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EXPERIMENTAL EVALUATION OF HONEY AS CARRIER FLUID FOR MR BRAKE APPLICATION

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ABSTRACT
Application of Magneto-Rheological Fluids (MRF) in diverse applications is escalating due to their non-polluting operation and online controllability of shear stress/viscosity. However, settling of MR particle in a silicone based MRF, limits their full-fledged implementation in the intended application. To overcome this problem, an endeavor is made to develop a MRF using Honey as carrier fluid and Coconut oil as surfactant. Efficacy of the synthesized MRF is evaluated by performing static and dynamic testing on a developed MR brake test setup and comparing the test results with silicone based MRF. The static performance is evaluated by measuring the braking torque for different applied current using a torque wrench, while the dynamic performance is evaluated by measuring the braking torques from the current and voltage drawn by the motor. Finally a detailed discussion on the obtained results will be provided

Key words: MR Brake; MR Fluid; Carrier fluid; Honey; Braking Torque

I. INTRODUCTION

The automotive industries are committed to develop impervious, economical and efficient performing vehicles. In this regard, the advanced electro-mechanical systems are replacing the conventional mechanical systems due to their fast and more reliability operation [1]. In the present work development of one such electro-mechanical system, "Magneto-Rheological Brake" [2-5] is discussed. A Magneto-Rheological Brake comprises of (i) electromagnet, (ii) Magneto-Rheological Fluids (MRF), (iii) casing, (iv) rotating disk, and (v) a shaft, as shown in Fig. 1. The electromagnet, MRF and rotating disk are encompassed within the disk [6].

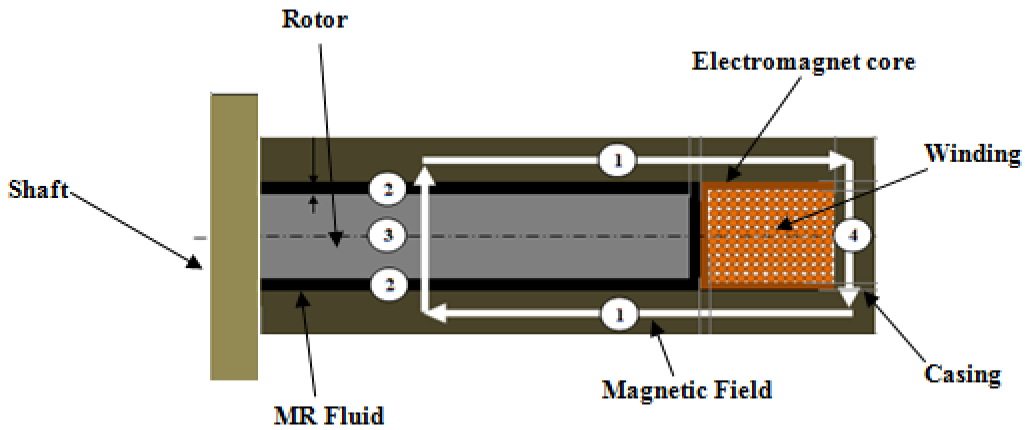

Fig. 1 Schematic representation of MR brake

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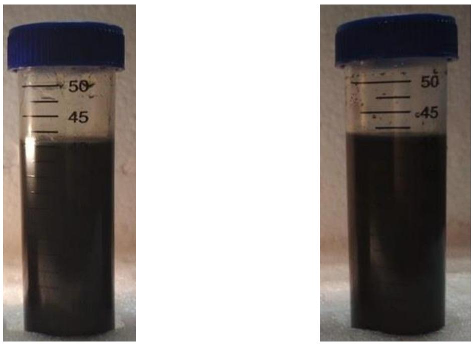
MRF are known as a smart fluid as they have their rheological behavior can be adapted in accordance with the applied magnetic field and the changes can be manifested in the form of proportional increase in the shear stress/viscosity of the fluid [7]. It has established that with the application of magnetic field, the viscosity of the MRF can be changed by 100-1000 times in milliseconds [8-9]. Generally, Magneto-Rheological Fluids (MRF) consists of surfactant coated micro to nano sized carbonyl iron particle and dispersed in a carrier fluid [10-11]. The carrier fluids are utilized to carry the particle to desired location and surfactants are added to the particles to reduce agglomeration of MR particles [12-13]. Surfactants provide steric repulsion force which reduces the attractive Van-der-Waal force between the particles and hence avoiding agglomeration. Electromagnet comprising of an electromagnet core and winding (Fig .1), is employed to magnetize the MR fluid by supplying magnetic field to the MR region [11]. To control the braking performance of the MR brake [14], the magnetic field generated by the electromagnet passes through electromagnet core-casing-MR fluid-rotor- MR fluid-casing- electromagnet core to form a closed loop, as shown in Fig. 1.

