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MmeMeim05-001 - Magnetocrystalline Anisotropy Energy Analysis by Rotational Magnetic Barkhausen Noise in Low-Carbon Cryogenic Fe–9%Ni Steel

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Introduction

Catastrophic failure of mechanical components can result in substantial losses, making the development of efficient methods for monitoring and predicting service life essential. In ferromagnetic materials, magnetocrystalline anisotropy energy (MAE) is associated with preferential magnetization along specific crystallographic directions. Although MAE is typically estimated using crystallographic texture obtained via X-ray diffraction (XRD), this approach requires complex experimental procedures and is unsuitable for rapid field applications.

Objectives

This study aims to evaluate the capability of determining the magnetocrystalline anisotropy energy (MAE) of a cryogenic Fe–9%Ni alloy using the rotational Magnetic Barkhausen Noise (MBN) nondestructive technique, comparing the results with those estimated from the texture obtained via XRD.

Methodology

Table 1. Chemical composition of the studied alloy (wt. %)

Ni	Mn	Si	Cr	C	Mo	Nb	P	S	Fe
8.570	0.560	0.217	0.102	0.058	0.045	0.029	0.002	0.002	Bal.

Nomenclature	Heat treatment temperature	Time (min)
FeNi_AR	-	-
FeNi_100	900 °C	100
FeNi_1000	900 °C	1000

Figure 1. Flowchart of the nomenclature and processing of each sample.

- MAE in Polycrystalline Materials: generalized spherical harmonic series expansion method for the orientation distribution function (ODF):

$$\bar{E}(\theta,\varphi) = \oint E(\theta,\varphi,g) f(g) dg$$

Results and Discussion

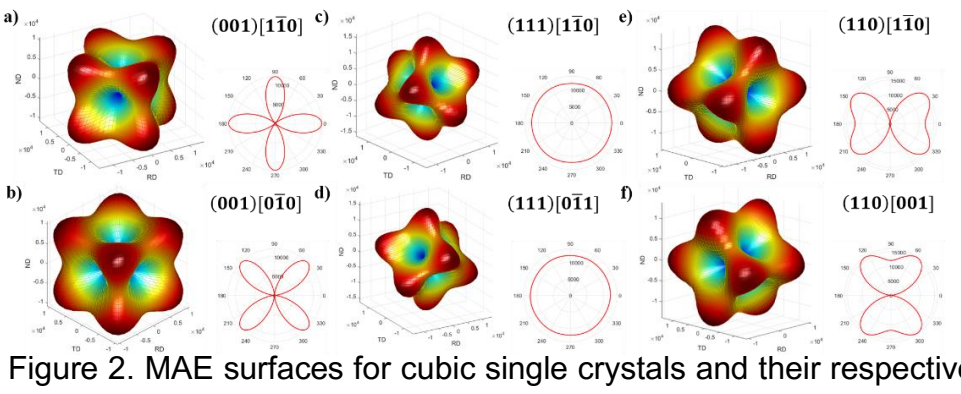


Figure 2. MAE surfaces for cubic single crystals and their respective representations in the RD-TD plane for the main texture components.

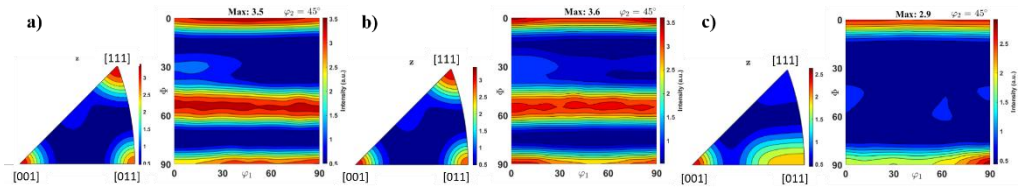


Figure 3. Crystallographic texture determined by XRD, represented by Z-IPF and ODF at the ϕ_2 = 45° section for samples (a) FeNi_AR, (b) FeNi_100, and (c) FeNi_1000.

