Enhanced yield stress of magnetorheological fluids with dimer acid

Jianjian Yang, Hua Yan*, Xuemei Wang, Zhide Hu

Department of Chemistry and Material Engineering, Logistic Engineering University, Chongqing 401311, People’s Republic of China

A R T I C L E   I N F O

Article history:
Received 9 October 2015
Received in revised form 1 December 2015
Accepted 22 December 2015
Available online 29 December 2015

Keywords:
Magnetic materials
Magneto rheological fluid
Microstructure
Yield stress
Dimer acid

A B S T R A C T

A silicone oil-based magnetorheological fluid was prepared with carbonyl iron powder as magnetic particles and silicone oil as carrier. Dimer acid was employed as surfactant. The viscosity, yield stress, and flow behavior of MRFs under steady shearing flow were analyzed. It is found that the addition of dimer acid provoked a significant increment in field-induced yield stress, suggesting a strengthened chain microstructure was developed by the dimer acid modified particles.

© 2015 Elsevier B.V. All rights reserved.

1. Introduction

Magnetorheological fluid (MRF) is a kind of smart material, which consists of micro-sized magnetic particles and additives in a liquid carrier [1]. Because of the magnetic polarization of micro-sized particles in the presence of a magnetic field, elongated aggregates are formed in the direction of the field [2]. As a result, MRFs manifest a visco-plastic behavior characterized by the field-dependent yield stress.

The yield stress of MRF depends on the composition, particle size and content, and can be enhanced by a variety of schemes. Such as employing bimodal distribution suspension [3,4], using magnetizable fibers as dispersed phase [5], adopting ferrofluid as continuous phase [6], etc. Recently, Ulicny et al. [7] and Kligenberg et al. [8] have reported that the field-induced yield stress of MRFs can be enhanced by the addition of nonmagnetizable spheres. The authors suggested that nonmagnetizable spheres created an additional mean force of attraction between magnetizable spheres with a change in the microstructures. And it seems of interest that the change of inter-particle nonmagnetic attraction might facilitate the magnetic field-induced structure, ultimately be responsible for the MR response. In order to clarify this point, a kind of dicarboxylic acid, dimer acid with two carboxyl end groups, was employed to change the surface polarity of magnetic particles for the purpose of designing advanced MR fluids with a better performance. Meanwhile, the oleic acid (containing only one carboxyl end group) covered magnetic particles are prepared for comparison purpose.

2. Experiments

Soft carbonyl iron (CI, density 7.9 g/cm³) used throughout this research is a commercial product (Shanxi XingHua Chemical Company, China). The iron particles are spherical and polydisperse with the median grain diameter 5.35 μm. Methyl silicone oil with a viscosity of 0.35 Pa s at 25 °C was used as carried liquid. We used silica nanoparticles (Aladdin, 50 nm) as thixotropic agent, dimer acid (DA, Technical quality) and oleic acid (OA, Analytical reagent) as surfactans. Dimer acid is produced from the use of unsaturated fatty acids (oleic acid and linoleum acid) and obtained by mutual polymerization. It can improve the hydrophilic property of materials with two end carboxylic acid groups. The content of dibasic acid is about 80–85%. The magnetorheological fluids were prepared by ultrasonic dispersion and high-speed mechanical ball-milling for a long time to ensure the required homogeneity. The as-obtained suspension contained 15 vol% of iron particles and was labeled as CI, OA/CI or DA/CI suspension.

FTIR (6700, US) and contact angle meter (FM41Mk2 EasyDrop, Germany) were used to characterize the functional groups and hydrophobicity of the iron particle surface before and after the modification. The steady-state rheological measurements were carried out at 25 ± 0.1 °C in a controlled stress magnetorheometer (MCR 301, Physica-Anton Paar, Austria). The measuring system geometry was a 20 mm diameter parallel-plate set for a gap width of 1 mm. A homogeneous magnetic field was set perpendicular to the shear flow direction.
3. Results and discussion

The transmission FTIR spectrums for CI, CI/OA and CI/DA particles are shown in Fig. 1. Weak bands near 3 426 cm$^{-1}$ prove the existence of O–H on the CI surface. Typical adsorption of OA is illustrated in Fig. 1 (CI/OA) where the characteristic bands are: for C=O at 1709 cm$^{-1}$, for the –CH$_2$ at 2923 and at 2853 cm$^{-1}$, and the bend vibrations related to O–H at 1403 cm$^{-1}$. The adsorption of OA is also verified by the water contact angle of 134°, which indicates the lipophilic property of CI/OA particle surface. The IR measurements preformed on the CI/DA particles prove the existence of the dimer acid, by showing a wide stretching vibration characteristic of the hydrogen-bonded O–H at 3200–3600 cm$^{-1}$, the stretching vibrations of methylene groups at 2923 and at 2853 cm$^{-1}$, and a stretching vibration characteristic of the carbonyl at 1634 cm$^{-1}$. The CI/DA particle surface property is hydrophilic with a contact angle of 0° due to the infiltration of water drop.

Fig. 2 shows that the off-state viscosity of MRFs decrease by increasing the shear rate, characterized for the non-Newtonian property. The viscosities of the MRFs increase by the addition of organic acid. Moreover, the viscosity of CI/DA suspension is higher than that of pure CI or CI/OA suspension. This phenomenon indicates that, the free carboxyls of dimer acid covered iron particles might form weakly bonded structure in the fluid which introduces a modest particle interaction. And the viscosity reduces significantly once the bonded structures collapse under shear.

The yield stress is the minimum stress value required for the onset of flow and is of special interest in torque transfer applications. It gives a quantitative idea of the point where all internal structures in suspensions are broken. The effect of surfactant on the field dependence of the yield stress can be characterized by fitting the shear stress-shear rate data to the Bingham model equation ($\tau = \tau_y + \eta \dot{\gamma}$). In Fig. 3, the yield stress of CI, CI/OA and CI/DA suspensions are shown as a function of magnetic flux density $B$. It is obvious that the MR effect of CI/DA suspensions is higher than that of CI/OA suspension, which indicates that the oleic acid has little effect on the achievable yield stress.

Power model of non-linear regression was adopted to fit the yield stress versus magnetic flux density curve with $R^2 \geq 0.96$. The yield stress measured in the CI, CI/OA and CI/DA suspension increases with $B^{1.67}$, $B^{1.55}$ and $B^{1.75}$ dependence respectively. It is demonstrated that the yield stress achieved in suspension with CI/DA increases with the magnetic field faster than that in the CI suspension. The exponent value of yield stress in CI/DA suspension deviates from the prediction value of 1.5 [9]. These results indicate that the addition of proper dimer acid provokes a significant increment in field-induced yield stress.

The shear flow behavior of MRF is commonly explained by a competition of hydrodynamic and magnetostatic forces, which are
دانلود مقاله

http://daneshyari.com/article/1642067

امکان دانلود نسخه تمام متن مقالات انگلیسی
امکان دانلود نسخه ترجمه شده مقالات
پذیرش سفارش ترجمه تخصصی
امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
دانلود فوری مقاله پس از پرداخت آنلاین
پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات