Magnetostriction of Polycrystalline TbDy at Cryogenic Temperatures

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Outline

- Introduction
- Recent Measurements at 77 K
- Thermal Expansion Measurements
- Future Work
- Conclusions
Materials:

$\text{Tb}_{0.66}\text{Dy}_{0.40}$
- Estimated anisotropy minima at 77K

$\text{Tb}_{0.76}\text{Dy}_{0.24}$
- Estimated anisotropy minima at 4K

Rolling:

Plane Rolled:

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\sigma
\rightarrow
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Form Rolled:

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\sigma
\rightarrow
\sigma
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Plane rolled

Tb$_{0.6}$Dy$_{0.4}$ specimen was (plane rolled 55 %, 350$^\circ$C 1.5 hrs) x2

\[ \text{Tb}_{0.6}\text{Dy}_{0.4} \text{ specimen (plane rolled 55 %, 350$^\circ$C 1.5 hrs) \Rightarrow 3000ppm at 6 ksi, 4.5 Oe} \]
Plane rolled

$\text{Tb}_{0.6}\text{Dy}_{0.4}$ specimen was (plane rolled 25 %, 350$^\circ$C 3 hrs) x4
Texture Determination by Measurement of Thermal Expansion

- Anisotropic thermal expansions reported for single crystal Tb/Dy at 400°C\(^1\)
  - Tb: \(9.1 \times 10^{-6}/\text{K} \text{ (a-axis), } 17.9 \times 10^{-6}/\text{K} \text{ (c-axis)}\)
  - Dy: \(4.7 \times 10^{-6}/\text{K} \text{ (a-axis), } 20.3 \times 10^{-6}/\text{K} \text{ (c-axis)}\)

- Measured for single crystal (30°C to 300°C)
  - Tb: \(3.8 \times 10^{-6}/\text{K} \text{ (a-axis), } 14.5 \times 10^{-6}/\text{K} \text{ (c-axis)}\)
  - Dy: \(3.4 \times 10^{-6}/\text{K} \text{ (a-axis), } 15.2 \times 10^{-6}/\text{K} \text{ (c-axis)}\)
  - Tb\(_{0.6}\)Dy\(_{0.4}\): \(3.1 \times 10^{-6}/\text{K} \text{ (a-axis), } 15.2 \times 10^{-6}/\text{K} \text{ (c-axis)}\)
  - Plane-rolled Tb\(_{0.6}\)Dy\(_{0.4}\): \(4.0 \times 10^{-6}/\text{K} \text{ (rod-axis, ideally would be a-axis value)}\)
  - Form-rolled Tb\(_{0.6}\)Dy\(_{0.4}\): \(4.5 \times 10^{-6}/\text{K} \text{ (rod-axis, ideally would be a-axis value)}\)

- Thermal expansion measurements offer a relative measure of texture useful for comparing specimens.

Form-rolled vs. Plane-rolled at 10 K

As expected, even with a higher applied load, the form-rolled specimen exhibits lower magnetostriction than the plane-rolled specimen.

Curve shows 10 K magnetostriction
Magnetostrictive Materials: Future Work

Textured polycrystals will be produced as outlined for various degrees of deformation and the magnetostriction will be measured along the axis which coincides with the rolling direction.

X-ray diffractometry, hardness testing, metallography, and bulk thermal expansion measurements will be used to characterize the microstructure.

Begin to investigate machinable, TbDyZn single crystals

New cryostat for magnetostrictive testing between 4 K and 77 K

A sealed rod filled with TbDy chunk material will be sent to American Superconductor for a drawing test.

Cycling tests
Magnetostrictive, Cryogenic Heat Switch

Superconducting solenoid: bi-metallic housing compensates for crystal expansion

Lead to experiment

Fixed contact

Lead to cooler

Magnetoestrictive polycrystal, ThDy
No return spring necessary

Double, re-entrant insulator, stainless steel provides 15 microwatts/K isolation

Drawing scale 1/1

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Second Generation MagnetostRICTive
Superfluid Helium Valve

superconducting solenoid
LTCS or HTCS

terbium dysprosium actuator

dial and seat

cycled open &
close 300+
times

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