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STUDI DI PERUGIA



A Benchmark Problem of Vector Magnetic Hysteresis for Numerical Models

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TEAM-3 July 2, 2013





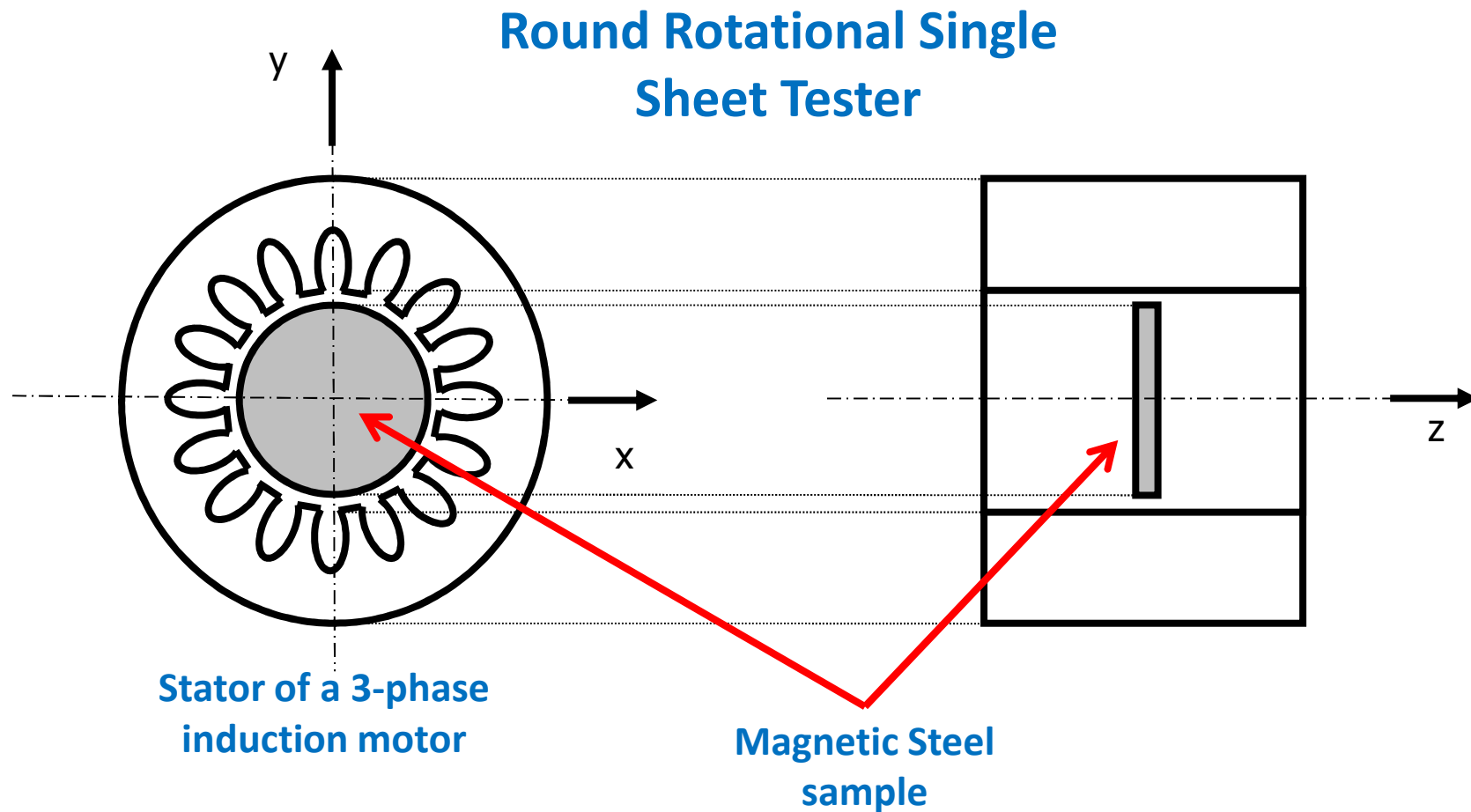
Overview



- **Vector hysteresis modeling applications:**
Transformers, Electrical Motors, Generators ...
- **The modeling difficulties for the magnetic steels:**
2-D phenomena, grain size and orientation, structural stress, presence of enclosures ...
- **Phenomenological approaches:**
models based on a parameters identification starting from a suitable experimental data set.
- ***Benchmark for 2-D characterization of NOG and OG magnetic steels***
to stimulate the discussion and the comparison among the different modeling techniques at macro-magnetic scale in use in the scientific community.
- ***Vector Hysteron Model***
a possible approach to model vector hysteresis in magnetic steels.



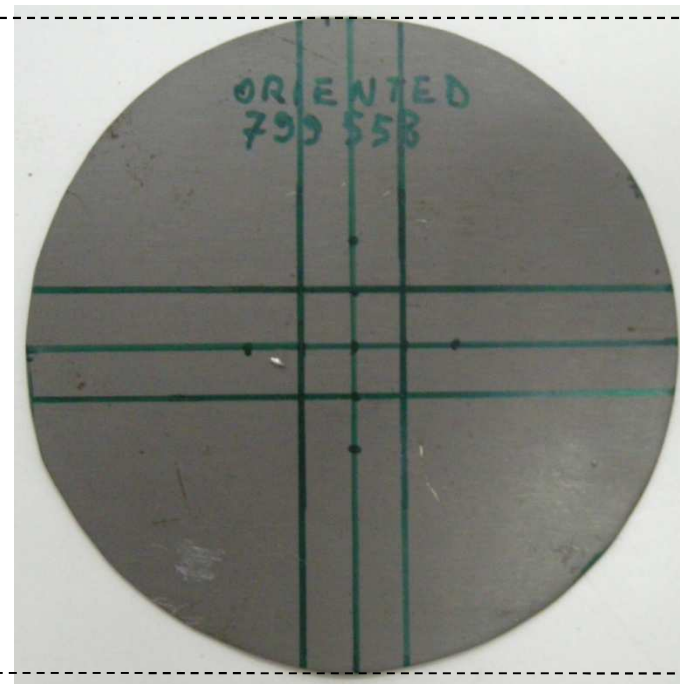
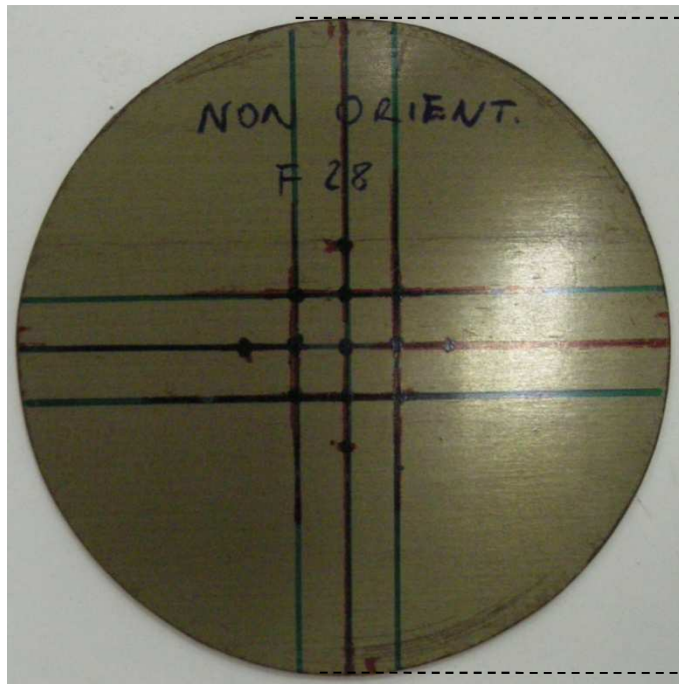
2-D experimental characterization of magnetic steels



