Molecular Based Rheology of Magneto-Sensitive Elastomers

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Magneto elastomers are a class of smart materials whose mechanical properties can be controlled by the application of an external magnetic field. Recently, magneto elastomers have been used in the automobile applications such as stiffness tunable mounts and suspension devices. Such materials typically consist of micron-sized iron particles dispersed within an elastomeric matrix. Orientation distribution of these particles in an elastomer can be either isotropic or anisotropic, depending on whether they have been aligned by an applied magnetic field before cross-linking. Experimental tests indicate the increase of dynamic shear modulus with increasing magnetic strength. The latter can be controlled by the distance between permanent magnets or by the electric current through the coils of an electromagnet.

Till now the behavior of magneto-sensitive elastomers has been analyzed by using the continuum-mechanics approach, in which the electromagnetic equations are coupled with the appropriate mechanical deformation equations. However, the continuum approach assumes a homogeneity of a media and does not account for a real composite structure. Thus, its predictive power is very restricted.

The goal of the proposed PhD studies is to develop a microscopic theory of mechanical properties of magneto-sensitive elastomers which will take molecular structure of these materials explicitly into account. Molecular models proposed earlier for elastomers with included rod-like particles will be modified in the present project to describe interaction of included particles both with the external magnetic field and with network fragments. Anisotropy of dynamic mechanical properties will be studied as a function of the magnetic strength for different geometries of application of the mechanical strain with respect to the direction of the magnetic field. The effects of the following structural characteristics on the magneto-mechanical behaviour will be studied: (i) the degree of cross-linking, (ii) the particle size and (iii) the particle concentration. Thus, the theory will be able to relate the molecular structure of magneto-sensitive elastomers with their mechanical properties. Additionally, the theory can be advanced by considering such magneto-sensitive elastomers in which the nano-sized particles are covalently attached to the polymer network. In the latter case, the formalism recently developed for light-sensitive polymers can be used. Furthermore, the approaches within the theory will benefit from very new concepts of rheology and statistical-mechanics of particle filled polymer melts and networks.

Possible applications of the theory could also be found for new kinds of magnetic sensitive rubber materials containing metal coated carbon black surfaces.