# Equilibrium of kink-like torsional deformation of a magnetoactive elastomer in a magnetic field

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## 1. Introduction

In this work, we investigate the effect of the magnetoelastic moment of forces on the torsional deformation of a magnetoactive elastomer (MAE) beam. The interplay between magnetic fields and mechanical elasticity in soft matter materials like MAEs offers significant potential for tunable and active soft components.

## 2. Problem Setup

We consider a thin, long MAE beam with an aspect ratio of *a* >> *b* >> *c*. Initially, in the absence of an external magnetic field (*H* = *0*), the beam is subject to a uniform torsional deformation.

This uniformly twisted beam is then placed in a uniform external magnetic field, oriented such that **H || b**.

## 3. Kink-Like Localization

It was found that the moment of force generated by the magnetic field in a magnetized MAE can cause localized kink-like torsional deformation in the MAE beam.

The effect of the moment of forces created by the magnetic field leads to the localization of the torsion region, forming a kink-shaped torsion of length *l*, outside of which there is no torsion.

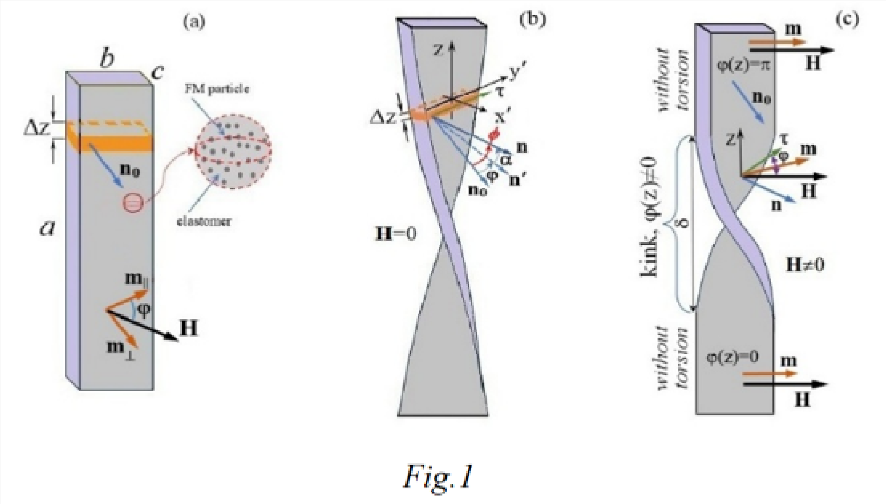


*Fig. 1. Schematic layout of the MAE beam showing (a) original state, (b) uniform torsional deformation at H=0, and (c) localized kink-shaped torsion in a magnetic field.*

## 4. Theoretical Model

During the torsion of the beam, its initial normal vector rotates around the *z* axis and then around the *y'* axis, transforming into the normal vector of the deformed beam. The rotation corresponds to the angle between the magnetic field vector **H** and the unit vector directed along the selected section.

The total torsional bending energy of the beam is written and minimized via variational derivatives to obtain a differential equation describing the state.

$$W = \int_{-\infty}^{+\infty} (w_e(z) + w_m(z))dz = -\frac{aS}{2}\chi_\perp H^2 + \frac{1}{2}\int_{-\infty}^{+\infty}\left(GJ\left(\frac{\partial\varphi}{\partial z}\right)^2 - S\Delta\chi H^2\cos^2\varphi\right)dz$$

$$GJ\frac{\partial^2\varphi}{\partial z^2} - S\Delta\chi H^2\cos\varphi\sin\varphi = 0$$

$$\varphi(z) = 2\arctan e^{z/\lambda}\text{ , where } \lambda = \frac{1}{H}\sqrt{\frac{GJ}{S\Delta\chi}}$$

## 5. Conclusions

A kink-like torsion can be successfully stabilized in an elastomer beam by an external magnetic field, provided that the characteristic kink length is less than the total length of the beam (*l* < *L*).

### References

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[2] L. D. Landau and E. M. Lifshits, Theory of Elasticity, Pergamon Press, New York (1959).