Commercial Steel Samples

Not Oriented Grain

Oriented Grain



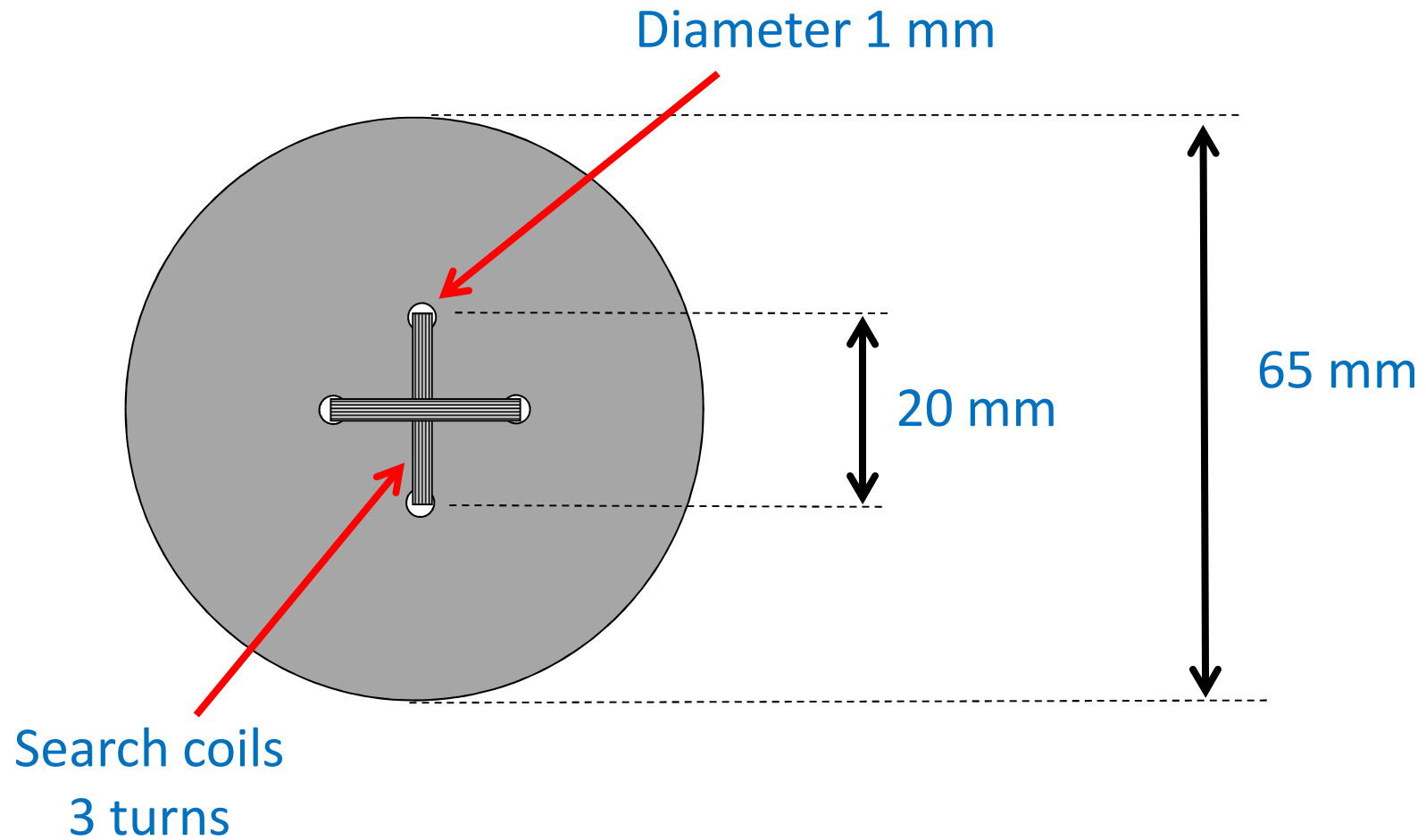
65 mm

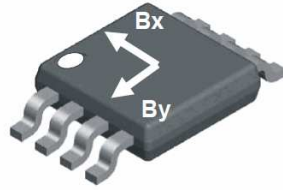
Thickness 0.65 mm

Thickness 0.3 mm



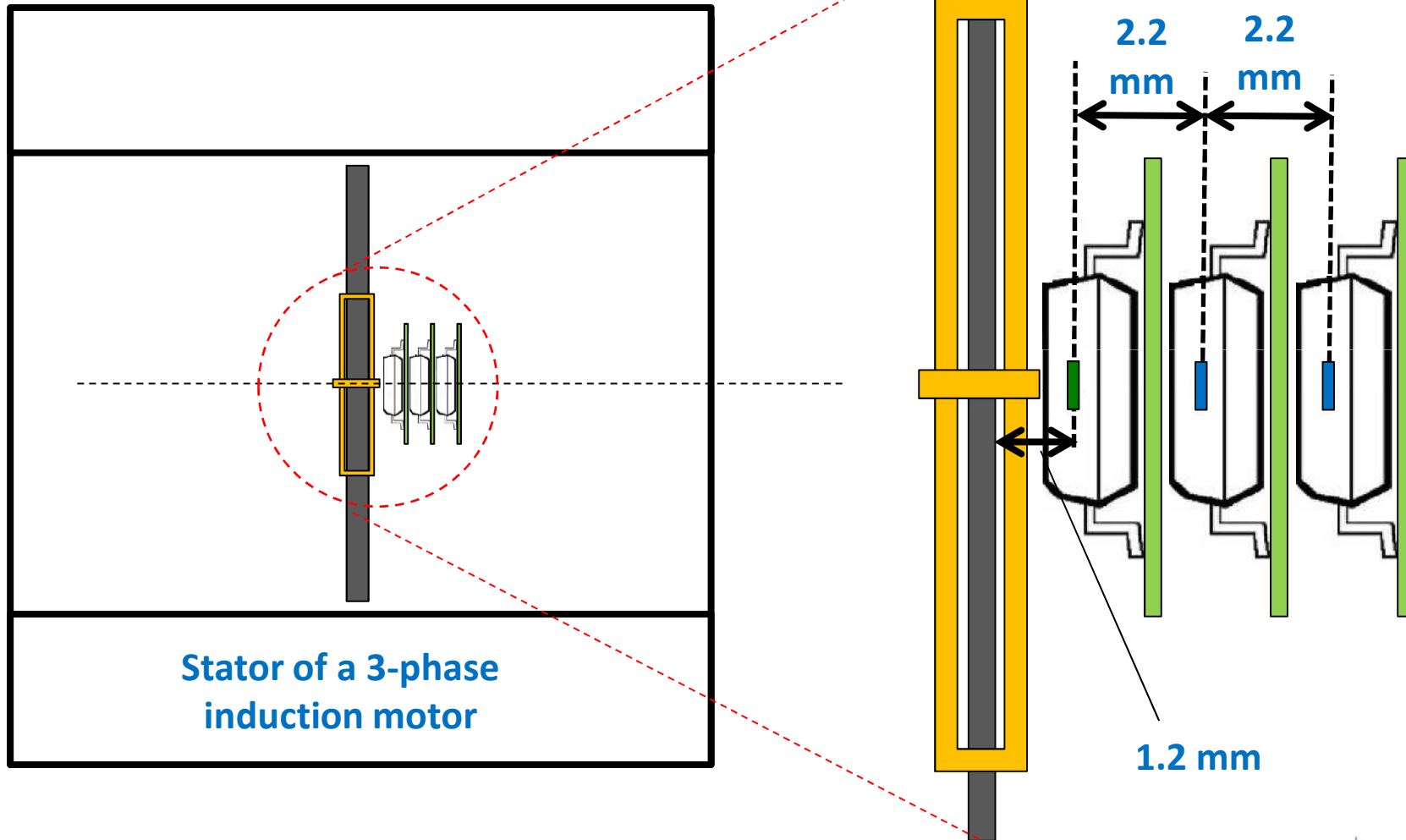
Magnetic Induction Probes