Compared to a conventional disc brakes MR brakes employing magneto-rheological fluid (MRF) do not require: periodic replacement due to wear, has a quick response time, compact size, and does not pollute the environment [15]. Further MR brake provides (i) continuous braking torque, (ii) faster response time (micro seconds), (iii) simple mechanical parts (with small size and light weight), (iv) noiseless operation [16-17]. Therefore, the MR brakes are considered as a superior replacement for disc brakes. However, the successful implementations of MRF in the MR brake in automobiles are hindered due to the settling of high density iron particles in low density carrier fluid [18]. Nevertheless, the settling rate of the iron particles can be abridged by increasing the density of carrier fluid, but this methodology results in reduction of shear stress with magnetic field [19]. Therefore the objective of the present work is to reduce the settling of the MR particle in the MRF, without compromising their magnetic property. In the present work an endeavor is made to overcome the aforementioned problem by using honey as carrier fluid with proper surfactants. Honey was used due to its high viscosity and coconut oil was used due to the presence of higher percentage of oleic acid. The settling performance and shear stress values for the developed MRF were evaluated by the authors earlier [20] and it was envisaged that the honey based MRF was providing a better ON state performance compared to silicone based MRF [21]. However its performance in the MR brake is yet to be established.
To demonstrate the efficacy of the synthesized MR fluid, a MR brakes test setup consisting of a DC motor, motor controller, and variable DC supply is developed. The performance of the synthesized MR fluid is evaluated by determining the static and dynamic braking torque and the obtained results will be compared with established silicone oil based MRF. The static braking torque of developed MR brakes is estimated using a torque wrench and an experimental setup is developed to estimate the braking torque during dynamic condition. The obtained results are presented and discussed in details.

II. SYNTHESIZING OF MR FLUIDS

To develop MR fluids; 80% (by weight) of carbonyl iron particle was mixed with 0.5% surfactant and 19.5% of surfactant. Carbonyl iron particle of mean size of 3 microns purchased from SIGMA ALDRICH. To reduce the agglomeration of the iron particle, initially surfactants were added to iron particles to reduce the Van-der-Waal attractive force between the particles by adding steric repulsive force. The MR fluid was developed by mixing the iron particle with surfactant for 10 minutes. The carrier fluid was divided into four parts and added to the mixture after every five minutes of stirring (i.e. starting, 5 min., 10 min…… 30 min.).



(a) MRF 1 (b) MRF 2

Fig. 2 Two different type of synthesized MR fluid

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Since, honey as carrier fluid is used for the first time to develop MRF, it is necessary to compare their performance with the established MRF. For this MRF with silicone oil was also developed and their performance will be evaluated using developed MR brake setup and will be compared with the results of honey based MRF. Therefore in the present work, two types of MR fluid: (i) MRF 1- Honey as carrier fluid and coconut as surfactant and (ii) MRF 2- Silicone oil as carrier fluid and oleic acid as surfactant, was developed. The two type of MRF is shown in Fig. 2

III. EXPERIMENTAL SETUP

To evaluate the performance of the synthesized MR fluids (i) MRF1: Honey as carrier fluid, and (ii) MRF 2: Silicone oil as carrier fluid, an MR brake experimental setup of outer radius 0.11m and thickness 0.026m was developed. Its performance was evaluated by measuring the braking torque. Manufactured electromagnet core and rotor is shown in Fig. 3(a) and Fig. 3(b) respectively. Two sets of experiments: (i) static and (ii) dynamic, were performed on the developed MR brakes. In braking torque during the static testing was measured using torque wrench while during dynamic testing, braking torque using was determined using voltage and current extracted by the motor.

