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The damping effectiveness of Magnatec oil-based MR fluid Investigation of utilizing MR dampers with varied designs

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ABSTRACT

Magnetorheological (MR) fluids are a talk of the day due to their potential applications in various fields. In the present work, six different MR fluids were prepared based on the variation in the percentage of carbonyl iron (CI) particles and carrier liquid. The smart material CIparticle was well characterized by XRD, SEM-EDAX and VSM measurements. The effect of carrier fluid on sedi- mentation was tested using CI 50% and compared with the other carrier oil used. The Magnatec oil acts as a better candidate due to its sedimentation stability and thermalresistance. Therefore, the rheological measurement was examined for the three magnetorheological fluids (MRF) prepared, namely MRF 32, MRF 50 and MRF 80 with Magnatec oil as carrier liquid. The three various size annular gaps between the piston and the inner cylindercasing was also studied. Among the three variations, 1, 1.5 and 2 mm, the maximum damping force was obtained for 1-mm annular gap. A number of experimentations were carried out to investigate the performance of the MR fluid as well as the annular gap. Cyclic load test was performed with various annular gaps, and 0.536 kN was the maximumdamping force for 1-mm annular gap.

Keywords: ***Annular gap, · MR fluid, · Sedimentation, Magnatec oil, · MR damper, · Damping force.***

1. INTRODUCTION

In the present scenario, magnetorheological (MR) fluids place a notable position due to their potential application inseveral areas. MR damper is used in automobile, buildings,prosthetic legs, body armor and washing machines for vibration control application. MR fluid was discovered by Rabinow in the late 1940s at the US National Bureau of Standards (Rabinow 1948, 1951; Milecki and Hauke 2012).MR fluid consists of a suspension of iron particles of microsize ranging from 0.5 to 10 lm in a carrier fluid which includes synthetic mineral oil, hydrocarbon oil, glycol or water. MR fluids are available in various configurations byweight of 20–80% (Lim et al. 2005; Jang et al. 2005; Zhanget al. 2008; Zite et al. 2006a, b). MR fluid goes under smartmaterial classification because of its rheological conduct; the material changes its property as a liquid to semi-solid state when a magnetic field is applied. (Jolly et al. 1999; Carlson et al. 1994; Nair et al. 2019). The diameters of the material utilized were reached from 0.5 to 1.0 lm, and the carrier liquids utilized were synthetic hydrocarbon oil, mineral oil, glycol and so forth (Lefrançois Perreault et al. 2018). The magnetized particles are linked to one another leading to the formation of hierarchical chain formation, lead using to field-induced viscosity and shear modulus. Hence, the MR effect was influenced by size and spacial distribution (Falco et al. 2019; Radzir et al. 2015).

The main disadvantage of the MR fluid is settling of ironparticles, due to mismatch of density between the base fluid and heavy magnetizable elements. These particles undergo settling ensuing reduction in the constancy (Bella et al. 2018; Bai and Chen 2019; Viota et al. 2005). The reorga- nization of magnetic elements in the oil is tough enough due to Brownian motion. Consequently, several researchers are developing MR fluid to advance the constancy of MR fluids. The steadiness of the fluid is improved by modifyingthe components coating iron particles, using worm-shaped nanoparticles, sphere-shaped nanoparticles, surfactants,additives, thick MR fluid (Pan et al.2005; Ahamed et al. 2016; Gordaninejad and Kelso 2000). Though there are several factors affecting the stability of MR fluid, its application toward vibration controlling devices is note- worthy. Currently, many researchers have been focused on damper with MR fluid for seismic control (Vessonen 2003; Zhen et al. 2008; Yang et al. 2002; Fernando and Carlson 2006; Park and Chin 2001). Semi-active MR damper offers structural control. Some of the various vibration response reduction devices are mutable cavitydampers, friction damper, tuned mass damper and fluid dampers that are stable and use lesser power (Wang et al. 2008; Jun et al. 2005; Fuchs et al. 2004). For automobile and earthquake resistance of building applications, the existing MRF has more sedimentation and less thermalresistance; therefore, the newly developed MRF has less sedimentation, and more thermal resistance will help the damper to provide better damping force.

The objective of the present work is to study the rheo- logical properties of the Magnatec oil-based MR fluid and its damping performance using MR damper with various annular gap.

2. SYNTHESIS OF MR FLUID

Three samples of MR fluids were synthesized by varying the percentage composition of carbonyl iron, namely 32%, 50% and 80%. The estimated quantity of commercially available carbonyl iron was mixed with the carrier liquid for about 24 h using an overhead stirrer with a rotating speed of 400 RPM (Fig. 1). Castrol Magnatec oil was used as a carrier fluid in the current study.