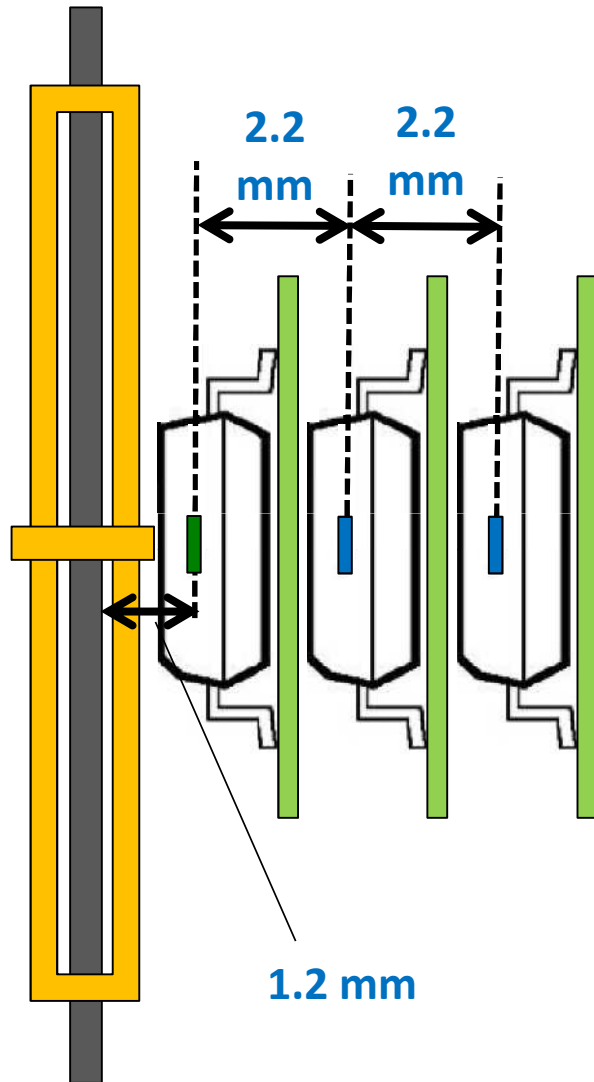


H-Probes

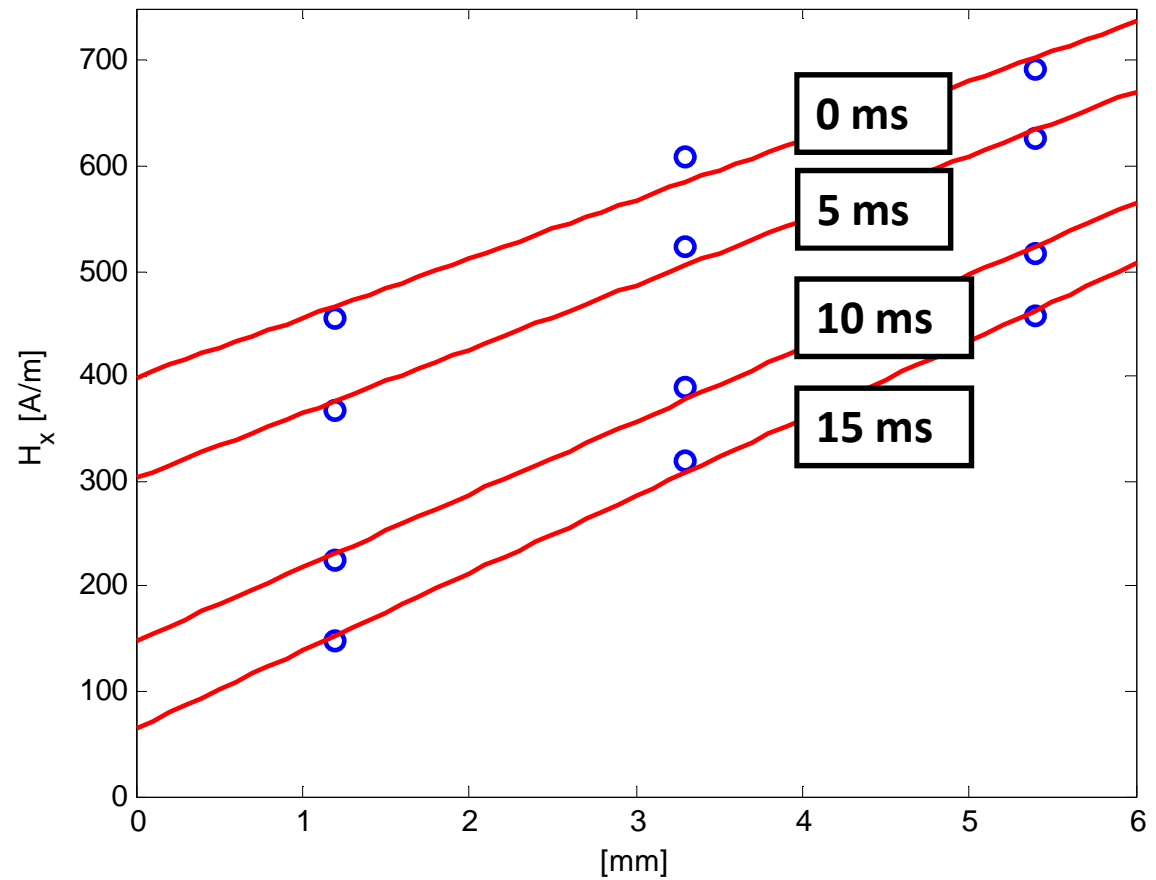
Biaxial Hall sensor
2AS-10 Sentron®



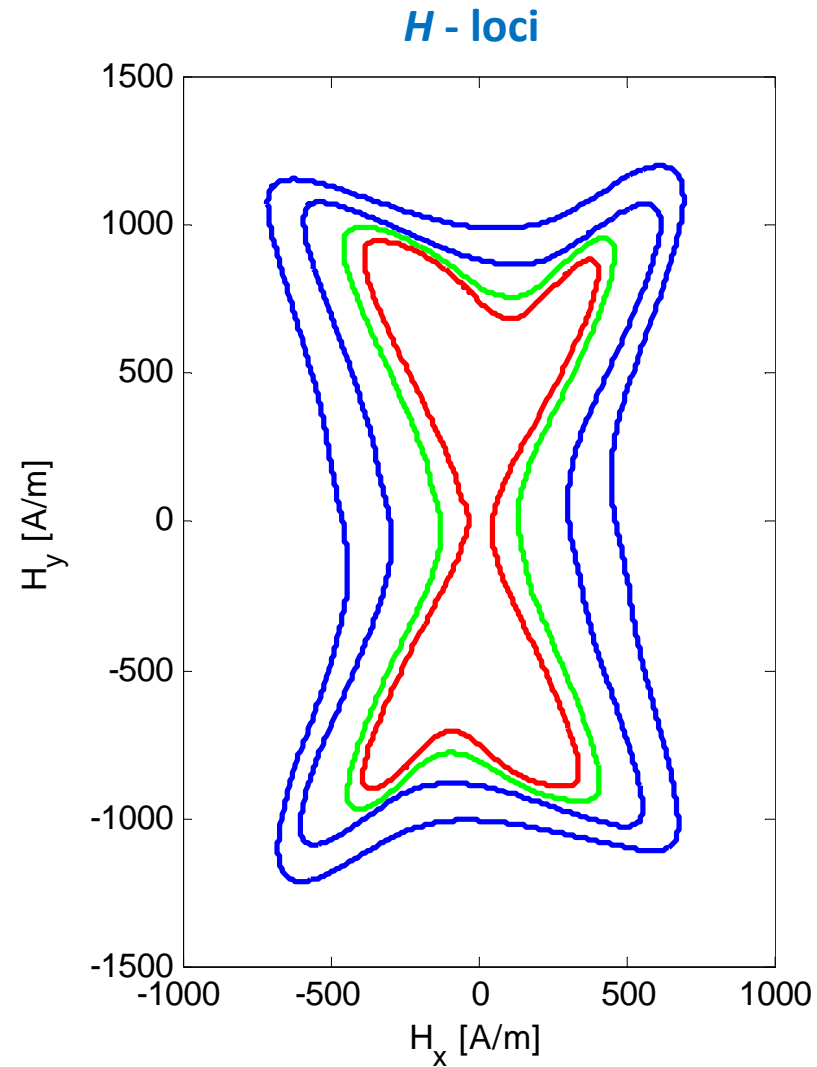
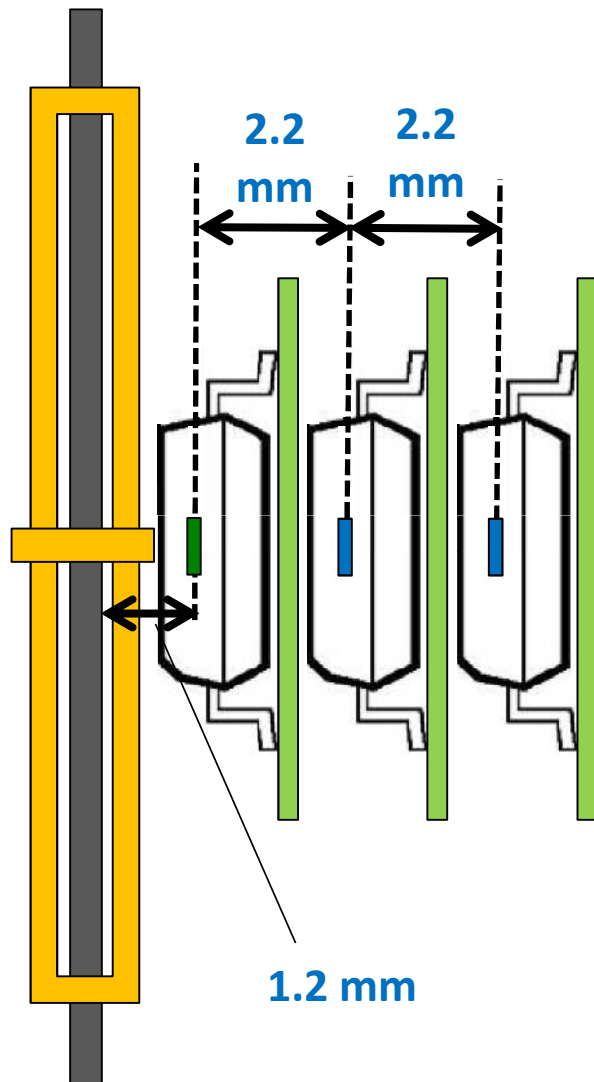
Extrapolation procedure



