A Review On Electrorheological (ER) Fluids And Its Applications

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Abstract:-

Electro-rheological fluid (ER) technology is an old ''newcomers'' coming to the market at high speed. Various industries including the automotive industry, production sector, and robotics are full of potential ER fluid applications. Electro-rheological fluid technology has been successfully employed already in various low and high volume applications. A structure based on ER fluids might be the next generation in design for products where power density, accuracy and dynamic performance are the key features. Additionally, for products where is a need to control fluid motion by varying the viscosity, a structure based on ER fluid might be an improvement in functionality and costs. Two aspects of this technology, direct shear mode (used in brakes and clutches) and valve mode (used in dampers) have been studied thoroughly and several applications are already present on the market. Excellent features like fast response, simple interface between electrical power input and mechanical power output, and precise controllability make ER fluid technology attractive for many applications.

This paper presents the working principle, methodology to prepare low cost ER fluids, their properties and different applications of ER fluids. The study shows that excellent features like fast response, simple interface between electrical power input and the mechanical power output, and controllability make MRF the next technology of choice for many applications.

Key Words: - ER Fluids, ER Clutch, ER Damper, Mechatronics

Introduction: - Electro rheological (ER) fluids basically consist of particles that are held in suspension by a non- conducting fluid. The suspending liquid which should have a high electrical resistivity is typically low viscosity hydrocarbon or silicone oil. The particles dispersed in this liquid are commonly metal oxides, alumino silicates, silica, organics or polymers. In particular, the particles are very small and have sufficiently low concentration to allow the fluid to maintain a relatively low viscosity in the absence of an applied electric field. ER fluids are suspensions consisting of dielectric particles of size 0.1-100 micro meter (μm.) and dielectric fluid. In their liquid like state, they exhibit fluid like properties. In their activated conditions, they exhibit solid like state.

Smart Fluid:-

The fluids which change some of its physical properties, according to application of electrical input itself, that type of fluid are called as smart fluids

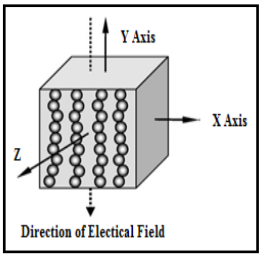
Types of Smart Fluids:-

- Electro Rheological Fluids: - The change in its properties by application of electrical field. Simply it is called as ER fluids.
- Magneto Rheological Fluids: - The change in its properties by application of magnetic field. Simply it is called as MR fluids.

Types of ER fluids

- Positive ER fluids: - The property of increase in the viscosity by applying the electric field to the ER fluid induced is termed the positive ER fluid. Many particle- fluid combinations have been tried in order to find an increment in viscosity.
- Negative ER fluids:- The property of decrease in the viscosity by applying the electric field to the ER fluid induced is termed the negative ER fluid.

Electro Rheological Material Behavior:-



The electro rheological effect occurs in electro rheological fluids when an electric field is applied causing the uniform dispersed solid particles to become polarized. Once polarized, they begins to interact with each other, and form chain like structure, parallel to electrical field direction, connecting the two electrode. Upon further intensification of the electrical field, chains begin to form thicker column.

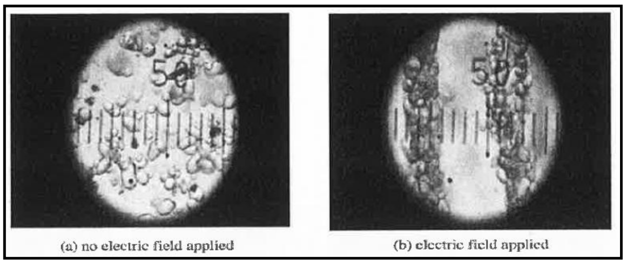


Figure: 1 Chain Formations in Electro Rheological Fluid.

