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"EFFECT OF NANOPARTICLES ON PERFORMANCE OF MAGNETO-RHEOLOGICAL FLUIDS IN VIBRATION SUPPRESSION"

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ABSTRACT

Vibration in any working element causes undesirable effects and affects performance. So it has to be suppressed. One of the right ways to suppress the vibration is, bypassing the vibration through a fluid medium. If that fluid medium is behaving smartly, then our objective will be achieved inefficient manner. So we are choosing Magneto rheological fluid (in short MR fluid) as a fluid medium, which is already known as a smart fluid. It is found that because of the physical property and rheological behavior it gives extraordinary results. This paper discussed the properties and operational behavior of the MR fluids in detail. It also summarizes the problems associated with the MR fluids and possible ways to make this smart fluid smarter than before.

KEYWORDS: *Magneto Rheological Fluid*

Article History

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INTRODUCTION

The definition of MR fluid is "a non-colloidal mixture of ferromagnetic particles dispersed in oil or water medium".

MR is, in fact, a carrier fluid, usually oil, which is filled with micrometer-sized magnetic particles. It usually consists of 20-40 percent iron particles, suspended in mineral oil, synthetic oil, water or glycol. Those iron particles are carbonyl iron of size nearly 10 micrometers. The specific reason to use carbonyl particles is its high saturation magnetic property. The fluid also contains a substance which prevents the iron particles from settling.

The overall aspect is like a greasy quite heavy mud, since MR fluid density is more than three times the density of water. This material becomes suddenly smart and interesting as soon as a magnetic field passes through it. The ferromagnetic particles feel the induction field and acquire a magnetic bi-pole, and then they move and redesign their arrangement start to flow and to form chains and linear structures (Figure. 1b). These microscopic chains have the macroscopic effect to change the apparent viscosity of the fluid.

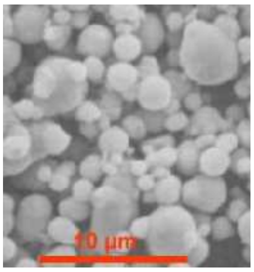

Figure 1: Microphotography of an MR Fluid with no Magnetic Field, (Particles are randomly Dispersed)

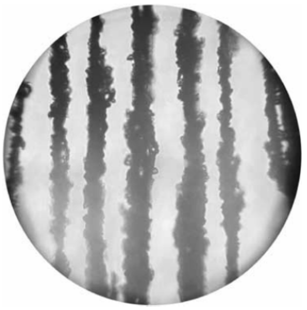

Figure 2: Microphotography MR Fluid with an Applied Magnetic Field with Parallel Chains of Carbonyl Iron

"OFF" POSITION

The MR fluid is not magnetized and the particles inside, distributed randomly, allow the fluid to move freely, acting like a regular fluid. (Figure 1)

"ON" POSITION

However, when the system is turned "on", and a charge which creates a magnetic field is applied, the particles become energized and align into fibrous structures, usually perpendicular in the direction of the magnetic flux. This restricts the movement of the fluid, proportional to the power and intensity of the magnetic field. (Figure 2)

OPERATIONAL BEHAVIOR

The yield shear stress is the main figure of merit of an MR fluid and derives from the non-Newtonian behavior of these fluids. The MR fluid behavior follows a so-called Bingham law, which means that it exhibits a non-zero shear stress value for a zero shear rate, behaving more like a solid than like a liquid, as shown in Figure 3. The value of the shear stress at no shear rate is called the yield stress of the MR fluid and is controlled by the applied magnetic field as shown in Figure 4. Greater the field strength, higher the yield stress. The higher the yield stress the higher the force the material can withstand without flowing.

