Phase field modeling on the magnetization vortex of ferromagnetic materials

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Abstract: A finite element based phase field model is developed to predict the domain evolution of ferromagnetic materials. The phase field model is based on a thermodynamic theory of ferromagnetic materials which employs the strain and magnetization as independent variables. The phase field equations are shown to reduce to the common micromagnetic model when the magnetostriction is absent and the magnitude of magnetization is constant. The strain and magnetization in the equilibrium state are obtained simultaneously by solving the phase field equations via a nonlinear finite element method. The finite-element based phase field model is applicable for the domain evolution of ferromagnetic materials with arbitrary geometries and boundary conditions. The stability of magnetization vortex in ferromagnetic nanostructures subjected to different mechanical strains is investigated by using a real space phase field model, which explicitly includes the coupling between magnetization and mechanical strain. Phase field simulations show that a compressive strain makes the magnetic vortex–antivortex pair stable in rectangular ferromagnetic platelets, which is unstable in the absence of an external magnetic field and strain. The magnetic clockwise (CW) and counterclockwise (CCW) vortex pairs disappear in ferromagnetic platelets under an external magnetic field through the annihilation of the vortex and antivortex, or through expulsion when external strain is absent. In the presence of tensile strain, the expulsion of CW and CCW vortices is suppressed in ferromagnetic platelets. However, external strain has less effect on the annihilation of CW and CCW vortices.

Keywords: Phase field model; Ferromagnetic domain; Magnetization vortex; Magnetostriction; Finite element method

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