H_x measurements



Extrapolation procedure



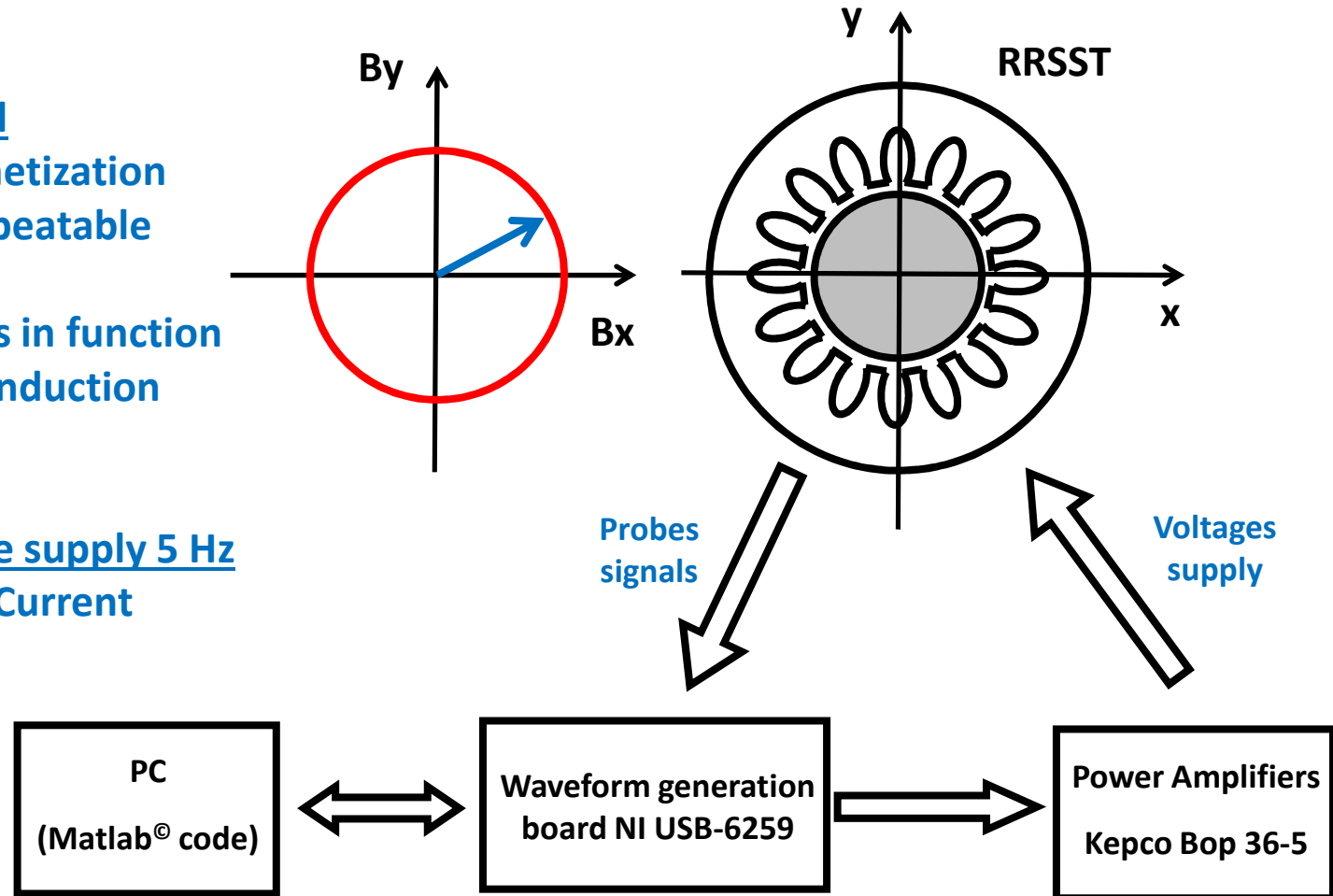
Feed-back control

Feed-back Control

- Sinusoidal Magnetization
- Accurate and repeatable measurements
- Rotational losses in function of the magnetic induction amplitude

