# INFLUENCE OF DIPOLE FORCES ON DYNAMICS OF FERROFLUIDS

**V. T. Lebedev, G. P. Gordeev, A. I. Sibilev**

Presented results [1, 2] are devoted to the study of ferrofluid dynamics as dependent on long range interparticle interaction induced by dipole magnetic fields. In order to investigate this complex problem we have performed a series of neutron spin-echo experiments, study of ferrofluids by electron microscopy,inelastic light scattering and also magnetization measurements.

Samples used in the experiment contain magnetite dispersions in light (LW) and heavy (HW) water or in tetradecane (TD) with concentrations $C$: 0.55(HW), 2.1(LW), 2.42(HW), 5.00(TD) vol%. In different samples magnetic grains have the most probable radius in the range of $R_p = 30 - 50$ Å.

Data on inelastic neutron scattering from the nuclear subsystem of ferrofluid in a zero external field reveals the behaviour of intermediate scattering function like a relaxation process with a single effective time: $S_{H=0}(q,t) = \exp(-t/\tau)$, where $q$ is the momentum transfer and $t$ is the time. The fitting parameter $\tau = \hbar/\omega_N$ reflects a relaxation rate or a characteristic energy transfer $\omega_N$.

The energy $\omega_N$ is shown for the samples of different concentrations and solvents (Fig. a). For a nonmagnetic dispersion the dynamics could follow a Stokes-Einstein diffusion,involving a self-diffusion coefficient $D_s = k_BT/6\pi\eta R_h$, with $k_BT$ the thermal energy, $\eta$ the viscosity of the solvent and $R_h$ the hydrodynamic radius. We would therefore have to separate a variation of energy $\omega_N \sim D_s$ through $\eta R_h$. We claim here that the sensible variation of $\eta R_p$ will not be sufficient to keep $k_BT$ constant in the data of Fig. a. Instead we propose to take into account the long range forces.

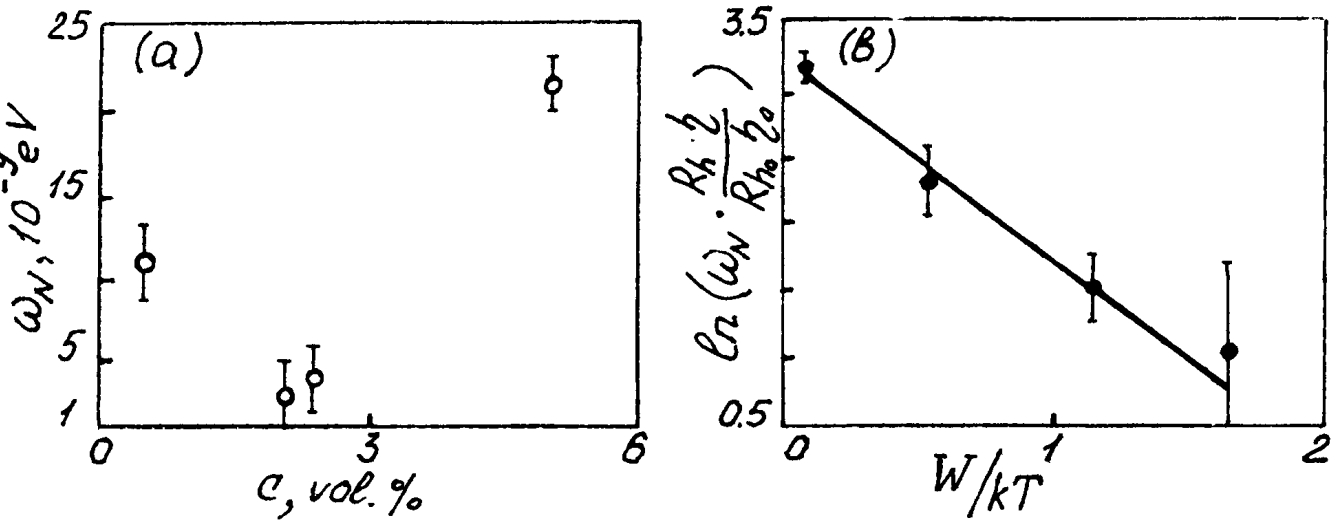


**Fig.** a)Energy changes vs.concentration. b)Linear dependence of $\log\Omega_N$ vs.$W/k_B$T

The scattering function $S_{H=0}(q,t)$ involves a region of size $R_q \tilde{} 1/q$, where the number of particles (volume $v_p$ and magnetic moment $\mu$) is $R_q^3 C/v_p$, and the interaction energy with $n$ neighbours $W = n^{1/2} 2\mu^2/R_q^3$. Considering the usual magnetization of magnetite $M = 0.4kG$ and using the most probable values of radii from electron microscopy for $R_h$, the normalized energies $\Omega_N = \omega_N(\eta R_h)/(\eta_o R_{ho})$ seem to have a linear dependence of $\log\Omega_N$ versus $W/k_BT$ (Fig. b). For convenience here we use the dimensionless values of $\eta R_h$ devided by this one for the most dilute fluid. The proposed dynamic model promises to be able to explain the essential common features of ferrofluid dynamics for a variety of different magnetic dispersions. These results show nontrivial behaviour of the nuclear subsystem of ferrofluid which is governed by dipole forces, although further experiments and theoretical studies are needed to improve this model.

REFERENCES

1. *Lebedev V.T., Gordeev G.P. et al.* Preprint PNPI-1839, 1992. 40 p.
2. *Lebedev V.T., Gordeev G.P. et al.* J.Magn.Magn.Materials, 1993. V.122. P.83–89.