3. CHARACTERIZATION OF MR FLUID

3.1 XRD of carbonyl iron

Depicts the powder XRD (X-ray diffraction) pat- tern of commercially available CI particles, and XRD-6000(Shimadzu, Tokyo, Japan) was utilized to record the XRD spectra using CuKa radiation. The whole trial was held outat room temperature measured in 2h scale, at a range of 20°–70°, with a scanning speediness of 0.03°/s and a step time of 4 s. The plane Fe (110) at 448 is significant for CI particle, which corresponds to the JCPDS File No.32-1383. The mean particle size of the material was ana- lyzed utilizing the most intense plane (110) by the Scherrerequation. The mean particle size was found to be approx- imately 13.8 lm.

3.2 SEM image of carbonyl iron

The morphological shape of the sample was found with thehelp of scanning electron microscopy. The characteristic morphology of the CI particle. Worm type structure is observed in the case of CI particle. The experimentation was held away at room temperature using the model JSM-6390, JEOL USA, Inc., Peabody, MA. TheEDAX spectrum indicates 95% of Fe in the sample.

3.3 Magnetic measurement: vibrating sample magnetometer

The important magnetic parameters such as magnetic sat- uration (l_s) and coercivity (HCi) are measured using avibrating sample magnetometer (make and model Lake- shore VSM 7410). it is clear that the sample indicates the maximum l_s of173 emu/g, and a coercivity of 12.3 G (Fig. 4: inset).

3.4Sedimentation stability

The constancy of the MR fluid is mainly dependent the smart material and the carrier liquid used. The sedimentation studies were carried at room temperature, byvisual observation and the ratio was calculated as below wear. The resultant work was analyzed with the MR fluid having Magnatec oil as the carrier liquid.

Fig. 1 Scheme of preparing ofMR fluid

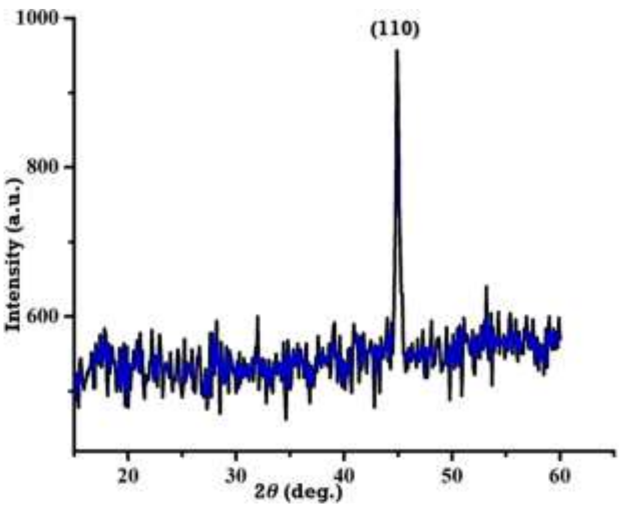

Fig. 2 XRD pattern of carbonyl iron particle

4. MR DAMPER

The prototype shear mode MR damper is filled with an MRfluid as shown in Fig. 11a. The main cylinder houses a piston, a magnetic circuit, and MR fluids MRF 32, MRF 50and MRF 80. In MR fluid, shear occurs in between the cylinder inner housing and piston poles, which contains a flow gap with various sizes. It takes in a density of 3.4 g/ cm^3. The total axial length of the flow duct is 5 mm which is exhibited to the applied magnetic field. The damper is25 cm long in its extended position, and the main cylinder is 5 cm in diameter. The main piston has the magnetic circuit, 110 ml of MR fluid, and the damper has a 2.5 cm stroke. The intensity of magnetic field can be altered from0 to 180 ka/m for currents of 0–2.5 amps in the electro- magnet coil, which receives a resistance of 3.8. The total inductance of the MR fluid valve is 35 mH, resulting in theresponse time constant of 20 ms. Forces of up to 2000 N can be generated by the device and are stable over a broad temperature range, varying less than 10% in the range of - 40 to 150 °C. The piston with three annular gap and various MR fluids was considered (Fathima et al. 2014).

