Strain dynamics in a driven magnetostrictive ribbon

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Modeling dynamical properties of real physical systems is generally difficult. This task can be even more challenging when a physical system exhibits a broad spectrum of dynamical features not usually found in a single system. Surprisingly, such a physical system was realized quite early by Vohra and his group [1], almost two decades ago. Their study consisted of application of both sinusoidal (ac) and static (dc) magnetic fields to study the strain bifurcations in magnetostrictive ribbons. These authors report an extraordinarily large number of dynamical features such as (a) quasiperiodic (QP) route to chaos when the amplitude of the ac magnetic field $h_{ac}$ was increased in the presence of an additional dc magnetic field $h_{dc}$, (b) period doubling (PD) route to chaos when $h_{dc}$ was increased keeping the ac field fixed, (c) suppression and shift of period doubling bifurcation point and induced subcritical bifurcation under small amplitude near resonant conditions, (d) control of chaos, specifically, suppression and induced chaos with the application of a near resonant perturbation to one of the subharmonics, and (e) stochastic resonance. Modeling such a rich dynamics exhibited by a single system in terms of relevant strain and magnetic order parameters had remained a challenge until we proposed a model that recovers several dynamical features. The model equations are general enough that they can be adopted for explaining the dynamical features of magneto-elastic beam and magnetomartensites. Indeed, we devise a unified model with strain and magnetization as order parameters that predicts not only several of the above dynamical features of magnetostrictive ribbons but also several dynamical properties of magneto-elastic beam and magnetomartensites.

Our starting point is to write down the relevant free energies in terms of the two order parameters of the system. Here, we show that the model recovers the observed period doubling route to chaos as function of the dc field for a fixed ac field and quasi-periodic route to chaos as a function of the ac field keeping the dc field constant. The model also predicts induced and suppressed chaos under the influence of an additional small amplitude near resonant ac field. We also investigate the influence of a low amplitude near resonant field on the period doubling route. The model equations also exhibit symmetry restoring crisis with an exponent close to unity. The model can be adopted to explain certain results on magnetoelastic beam and magnetomartensitic ribbon under sinusoidal driving conditions. In the latter case, we find interesting dynamics of a periodic one orbit switching between two equivalent wells as a function of an ac magnetic field that eventually makes a direct transition to chaos under resonant driving condition. The model is applicable to materials with two order parameters in similar geometric conditions. Our analysis suggests rich dynamics in coupled order parameter systems like magneto-martensites and magnetoelastic materials. The general nature of these equations suggest much richer dynamics in ferromagnetic martensites samples that posses even stronger elastic and magnetic nonlinearities [2]. The model also explains some old results on internal friction studies of martensites.


References
