International Journal of ChemTech Research
CODEN (USA): IJCRGG ISSN : 0974-4290
Vol.6, No.6, pp 3303-3306, Aug-Sep 2014

ICMCT-2014 [10th – 12th March 2014]
International Conference on Materials and Characterization Techniques

A Study on Properties and Selection Criteria for Magneto-Rheological (MR) Fluid Components

Bhau K. Kumbhar[1,*], Satyajit R. Patil[2]

[1,2]Department of Automobile Engineering, Rajarambapu Institute of Technology, Sakharale, Sangli, 415 414, India
[2]Department of Automobile Engineering,Rajarambapu Institute of Technology, Sakharale, Sangli, 415 414, India

*Corres. Author: bkumbhar2050@gmail.com

Abstract: Magneto rheological (MR) fluid technology has been proven for many industrial applications like shock absorbers, actuators, seat dampers, etc. However, MR fluids can only exhibit a yield stress of 50–100 kPa at a magnetic field of 150–280 kA/m. Hence, the proper selection of various MR fluid components like carrier fluid, magnetic particles and additives to satisfy the high yield stress applications remained a challenge. Basically, MR fluid is the colloidal suspension of micron sized, polarizable magnetic particles in the magnetically neutral carrier fluid whose viscosity can be varied from liquid to semisolid with the help of magnetic field. This paper presents basic properties of the MR fluids and their developments during recent years. This paper discusses the possible candidates of carrier fluid like mineral oil, synthetic oil, silicone oil, etc.; magnetic particles like electrolytic iron particles, carbonyl iron particles, iron/cobalt alloys, etc.; various additives and surfactants. The comparison of mineral oil, synthetic oil and silicone oil used as carrier fluids for MR fluid formulation has been made on the basis of various properties. Coating materials like polystyrene (PS), gaur gum, etc. and their effects on MR fluid performance are also discussed. Thus, this study addresses various MR fluid components, their concentrations and their effects so as to select the optimum components and their proportions to suit challenging industrial applications.
Keywords: Magneto-rheological (MR) fluid; Properties; Selection; Carrier fluid; Magnetic particles; Additives.

1. Introduction

Magneto-Rheological (MR) fluid is in a free-flowing liquid state in the absence of a magnetic field while each magnetic particle forms a dipole (north and south) on application of magnetic field as shown in Fig. 1. These dipoles attract each other to form a strong bonding in between them. As a result of this, chains are created. The MR effect is reversible.

For anMR fluid, the yield stress can be controlled, increasing or decreasing with the strength of the magnetic field as$\tau = \tau_{y(H)} + \mu_p \dot{\gamma}$ (1)

Where,τ_y is the yield stress due to the applied magnetic field H, μ_p is the constant plastic viscosity and γ is the shear-strain rate.

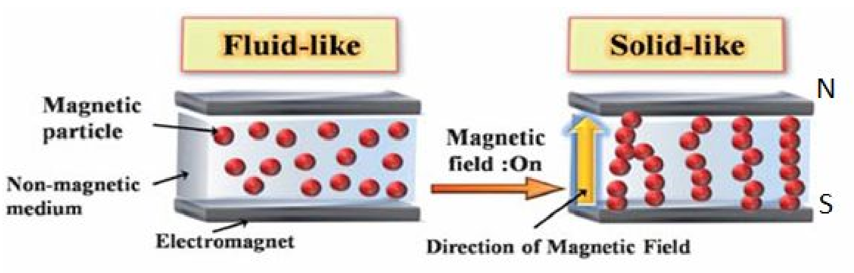


Fig. 1 Structural change in MR fluid [1]