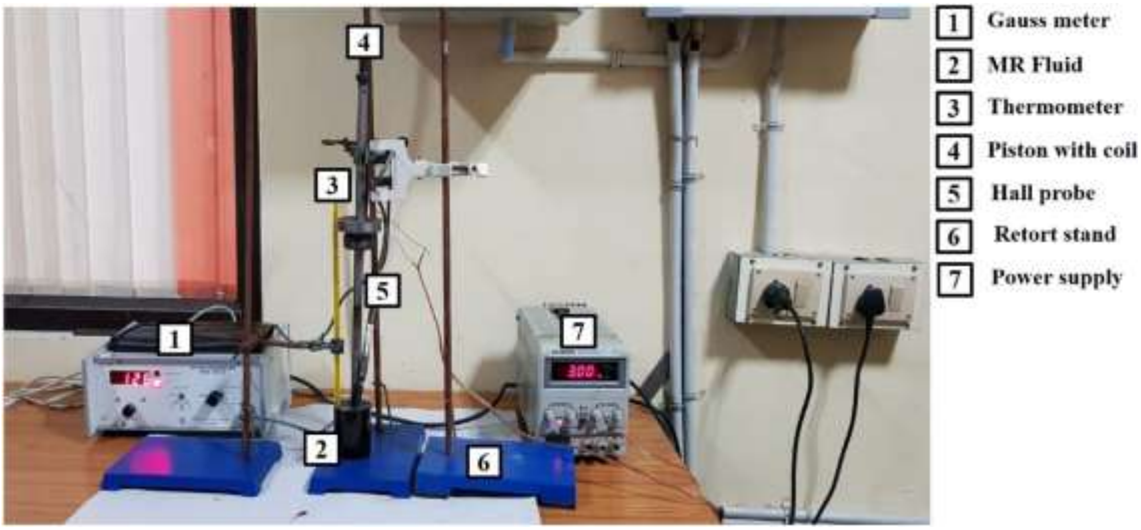

Fig. 3 Temperature study test setup

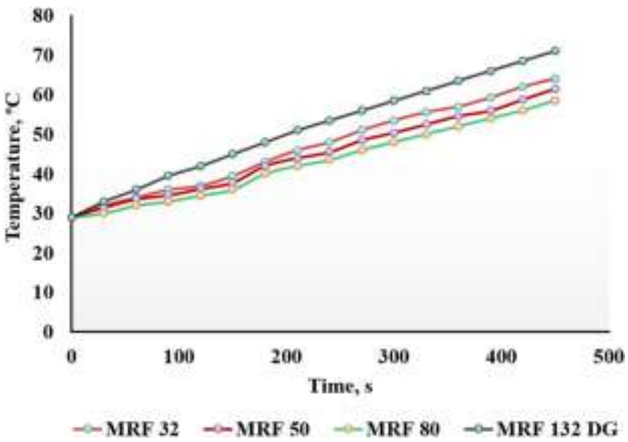

Fig. 4 Temperature versus time

5. FINITE ELEMENT METHOD MAGNETICS (FEMM)

Finite element analysis is done for shear mode MR damper;distribution of magnetic flux density in annular gap for various current is determined using finite element method magnetics (FEMM) software. The proposed MR damper annular gap 1 mm is analyzed. The coil has 330 turnsapproximately of 22 standard wire gauge and has a thick- ness of 0.711 mm. The maximum magnetic flux density is

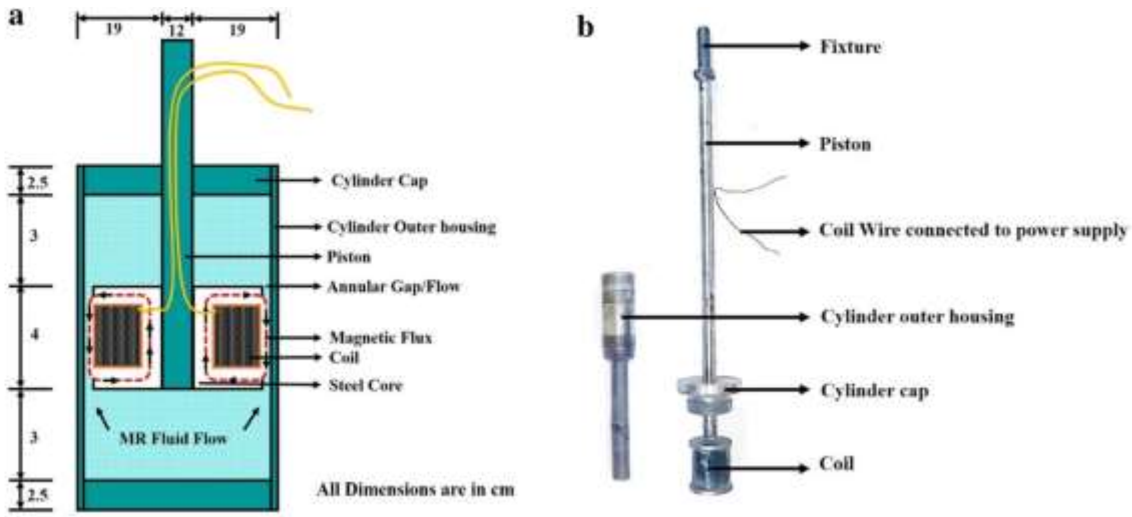

Fig. 5 a Section view of proposed MR damper, b fabricated MR damper

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