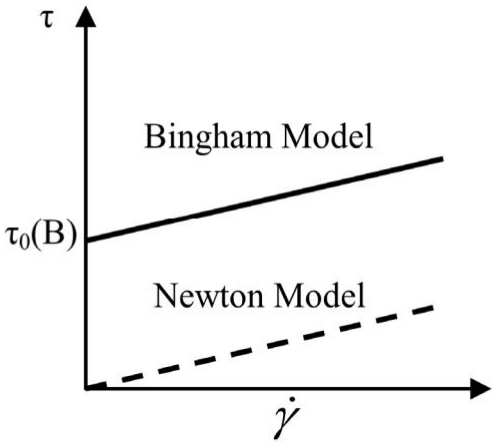

Figure 3: Bingham Model of MR Fluid

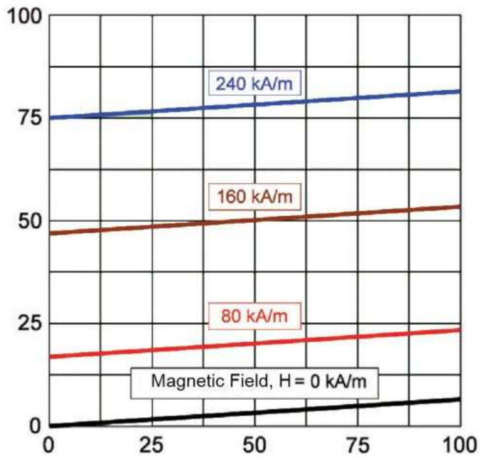

Figure 4: Effect of the Magnetic Field on the Yield Stress

Bearing a load is possible only because MR fluids can modify their aggregations' states changing from a viscous free-flow liquid to a quasi-solid state.

OPERATIONAL MODES

In order to exploit MR fluid properties, there are three main ways envisioned in current engineering applications

- Flow mode,
- Shear mode,
- Squeeze mode

Flow mode, also called valve mode, exploits the fluid between two fixed walls, the magnetic field is normal to the flow directions and is typical for linear damper applications.

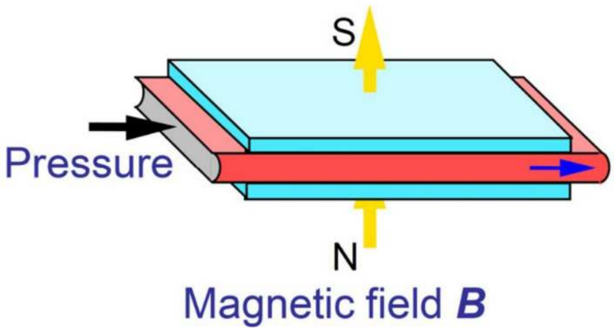

Figure 5

A shear mode is mainly used in rotary application such as brakes and clutches and the fluid is constrained between two walls which are in relative motion with the magnetic field normal to the wall direction.

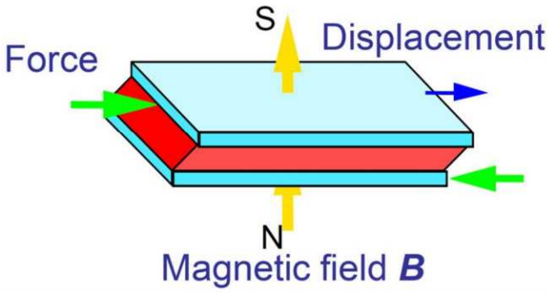

Figure 6

Squeeze mode is used mainly for bearing applications, is able to provide high forces and lower displacements having the magnetic field normal to walls directions.

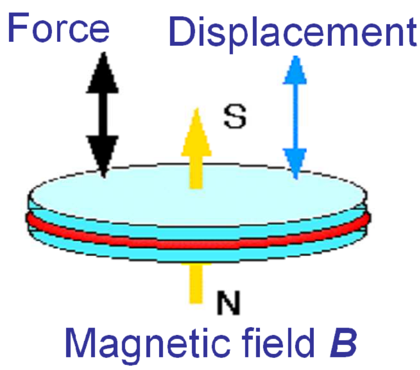

Figure 7

In all the above-mentioned cases the working principle is the same: the applied magnetic field regulates the yield stress of the fluid and the magnetic particles inside increase the fluid's viscosity, rendering it viscoelastic solid. So the amount of dissipated energy of the system is simply controllable by acting on the coil current and the system can provide semi-active behavior.