2. Properties of MR fluid

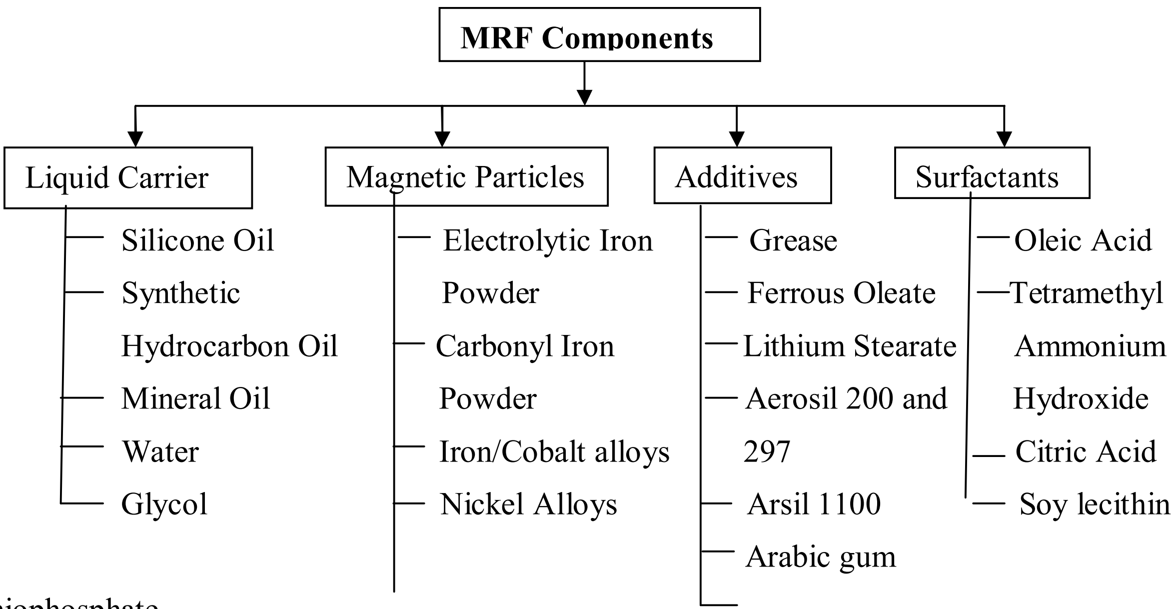
The properties of typical MR fluid and its comparison with Electro-rheological (ER) fluids and Ferro-fluids are as shown in Table 1 [1-3].

Table 1.Comparison of MRF, ERF and Ferro-Fluids

Property	MR Fluids	ER Fluids	Ferro fluids
Particulate Material	Iron(Carbonyl/Electrolytic), ferrites, etc	Zeolites, Polymers, SiO_2	Ceramics, ferrites, iron, cobalt, etc.
Particle size	0.1-10μm	0.1-10μm	2-10 nm
Suspending fluid	Nonpolar and polar liquids	Oils	Oils, Water
Required field	~ 3 kOe	3 kV/mm	~1 kOe
Off viscosity (Pa.s)	0.1-1	0.05-1	0.002-0.5
Density (g/cc)	3 –5	1-2	1-2
Reaction time	15 – 25 milliseconds (ms)	Some ms	Some ms
Work temperature	-50 to 150° C	-25 to 125° C	-
Max. yield stress	50-100 kPa	2-5 kPa	10 kPa
Stability	Good	Poor	Good
Typical supply	2-25 V, 1–2 A	2-5kV@1-10 mA	-
Deviceexcitation	Electromagnets or permanent Magnets	High voltage	Permanent magnet

3. Components of MR Fluids

Although the formulation of MR fluid depends on the needs of the application, MR fluid typically contains the basic components as shown in the Fig. 2.



