University at Buffalo
Department of Mechanical and Aerospace Engineering
MAE 438/538 Prof. D.D.L. Chung Smart Materials

Magnetorheology

Magnetorheology refers to the phenomenon in which the rheological behavior changes upon application of a magnetic field. A magnetorheological fluid (abbreviated MR fluid) is a non-colloidal dispersion of fine magnetic (ferromagnetic or ferrimagnetic) particles in a liquid medium. The most common particles are iron, which is ferromagnetic. It exhibits shear thinning. Upon application of a magnetic field, the magnetic dipole moments of different particles align, resulting in columns of particles in the direction of the magnetic field (Fig. 1). Thus, the viscosity of the fluid increases with increasing magnetic field at any shear rate.

Due to the remanent magnetization upon removal of the magnetic field, magnetorheology is not as reversible as electrorheology. Furthermore, the speed of response is lower for MR fluids than ER fluids. However, MR fluids are free from conduction and dielectric breakdown phenomena, from which ER fluids suffer. Hence, a wider range of liquids can be used for MR fluids than ER fluids; conductive liquids, water and antiwear (lubricity) additives (e.g., graphite) can be used for MR fluids and purity is not as important in MR fluids. Moreover, MR fluids have higher field-induced yield strength, wider operable temperature range and lower voltage requirement for the power supply. The typical properties of MR and ER fluids are compared in Table 1. The ultimate strength of MR fluids is limited by magnetic saturation, whereas the ultimate strength of ER fluids is usually limited by the dielectric strength of the liquid carrier.

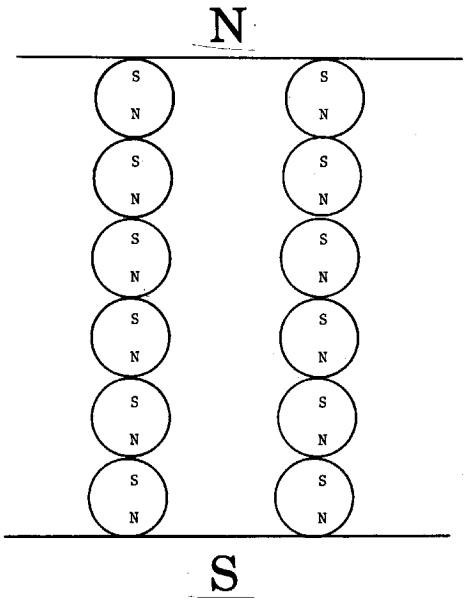

Fig. 1 Columns of magnetic particles in a magnetorheological fluid in the presence of a magnetic field in the direction of the columns.

Table 1. Typical properties of MR and ER fluids

	MR fluids	ER fluids
Maximum yield stress	50-100 kPa	2-5 kPa
Plastic viscosity	0.2-1.0 Pa.s	0.2-1.0 Pa.s
Maximum field	~ 250 kA/m	~ 4 kV/mm
Response time	ms	ms
Density	3-4 g/cm^3	1-2 g/cm^3
Operable temperature range	-50 to 150°C	+10 to 90°C
Power supply	2-25 V	2000-5000 V
	1-2 A	1-10 mA
	(2-50 W)	(2-50 W)
Stability	Not affected by most impurities	Cannot tolerate impurities