A FEM Study of displacement sensor based on L-L Magnetostrictive/Piezoelectric block magnetoelectric composite material

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Introduction

Multiferroic magnetoelectric(ME) materials have stimulated a great amount of research interest in recent years cause its prospective application in multi-functional device. The study of multiferroic revived in 1990s thanks to composite ME material, In fact, the ME coupling property of composite material is described as a result of the product property. Magnetostrictive-piezoelectric composite material turns out to have the largest coupling coefficient. Also, the connectivity schemes have been studied. Different from traditional L-L laminate composite, we studied the L-L block comsopite via mathematical modelling and FEM method with COMSOL Multiphysics®.

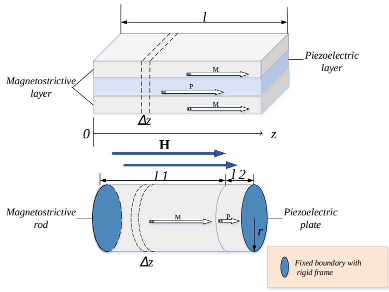

Fig 1. Connetivity scheme

Modelling

For magnetostrictive/piezoelectric ME composite material, its ruling equation is consist of both magnetostrictive and piezoelectric constitutive equation of course, both of whom are non-linear actually but in practical we consider the nonlinearity of magnetostrictive material only for its being quite strong.

Nonlinear constitutive equation for magnetostrictive material

$$\varepsilon_i = \frac{3}{2}\lambda_s\left(\left(\frac{m_i}{M_i}\right)^2 - \frac{1}{3}\right) \quad \varepsilon_x = -\frac{\lambda_s}{2}\left(\frac{M_x}{M_s}\right)^2, \varepsilon_y = -\frac{\lambda_s}{2}\left(\frac{M_y}{M_s}\right)^2, \varepsilon_z = \lambda_s\left(\frac{M_z}{M_s}\right)^2$$

Linear constitutive equation for piezoelectric material

$$D = e^T\varepsilon_e + \kappa E \qquad \sigma_e = c_e\varepsilon_e - eE$$

Implementaiton with COMSOL Multiphysics

Realization of material model

Magnetostrictive material

$$s - S_0 = c_E \cdot (\varepsilon - \varepsilon_0) - e^T \cdot E$$
$$D = D_r + e \cdot (\varepsilon - \varepsilon_0) + \kappa \cdot E$$
$$\varepsilon = \frac{1}{2}[(\nabla u)^T + \nabla u]$$
$$-\nabla \cdot \sigma = F_V \qquad \sigma = s$$
$$\nabla \cdot D = \rho_V \qquad E = -\nabla V$$

PZT

$$\sigma = c_E \cdot (\varepsilon - \varepsilon_0)$$

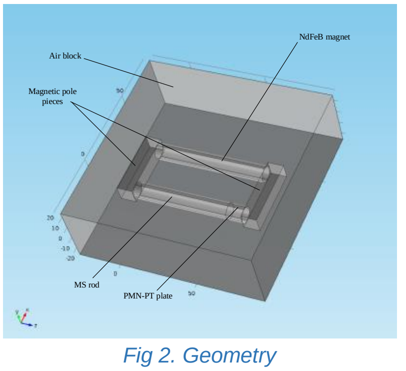

Fig 2. Geometry

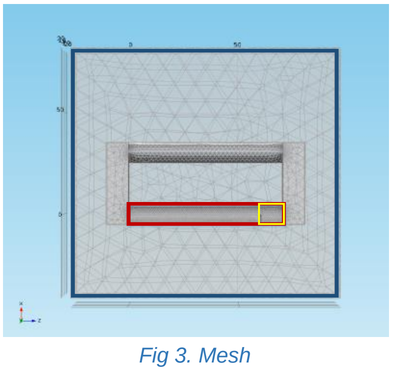

Fig 3. Mesh

Results and conclusion

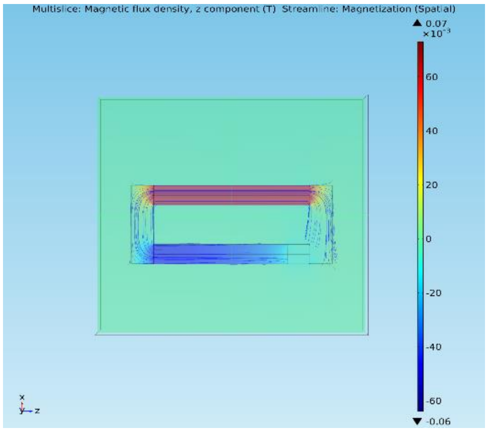

Fig 4. Magnetic flux density (z component)

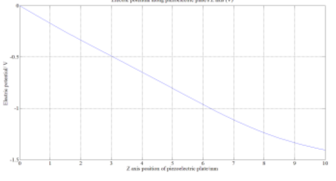

Fig 5. Electric potential (Z axis)

The z component of magnetic flux density is obtained, which is much the same as we expected for the desiged magnetic circuit. Also, the electric potential, absolute value of magnetic field, and total displacement are selected, whose trend and magnitude are in consistent with experiment and theoretical expectation.

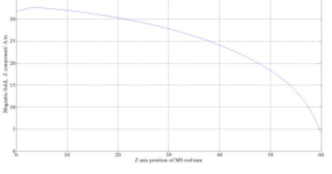

Fig 6. |Magnetic field| (z component)

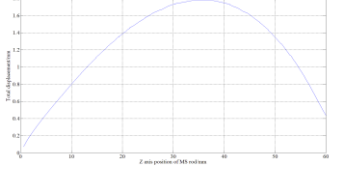

Fig 7. Total displacement (Z axis)