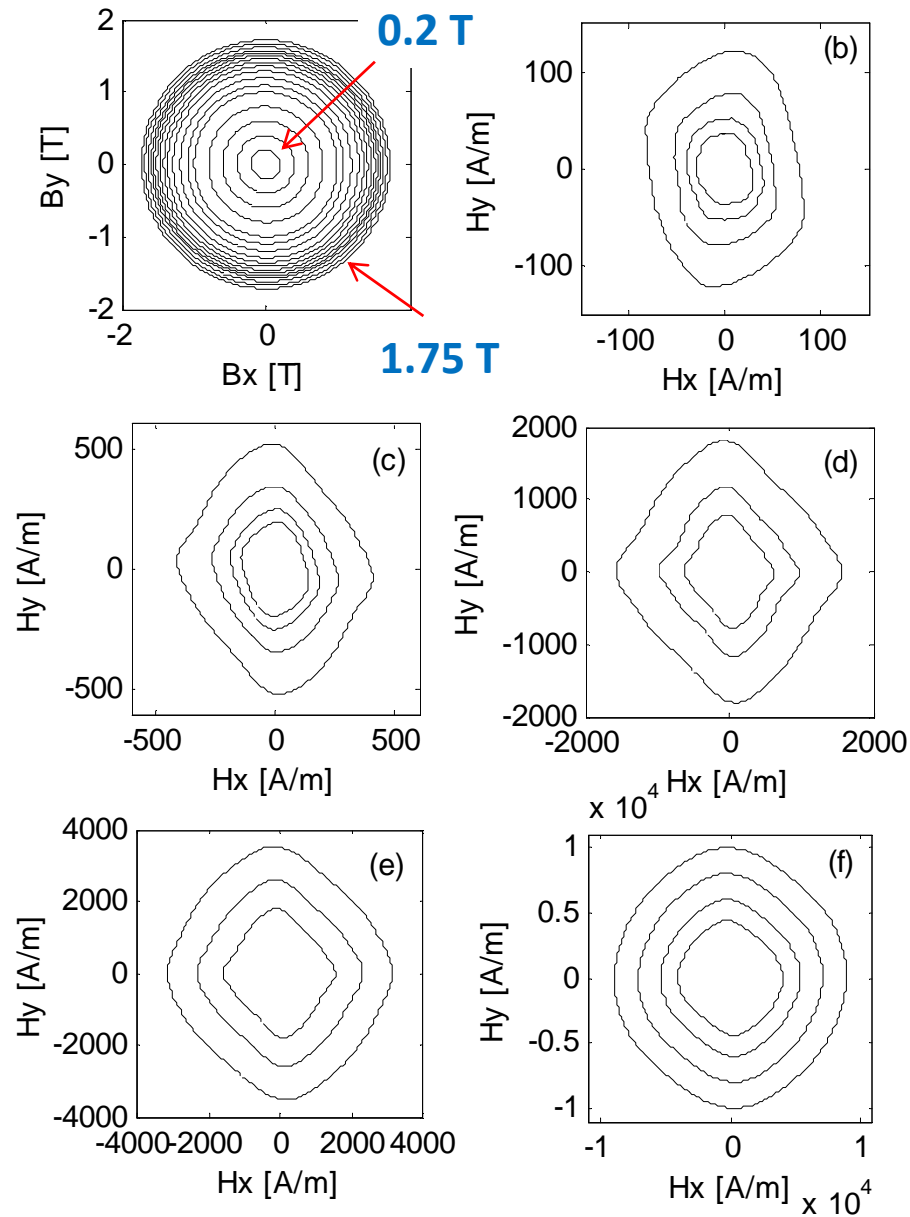
Frequency Voltage supply 5 Hz

- Negligible Eddy Current effect

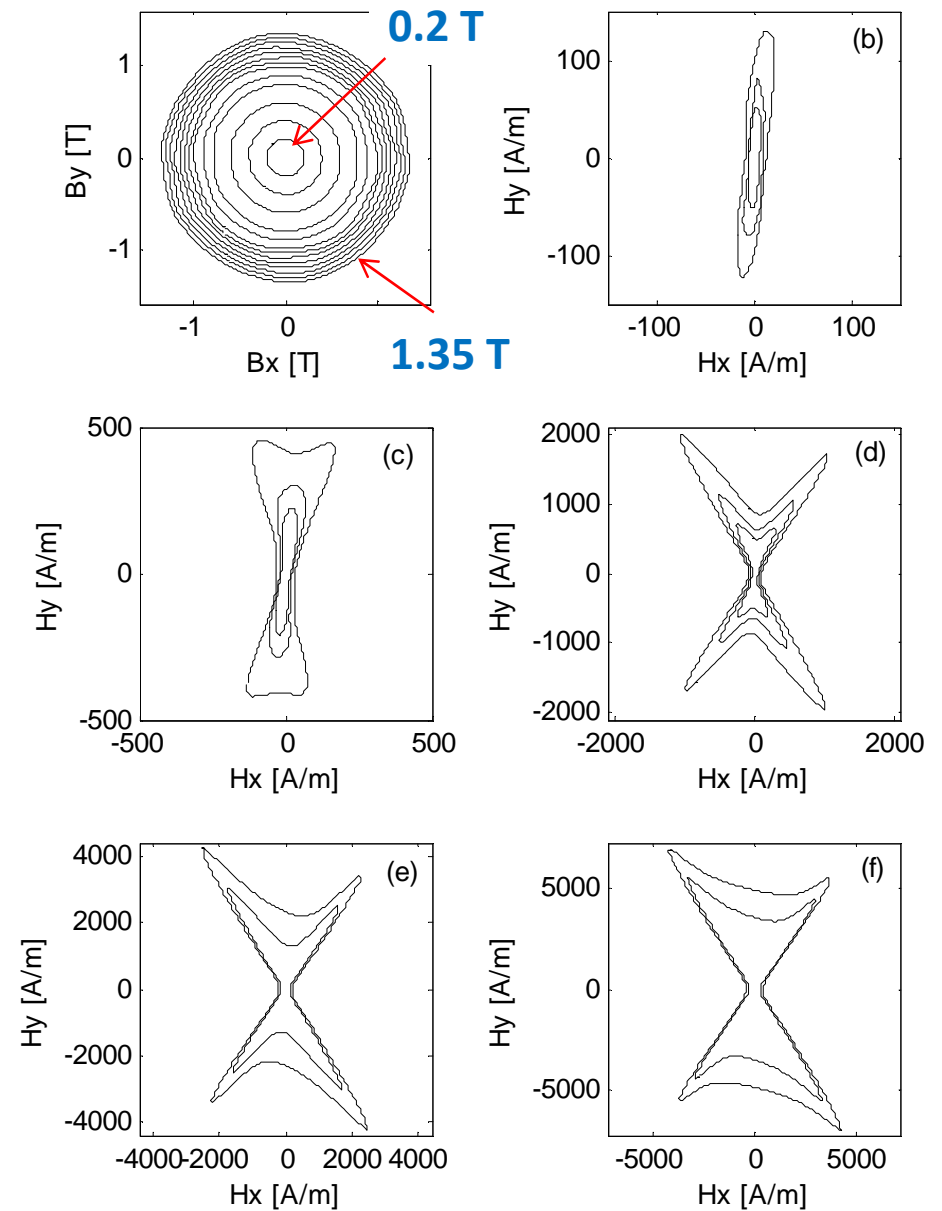


Experimental Results (benchmark data)