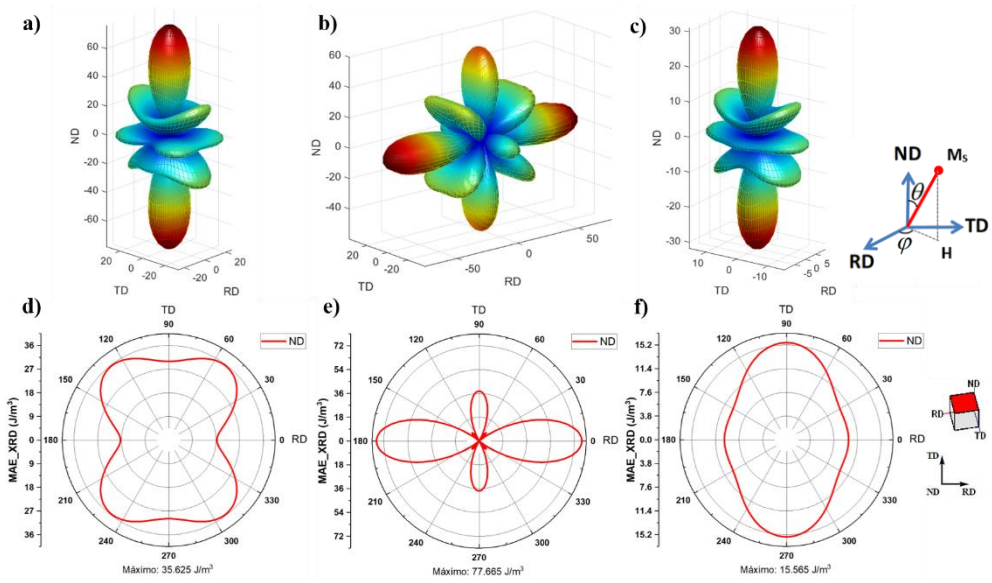


Figure 4. 3D surface simulation of MAE (a), (b), (c) and polar representation of MAE in the RD-TD plane (d), (e), (f) for the FeNi_AR, FeNi_100, and FeNi_1000 samples, respectively.

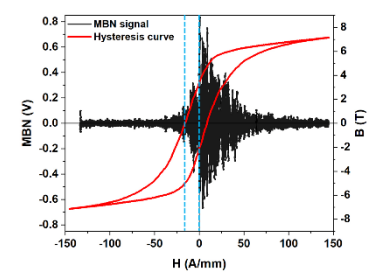


Figure 5. Total MBN signal measured in the rolling direction (0°), highlighting the range between saturation and remanence (S-N), and the corresponding hysteresis loop of the FeNi_AR sample excited at 125 Hz.

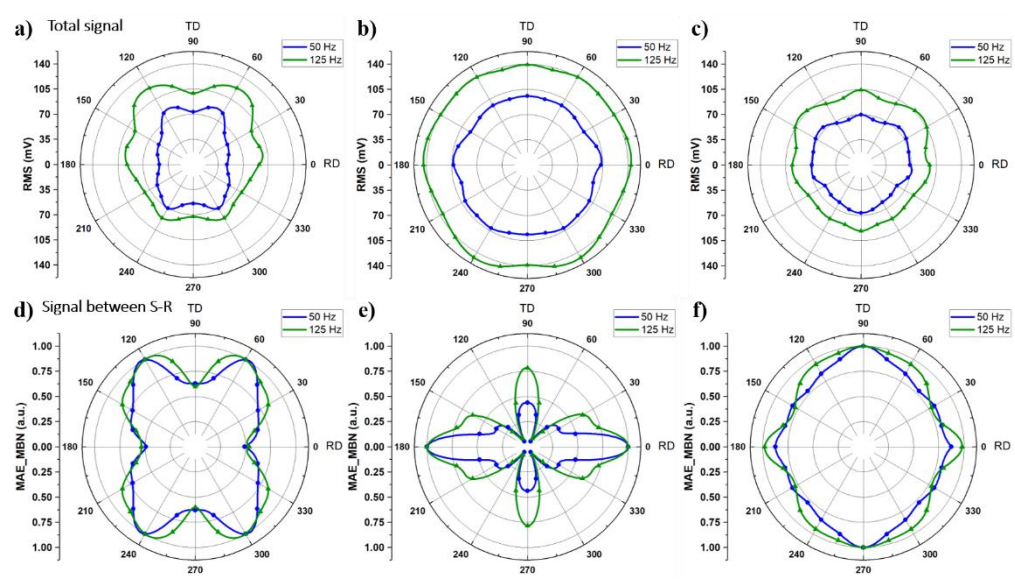


Figure 6. Angular dependence of RMS values at excitation frequencies of 50 Hz and 125 Hz, obtained from the full MBN signal (a), (b), (c), and MAE estimated from normalized RMS data within the MBN signal range between saturation and remanence (d), (e), (f) for samples FeNi_AR, FeNi_100, and FeNi_1000, respectively.

Conclusions

The results indicate that rotational MBN is capable of adequately estimating MAE behavior in the Fe-9%Ni alloy and confirm that this correlation arises from the influence of crystallographic texture on the magnetization process within the signal range between saturation and remanence.

References and Acknowledgments

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