Magneto-elastic instabilities in soft-actuators

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1 Introduction

Traditional engineering design focusses on the load-bearing capabilities of materials, and develops functionality by adding the structure. However, hybridising with functional materials allows non-load bearing capabilities to be integrated, that simplify the design. Material anisotropy can effect this multi-functionality in complimentary ways, however its effects need to be understood.
In this talk, I will show some results in the production of tailored anisotropy in elastomers obtained by dispersing magnetic fibres into the elastomeric matrix [1]. Thin films of this multi–functional composite can be actuated when embedded into an external magnetic field. The presence of an instability controlled by the magnetic torque is highlighted that allows the composite to undergo a transition from a bending-only deformed configuration for the 0° fibre specimen, to twisting only, achieved for fibres at 90°. Intermediate angles show both bending and twisting as shown in Fig. 1 [2].

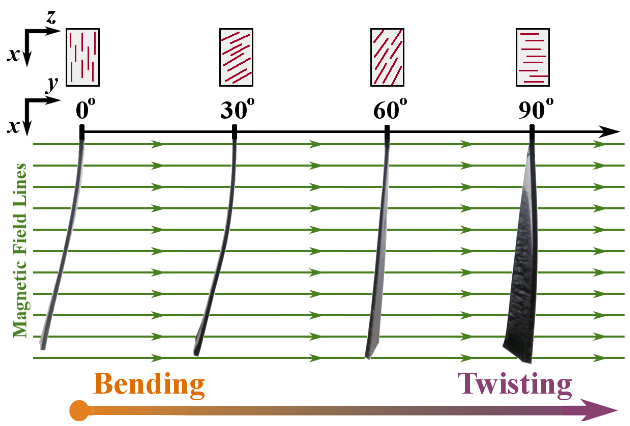

FIGURE 1 – Static Actuation of selected specimens in a homogeneous magnetic field for 0 °, 30 °, 60 ° and 90 ° fibre angles. A transition from pure bending for 0 ° to pure twisting for 90 ° is observed.

To describe this experimental data, we derive, in the consistent theoretical framework of 3D variational magneto-elasticity, the governing equations for the finite motion of a magneto-elastic rod reinforced with isotropic (spherical) or anisotropic (ellipsoidal) inclusions. In doing so, we consider the particles weakly and uniformly magnetised and therefore the potential energy of the system is additively decomposed into a purely mechanical term plus a part accounting for the interaction between the deformation and the applied field. The particles are further assumed rigid and firmly embedded into the elastomeric matrix, this in turns makes the demagnetization tensor dependent only on the current orientation of the particles and not on their stretch. It is further introduced an *ad-hoc* choice of the susceptibility that accounts for both magnetically isotropic or anisotropic materials. These assumptions made possible to derive a closed form expression for the quasi-static motion of the rod in terms of the external magnetic field and of the body forces that act on the beam. It is shown that under certain conditions on the particle distribution and the applied field, the motion of the beam is governed by the classical elastica equation with forcing terms controlled by the external magnetic field. The applications of this theory to the experimental data in [1] will be discussed and will allow us to highlight different kind of instabilities which can be hindered to exploit novel actuator configurations.

Références

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