A change in the suspension's rheological properties is associated with this change in its structure. The columnar particles structure give the fluid a greater yields stress. Upon removing the electrical field, the particles lose their polarization and return to their freely roaming state. The period of time over which these events occurs is on the order of milliseconds.

An electro rheological material is a suspension of very fine dielectrical particles in an insulating medium exhibiting controllable rheological behavior in the presence of an applied electrical field. The operational mode can be classified as

a) Flow mode: - In flow mode, two electrodes are fixed and vibrational control is obtained by controlling the flow motion between two fixed electrodes.

b) Shear Mode: - In shear mode, one electrode is free to rotate relative to another electrode so vibration control is obtained by controlling shear force.

c) Squeeze Mode: - In squeeze mode, the electrode gap is varied and electro rheological fluid squeezed by normal force.

Electro Rheological Fluids & Its Properties

Electro rheological fluids belong to a class of colloidal suspensions which exhibit large reversible changes in their rheological behavior when subjected to external electrical fields. Many researchers presently have been actively studying the mechanism and application of electro rheological fluid. One silent property of the electro rheological fluid itself is that it has a very fast response characteristic to electric field and hence wide control bandwidth. This inherent feature has triggered tremendous research activities in the development of various engineering application. These include shock absorbers, engine mount, machine mount and smart structure. Electro rheological fluid is known as a functional fluid, whose yield shear stress can be varied by the applied electric field strength. This unique fluid was known to world through the patent obtained by W. Winslow [1]. This special fluid has recently gathered greater attention due to scope for their commercial success in state of art automobile. Willis M. Winslow [1] discovered the effect of electro rheological effect in 1942, and since then there has been much struggle first to completely understand the effect, and second to develop electro rheological fluid with properties that meet the design requirement for practical applications. Some of the properties of electro rheological fluids that have hindered them from performing sufficiently for many applications are yield stress, temperature stability, and power consumption.

The properties of electro rheological fluids depend on particle size, density, carrier fluid properties, additives and temperature. A higher concentration of volume fraction of the dispersed particulates phase can give the fluid a much higher electro rheological effect, but at the same time can cause problems. Sedimentation is a major factor, since higher concentration of solid particles increase the amount of settling that will occur. The other potential problem is an increase in the zero field’s viscosity. The most obvious property affected by temperature is viscosity, which decrease as temperature increases. The dynamic yield strength also decreases with increase in temperature. The more extensive change in dynamic yield strength for electro rheological fluids is primarily due to change in conductivity and relative permittivity of the particle and oil components of the fluid over the temperature. The voltage required to include rheological changes through a given thickness of electro rheological fluid is relatively small (Approximately 1 to 4 KV/mm). Typically, the current densities of electro rheological fluid are between 10^{-6} to 10^{-3} amp/cm^2. Current density measurements are used to predict the power consumption of particular electro rheological fluids. One of the most important properties of an electro rheological fluid is its dynamic yield stress, which is the minimum stress required to cause the fluid to flow under the applied field. Usually, higher dynamic yield stress is desired and in current electro rheological fluids they range approximately 100 Pa to over 3 KPa. However, it is very difficult to compare various electro rheological fluids and their properties due to lack of standard testing procedure and conditions, as well as the strong dependence of electro rheological properties on their composition. But in general, for an electro rheological fluid to be used in a practical application it should meet the properties provided in following table,

Sr. No.	Property Description	Description
1	Dynamic yield stress at 4.0 KV/mm	< 3.0 KPa
2	Current density at 4.0 KV/ mm (DC)	< 10 μA/cm^2
3	Zero field viscosity	0.1-0.3 Pas (1-3 Poise)
4	Operating Temperature Range	-25° C to + 125° C
5	Dielectric break down strength	> 50 kV/mm
6	Particle size	10 μm
7	Response Time	< millisecond
8	Density	1-2 g/cm^3
9	Maximum Energy Density	0.001 Joule/cm^3
10	Power Supply	2-5 kV@1-10 mA
11	Ancillary Materials	Any Conductive Surface
12	Color	Any, Opaque Or Transparent
13	Other	Chemically and Physically stable, low conductivity and high breakdown voltage

Characteristics of ER Fluids

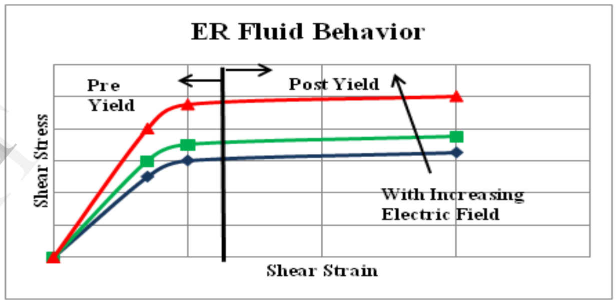


Figure 2(a):- Electro rheological denoting the pre and post yield material behavior regions

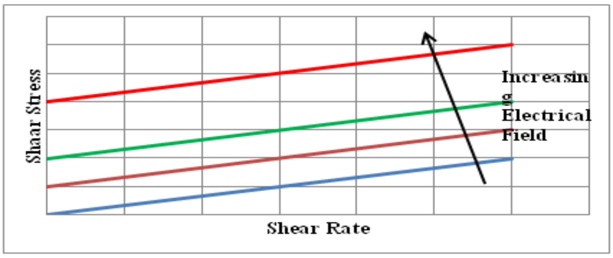


Figure 2. (b): -Electro rheological denoting the pre and post yield material behavior regions

For the most part, electro rheological materials have been considered for applications involving shear loading conditions. The typical constitute behavior of an electro rheological material in shear is as shown in fig. 2 (a) & 2 (b). The post-yield manifestation of electro-rheological effect was first observed by Winslow [1] in 1949. At that time, materials behaving in this manner were labeled electro viscous fluids since from a macroscopic viewpoint the most notable change of flowing electro rheological suspension was a change in apparent or effective viscosity. Some years later, it was determined that the actual viscosity of the material, υ remains relatively constant as the applied electric field was varied, while the property that changed was τ_y the yield stress of Bingham plastic like suspension. The idealized behavior is shown in fig. 1 (a) & 1 (b). Bingham plastics are also called as ideal plastic fluids. The fluid having no viscosity is called as ideal plastic fluids. A assuming that the shear stress exceeds the yield stress of the material can be represented by the constitutive equation,

$$\tau = \tau_y + \vartheta_\gamma$$

Where,

τ – Shear stress

τ_y – Yield Stress

ϑ_γ – Shear Strain

In comparison to the post yield behavior, the controllable visco elastic material behavior of electro rheological material in the phase remains virtually uninvestigated. Since the shear yield stress in an electro rheological material increase with increasing applied electric field and the yield strain normally remains at approximately 1 % for all fields. The behavior of fluid under the application of electric field as shown in figure 3.

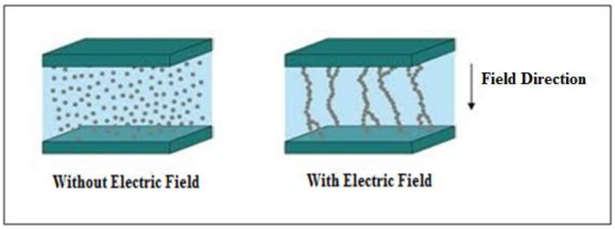


Figure 3 Behavior of suspended particles in electro rheological fluid under electric field

Typical Carrier Fluid & Particles

Commercially available ER fluids having very high cost, hence here are some carrier fluids and particles used to prepare ER fluids. By various proportion of concentration we can achieve many ER fluids according to our applications.