(a) Electromagnet core (b) Rotor

Fig. 3 Manufactured rotors

Static Performance

The MR brake setup used for static testing is shown in figure Fig.4. One side of the MR brake was attached to the bench wise while other end was attached to an aluminum coupler which aids in connecting to the torque wrench as shown in Fig.1. The electromagnet of MR brake was powered using Agilent DC power supply. 1A to 2A of current was provided to the electromagnet and the variation in braking torque was measured using a torque wrench. Desired torque is set in the torque wrench and rotated. The torque value is increased till the shaft rotates freely.

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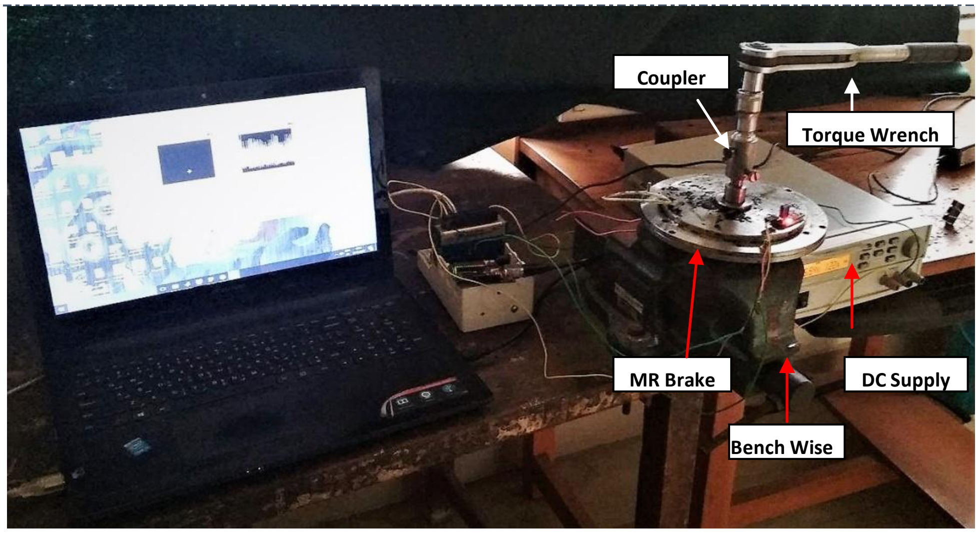

Fig. 4 Static performance test setup

Dynamic Performance

To estimate the braking torque of the developed MR brake, dynamic testing was performed at 200RPM using a developed experimental setup as shown in Fig. 5. This setup consists of 0.5hp DC motor, variable DC supply, jaw coupling, and MR brake. The motor shaft was connected to the MR brake shaft, using a jaw type coupling. Variable DC supply was used to control the speed of the DC motor. To avoid the leakage of the fluid from the casing, rotary seals were provided in the casing. The braking torque value during dynamic condition is estimated from the values of voltage and current drawn by the motor.

