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Tentative topic of the invited talk

Rheology modification by electrically conducting particles in a magnetic field.

Abstract of the invited talk

The effect of a magnetic field on the rheology of a suspension of electrically conducting silver particles is experimentally measured using a rheometer with a magnetorheological attachment. Conducting and silver particles are used as the conducting particles of size 4-10 μm are suspended in silicone oil of viscosity 20-150 mPa-s with volume fraction is in the range about 25%. Rheology measurements are also carried out with the addition of small amounts of magnetic iron carbonyl particles with volume fraction in the range of 1%. The rheology measurements are carried out in a parallel plate rheometer.

The results show that there is a small but discernible increase in the viscosity and an appreciable yield stress for samples with only conducting particles. The viscosity first shows a linear increase as the magnetic field is increased in the range 1-2 T, and then saturates magnetic field of order 4 T. The addition of a small volume fraction of magnetic particles, with volume fraction less than 1%, results in an increase in the viscosity by an order of magnitude. The increase in the viscosity is not observed when a suspension of electrically insulating particles of the same volume fraction is used, and an equal volume fraction of magnetic particles is added.

The results are fitted using the Herschel-Buckley model, and a significant increase in both the yield stress and the dynamic viscosity are reported. Oscillatory rheology tests also reveal a corresponding increase in the storage and loss modulus due to the presence of electrically conducting particles. This provides an opportunity for designing smart fluids, where the yield stress and viscosity can be controlled using the magnetic field, volume fraction of conducting particles and volume fraction of magnetic particles as control parameters.

The reason for the increase in viscosity of the fluid due to conducting particles is examined in the dilute limit by considering a spherical conducting particle in shear flow subject to a magnetic field1, 2. When a suspension of conducting particles is subject to shear flow, there is particle rotation due to the fluid vorticity. Eddy currents are induced in a rotating conductor in a magnetic field due to Faraday’s law of induction. These eddy currents impart a magnetic moment to the conductor in accordance with Ampere’s law. The cross product of the magnetic moment and the magnetic field results in a torque, which tends to decrease the particle angular velocity. The torque exerted by the particles results in an antisymmetric component of the stress tensor, termed the couple stress, which modifies the rheology of the fluid.

There are three viscometric coefficients in the couple stress, one in the plane of the vorticity and magnetic field, and the other two perpendicular to the vorticity and perpendicular to the magnetic field. Two of these are related from the condition that the torque is perpendicular to the angular velocity of the particle and the magnetic field. The two independent viscometric parameters depend on the particle volume fraction, a dimensionless ratio Σ of the characteristic magnetic and hydrodynamic torque on the particle, and the parameter β which is the ratio of the angular velocity and the current relaxation rate in the conductor. Functional forms for these are derived, and these are used to determine the change in the stress due to the rotating conductor in a magnetic field.

A comparison between the experiments and the single-particle calculation shows that the augmentation in the viscosity is significantly under-predicted by the theory. The possible explanations for these, and a modification to the theory due to particle interactions will be discussed.

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