively inexpensive carbonyl iron are generally limited to sizes greater than 1 or 2 microns. The magnetizable particles in the MR fluid are usually coated with a surfactant in order to prevent the particles from getting close to each other that would cause agglomeration. These coatings take up a volume and limit the concentration of magnetic solids. The importance of the “off-state” viscosity of MR fluid comes from the figure of merit for MR fluid which is given by the “turn up” ratio defined as the ratio of the “on-state” yield stress to the “off-state” viscosity. “On-state” refers to the state of the MR fluid under an applied magnetic field and the on-state yield stress behavior depends on the magnetic properties and the volume fractions of the magnetic phase. The off-state viscosity, which is a function of carrier liquid, additives, surfactants, particle loading and particle size distribution, is the value when no magnetic field is applied. The maximum force/torque that an MR device can deliver depends on the properties of MR fluids, their flow pattern, and the size of the device. MR fluids, on the other hand, have a 50 to 100 kPa maximum yield stress, are not affected by most impurities, and are not sensitive to temperature. Moreover, MR fluids can be controlled with a low-power (e.g., less than 50 watts), low-voltage (e.g., ~12-24 volts), current-driven power supply with ~1-2 amps output. Therefore, MR fluids are particularly promising for natural hazard mitigation and cost sensitive applications.

Devices that use MR fluids include servo valves, dampers, shock absorbers, actuators, clutches, brakes, chucking and locking devices, etc. To date, several MR fluid devices have been developed for commercial use by the LORD Corporation. Shock absorbers, Vibration dampers, seismic vibration dampers [5, 6] and clutches are the most common applications of MR fluid.

III. MAGNETO-RHEOLOGICAL FLUID DAMPER

Among MR devices, MR dampers have been most widely studied and developed for commercial applications. When MR fluid is used in MR damper, the areas where it is exposed to magnetic flux lines are referred to as activation regions which resist the flow of fluid from one side of the piston to the other when a magnetic field is present. Varying the magnetic field strength has the effect of changing the apparent viscosity of the MR fluid. The reason why the phrase "apparent viscosity" is used instead of "viscosity" is that the carrier fluid exhibits no change in viscosity, but the MR fluid mixture thickens (even becoming a solid) when it is exposed to a magnetic field. As the magnetic field strength increases, the resistance to fluid flow at the activation regions increases until the saturation current has been reached. The saturation current occurs when increasing the electric current fails to yield an increase in damping force for a given velocity.

The resistance to fluid flow in the activation regions is what causes the force that MR dampers can produce. This mechanism is similar to that of hydraulic dampers, where the force offered by hydraulic dampers is caused by fluid passage through an orifice. Variable resistance to fluid flow allows us to use MR fluid in electrically controlled viscous dampers and other devices. In the present study we have designed and fabricated a new MR damper Figure 1. The damper assembly consist of parts like cylinder, piston, hollow rod, piston rod, left bronze plate, right bronze plate, left cover, right cover, eye nuts, screws etc. The assembly of the damper is shown in the figures below. All the parts are made up of low-carbon steel material except left & right bronze plates which are fastened to the piston with screws as shown in the Figure3. The electro magnet or the coil is wound on the piston with 80 turns. The gauge of the wire is 26 ASW. The gap maintained in the damper (gap between cylinder and piston) is 0.4 mm.

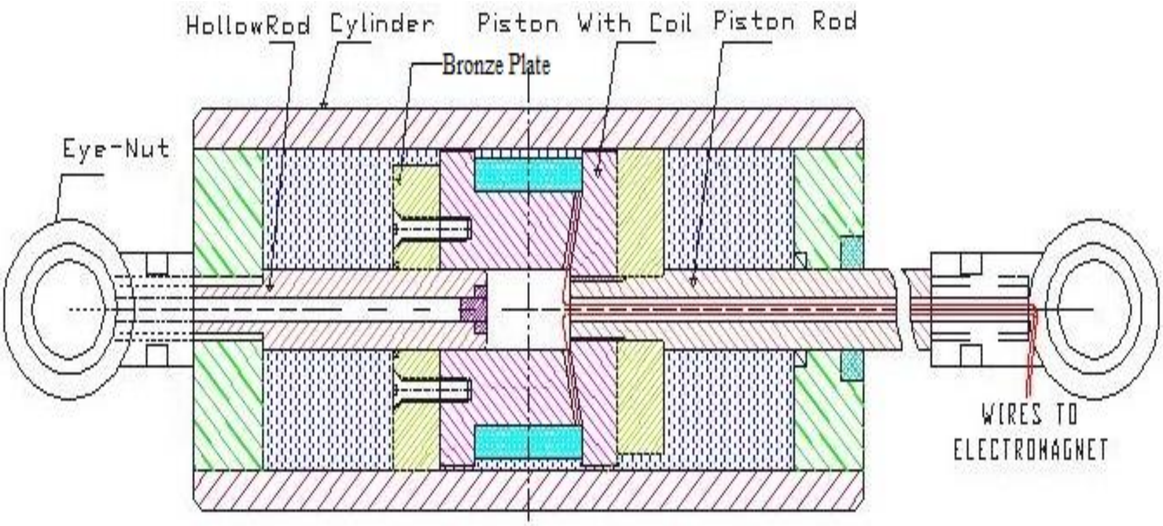

Figure.1: Assembly of damper (2D view)

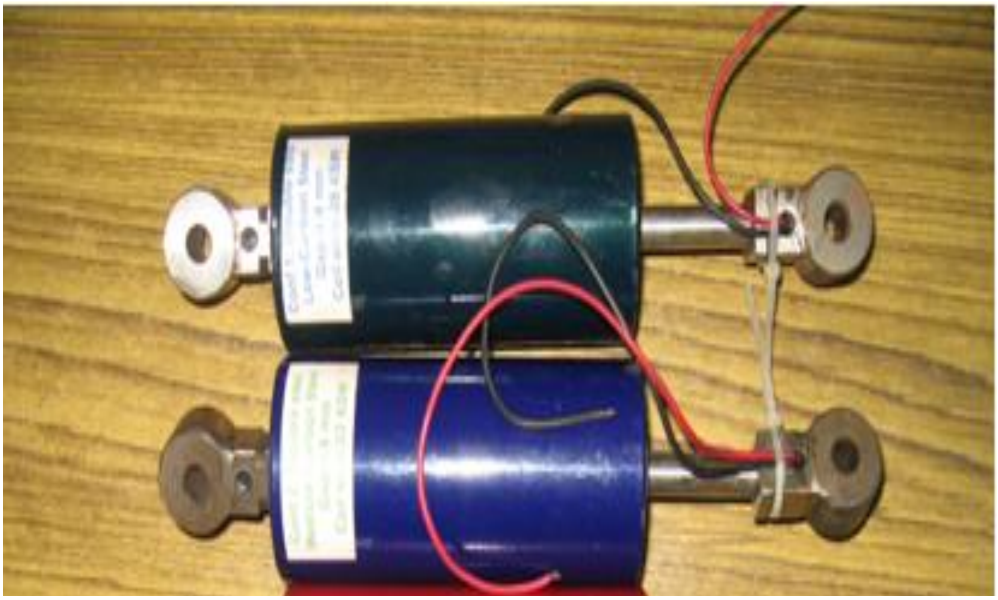

Figure.2: Fabricated dampers

IV. EXPERIMENTAL SETUP

The experimental setup used in the study of MR dampers consist of structure, vibrator, MR damper, accelerometer (pick up), signal conditioner, digital storage oscilloscope (DSO), power supply system. A brief description of each is presented in the subsequent paragraphs. A complete experimental set-up is shown in figure3.

Figure.3: Experimental Setup

Structure : a structure made of aluminium replicating a common type of tall building- structure, is manufactured and used in the analysis. The structure has a height of 1.3m and is 0.3m wide. The thickness of the aluminium plate is 10mm. To support the aluminium structure and to connect it with the vibrator another supporting structure made of hollow iron square pipes is also fabricated (blue collared) as shown in the figure 3.

Vibrator : vibrator is an electric motor used to vibrate the structure. The motor can be operated in three different speeds i.e. 1300rpm, 1350rpm, & 1440rpm, hence giving different vibration frequencies. This motor or vibrator is connected to the aluminium building with a rigid link as shown in figure.4.

.*Pick up*: pick up is a transducer of acceleration type, (Model 352C33) manufactured by PCB PIEZOTRONICS. It is a highly sensitive accelerometer used to sense the vibrations in the structure figure 4.

MR dampers: Single coil (stage) MR damper figure5.

Signal conditioner: it is a device which collects the signal from pick up and passes the signal to any read out device. (Model XYZ) manufactured by PCB PIEZOTRONICS figure 5.

Figure.4: Vibrator and pick-up (transducer)

Figure.5: Damper, Power supply and Signal conditioner

Power supply; electronic type power supply system have been used to power the dampers figure 5.DSO : digital storage oscilloscope is used as a read out device. The signals or frequencies can be read out, analysed and can be stored by using this device.

V. TESTING OF MR DAMPERS

To investigate the behaviour of the MR damper and the structure, a series of experiments were conducted .The experimental investigation of the MR damper which is filled with MRF-132DG was performed. Experimental results of variable input current tests are presented. Variable input current effect tests were conducted to investigate the behaviour of the MR fluids. In the experiment, speed of the motor i.e.the vibrator is of 1300, 1350, 1440 rpm were employed. The input current to the damper coil was constant at 0, 0.5, 1, 1.5 and 2 A respectively. Sample results can be seen in the figures 6 and 7.

