

Modelling Unidirectional Anisotropy in Ultra-Soft Co-based Amorphous Alloys with the Jiles-Atherton Framework Using Magnetisation-Dependent Pinning and an Effective Bias Field

Michał Nowicki^{1, a)}, Roman Szewczyk^{1, b)}, Andriy Marusenkov^{2, c)},
Anton V. Nosenko^{3, d)}, and Vasyl V. Kyrylchuk^{3, d)}

¹*Warsaw University of Technology, Institute of Metrology and Biomedical Engineering, 02-525 Warsaw, Poland*

²*Lviv Center of the Institute of Space Research, 79060 Lviv, Ukraine.*

³*G. V. Kurdyumov Institute for Metal Physics of the N.A.S. of Ukraine, UA-03142 Kyiv, Ukraine*

^{a)} *Corresponding author: michal.nowicki@pw.edu.pl*

^{b)} *roman.szewczyk@pw.edu.pl*

^{c)} *marand@isr.lviv.ua*

^{d)} *itrij@ukr.net*,

Abstract. Ultra-soft Co-based amorphous alloys, such as MELTA MM-5Co (nominal composition $\text{Co}_{67}\text{Fe}_3\text{Cr}_3\text{B}_{12}\text{Si}_{15}$), reach an initial relative permeability above 10^5 and have near-zero magnetostriction. They are routinely used as cores of fluxgate magnetic sensors. Under certain processing conditions, these alloys develop unidirectional anisotropy that appears as a horizontal shift of the hysteresis loop. We show that this behaviour can be reproduced within the isotropic Jiles-Atherton framework by adding two ingredients to the standard model: an effective bias magnetic field H_{const} that represents exchange-bias coupling between the soft amorphous matrix and semi-hard magnetic phases, together with a magnetisation-dependent pinning function $k(M)$. We performed a joint identification of two states of the same alloy (as-received and demagnetised) using differential evolution with a Gaussian-weighted sum of squared errors. The direct ordinary differential equation formulation, which remains mathematically valid when k depends on M , was used throughout. Both samples reached a coefficient of determination $R^2 > 0.9995$ (0.999587 and 0.999599). Intrinsic parameters were shared by the two samples; only the sample-specific bias fields differed (+0.133 A/m for the as-received sample, essentially zero after demagnetisation), which captures the loop shift and its removal. The structurally isotropic amorphous matrix is well described by the standard Langevin anhysteretic curve, while the macroscopic unidirectional anisotropy reduces to an additive bias field. This keeps the model physically transparent and avoids the complications of anisotropic anhysteretic extensions.