PROS

Compared with other devices, magneto rheological fluid devices have the following advantages:

- Control and adjustment of the continuous change of performance can be accurate real-time controlled;

- The main working components are not easy to wear and long working life;
- The structure is simple, the work is soft, the noise is low, and the response speed is fast;
- The need to control the low energy consumption, easy to combine with computer technology, intelligent control form.
- Can be stably operated in a wide range of temperature (-40 to150 C)
- MR fluids are not toxic and are insensitive to impurities
- They require relatively very low power input.
- Produce high yield stress up to 100 k Pa

CONS

Even though the fluid and its devices having lots of benefits, everything can't be fine. So in this session, the challenges and it will be discussed.

The following are the challenges associated with the MR fluids,

- Sedimentation
- In Use Thickening(IUT)
- The cost associated with devices
- Deterioration
- Temperature effect
- Durability.

From above the problems, this paper deals only about sedimentation and IUT. Because these two problems are associated with one of the most important properties of MR fluid, that is low-off state viscosity. While having an MR fluid, high yield strength in the on-state is important, it is equally important that the fluid also has a very low off-state viscosity.

SEDIMENTATION

It is known that MR fluid consists of iron particles in the fluid medium. So it is clear that there must be a high-density difference between solid and liquid. Because of this density difference, the iron particles which disperse in oil medium start to settle down which leads to poor dispersion stability.

This phenomenon is predominant if the fluid kept in off state for a longer duration. Though it looks like not a major problem, it seriously affects the performance of the fluid. Especially when the device comes to ON state after being in OFF state for a certain period of time.

To overcome this sedimentation, additives like microcrystalline cellulose, carbon nanotubes, silica graphene oxides were used. It is found that the results will be better if synthesized magnetite nanoparticles were added to the carbonyl iron (CI) particles in MR fluids.

It can't predict the effect by trial and error method, so a test has to be done with 2 varieties of fluids having 0% magnetite, and 0.5 weight % of magnetite particles.

As small nano size magnetite particles fill the gap between the large size CI particles, the dispersion stability is increased. This is because; the smooth spherical surface of the CI will turn into the irregular spherical surface which increases the contact area and due to this the sedimentation phenomena gets reduced.

IUT

This is one of the major problems which are not taken into account seriously. IUT was not identified as a serious problem until long-term life testing to qualify commercial MR fluid truck seat dampers was well underway.

If an ordinary MR fluid is subjected to high stress and high shear rate over a long period of time, the fluid will thicken. Superficially, this process appears much like the process of churning cream to make butter. An originally low-viscosity, i.e. low off-state, MR fluid progressively becomes thicker and thicker until it eventually becomes an unmanageable paste having the consistency of shoe polish.

The IUT phenomenon appears as a progressive increase in the off-state force. The off-state force increase that is the hallmark of the IUT problem is due to an increase if the off-state viscosity of MR fluid subjected to long-term stress. The cause of this viscosity increase is believed to be due to spilling of the friable surface layer from the surface of the carbonyl iron particles that typically comprise the particle component of MR fluid. This surface layer composed of iron oxides, carbides and nitrides are rather brittle.

When subjected to high inter-particle stresses this surface layer fractures and breaks into small pieces that separate from the primary particle. These very small nanometer-sized secondary particles have a very large surface area to weight ratio. As such, even a very weight, small amount of these secondary particles is capable of significantly affecting the rheology of the overall MR fluid.

Replacing 0.5% of the mass of carbonyl iron with the same mass of nano-sized ferrite particles results in almost a factor of two increases in MR fluid off-state viscosity. Replacing1% of the carbonyl iron mass with ferrite results in approximately a factor of three increases in viscosity. Thus, even if only a small portion of the carbonyl iron particles is shed secondary nano-sized debris, a very large increase in off-state viscosity can occur.

EFFECT OF NANO-PARTICLES IN VISCOSITY

From the above discussions, it is sparking that adding of nanoparticles in a proper way leads to the improvement of performance of MR fluids. And it is evident that the improvement of performance can be done by altering the viscosity.

So, in order to reduce the temperature induced and to avoid sedimentation in a magneto rheological fluid when exposed to the magnetic field, it was momentous to use additives along with the magneto rheological fluid.

