• *Letter*

New Dispersed Phase of Electrorheological Fluids: TiO_2 Coating Graphite Particles

Sujuan XU† *and Biao WANG*
Harbin Institute of Technology, Harbin 150001, China
Shouqiang MEN and Kunquan LU
Institute of Physics, Chinese Academy of Sciences, Beijing 100080, China
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We have prepared novel coated particles, with a conductor graphite core and a dielectric TiO_2 coating, as the dispersed phase of electrorheological fluids. One order of magnitude enhancement in the shear stress is obtained by using such composite particles, when it is compared with that of TiO_2 particles. The experimental results show a way to get excellent ER system.

Electrorheological(ER) fluids have a great potential for many applications because of ER effect: changing from a liquid-like state to a solid-like state when an electric field is applied to them. However, large scale of utilization of ER fluids has not been realized for lack of excellent ER systems. Part of the difficulty in developing high performance ER fluids lies in the difficulty of finding a single material that can fulfill all the electrical and mechanical requirements of ER fluids suitable for application. In this letter, we propose a novel dispersed phase of ER fluids: TiO_2 coating graphite particles. Through both physical argument and experiments we demonstrate that replacing TiO_2 particles by these coated particles will have a great enhancement in shear stress of ER fluids. By coupling physical understanding of the ER mechanism with the experimental preparation of the coated particles, we show that there can be a path for continuous improvement in order to optimize ER fluid performance.

We now describe the preparation process for the coated particles. The core particles used were graphite spheres (provided by group 402 of Institute of Physics, CAS) with diameters 5~10 μm. Compared to metal sphere, graphite has the advantage of low density which is important both for better response time and for avoiding sedimentation from gravity. The coating material used was Ti oxide, chosen for its hardness, wear resistance and high dielectric constant. Titanium dioxide was deposited using sol-gel method[1]. A given amount of tetrabutyl titanate(TBT) was dissolved in ethyl alcohol (the concentration was 0.5~1.2 mol·L^{-1}) and subsequently a suitable amount of diethanolamine (DEA) was added to the TBT solution under a nitrogen atmosphere (DEA/TBT molar ratio R=1~2). After stirring the solution at room temperature for 2 h, a suitable amount of water-ethyl alcohol(1:5~10) solution was added (water/TBT molar ratio W=2). TBT concentration cited in the text is the final concentration after the addition of DEA and ethyl alcohol solution of water. When a clear sol was obtained after the addition of water, the graphite particles pretreated in 60% HNO_3[2] were added into the sol and mechanically mixed to ensure good contact between the surface of the particles and the sol. The suspension of graphite particles is then filtered to recover the particles. The particles recovered were dried at 70°C and heat treated at 550~650°C. These operations were repeated to increase the thickness of the coating. The film thickness was controlled by two variables: sol concentration and time of coating.

The coated particles were dispersed in silicon oil to form ER fluid. The shear stress measurements were carried out using a coaxial cylinder rotational viscometer modified for ER experiments (type NXS-11, Instrument Factory of Chengdu)[3]. The shear stress was measured with a 50 Hz ac field applied between the electrodes. Figure 1 shows the measured shear stress for coated particles/silicone oil ER system as a function of electric field strength. Shear stress over 1.2 kPa was obtained at 1.7 kV for 25% volume concentration coated particles ER system. For comparison, we also showed the shear stress measured for the TiO_2 particles/silicone oil system (see also Fig.1). The shear stress enhancement of the coated particles system was over one order of magnitude.

It is well known that the particles in ER fluids will be polarized upon the application of an electric field and they will form a chain-like structure once the external field exceeds a certain value. In this case the

† To whom correspondence should be addressed
E-mail: sjxu@aphy.iphy.ac.cn

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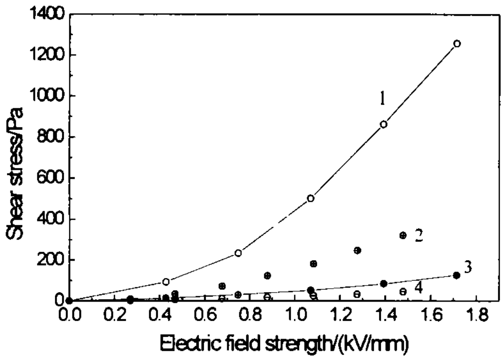

Fig.1 Shear stress of ER fluids as a function of electric field strength
1–25% coated particles, 2–15% coated particles, 3–25% TiO_2 and 4–15% TiO_2

local electric field in the gap region between particles is enhanced largely. Polarization and the shear stress of the ER system increase with the enhancement of the local electric field. Our theoretical calculations show that the local field around coated particles is greatly higher than that around pure dielectric particles if the core material of the coated particles is conductive and the shell material is dielectric[4]. The local electric field also changes with the thickness, dielectric constant and conductivity of the coating. This argument tells us that particles with a conductive core/dielectric shell have a great potential as dispersed phase of ER fluid.

In conclusion, we prepared graphite core/TiO_2 shell composite particles and used these particles as dispersed phase of ER fluid. The shear stress of composite particles/silicone oil system increased one order compared to TiO_2/silicone oil system. We believe that further optimization of the preparation conditions and understanding on the theoretical basis will lead to improvement towards the ultimate goal of practical applications.

Acknowledgement

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