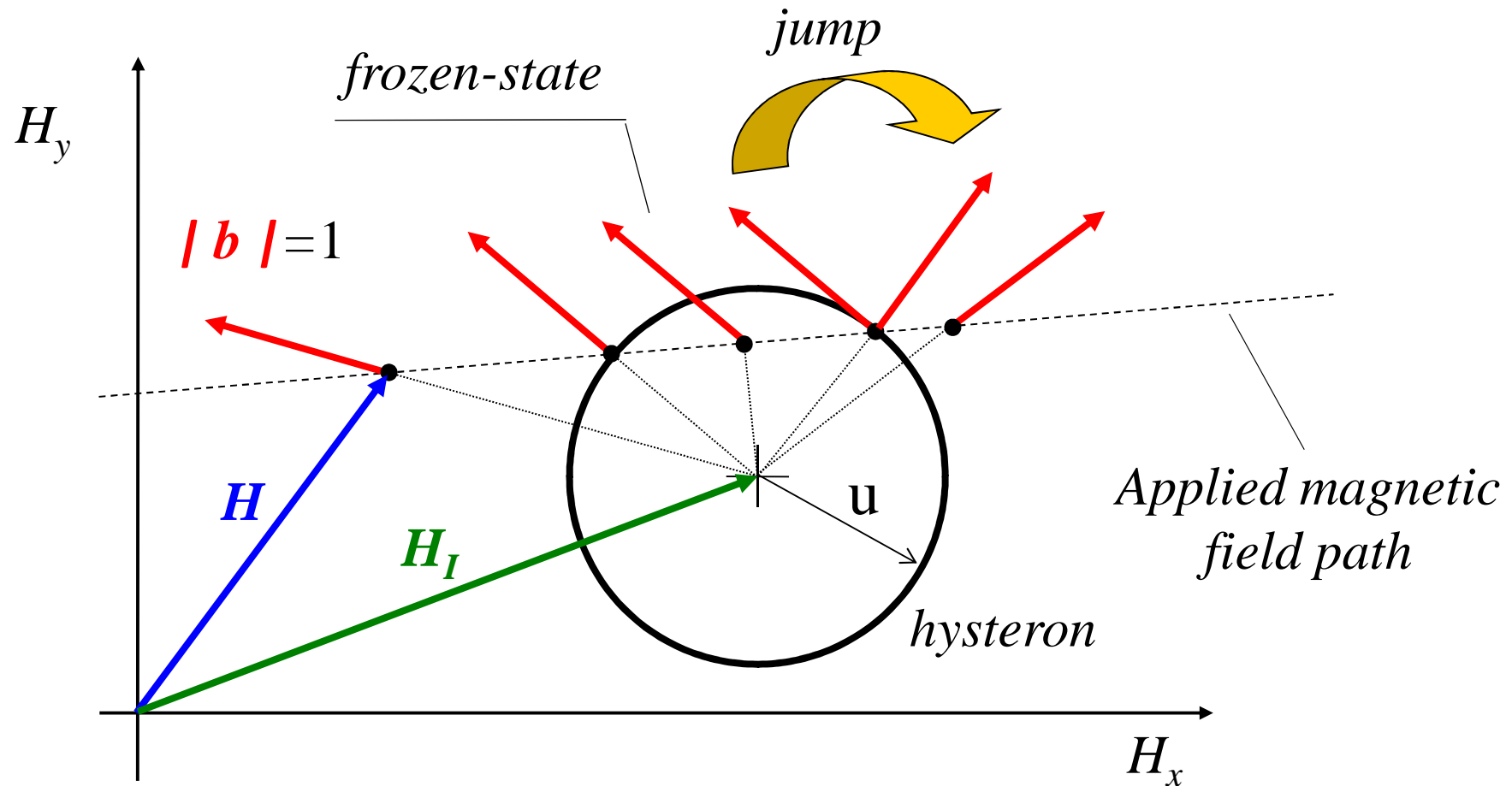
Not Oriented Grain



Oriented Grain



Vector Hysteron Model



E. Della Torre, E. Pinzaglia, E. Cardelli, "Physica B", Vol. 372, 2006.

E. Cardelli, E. Della Torre, A. Faba, "IEEE Transaction on Magnetics", Vol. 46, NO. 12, 2010.



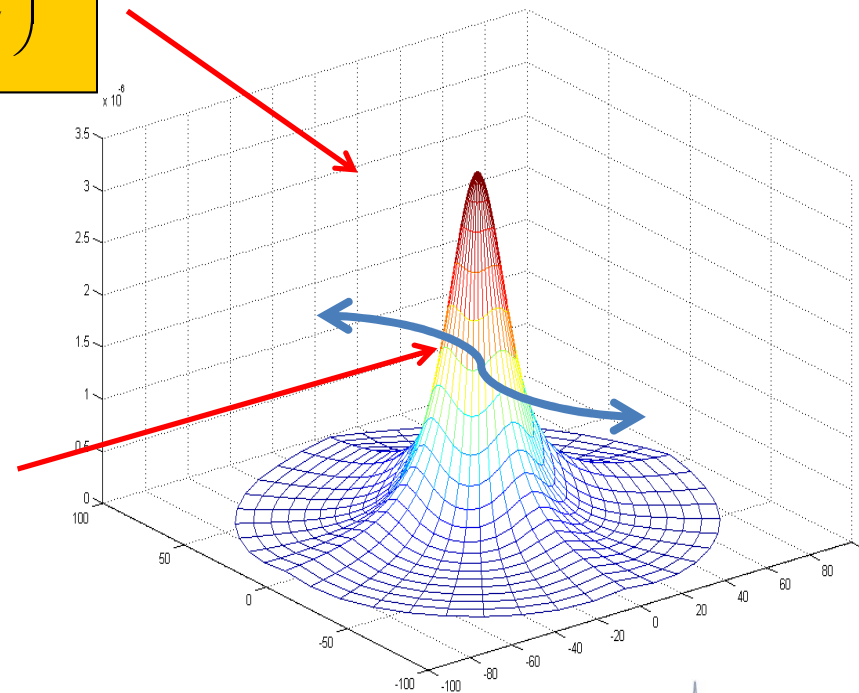
Vector Hysteron Model

$$B(H_x, H_y) = \int_{-H_{IxS}}^{H_{IxS}} \int_{-H_{IyS}}^{H_{IyS}} \int_{u_0}^{+\infty} P(H_{Ix}, H_{Iy}, u) Q(H_x, H_y, H_{Ix}, H_{Iy}, u) du dH_{Iy} dH_{Ix}$$

$$P = \left(\frac{\sigma_x}{\sigma_x^2 + H_{xi}^2} \right) \cdot \left(\frac{\sigma_y}{\sigma_y^2 + H_{yi}^2} \right) \cdot \left(\frac{\sigma_u}{\sigma_u^2 + (u - u_c)^2} \right)$$

