Influence of isotropic and anisotropic particle distribution on the mechanical properties of magneto-sensitive elastomers

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Magneto-sensitive elastomers (MSEs) are smart materials that can change their shape and mechanical behavior under external magnetic field. Mechanical properties of MSEs in a homogeneous magnetic field are usually studied in the frame of continuum-mechanics or microscopic analytical approaches. The continuum-mechanics approach, based on consideration of deformation-dependent demagnetizing factor N [1], predicts always the elongation of MSEs. The microscopical approach takes explicitly the dipole interactions between magnetic particles and predicts a different sign of magneto-induced deformation depending on the form of spatial distribution of magnetic particles [2]. In this study we show that the continuum-mechanics approach can be only applied to the MSEs with isotropic distribution of magnetic particles. For that we calculate the averaged magnetic induction $\langle B \rangle$ inside the spherical and ellipsoidal MSE samples, which contain isotropic and anisotropic distributions of magnetic dipoles. In the case of isotropic particle distributions, represented in our study by three different lattices, we have found good convergence of $\langle B \rangle$ to their values calculated using the demagnetizing factor N. Contrary, anisotropic chain-like and plane-like particle structures provide results for $\langle B \rangle$ which differ considerably from their values predicted from demagnetizing factor N. This shows that the demagnetizing factor has an isotropic nature and thus is not applicable for anisotropic microscopic structures.

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[1] Landau L.D., Lifshitz E.M., Pitaevskii L.P., Electrodynamics of Continuous Media, Vol. 8, Butterworth-Heinemann, 1984, p. 460.

[2] Ivaneyko D., Toshchevikov V.P., Saphiannikova M., Heinrich G., Macromolecular Theory and Simulations, 2011, 20, 411.