Residual magnetization of magnetic field-induced bending deformation of a magnetically active elastomer beam

A. V. Kyryliuk, V. M. Kalita, Yu. I. Dzhezherya, S. V. Cherepov, Yu. B. Skirta, S. A. Reshetnyak, A. V. Bodnaruk, S. M. Ryabchenko
Institute of Physics, NAS of Ukraine, Prospekt Nauky 46, Kyiv 03028, Ukraine
Institute of Magnetism of the NAS of Ukraine and MES of Ukraine, 36-b Vernadsky Blvd., Kyiv 03142, Ukraine
National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Prospekt Peremohy 37, Kyiv 03056, Ukraine
vmkalita@ukr.net
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1. Introduction

Magnetoactive elastomers (MAE), which belong to the class of "smart" materials, are composites with a filler of magnetic micro- or nanoparticles in a matrix of a highly elastic elastomer.
We studied the bending of a beam MAE with one fixed end and the other end free, induced by a transverse magnetic field.

2. Experimental Setup

In the experiment, we measured the displacement of the free end of the beam, which is indicated by *d* in Fig. 1. During bending, a small section of the beam ΔV rotates in the *yz* plane, the angle of rotation for the selected section of the beam is indicated by φ(*z*).
The angle between the magnetic field **H** and the normal to this small section of the beam is equal to the difference β - φ(*z*).

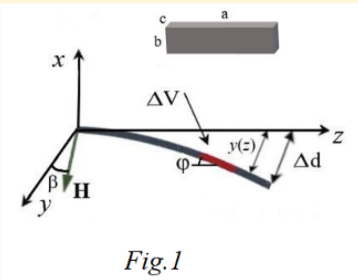

Fig. 1. Schematic of the MAE beam bending in a transverse magnetic field H with coordinate axes and angle notations.

3. Results & Discussion

The magnitude of the bending is affected by the direction of the magnetic field sweep. The curves δ(**H**), where δ = *d/L* (*L* — length of the beam), for an increasing or decreasing magnetic field are shifted against each other (Fig. 2).

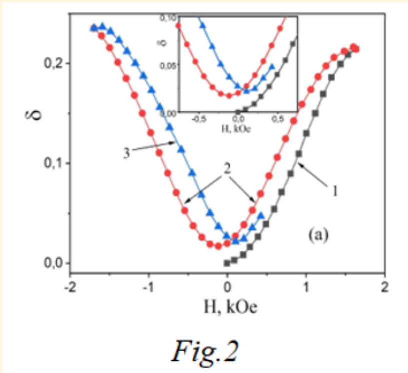

Fig. 2. Field-induced bending deformation δ vs. magnetic field intensity H, showcasing the hysteresis curves and residual states.

Key Characteristics:

- The sign of δ(**H**) does not depend on the sign of the field.
- When the direction of the field changes, **H** → -**H**, the beam bends in the same direction.
- In a small field, the deformation is proportional to $\mathbf{H}^2$.
- After the first introduction of the output of the positive field, the beam acquires residual plastic deformation.

4. Mechanisms of Hysteresis

Hysteresis δ(**H**) can occur due to:

1. Averaging of local plastic (inelastic) deformations of the elastomer matrix in the vicinity of magnetic nanoparticles.
2. Slow evolution of displacements of magnetic nanoparticles and matrix environments in the vicinity of their fixation due to the magnetorheological effect.

5. Conclusion

- The change in the shape of the sample occurs mainly due to elastic deformations of the MAE matrix.
- When the field is removed, the shape of the MAE is almost completely restored.
- The magnitude of the contribution to the bending from plastic deformation is directly proportional to the square of the magnetic field strength.
- This fully explains why, due to the residual bending, there is no change in the sign of the bending when the field sign is inverted.

References

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