VISCOELASTIC PROPERTIES OF FERROFLUIDS

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Magnetic fluids (ferrofluids) present colloidal suspensions of single-domain ferromagnetic particles in a carrier liquid. The typical diameter of the particles is about 10-15 nm. In order to prevent the irreversible coagulation of the particles under the action of the colloidal dispersion forces, they are covered by special layers which screen these forces. For many modern ferrofluids the surface shells consist of surfactant molecules; the typical thickness of these layers is about 2-2.5 nm.

One of the interesting and important features of ferrofluids is their ability to change rheological properties under the action of external magnetic field. The first theories of the magnetorheological effects in ferrofluids [1,2] deal with very dilute systems, where any interactions between the particles can be ignored. The maximal magnetoviscous effect predicted by these models does not exceed several per cent. However, experiments, carried out in recent decades with various commercial ferrofluids, demonstrate increase of their viscosity under the field by one-two orders of magnitude [3,4]. Especially strong magnetoviscous effects are observed when magnetic field is aligned along gradient of the fluid shear flow. Analysis shows that the strong magnetoviscous effects can take place due to appearance of heterogeneous aggregates consisting of the ferrofluid particles [4-7]. Two types of the structures in ferrofluids are well-known – the linear chains and the dense bulk "drops" as well.

Theories of magnetorheological properties of ferrofluids are mainly devoted to steady flow of these systems. However, from scientific as well as practical viewpoints, study of non-stationary flow of ferrofluids presents significant interest. Experiments [8] with typical commercial ferrofluids have demonstrated pronounced viscoelastic (relaxation) effects with the time of rheological relaxation about ten seconds. These magnitudes of the relaxation time are about 4-5 decimal orders of magnitude greater than the classical theories [1,2] predict.

One can suppose that experimentally detected relaxation viscoelastic phenomena in ferrofluids appear due to finite rate of evolution of ensembles of heterogeneous aggregates after alternation of macroscopical shear rate of the fluid. Characteristic time of evolution of these ensembles can determine the time of macroscopical viscoelasticity of the fluid.

We propose a simple statistical model of kinetics of evolution of the chain-like aggregates in ferrofluids and effect of this process on the macroscopical nonstationary viscoelastic (relaxation) properties of ferrofluids. Our analysis shows that the viscoelastic phenomena can be determined by evolution of the heterogeneous aggregates in ferrofluids. In spite of the conscious oversimplification of the model, it leads to reasonable agreement with known experimental results.

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