

Magnetic energy of two particles

In order to find the magnetic energy of the two spheres in the non-magnetic medium ($\mu = \mu_{\text{magnetic}} | \mu = 1$) without electrical currents, one needs to solve the Laplace equation (LE). The result of this computation, which was done elsewhere, can be presented as a series in terms of dimensionless inverse distance as follows

$$U_{\text{int}} = -\frac{3\mu_0 a V}{4 \pi} \sum_{ij} \frac{m_i^2}{r_{ij}^3} = 2U_{\text{int}} \sum_{ij} \frac{m_i^2}{r_{ij}^3},$$

(1)

where every coefficient $m_i$ is of a type $m_i = C^{(ij)}_0 + C^{(ij)}_1 \cos^2 \theta + \beta_i \frac{m_i^2}{3} \cos \theta \sim 1$. To compare this result and to better understand it from more “physical” point of view, we develop the model of self-consistent dipole (SCD). We consider spherical particles mutually magnetizing each other via dipole interaction.

Comparison of different energies

To compare energies obtained according different approximations we plot them as functions of scalarless distance $r/a$ for four different configurations ($\theta = 0^\circ, 30^\circ, 60^\circ, 90^\circ$). Slope of each curve define the force acting on particles. In the cases $\theta = 0^\circ, 30^\circ$ one can observe that all approximations qualitatively agree, and that the forces are attractive. In the case $90^\circ$ all approximations predict repulsive force. And for $60^\circ$ we have discrepancies in predictions for different models.

Discussion

1) It is interesting that more accurate models predict attraction for such a high $\theta$, thus enhancing particles ability to form clusters. 2) It looks like the changes in the magnetic energy model do not lead to changes in a shape factor of the sample.

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