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Mechanical stress estimation through classical and magnetic Barkhausen noise energy hysteresis cycle

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In this study relations between external stress and magnetic indicators read on experimental and simulated classical and magnetic Barkhausen noise energy cycles are established. The objective is to determine the most sensitive magnetic stress indicator and to explain why.

Keywords: Magnetization mechanism, magnetic non-destructive testing, irreversible domain wall motions

1. Submission

Magnetism can take different aspects in contemporary non-destructive testing [1]. In our group, we specifically focus on the magnetization mechanisms and on the evaluation of residual mechanical stresses through these mechanisms. Mechanical internal stresses are a determinant factor to material performance, structural integrity, and lifetime of industrial systems [2]. Their estimation is of significant interest when it comes to anticipating failures and degradations. Ferromagnetic steels are targeted. They are used in the construction, transportation, and energy domain. The magnetization mechanisms can be classified into five categories [3]:

- the magnetic domain wall bulging (low amplitude range),
- the domain wall irreversible motions (middle amplitude range),
- the magnetization rotation (high amplitude range),
- the domain wall frequency dependence, ripples, and avalanches phenomena,
- the macroscopic eddy currents (skin effect).

These mechanisms exhibit different sensitivity to stress, and a first work consists in establishing these sensitivities. Also, most of these mechanisms are superimposed in a standard magnetization process. Therefore, a second work consists of developing a characterization setup that allows isolation of each mechanism. For this, measurements and simulations can be associated. This study focuses on the mechanical stress influence on standard magnetization $B(H)$ and magnetic Barkhausen noise energy hysteresis $MBN_{\text{energy}}(H)$ cycles [4][5]. Experimental results obtained in uniaxial traction situations are confronted with simulation ones to establish the simulation parameters. A multiscale simulation method based on a statistical distribution of the magnetic domains and the knowledge of

the crystallographic texture is used to predict the an hysteretic behavior of both classical and Barkhausen noise cycles [6]. A parametric study of simulation results under tensile stress, and magnetic excitation in every space direction of the lamination plan (FeCo alloy Fig. 1) allows defining the most stress-sensitive situation. It allows defining the best magnetic indicator and the best position to observe stress in typical ferromagnetic steels.

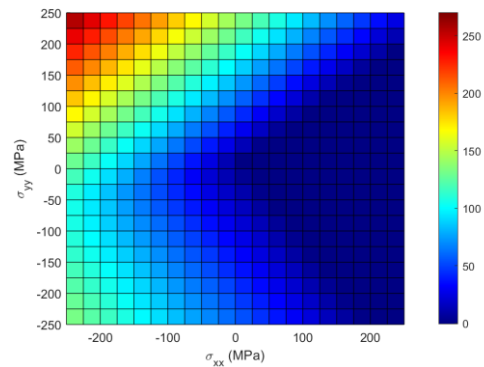


Figure 1 : Evolution of the predicted normalized $H_{95}: H$ at $M = 0.95 \times M_{\text{sat}}$, under biaxial stress states. The magnetic excitation and the magnetic sensors are along x (RD).

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