Bias fields stabilize precession of nanorods in Magnetic Rotational Spectroscopy experiments

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Keywords: microrheology, magnetic nanoparticles, stability analysis

Magnetic Rotational Spectroscopy (MRS) is a microrheology technique used to characterize rheological properties of liquids from motion of externally driven elongated magnetic nanoparticles. Under the action of a planar rotating magnetic field, magnetic nanoparticles perform two kinds of planar rotational motions – synchronous and asynchronous. However, scientific literature has reported 3D rotational motions possibly caused by external bias fields (such as the earth's magnetic field). In this work, we aim to develop a 3D model for ferromagnetic nanorods rotating in Newtonian liquids under the action of external torques to further understand these dynamics. The theoretical model is developed based on a torque balance approach. The model shows dependence on two experimental parameters – frequency of rotating magnetic field and magnitude of the bias field. Phase portrait approach helps us categorize different kinds of dynamics. Stability analysis helps us theoretically quantify time needed to attain stabilization. We have also performed MRS experiments with Ni nanorods in viscous liquids. In experiments, we observe that non-planar dynamics exist even if the applied field is planar. A precessing field stabilizes the out-of-plane dynamics. This work has lead to development of better understanding of the out-of-plane dynamics of elongated nanoparticles subjected to planar rotating fields. This opens up avenues to apply these dynamics in microrheology and sensors for weak magnetic fields.