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Magnetorheological Hysteresis in Concentrated Magnetic Elastomers

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The work deals with theoretical explanation and physical modelling of experimentally observed nonlinear and hysteretic magneto-rheological effects in elastomers with micron-sized magnetizable particles

1) Hysteretic relations between mechanical stress and uniaxial deformation (either elongation or contraction) of the samples placed in a magnetic field aligned along the deformation axis. Note that these effects have been observed only in the field presence; without the field the MRE samples demonstrated the linear Hook behavior. The area of the hysteresis loop does not depend on the rate (frequency) of the samples deformation; therefore, these hysteresis can not be explained by the viscous effects in the host polymers. Explanation of these phenomena is based on the concept that (i) because of adhesion, the particles in the ME composites are surrounded by relatively dense and, therefore, rigid polymer coats and (ii) under the field action the particles form anisotropic structures (columns) aligned along the field.

Under the field the magnetized particles approach and their coats interpenetrate. While the sample stretching, the particles move apart, their coats disintegrate, a laterally situated particle can move into the gap between these particles and to stuck there. Analysis shows that these factors provoke the non-linear and hysteretic dependence of the macroscopic stress on the sample elongation.

2) Hysteretic dependence of the composites shear modulus on the magnetic field applied along the MRE shear. This effect is explained by formation, under the field action, of the anisotropic structures, which dramatically enhance the composite rigidity. The chain length hysteretically depends on the field strength; this dependence leads to the hysteretic dependence of the macroscopic elastic moduli on the field. Two kinds of the composites have been considered: (i) with isotropic spatial distribution of the particle (samples, cured without the field); and (ii) with the anisotropic internal macroscopic structures, appeared while the sample synthesis under an applied field. The results demonstrate that the rheological moduli of the initially anisotropic composites can be several times more than those of the isotropic ones.

The theoretical results are in quantitative agreement with the results of experiments with the samples in a wide region of the particles concentration for composites with various host polymers.

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