Here aluminum oxide and titanium oxide nanoparticles were taken based on the fact that titanium oxide has the property to enhance iron powder's magnetic property and aluminum oxide has the tendency to get absorbed in the iron-oil interface and also avoids the aggregation between the iron particles induced by its magnetization.

In this investigation aluminum oxide and titanium oxide nanoparticles of an average size of 98.60 nm and 20.35 nm were infused with MR fluids. In this study, 0.1% (0.17gms), 0.2% (0.34gms) of TiO2 and 0.1% (0.16 gms), 0.2%

(0.32 gms) of Al2O3were added to the magneto rheological fluid composition.

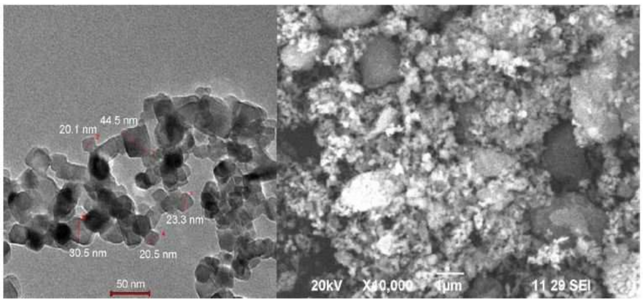

Figure 8: SEM Images of TiO2 and Al2O3 Nanoparticles

The SEM images of TiO2 and Al2O3 nanoparticles are shown.

From the results, it was observed that titanium oxide of 0.2% concentration when impregnated with MR fluid provides better viscosity (nearly doubles) and reduces the temperature in MR fluids when compared to other nanoparticles.

Visualization of Effect of Al2O3 and TiO2 in Viscosity and Temperature

Following graphs are showing the effect of Aluminum oxide and Titanium oxide nanoparticle in MR fluid. As the percentage of oxides increase, the viscosity of MR fluid increases and it also increases with respect to the current in both the cases. In case of temperature, it decreases with respect to the percentage of oxide and current.

