Droplet dynamics and rheology of nondilute ferrofluid emulsions in simple shear

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This work investigates the response of semidilute magnetic emulsion subjected to simple shear flows and a uniform external magnetic field. Our analysis employs a three-dimensional numerical domain where monodisperse ferrofluid droplets are randomly suspended in a non-magnetic Newtonian carrier fluid. The incompressible Navier-Stokes equations are solved using a second-order projection method. Moreover, we use the level set method to capture the interface and, assuming the droplet surfaces are free of surfactants, implement a repulsive force between droplets to avoid coalescence. We set different droplet concentrations and magnetic capillary numbers. First, in the absence of a magnetic field, we determined the effective viscosity for different droplet concentrations and shear rates, obtaining results that agree well with previous works. Later, we observed that the deformation and inclination angle of the droplets increase with the magnetic capillary number, while they decrease when the volume fraction increases. The droplet inclination angle is the angle between its main axis and the main flow direction (x-direction). We found that droplet-droplet interactions can significantly change the dynamics and droplet geometry, leading to a dynamic response. These geometrical changes cause variations in both viscosity and bulk magnetization. As the magnetic capillary number and volume fraction increase, both properties rise. However, when normalized by volume fraction, we observed that droplets in dilute regimes contribute more significantly to these bulk properties. Overall, we investigated the effects that the presence of multiple ferrofluid droplets has on the bulk properties of the emulsion.

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