SMART MATERIALS: ELECTRORHEOLOGICAL FLUIDS

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Abstract:- *A research is never ending process. The instable demand in the international market place for high performance structural and Mechanical systems for the aerospace, defence and advanced manufacturing industries has triggered the evolution of advanced composite materials. With world's technological revolutionary era, we come across various smart materials which can be successfully implemented into new practices for the fulfilment of human as well as technology requirements. Radical improvements of industrial processes cannot be achieved solely by increasing the efficiency of traditional production techniques and tools, but requires new solutions, employing novel ideas. One promising and novel technique exists which is based on the electrorheological effect present in the electrorheological fluids. This paper focuses on microstructure behavior & properties of ER fluids along with preparation & applications in engineering field so as to focus the evolution of new areas in which ER fluids can be used, which will become a new horizon for the new generation.*

Key Words:

1. INTRODUCTION

1.1 What is Rheology:

It is the relationship between shear stress and shear strain for solid materials & relationship between shear stress and shear strain for liquids. For liquids it is called the science of fluidity. The fluidity of material is usually based on properties curves.

1.2 Electrorheological fluids:

Electrorheological 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 the world through the patent obtained by W. Winslow in (1948). He reported the following features of suspension of silica gel particles in low viscosity oils.

1) In an electric field of magnitude of the order of 3 kv/mm, the suspension show a tendency to fibrillate on highly elongated condensed structures of particles formed parallel to the field.

2) A force proportional to the square of the electric field is necessary in order to shear the fluid between the electric plates. Thus at low shear stresses, the system behaves like a solid.

3) At stresses greater than this yield stress, the fluid flows like a viscous fluid, But with a large viscosity, again proportional to the square of the electrical field.

In the early 1980's, R Stan way, Sproston, developed a class of ER fluids made from ionic polymers with greatly improved properties.

□□ER fluids are colloidal suspensions of particles of size 1-100 microns in no conducting solvents

□□The viscosity of ER suspensions can increase 2-3 orders of magnitude when electric fields ~1kV/mm are applied across them. The response takes ~ 1ms.

□□More recently, un-hydrous fluids (with no absorbed water) have been developed by the C.J.Cow and C.F.Zukoski at the University of Illinois. These "third generation" ER fluids are very promising for future applications.

1.3 Microscopic view: The widths of bright bands increase with increasing electric field. It is well known that when an electric field is applied, the ER fluid undergoes a transition to a gel-like state, the particles first form chains along the field direction, which then coalesces into columns, if the particle concentration is not too dilute.

Fig. Scattering pattern of the ER fluid.

(1). E = 0, (2). E = 510 V/mm. (3). E = 710 V/mm

1.4 Two-types of ER Fluids:

An ER fluid is a substance which changes its apparent viscosity (rheological characteristic) according to the strength of the electric field immersing it, and its main features include a fast response speed and extremely low power consumption, among others The ER fluids currently being developed may be classified into two types in terms of their characteristics:

(a)Particle-type:

ER fluids of this type are colloidal fluids which are solvents containing dispersed particles, and show characteristics as shown in Fig.4 (a). The horizontal axis represents shearing speed, while the vertical axis indicates shearing stress, & the characteristics change according to the strength of the electric field *E* as shown in the diagrams. It is clear from this diagram that the particle-type ER fluids exhibit the characteristics of a Newtonian fluid when no electric field *E* is present but that they reveal the characteristics of a Bingham fluid when an electric field is applied. In other words, when a voltage is applied, these ER fluids behaves very much like Coulomb friction.

(b)Homogeneous-type:

Fluids of this type have been developed by using low molecule liquid crystal or macromolecular liquid crystal, and exhibit characteristics as shown in Fig.4 (b). Shearing stress nearly proportional to shearing speed is generated and its slope namely viscosity can be controlled by the electric field. As a result, it is possible to acquire a mechanical control force proportional to the speed under a constant electric field and to mechanically realize what is equivalent to the so-called differential control.

(a) Particle type (b) Homogeneous-type

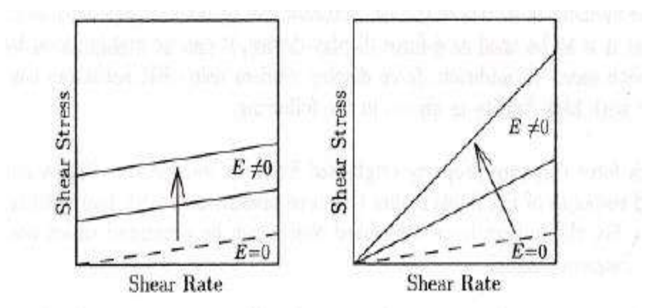
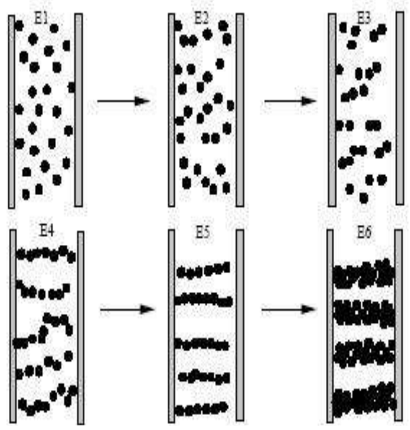


Fig.4: Characteristics of Particle-Type and homogeneous ER Fluids

1.5 Structure of Electrorheological fluid (ERF):



(Fig 5)

Particle polarization and single sphere width chain formation with increasing field, E. Particle chaining changes fluid properties.

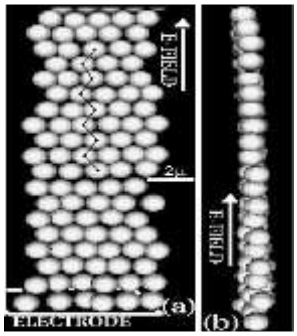


Fig6 Two views of a 'sheet' in planes parallel to the E-field

ER fluid is the foundation of ER technique. If a suitable ERF is not developed, then the ER technique will have no application to engineering. Today, many countries have developed some kinds of ERF with satisfactory properties and have begun production on a large commercial scale after receiving a patent. There are many different types of ERFs. Typically, they are composed of three parts:

1. **Base liquid**: Normally, the base liquid comprises mineral oils and other solutions, that are chosen for their electrical insulator properties The main property of a base liquid is its viscosity and electrical conductivity (10-9-10-4 ohm/cm is normally required).

2. **Additives:** A highly polarizable suspended solid particle. It is these additives that cause the obvious ER effects in an ERF. The additives typically consist of tiny particles or powders whose diameters are about 5-25μm and can be suspended in the base oil a long time. According to the theory behind ER phenomenon, particles form many particle chains that can resist shear stress when an electric field is applied and can be easily polarized.

3. **Surfactant**: The surfactant can prevent degradation of particles from the ERF and activate the particles to cause the EF effect. According to the report, ER fluid can be a mixture of many kinds of base oils, particles, or powders. The properties of ERFs are not only related to the characteristics of the base liquid and particles, but also to their volume/mass fraction in relation to the base liquid. Presently, research concerning the properties and experimental procedures used to produce ER fluids as kept secret.

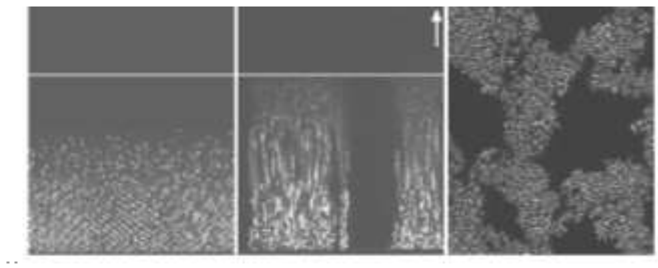


Fig 7 Fig 8 Fig 9

(Fig7) View of a 25%v.f. sample before the field is turned on. The spheres have sediment to the bottom.

(Fig 8) View after an electric field ~1kV/mm has been applied for about 15 minutes. The particles have formed into interlinked columns with regions devoid of particle.

(Fig 9) View of the 'columns' perpendicular to the electric field. The interlinked columns separated by void regions can be seen.

1.6 The ideal ERF should contain the following qualities in the view of its application in engineering:

1) Be able to produce an obvious ER effect when an electric field is applied i.e., the viscosity and yield stress can be developed on a large scale (even to the solid state). The highest yield stress of shear resistance in the ER fluid can reach 7-10 kPa. Surely, the higher the value the better. It has been repol1ed that, for the most ideal ERF produced so far, yield stress values can reach 20 kPa

2) Be able to turn the ERF into a solid at a low voltage (the lower the voltage the better). Normally, it is hoped that the electric field strength is no more than 3kV/mm. The fluid can be punctured with high voltage, i.e. discharge may occur.

3) The insulation value of the base liquid should be low (i.e. the electric resistance should be high). Thus, the strength of the electric fields can be raised and can make the ER effect more obvious and, at the same time, the power necessary to cause the ER effect can be lowered.

4) The chemical stability of the ERF should be high and should not degrade in storage and service.

5) The specific gravity of the base liquid should be close to that of the particles in it, and this ERF can prevent the sedimentation of its particles.

6) The ERF should be nontoxic for the safety of its users.

7) The production of ERF should be as easy and as economical as possible.

8) The ERF should be waterless. Water increases the current density so that more power is consumed. In addition, ERF will freeze at 0°c and boil at 100°c with water in it. Today, may scientists devote their research to finding waterless ERF and have succeeded on a large scale. ERF has been developed to withstand temperatures of 200°C, but the ideal operating range is 40-150°C.

9) The viscosity of the ERF should be as low as possible when no electrical field exists therefore, we can regulate its viscosity within a wide range, and this is one of the most important factors limiting its application in engineering.

10) The ERF should be non-corrosive and cause no wear and tear on metal particles.

