Barkhausen noise investigation using a micro-magneto-mechanically coupled material model

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Detection of biomagnetic signals of heart and brain typically requires high-performance magnetometers such as SQUIDs (superconducting quantum interference devices) or OPMs (optically pumped magnetometers). Since the aforementioned diagnostic facilities are intricate and costly, it is desirable to devise easy-to-use and inexpensive alternatives [1]. Composite magnetoelectric thin film sensors, involving magnetostrictive and piezoelectric thin film materials, are one such alternative [2]. The operation of composite magnetoelectric sensors is based on the interaction of multiple coupled fields: magnetic signals are transformed to electric signals via mechanics.

The performance of this sensor concept is partly limited by magnetic noise. In particular, we are interested in Barkhausen noise, i.e. the noise due to interaction of domain walls with defects. Since these interaction processes are intrinsic to the magnetostrictive material, we focus on the magneto-mechanical part and omit the piezoelectric part.

We use the generalized standard materials approach to model the micro-magneto-mechanical material behavior [3,4]. The formulation includes exchange energy, anisotropy energy, demagnetizing energy and elastic energy as conservative contributions. Furthermore, we include a dissipative contribution in the form of a dissipation potential. The coupled problem encompasses the following degrees of freedom: scalar magnetic potential, magnetization and displacement. We adopt the small strain setting for the mechanical problem and assume the strain to be composed of an elastic part, a magnetostrictive part and an eigenstrain contribution in an additive fashion. As for the magnetic problem, we achieve the constraint of magnetization to the unit sphere via the exponential map [5,6]. We use the finite element method to solve the coupled problem. By performing large sets of simulations with varying microstructures, we obtain ensembles of different signals. Our computation scheme for Barkhausen noise is based on averaging over these ensembles. We illustrate our magneto-mechanically coupled material model and our noise computation scheme with numerical examples.

References

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