

Using Experimental Data And Differential Evolution To Model And Understand Magnetic Hysteresis

S. Thieltges¹, U. Hartmann²

¹Fraunhofer Institute for Nondestructive Testing IZFP, Saarbrücken, Germany

²Saarland University, Institute of Experimental Physics, Saarbrücken, Germany

Abstract

This study presents a comprehensive approach to simulating and optimizing the magnetic behavior of hard magnetic samples using COMSOL Multiphysics, with a specific focus on a one-sided access scenario. The core objective is to bridge the gap between experimental measurements and computational simulations by incorporating measured data into the modeling process, thereby enhancing the accuracy and predictive capability of the model.

A detailed 3D model of the experimental setup was constructed using the Magnetic Fields interface within COMSOL Multiphysics, which is critical for validating the simulation results with respect to the measurements. The Jiles-Atherton model, known for its efficacy in describing the hysteresis behavior of magnetic materials, was employed to characterize the magnetic properties of the hard magnetic sample. In order to effectively incorporate the measurement data into the simulations, we utilized the MATLAB LiveLink for COMSOL. This incorporation facilitated the seamless transfer of experimental data into the simulation environment. A differential evolution algorithm, implemented in MATLAB, was coupled to the COMSOL model to optimize the Jiles-Atherton parameters for the sample under investigation. The algorithm is particularly well suited for handling the nonlinear and complex nature of the parameter space involved in magnetic hysteresis modeling. Initial parameter estimates were derived from preliminary measurements in order to start the optimization process. The differential evolution algorithm iteratively adjusts the Jiles-Atherton parameters of the sample, aiming to minimize the deviation between the simulated magnetic response and the experimental data. Designed for evaluating the difference between the modeled and measured hysteresis loops, the algorithm's fitness function focuses on key characteristics such as coercivity, remanence, and the shape of the hysteresis curve.

Throughout the optimization, the simulated results were periodically compared with the measurement data to ensure convergence towards the most accurate parameter set. This iterative process continued until the difference between the simulation and the experimental data was minimized to an acceptable level, indicating that the Jiles-Atherton parameters had been effectively tuned to reflect the actual magnetic behavior of the sample.

The results of this study yield a significant improvement in the accuracy of the simulated hysteresis loops as compared to simulations based on non-optimized parameters. The optimized parameters clearly provide a much more realistic representation of the experimental data, validating the efficacy of the differential evolution algorithm in fine-tuning the Jiles-Atherton parameters. Additionally, the integration of the MATLAB LiveLink with COMSOL Multiphysics proved to be a robust approach for incorporating experimental data into complex magnetic simulations.

In conclusion, the present study highlights the potential of using advanced optimization techniques and integrated simulation environments to greatly improve the modeling of magnetic systems. By accurately simulating the magnetic behavior of hard magnetic samples magnetized with a one-sided access yoke, this approach provides a valuable tool for designing and analyzing magnetic devices. Future work will explore the extension of the methodology to other magnetic

configurations and the inclusion of additional physical phenomena to further improve the model's predictive capabilities.

Reference

S. Thieltges et al., Reconstruction of the Ferromagnetic Hysteresis in the Rayleigh Regime by Means of Impedance Analysis of the Excitation Coil. *J Nondestruct Eval* 43, 37 (2024).
<https://doi.org/10.1007/s10921-024-01055-y>

A. J. Bergqvist, A Simple Vector Generalization of the Jiles-Atherton Model of Hysteresis. In: *IEEE Trans. Magn.* 32 (5), 1996, S. 4213–4215. DOI: 10.1109/20.539337.

Figures used in the abstract

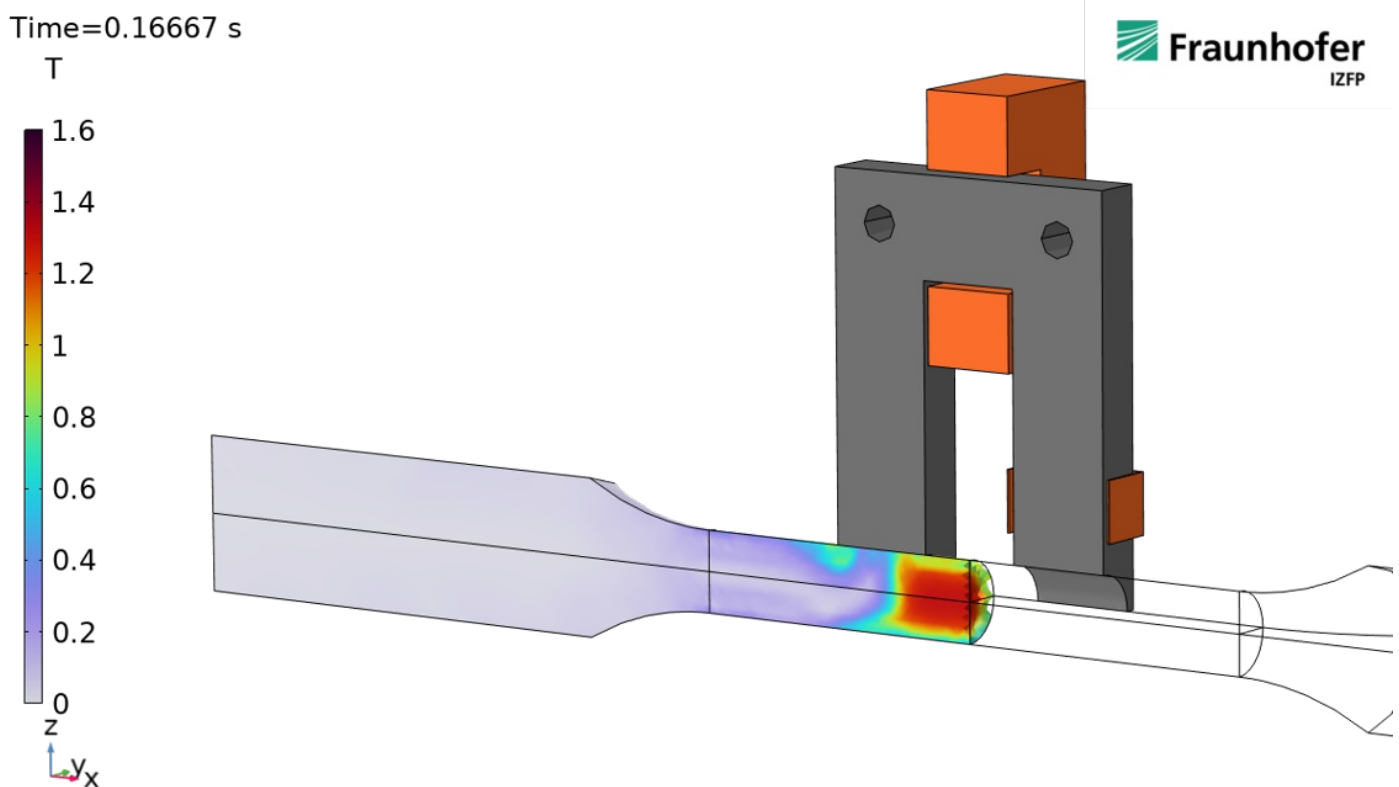


Figure 1 : Magnetized sample with a one-sided access yoke.