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MmeCa09-004 - Assessment of Magnetocrystalline Energy Estimation from Crystallographic Texture in a Cryogenic Fe–9%Ni Alloy by Electron Backscatter Diffraction

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Introduction

The combination of various metallurgical parameters, such as grain size, chemical composition, microstructure, crystallographic texture, and internal stress state, influences the material's anisotropic nature. In ferromagnetic materials, magnetization occurs more readily along specific preferred crystallographic directions, highlighting the influence of magnetocrystalline anisotropy energy (MAE). Thus, MAE strongly influences how these materials are utilized and manufactured, making its study a subject of significant interest in recent decades.

Objectives

This study aimed to evaluate the capability of the electron backscatter diffraction (EBSD) technique to determine the average MAE of a cryogenic Fe–9%Ni alloy subjected to different annealing treatments designed to induce distinct crystallographic textures.

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.

- Direct method (DM): average individual contribution of the crystallographic orientations of each grain

$$E(\theta,\varphi,g) = K_0 + K_1\left(\alpha_{g1}^2\alpha_{g2}^2 + \alpha_{g2}^2\alpha_{g3}^2 + \alpha_{g1}^2\alpha_{g3}^2\right) + K_2\left(\alpha_{g1}^2\alpha_{g2}^2\alpha_{g3}^2\right)$$

$$\bar{E}(\theta,\varphi) = \frac{1}{N_g}\sum_{i=1}^{N_g} E(\theta,\varphi,g_i)$$

- Generalized spherical harmonic series expansion method for the orientation distribution function (ODF):

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

- Statistical analysis of the number of grains:

$$A_{nec} = N_g D_g^2$$

- Mean squared error (MSE):

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2$$

Results and Discussion

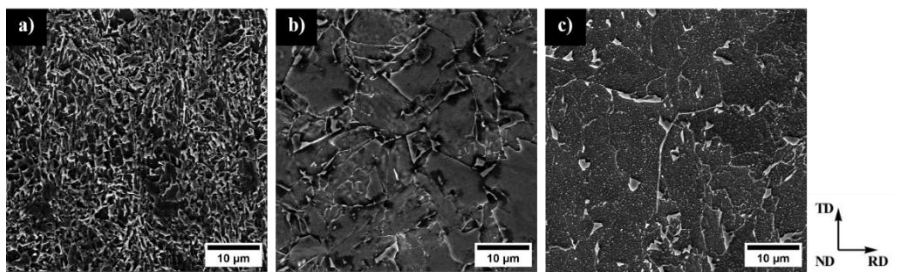


Figure 2. Microstructure observed by SEM of the RD–TD plane on surface of samples: (a) FeNi_AR, (b) FeNi_100, and (c) FeNi_1000.