Carrier Fluids	Carrier Fluids
Aldehydes	Grease
Aliphatic Esters	Ketones
Aroclor	Kerosene
Carbon Tertachloride	Linseed oil
Caster oil	Liquid Paraffin
Chlorobentzenediphenyl Alkanes	Mineral Oil
Chloroform	Nitrobenzene
Cotton seed oil	Olefins
di-2-ethylhexyl adipate	Olive Oil
Dibutyl Sebacate	Orthochlorotoluene
Dielectric Oils	Polychlorinated biphenyls
Different types of Ethers	Poly chloro trifluoroethylene
Diphenyl Ethers	Polyalkylene Glycols
Diphenyl Sulphoxides	Resin Oil
Transformer Oil	Silicone Oils

Table 1.a typical Carrier fluids

Additive Particles	Additive Particles
Alfa Silica	Alfa Methacrylate
Alginic Acid	Manitol
Alumina	Metallic Semi conductors
Alumina Silica Mixture	Boron
Aluminum Oleate	Methyl Acrylate
Aluminum Octoate	Methyl Methacrylate
Aluminum Stearate	Microcel- C

Additive Particles	Additive Particles
Azaporhin Systems	Microcrystalline Cellulose
Barium Titanate	Micronized Mica
Polyvinal Alcohol	Monosaccharides
Cadmiumsulphide phosphor	Molecular Sieves
Calcium Stearate	N-Vinylpyrrolide
Carbon	Nylon Powder
Cellulose	Olefins
Ceramics	Onyx Quartz
Charcoal	Phenolformaldehyde
Chlorides	Phthalocyanine
Colloidal Silica	Polystyrene Polymer
Colloidal Kaolin Clay	Porhin
Crystalline D Sorbitol	Phosphototungstomolybic Acid
Diallylether	Polymethacrylate Mixtures
Diethylcarbocyanine iodide	Pyrogenic Silica
Diphenylthiazoleanthra quinone	Quartz
Divinylbenzene	Rotten stone
Dyes	Rubber
Gypsum	Silica Gel

Table 1.a Typical Additive Particles

Preparation of ER Fluids:-

General procedure to prepare ER fluids, is as follows,

- Initially powder with different particles sizes will be prepared, with precaution that all particles should be same throughout.
- Powder will be passed through proper size sieve and weighed on electronic weighting pan.
- This powder will be then mixed with measured quantity of fluids which poured into the glass flask containing powder. While adding the oil into powder care should be taken to stir the mixture continuously so that powder gets mixed with oil throughout.
- This mixture will be stirred with the help of glass rod continuously for an half an hour for trough mixing, thus ER fluid will be prepared.
- After preparation of ER fluid, it will be passed through a vane pump for 4-5 times for obtained homogenous mixture and good results.
- Same process will be adopted for different combinations of base fluid and powder particles to obtain different ER fluid samples.

Testing and selection of ER fluids

From the prepared samples of ER fluids, for selection of proper combination of ER fluid following test will be conducted,

1. Viscosity Test
2. Temperature Range Test
3. Sedimentation Test
4. Break down Test, etc.

Applications of electro rheological fluids:-

The electrically controlled rheological properties of electro rheological fluids can be beneficial to a wide range of technologies requiring damping or resistive force generation. Examples of applications are active vibration suppression and motion control. Several commercial application have been explored, and many more to be still undiscovered mostly in the automotive industry for electro rheological fluid based engine mount, shock absorber, clutches and seat dampers. Following are some important applications of ER fluids.

- Control of flow of liquid through narrow channels
- Friction Devices such as clutches, Brakes
- Clamping and positioning devices in machining of materials
- Vibrators and impact devices

- Servomechanisms
- Robotics power transmission
- Pick & Pick application
- Damping Isolators
- Damper in Automobile
- Engine Mounts
- Artificial Human anatomy parts
- Intelligent Artificial in machine tool
- Machine Mounts

These are the areas where application of ER fluids is possible. This list still expanding day by day as many new areas remains untouched.

Conclusion:- Excellent features like fast response, simple interface between electrical power input and mechanical power output, and precise controllability make ER fluid technology attractive for many applications in years to come.

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