1.7. Preparation of ER fluid: -

Electrorheological fluids are named and realized according to their base liquid constituent. There are numerous electrorheological fluids such as:

1) Starch – based (STB) ER fluids

2) Silica – based (SIB) ER fluids

3) Arabic – gum based ER fluids.

Here we are going to discuss the preparation of SIB ER fluids as below:

1.7.1 Preparation procedure:

1) As already stated, two different ER fluids were prepared. For the SIB fluid, coarse silica was ground by planetary milling after adding a little water. This finely powdered, semi-solid mass was then heated in an oven at 70"C for 12-14 h. Care was taken to dry the powder without sintering it.

2) The dried mass was again milled (dry) to produce a homogenous fine powder. The shape and size of the particle were analyzed through an electron microscope. It was observed that the particles were irregular in shape with sizes ranging between 1 and 5μ

3) Xylene was used as the dispersing phase, to which triple distilled water and glycerol mono oblate (as surfactant) were added. This solution was continuously stirred as silica powder was gradually added. This resulted in a semi-solid paste which, after undergoing continuous shearing in the dashpot cylinder, ultimately turned into a homogeneous colloidal suspension having good flow ability.

4) Only after reaching this liquid state, the ER effect was demonstrated. The ohmic resistance of the fluid in the electrode gap was around 200 kilo-ohms. Two fluids with silica contents 36% (w/w) and 42% (w/w), respectively, were prepared. In both these mixtures, water and surfactant content was 5.5% (w/w) each.

5) For the preparation of the STB fluid, first kitchen floor was ground dry by planetary milling. The particles were found to be almost spherical in shape with sizes ranging between 15 and 25 um. The ground starch was added to mixture of xylene and a small amount of water.

6) The mixture was continuously stirred and the surfactant (glycerol mono oblate) was gradually added. Two fluids with starch contents 40% (w/w) and 55% (w/w), resp, were prepared. In both these suspensions, water and surfactant content was 4% (w/w) each.

7) The ohmic resistance of the electrode gap with these fluids was found to be 400 kilo-ohms.

2. The Prospect of the Applications of ER technique In Engineering:

The value of any new technique lies in its high performance, wide applicability, and social and economic benefits in comparison to other current techniques. The ER fluid fits these qualifications almost perfectly. There is no doubt that it can be used widely in the engineering filed of the future. Once ER techniques are adopted, achievement in the society and economy will be astonishing. It is possible that they may be used widely in the following future fields:

2.1 Automobile Industry. Researchers can design and produce new type components, which can perfectly meet the needs of the automobile by using the ER technique. For example, a variable speed fan clutch for the cooling of the engine a clutch for the automobile, a brake with controllable braking torque, shock absorbers, or suspension systems with controllable damping can all be developed using ER techniques. The characteristics of these components will be those of high performance, minimal wear and tear, long service life, simple to manufacture, low cost, easy to control with an electronic signal and a microcomputer, fine sensitivity, and quick response.

2.2 Hydraulic Industry. The valves for flow rate and pressure control, which are designed and produced, using ER technique, may take the place of various valves currently used. Compared to different kinds of valves available today, the characteristics of these new valves will include a simple structure, no moving parts (such as a valve core), no need for accurate mechanical processing (such as the processing of the hole and core valve), low cost, low wear and tear, long service life, and the flow rate and pressure can be easily controlled by using an electronic signal. So it is forecasted that these kinds of valves will bring a revolution to the hydraulic industry.

2.3 Fluid Sealing Field. Engineers can develop a new kind of electric controlled rotational sealing device using the ER technique to challenge rubber and magnetic fluid sealing. The advantages can be summarized as fine sealing effect, no wear and tear, long service life, and no need for strong magnetic fields.

2.4 Robot Industry. Engineers can design and produce flexible joints which are small in volume, quick in response, nimble, cause no wear and tear, and can be directly controlled by micro- computer. These ER joints can do a much better job than the hydraulic-electric control devices, which are used today.

3. Conclusions:

The most advanced characteristics of ER fluid as a smart material can be summarized as follows according to current reports:

1) As obvious ER effect can be seen when an electric field is applied, causing a change in the fluid e.g., from solid to liquid and vice versa In appearance, the fluid becomes thicker and thicker and this viscosity increases in accompanied by the development of shear resistance.

2) The change of the ER fluid from liquid to solid should be reversible when an electric filed is applied, i.e. the fluid goes from solid to liquid when the electric field disappears. The change in viscosity should be step less.

3) The change between liquid and solid should be very rapid under control of the electric field. It has been reported that the period of change is only about 10-5 seconds.

4) The change between liquid and solid can be controlled only by an electric signal (voltage). With this characteristic, the technique can be easily linked to modern. Advanced micro computer control techniques. ER technique is a new kind of future challenge because, as it's fascinating Properties become more widely used; it may bring about a revolution to some areas of industry. The ER fluid is the key to ER technique and should be put into engineering applications and ER fluid dampers are the good solution for vibration control.

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