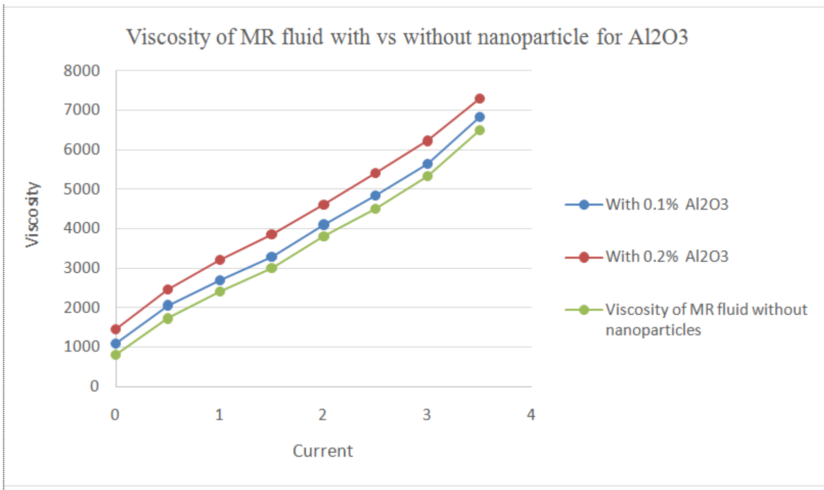

Figure 9

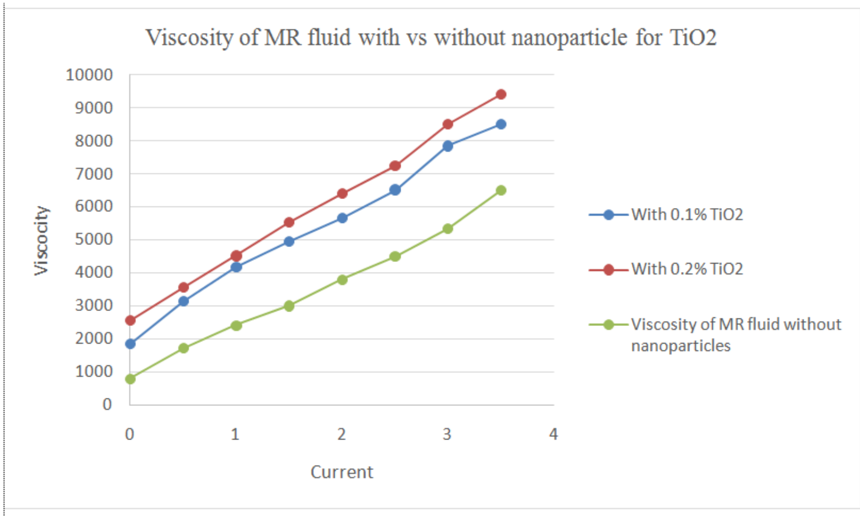

Figure 10

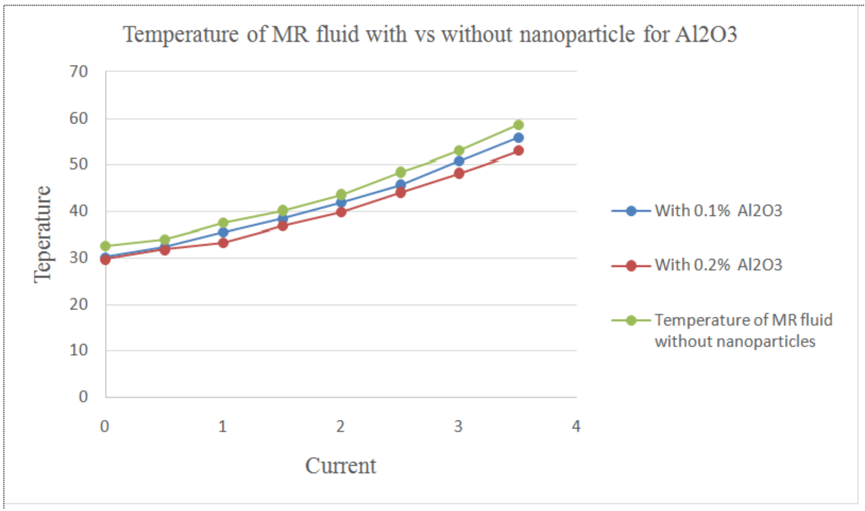

Figure 11

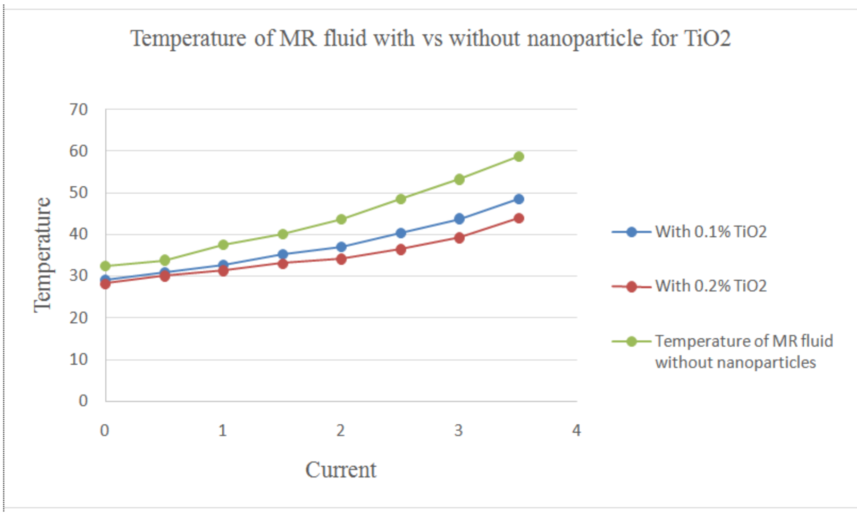

Figure 12

CONCLUSIONS

The above discussions have been carried out which lead to the following conclusions:

- A magneto rheological fluid damper, when impregnated with nanoparticles, can provide better stability, higher viscosity and better cutting performance during the hardening process.
- For achieving better damping capability, MR fluids impregnated with titanium oxide Ferro and magnetized particles
- Nanoparticles used along with MR fluids reduce operating temperature in the MR fluid.

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