Thiophosphate

Fig. 2 Components of MR Fluid

4. Selection Criteria for MR Fluid Components

The change in one or more components or in their properties influences the MR effect. The selection criteria for different MR fluid components are given below:

4.1. Liquid carrier

For the highest MRF effect the viscosity of the fluid should be small and almost independent of temperature[2]. Carrier liquid is the major constituent of MR fluids (50-80 per cent by volume) [4, 5]. The commonly used carrier liquids are:

4.1.1 Mineral and Synthetic oil

The rate of change of viscosity with respect to the temperature is more in case of mineral oil. Hence, this limits the use of mineral oils as a carrier fluid in MR fluid for low temperature applications. Synthetic oil posses some important properties like higher flash point, does not thicken at high temperatures, lower friction, high shear strength and high viscosity index

4.1.2 Silicone Oil

Silicone oil has good temperature-stability and good heat-transfer characteristics, oxidation resistance, very low vapour pressure, and high flash points. But, Silicone oil is very difficult to seal. There is little change in physical properties over a wide temperature span and a relative flat viscosity temperature slope and serviceability from -40 to 204°C. The different properties of these carrier fluids are evaluated in Table 2.

Table 2. Properties of Carrier Fluids

Properties	Mineral Oil	Synthetic Oil	Silicone Oil
Viscosity @ 40 °C (Pa-s)	0.028	0.1068	0.1100
Flash point°C	171 – 185	230	>300
Fire point°C	260 – 330	350	~ 500
Specific gravity	0.818 – 0.95	0.817	0.9124
Density at 25^0C (kg/m^3)	825	873-894	760
Pour point°C	-25to -50	-30 – 50	-50
Cloud point°C	-15	-20^0 C	-20
Market cost/ litre (Rs.)	~ 80	~800	~900

4.2 Magnetic Particles

The size of magnetic particles is approximate of the order of 1µm to 10µm [1]. As the size of magnetic particle increases, the attainable force also increases but at the cost of increased off state viscosity of MR fluid. The concentration of magnetic particles in base fluid can go up to 50% [6].Low coercivity, high saturation magnetization, high permeability, small remnance and small hysteresis loop are other characteristics of magnetic materials used for the formulation of MR fluid. [1].Carbonyl iron (CI) is chemically pure and the particles are mesoscale and spherical in nature in order to eliminate the shape anisotropy.

4.3 Additives

Highly viscous materials such as grease or other thixotropic additives are used to improve settling stability. Ferrous naphthanate or ferrous oleate can be used as dispersants and metal soaps such as lithium stearate or sodium stearate as thixotropic additives.Magnetic particles are coated with some materials like polystyrene (PS), gaur gum etc. to prevent CI particles from coming in contact with each other and to decrease the CI particle density to improve the sedimentation stability.

5. Conclusion

Silicone oil can be used as a carrier fluid where MR fluid application demands broader temperature requirements (from -40°C to 204°C). As viscosity changes rapidly with respect to the temperature as in case of mineral oils, their use in the formulation of MR fluid is restricted to the applications where temperature extremes are low. Carbonyl iron powder appears to be the main magnetic phase of most practical MR fluid compositions due to its high purity (~99.7%). The CI particles are mesoscale and spherical in nature which helps to eliminate the shape anisotropy. With the help of additives and proper coating of iron particles MR effect can be increased. Thus, with this, it is possible to explore the potential of MR fluid technology to suit various challenging industrial applications.

6. References

1. Genc S., 'Synthesis and properties of magnetorheological (MR) fluids', Ph. D. thesis, School of Engineering, University of Pittsburgh, 2002.
2. Kciuk M., Kciuk S., Turczyn R., 'Magnetorheological characterization of carbonyl iron based suspensions', Journal of achievements in materials and manufacturing engineering, 2009, 33, 135-141.
3. Premalatha E. S., Chokkalingam R., Mahendran M., 'Magneto Mechanical Properties of iron based MR Fluids', American journal of polymer science, 2012, 4, 50-55.
4. Shetty B. G and Prasad S.S.,'Rheological Properties of a Honge Oil-based Magnetorheological Fluid used as Carrier Liquid', Defence Science Journal, 2011, 61, 583-589.
5. http://www.lord.com/products-and-solutions/magneto-rheological-%28mr%29.xml
6. Baranwal D. and Deshmukh T.S., 'MR Fluid Technology and Its Application- A Review', International Journal of Emerging Technology and Advanced Engineering, 2012, 2, 563-569.

*****