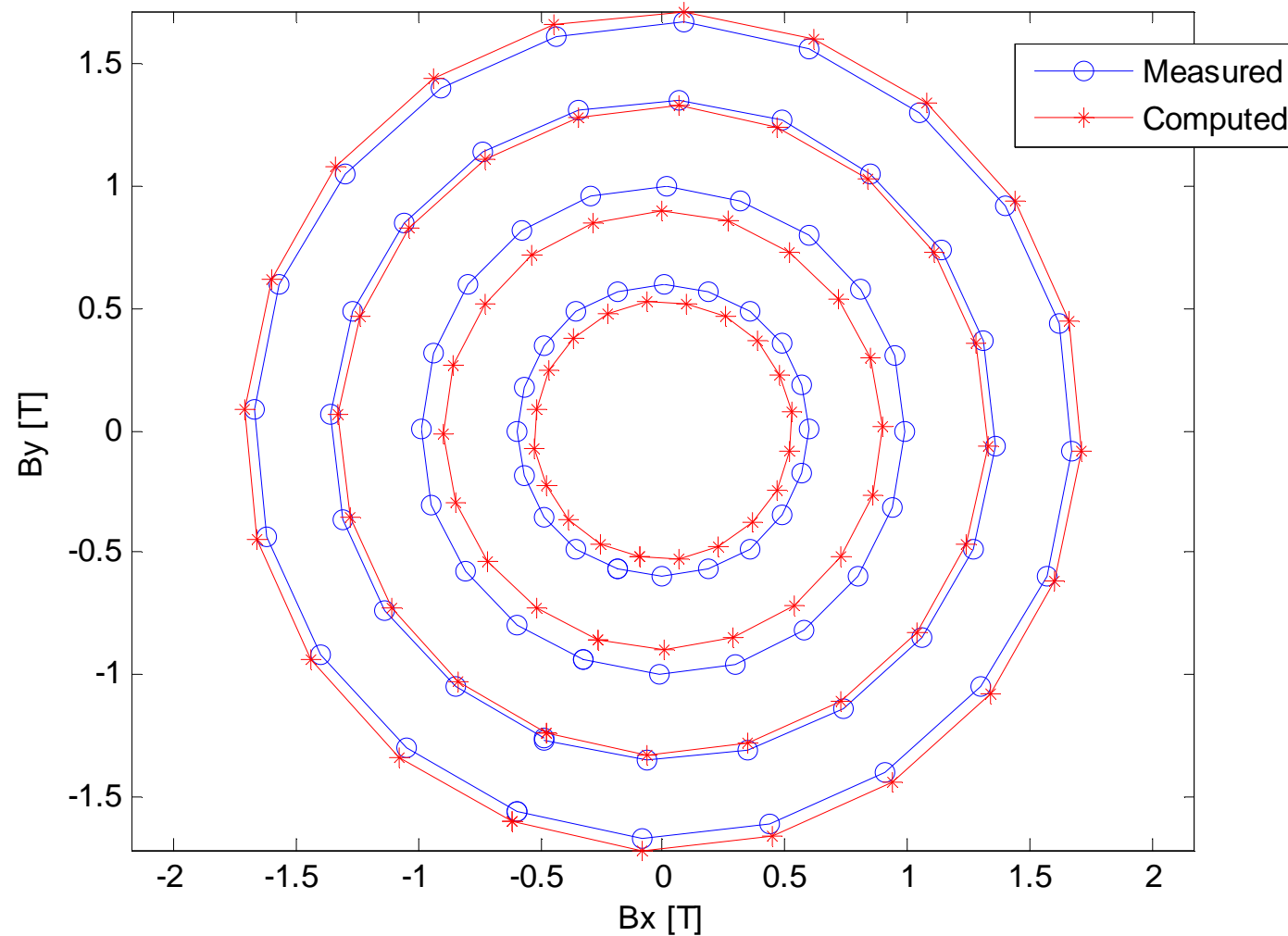
Moving model approach

$$H_{I0x} = f_1(B_x, B_y); \quad H_{I0y} = f_2(B_x, B_y);$$



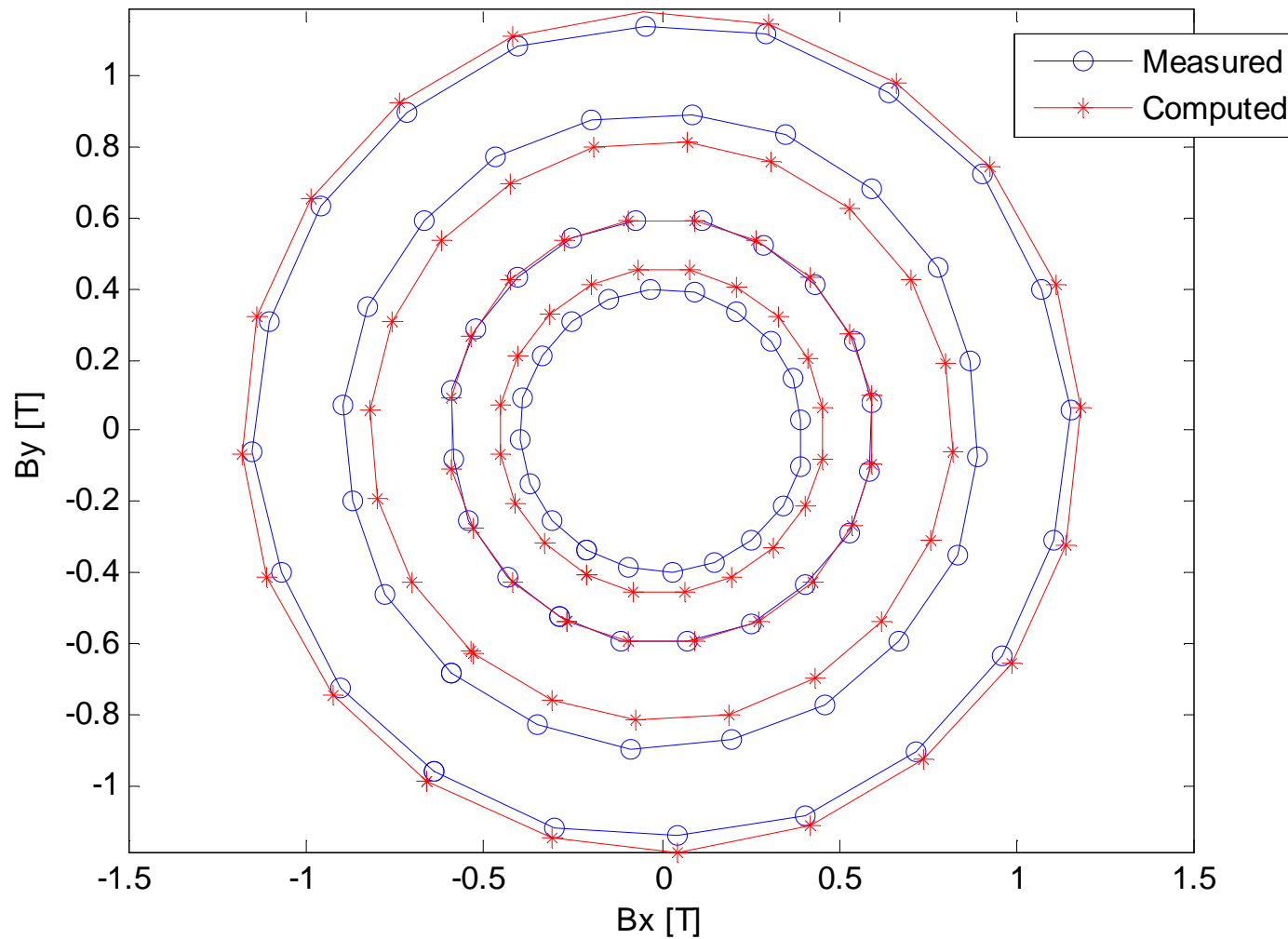
Numerical and Experimental Results

Not Oriented Grain

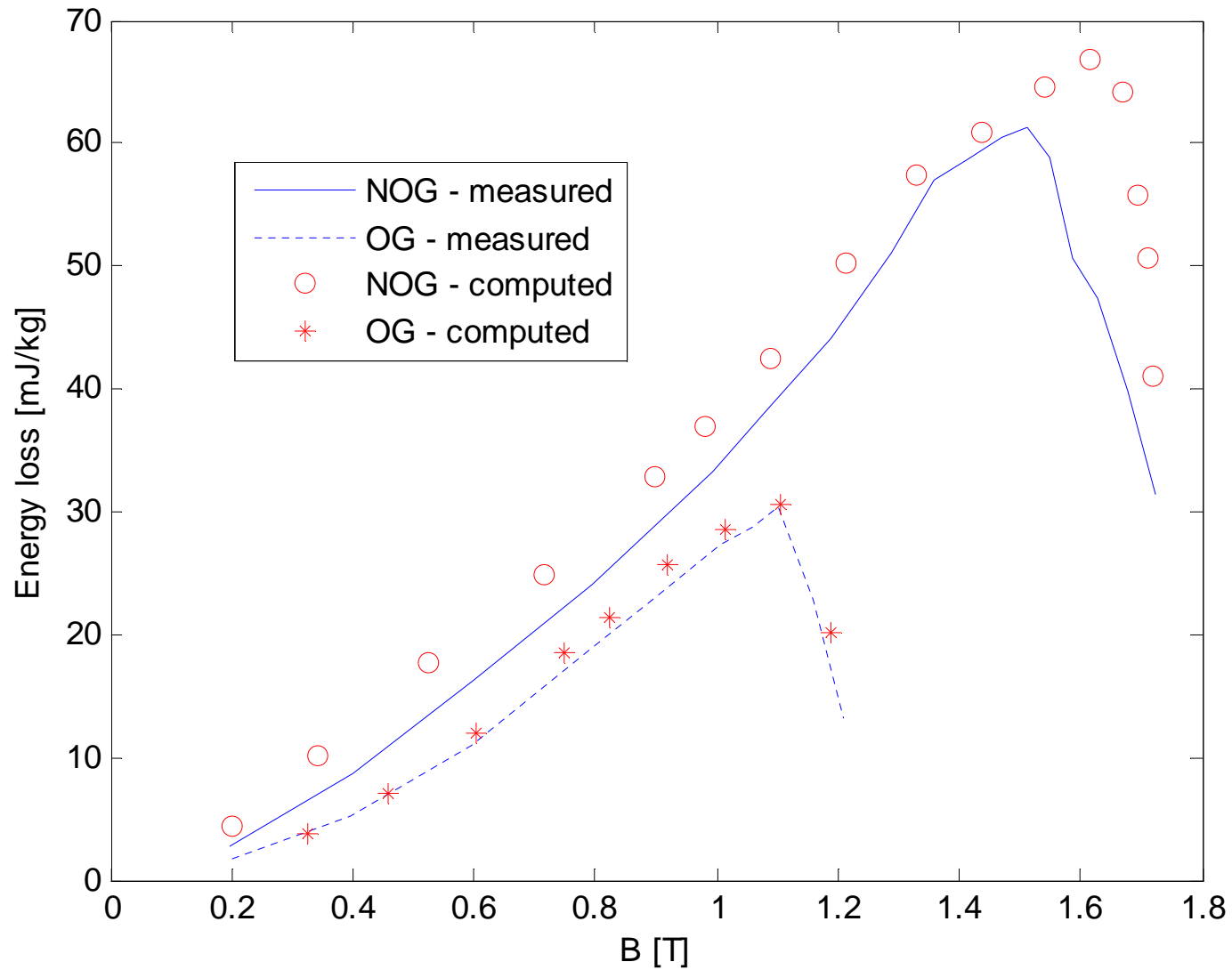


Numerical and Experimental Results

Oriented Grain



Static Rotational Losses



Conclusions

- We have proposed and described a **benchmark problem** for the validation, the development and the comparison of numerical methods to model the NOG and OG Si-Fe magnetic steels.
- **Experimental results** can be requested directly at the authors in the digital format (faba@unipg.it).
- We have also reported the numerical results we have computed via a **phenomenological vector hysteresis model** derived as an extension of the Preisach model.
- We hope this work can stimulate **the discussion and the comparison among the different modeling techniques** at macro-magnetic scale in use in the scientific community.