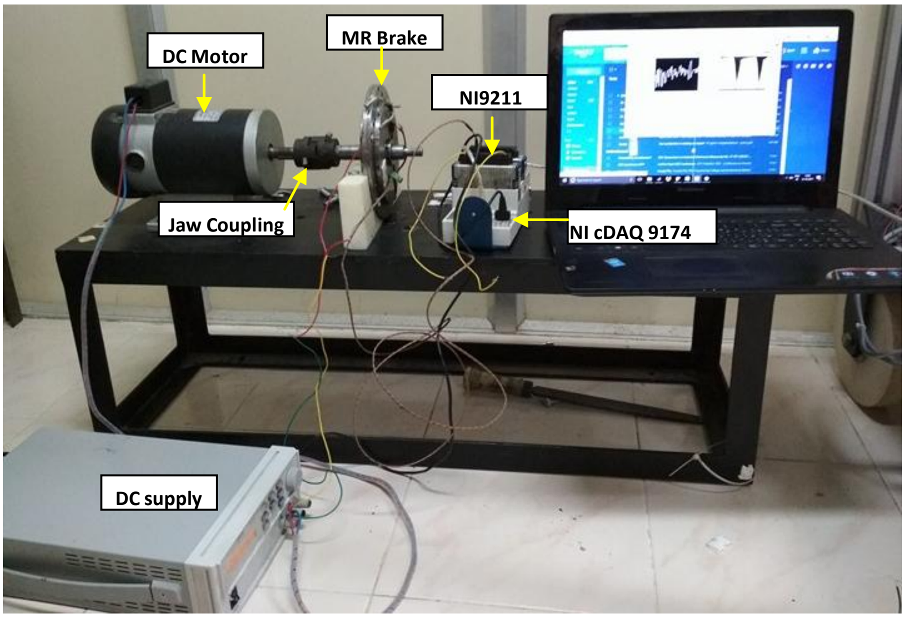

Fig. 5 Dynamic performance test setup

IV. RESULTS AND DISCUSSION

The measured braking torque values for different MRFs and input current is plotted in figure Fig. 6. From this figure it can be observed that the value of braking torque is maximum for honey based MRF compared to silicone based MRF.

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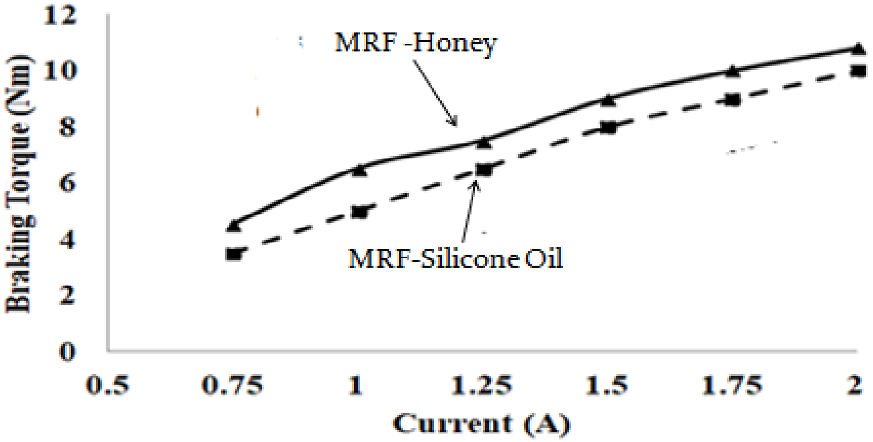

Fig. 6 Estimated Braking torque for different MRFs

Similarly the braking torque values obtained for dynamic condition is provide in Fig. 7. From the results obtained from static and dynamic testing it can be envisaged that the honey based MRF can provide a better braking torque.

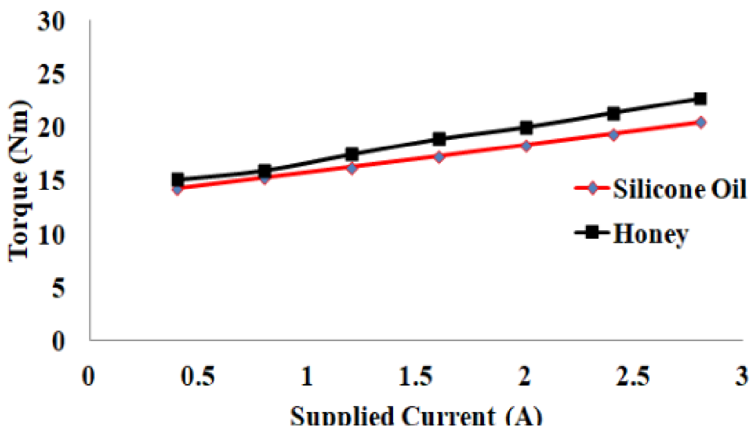

Fig. 7 Estimated Braking torque during dynamic testing for different MRFs

V. CONCLUSION

In the present work an endeavor is made to overcome the settling problem of MR fluid without compromising the braking performance, by adapting to the high viscous honey as carrier fluid. The performance of the developed MF fluid was evaluated by measuring the static and dynamic performance using a developed MR brake test setup and comparing the test results with established silicone based MRF. The static performance was evaluated by measuring the braking torque for different applied current using a torque wrench, while the dynamic performance was evaluated by measuring the power consumed by the motor. From the static and dynamic test results, it was concluded that the honey based MRF was providing a better results compared to silicone oil based MRF. Finally it was concluded that the MR fluid with honey provide a better braking torque compared to a established silicone based MR fluid.

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