Theoretical and Computational Analysis of 180° Magnetic Domain Wall Behavior of a Magnetoelastic Thin Film Under Torsional Stress

The cause of the time-dependent field signal from a non-contact magnetoelastic-type torque transducer for an automobile shaft rotated at high speeds is studied both analytically and computationally. When the field signal is measured as a function of time, an oscillation in the signal is observed. This introduces an uncertainty in the measured magnitude of the applied torque. It was postulated that this effect was related to an instability in the demagnetized region of the domain wall present in the current design of the transducer. To investigate this possibility, two physical phenomena were investigated as possible sources of instability in the domain wall region. Firstly, the high-speed rotational effect on the magnetization known as the gyromagnetic effect was considered. Secondly, inverse magnetostriction due to the applied mechanical stress is studied by numerical simulation.

The basic theory of magnetization distribution used here is the micromagnetic theory, which assumes a spatial scale much larger than that of the individual dipoles in the crystal, but much smaller than the magnetic domains, and the numerical calculation technique is the Finite Difference method. Following Labonte's method of the numerical simulation of a domain wall structure in thin films, a thin slice of ferromagnetic material is modeled as being made up of rectangular prisms, and the total free energy equation is minimized and the magnetization distribution in a 180° magnetic domain wall is simulated under various stress conditions and then analyzed.

The effect of the stress on the stability of the domain wall was investigated by evaluating changes in the domain wall structure as a function of applied stress. In particular, attention was paid to the presence of surface magnetic poles. It was observed that the surface pole has a peak in magnitude about the center of the wall region, and that the position of the peak is stable under the varied stress. The magnitude and polarization of the peak is not completely related with the applied stress. However, both the magnitude and the direction of the total summation of the poles along the surface of the wall region are well related to the applied stress.

As a result, conclusive observations regarding the cause of the instability of the measured magnetic field have not been made. However, the observed pole distribution on the free surfaces of the domain wall suggest that the pole strength is spatially variable enough to influence measurements of the radial component of the external field above the torqued annular shaft. Future studies of this phenomenon should include simulations of thicker domain walls having an axisymmetric, three-dimensional geometry.