Table.1 Frequencies measured at different speeds for different currents

FREQUENCY			
CURRENT	**1300 (rpm)**	**1350 (rpm)**	**1440 (rpm)**
0A	1024Hz	1049Hz	1405Hz
0.5A	794Hz	1010Hz	1148Hz
1.0A	613Hz	846Hz	882Hz
1.5A	517Hz	627Hz	661Hz
2.0A	324Hz	442Hz	485Hz

Sample frequencies in DSO:

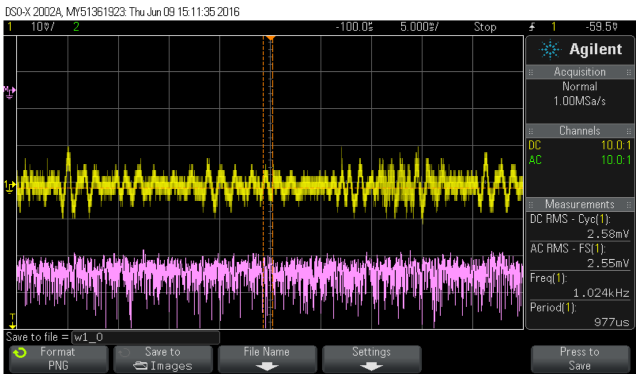

Figure.6: Frequency at 1300 rpm, 0A

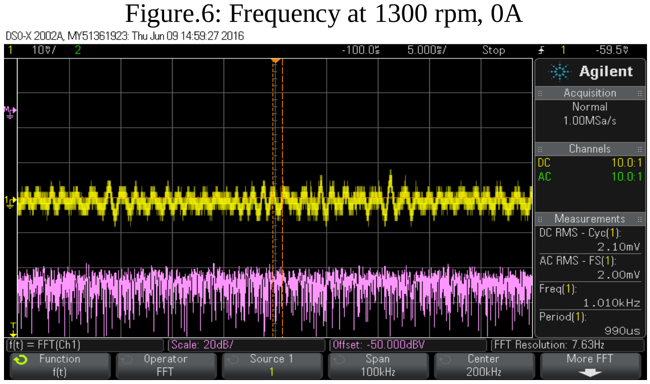

Figure.7: Frequency at 1350 rpm, 0.5A

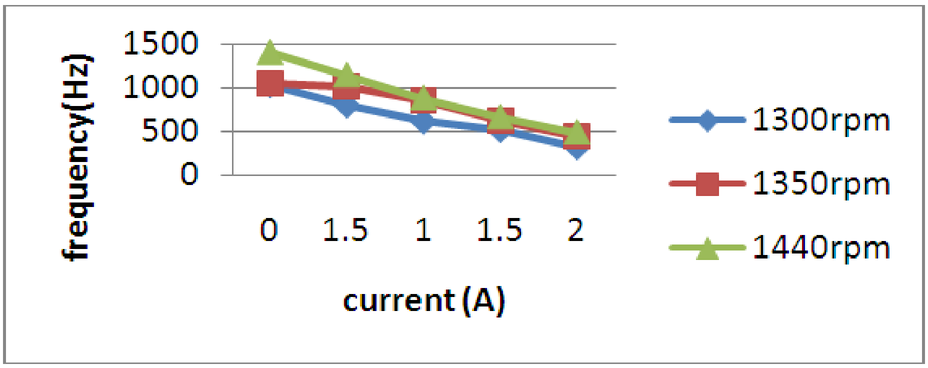

Figure.8: Frequency vs Current

VI. RESULTS AND DISCUSSIONS

From the Figure 8, we can observe that with the increase of input current there is a reduction in the output frequency of the test specimen for all the forcing frequencies (1300rpm, 1350rpm and 1440rpm) considered in the present study. This is also shown in detail in Table1.

It is observed that, when no current is passed to the damper (that is at 0A) the vibrating frequency of the structure is around 1024 Hz at 1300 rpm and 1049Hz, 1405 Hz for 1350 and 1440 rpm respectively.0A of current means it can be assumed that there is no damper attached to the structure. When current passing to the dampers is increased to 0.5A, the vibrations got reduced to 794Hz, 1010Hz and 1148Hzrespectively. When current is increased to 1 A, further the vibrations got reduced to 613Hz,846Hz and 882Hz.The same decrement in the vibrations have been observed as the current is increased to 1.5A and 2 A. Finally at 2 A the vibrations reduced to 324Hz, 442Hz and 485Hz respectively. MR fluids can be controlled with a low-power, current-driven power supply with ~1-2 amps output.Therefore, MR fluids are particularly promising for natural hazard mitigation and cost sensitive applications.

VII. CONCLUSIONS

In this study, a fundamental understanding of the behaviour of two Magnetorheological fluid (MRF) dampers has been developed throughexperimentation with the fluid MRF-132DG. The findings of the study are:

- High vibrational frequency values were observed when no current (I) is applied to the dampers (That means it is without dampers).
- The experimental results show decreasing in vibrational frequency (Hz) of the structure with increasing current (I) value to the dampers. The performances of the dampers are better for high input speeds (vibrations).
- For higher speeds of the vibrator, a linear decrement of vibrational frequencies (Hz) is observed for both the dampers.
- The lowest vibrational frequency (Hz) value was recorded for damper at lowest speed and maximum current (I) conditions.

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