Workshop on Magnetic Gels

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Dynamics of magnetic nanoparticles in viscoelastic media and under strong AC fields

Yu.L. Raykher

The really existing polymeric ferrogels, albeit conditionally, may be divided in two classes with respect to the size of the magnetic particles filling them. One type of substances, often prepared by admixing magnetic fluids to some gel matrix, contains really fine particles (about 10 nm). These systems are not highly concentrated, and due to that their magnetizations are weak in comparison, e.g., with solid ferrites. However, the particles, due to their small size, are quite mobile, take active part in Brownian motion, and can cover large distances (in their scale). If to look at these particles as the probes testing the internal state and structure of the gel, the crucial issue is the relations between the particle size and the structure “cell” of the gel mesh. Depending on that, the particles are either tightly trapped by the neighboring macromolecules or they are only “caged”. In the latter case they retain a certain freedom: can move easily inside the cage, and experience an strong resistance only when striving to leave it. For these reasons, those cases should differ considerably in their magnetic and mechanical response to an external field.

A theory of Brownian motion for a particle in a model environment, where both kinds of behavior are possible is proposed. The essential circumstance is that a simple expression covering a wide frequency (and, thus, displacement) range)can be obtained. Provided the particle has a magnetic moment, then its motion could be modified upon applying a magnetic field.

Another type of ferrogels, which one would rather call *soft magnetic elastomers*, has stronger matrices but, as well, a much stronger magnetic phase. For now existing systems the matrices are made of PVA or soft silicone rubber and filled with micron iron carbonyl particles of the size 2-5 microns. Being almost pure iron, the particles have the saturation magnetization about four times greater than that of any ferrite. At the filling fraction about 30 vol.%, the composites have specific density about 2, and display strong magnetodeformational effects.

In these systems the particles are, of course, tightly trapped, so that their motions and rearrangements are readily transmitted to the matrix, i.e., to the sample as a whole. This induces a number of macroscopically observed magnetodeformational effects: magnetodipolar striction and magnetic plasticity, in particular. As in this case both subsystems (magnetic and elastic) respond nonlinearly and strongly interact with one another, here the analytic theories become useless. The magnetomechanical problems for such materials can be solved either by computer modeling or imitated by some rough phenomenological equations. We use both approaches but the former is very cumbersome and slow in rendering results. The latter, phenomenological, one implies, however, a good portion of speculation. To make it more justified, we first perform a qualitative analysis on what goes on inside the system. This enables us to find a simple model that seem to be in general agreement with the evidence. One of the main conclusions it lead to is that the material in question under field develops inside it (hence, structurally) a mechanism of dry friction. The details of this effect make, in our view the most interesting issue in all the problem.