# Dynamic hysteresis characterization of Fe-Si materials: comparison of magnetic performances

Vittorio Bertolini[a], Marco Stella[a], Antonio Faba[a], Ermanno Cardelli[a]

[a] *University of Perugia, Department of Engineering, Via G. Duranti 93, Perugia, 06125, Italy*

The following work presents a comparison of magnetic performances of three different Fe-Si materials. Different shapes have been considered for each material. In particular, stripes, toroidal cores and disks have been experimentally characterized. An alternative sinusoidal magnetic field has been imposed to characterize stripes and toroids, while a rotating magnetic field has been imposed to characterize the disks. Measurements have been performed in a wide range of magnetic induction and frequencies to realize a complete characterization of the materials.

*Keywords:* Fe-Si Magnetic Materials; Magnetic Characterization; Scalar Hysteresis; Vectorial Hysteresis

## 1. Introduction

Fe-Si is one of the most famous alloys for magnetic materials. The high magnetic permeability and the high magnetic saturation induction make it the most adopted in the low-medium frequency range (approximately from the industrial frequencies to some kHz). Due to the variety of possible applications for these materials, continuous research is performed on these alloys to optimize specific aspects (linearity, magnetic saturation, permeability, static losses, dynamic losses, vibrations, mechanical stress…). So, a plethora of different Fe-Si materials are available in the market, mainly characterized by different Si quantity (and other minor alloy elements) and different manufacturing processes. Typically, the nominal performances of a material reported on a datasheet are obtained after a standard characterization, such as Epstein Frame or volt-amperometric method. However, different kinds of magnetic characterization could provide different information about the performances of the material. For this reason, in this work, three commercial Fe-Si materials have been considered for a thorough comparison: a NO10 and a NO20 by Backlack and a NO10 JNEX by JFE Steel (NO stays for Non-Oriented material). In this case, just the magnetic properties have been investigated. Different shapes have been taken in consideration: stripes, toroids and disks. For each shape, a different characterization has been performed. In particular, stripes have been characterized with the Epstein frame technique, toroids have been characterized with volt-amperometric technique, while disks have been characterized imposing a rotational magnetic (measuring B and H on the x and y axes) [1-4]. In this way, there is the possibility to realize a very accurate characterization of the materials. Furthermore, it can be observed if and how the behaviour of each material can change, according to the specific measurement, especially in comparison with the other sample.

## 2. Results and discussion

Measurements have been performed in the frequency range from 50 Hz to 3 kHz. The nominal magnetic induction range was from 0.2T to 1.5T (reduced for the higher frequencies, when it becomes more and more difficult to magnetize the material). In this document, some of the results are shown. In Fig. 1, different BH loops are presented. In particular, BH loops from Epstein measurements are shown for NO20 in Fig. 1(a), BH loops from toroid measurements are shown for NO10 JNEX in Fig. 1(b), BH loops from disk rotational measurements are shown for NO10 in Fig. 1(c). The working frequency is 100Hz in all the cases.

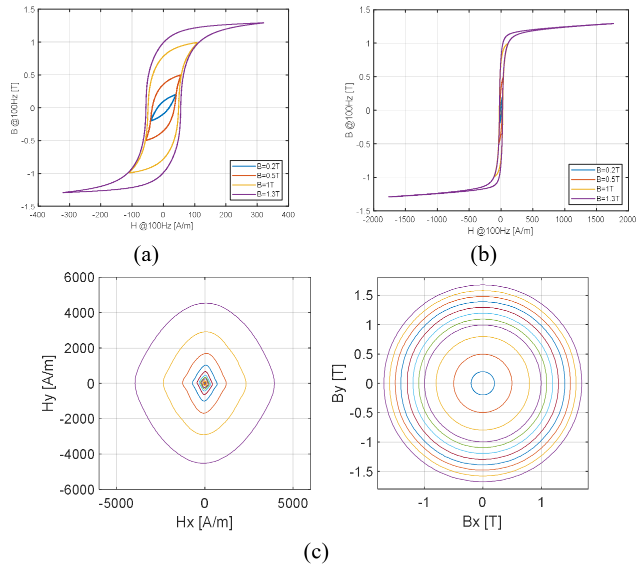


Figure 1: BH loops measured at 100 Hz with different techiques. (a) Epstein measurements performed on the NO20 material. (b) Toroidal volt-amperometric measurements performed on the NO10 JNEX material. (c) Disk rotational measurements performed on the NO10 material.

From a first glance, it can be seen how JNEX material seems to be the most performing material (very narrow BH loops). A complete comparison for all the frequencies will be proposed at the conference, showing exactly the relationships in terms of losses among the three materials.

## References

[1] Antonelli, E., Cardelli, E., Faba, A., “Single sheet tester efficiency macromagnetic analysis”, (2005) Journal of Applied Physics, 97 (10), art. no. 10E103.

[2] M. Stella et al., “Experimental measurements and numerical modelling of additively manufactured Fe-Si cores”, Journal of Magnetism and Magnetic Materials, vol. 591, 2024. doi:10.1016/j.jmmm.2024.171752.

[3] Cardelli, E., Faba, A., “Vector hysteresis measurements of not oriented grain SiFe steels by a biaxial hall sensors array”, (2014) Physica B: Condensed Matter, 435, pp. 34-39.

[4] Cardelli, E., Faba, A., “A benchmark problem of vector magnetic hysteresis for numerical models”, (2014) IEEE Transactions on Magnetics, 50 (2), art. no. 6749234, pp. 1049-1052.