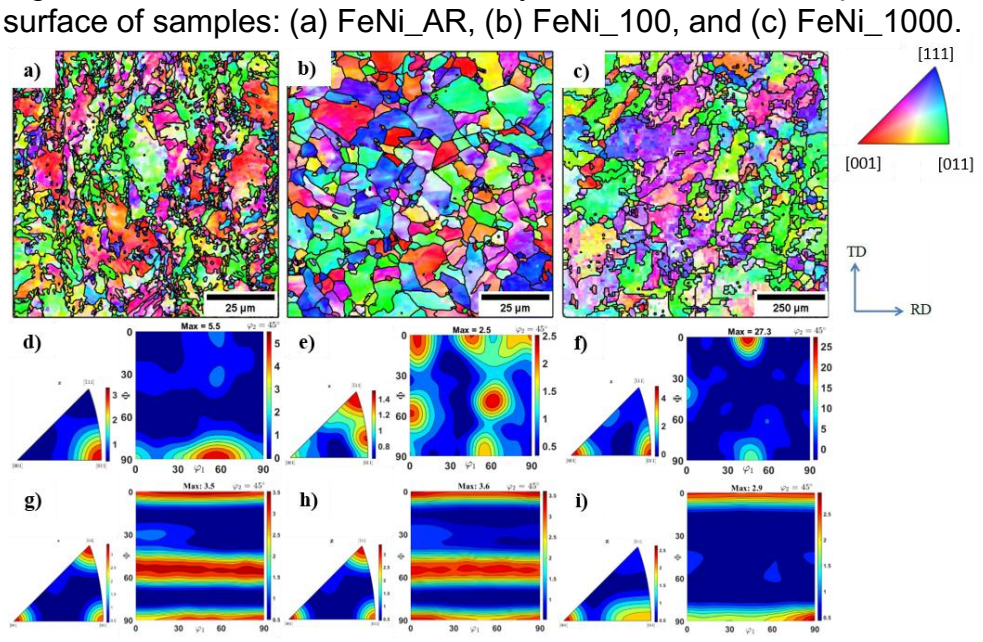


Figure 3. EBSD orientation maps (a), (b), (c); Z-IPF and ODF at ϕ_2 = 45° measured via EBSD microtexture (d), (e), (f) and via XRD macrotexture (g), (h), (i) for samples FeNi_AR, FeNi_100, and FeNi_1000, respectively.

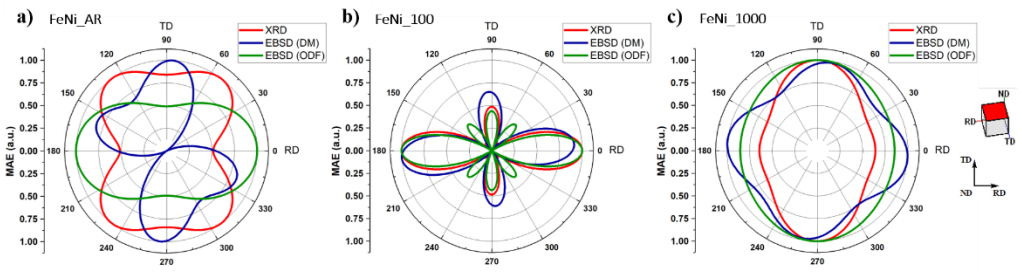


Figure 4. MAE behavior measured by XRD (red curve) and by EBSD using the direct method (blue curve) and the series expansion method (green curve) for (a) FeNi_AR, (b) FeNi_100, and (c) FeNi_1000.

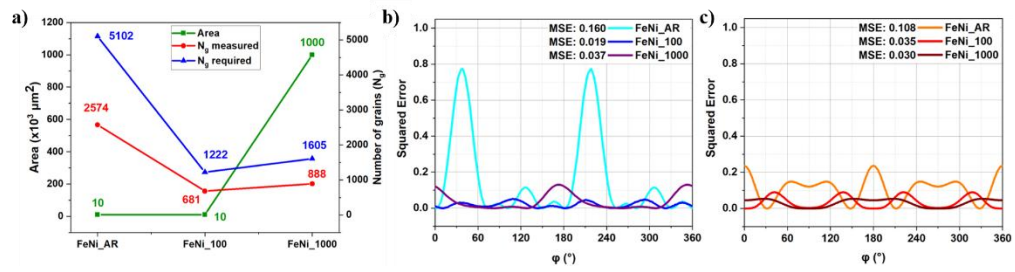


Figure 5. (a) Relationship between the orientation map scan area and the number of grains measured and required to estimate the MAE from EBSD; variation of the MAE squared error calculated via EBSD as a function of the angle ϕ and the mean squared error (MSE) estimated based on XRD data for the (b) direct method and (c) series expansion method.

Conclusions

The results demonstrate that EBSD is a reliable tool for predicting the overall MAE in Fe–9%Ni alloys, provided that adequate statistical representativeness of the measured microtexture is ensured.

References and Acknowledgments

T. L. Manh *et al.* Electron backscatter diffraction helps direct calculation of magnetocrystalline anisotropy energy in API 5L steels, Materials Characterization. 141 (2018) 86-96. https://doi.org/10.1016/j.matchar.2018.04.033.
Y. He *et al.* Angular magnetic Barkhausen noise of incline- and cross-rolled non-oriented electrical steel sheets, Materials Characterization. 177 (2021) 111200. https://doi.org/10.1016/j.matchar.2021.111200.
S. K. B. de Lima *et al.* Determination of magnetocrystalline anisotropy energy from the crystallographic macrotexture of an SAE 1075 steel subjected to different thermomechanical treatments, Materials Science & Engineering B. 332 (2026) 119658. https://doi.org/10.1016/j.mseb.2026.119658.

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