Preisach energy potentials in models for magnetostriction

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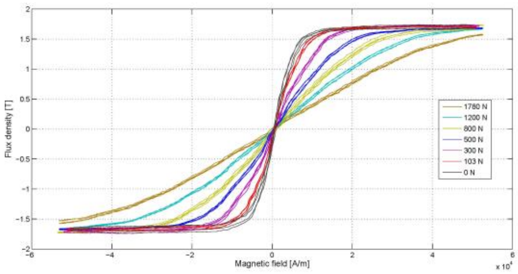
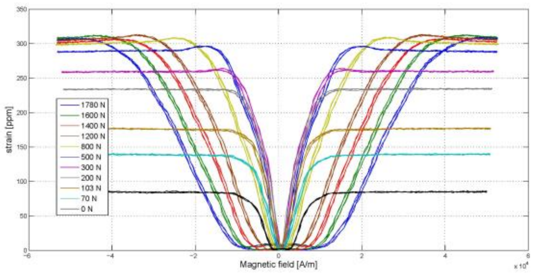
Magneto-elastic coupling in magnetostrictive materials such as Terfenol D or Galfenol manifests non-negligible hysteresis effects both in the magnetization and in the magnetostrictive material response. The observation that the experimental curves obtained at different constant values of the applied pre-stress exhibit a strong self-similar behavior leads to the hypothesis that a suitable mathematical model for this complex hysteresis behavior may consist of a single scalar Preisach operator and its energy potential operator. The auxiliary self-similar input variable for the hysteresis operators is defined as ratio between the magnetic field and a memoryless function of the stress. The main issue is to guarantee that the model is compatible with classical thermodynamics in the whole input range and that the balance between the power applied to the system and the potential increase coincides with the Preisach energy dissipation, which for cyclic processes admits the geometric representation in terms of the area of the hysteresis loop. In our setting, the reference magnetization hysteresis loop (left figure below) corresponds to the classical Preisach operator, while the “butterfly-shaped” magnetostrictive loop (right figure) is determined by the Preisach potential operator.

The original model proposed in [1] manifests a good agreement with experiments as long as the magnetic field remains bounded away from zero. For low fields, however, there is a discrepancy due to the fact that magnetic feedback becomes dominant. A modification of the model was proposed in [3] taking into account feedback effects and it was shown that the model preserves the thermodynamic consistency.

Understanding the energy balance is crucial for optimization of energy harvesting systems based on smart materials. A differential equation describing a simple magnetostrictive harvesting device was studied in [2] with the goal to study the efficiency of the process in dependence of the physical parameters of the device.

The idea of using Preisach potentials in modeling multifunctional materials was further extended to piezoelectricity. The thermodynamics of the temperature-dependent case was studied in [4], and an optimal control problem for piezoelectric energy harvesting was solved in [5]. This lecture will give an overview about the main mathematical aspects of the models.





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