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Modelling the Reorientation of Particle Chains in Magnetorheological Fluids to Predict the Yield Stress

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Abstract

Magnetorheological Fluids (MRFs) are suspensions of ferromagnetic micro/nano particles in nonmagnetic carrier fluids. Rheological properties of these materials are altered in the presence of a magnetic field (on-state). In contrast to ordinary fluids, MRFs can tolerate shear stress up to a threshold value in the on-state. The point at which the fluid transitions from a solid-like state to a fluid state is a key characteristic called yield stress. MRFs' yield stress strongly depends on intensity of the applied magnetic field and magnetic particles volume fraction. A mathematical model which can predict the yield stress can remarkably help designers develop more effective MRFs. It would also be a very helpful tool to maintain or control the output parameters of MR devices. In the present work, MRF samples with the same carrier fluid but different particle concentrations are tested through steady stress sweep tests at a wide range of magnetic field intensity to determine their yield stresses. Moreover, a new single dipole model (SDM) is proposed to simulate the resistance of particle chains against flow. The proposed SDM is integrated with a probability density function to interpret the reorientation of particle chains. The probability function is linked to the properties of the MRF. It is shown that the model provides a rather simple mathematical tool for predicting the yield stress of MRFs. The results also explain how the particle chains align with magnetic field and estimate the field strength the MRF reaches to its saturation MR effect at. The model also helps determine the saturation particle amount, suggesting that adding more particles not only does not make a significant improvement on the MR effect but also may lead to coagulation of particles as well as higher off-state viscosity which are not desirable for MRFs. The model predictions are in good correlation with the experimental data and provide quite reasonable predictions for prospective MRFs which help design more efficient ones for different purposes.

Keywords:

Magnetorheological Fluid Yield Stress Chains Orientation Magnetic Field Single Dipole Model