Improved Arctangent-Based Hysteresis Model for Residual Stress Analysis

Nait Ouslimane Ahmed[a]*, Sidi Ahmed Katia[b], Gabi Yasmine[c]

[a] *Department of Electrotechnics, Mouloud Mammeri University, Tizi-Ouzou, 15000, Algeria*
[b] Laboratory of energy systems modelling LMSE, University of Biskra, Algeria.
[c] *Fraunhofer institute for non- destructive testing IZFP. Saarbrucken, Germany*

The paper addresses the topic of residual stress in electromagnetic behaviour of the ferromagnetic material. Carbon steel parts is submitted to several stress loads near elastic- plastic area of hook law. The meso-macroscopic behaviour is collected at several operating points. After stress load, the hysteresis data are measured and illustrate a complex behaviour in hysteresis morphology where a big belly is observed near coercive field and a short neck in maximum induction zone. In order to describe the B-H curves, a modified Arctangent model is used. A Levenberg-Marquard optimization algorithm is applied for identification hysteresis model parameters. A comparison between experiments and model signals show good accuracy.

Keywords: residual stress in hysteresis, optimization, Levenberg Marquard algorithm

1. Introduction

In modern production, the development and implementation of a comprehensive based constitutive model for assessment of a stress-induced distortion plays an important role in high steel grade quality.

Many reviews in literature deal about hysteresis under stress [1]. Nevertheless, the complex morphology of residual stress, which occurs after plastic deformation still not yet solved. One of the first attempt where made by Gabi and all in description of skin passed layer of dual phase steel. The authors have stated the limit of the model [2].

In the following, a modified Arctangent model is then suggested in order to overcome problem of specific signature of residuals stress in hysteresis behavior.

2. Modified magnetic model

The modified Arctangent model is extended in order to take into account the residual stress phenomena in ferromagnetic materials. The magnetic flux density can be described by an arctangent function, given by:

$$B = c_1 . arctan\left(\left(\frac{\gamma-1}{c_1}\right) . \mu_0 \, H(B,\varepsilon)\right) + \mu_0 \, H(B,\varepsilon) \quad (1)$$

With:

$$\mathrm{H_i}(\mathrm{b},\varepsilon) = H_i^0(B,\varepsilon) - H_i^\sigma(B,\varepsilon) \quad (2)$$

$c_1 = \frac{2b_{sat}}{\pi}$, $\mathrm{b_{sat}}$ is flux density saturation.

$H_i^\sigma(B,\varepsilon)$ and $H_i^0(B,\varepsilon)$ represent the magnetic field induced by the effect of stress and the magnetic field at zero stress.

3. Hybrid Gauss-Newton/Gradient Descent Method

The optimization (LM) method is used to identify the parameters of the modified model. It combines both algorithms: steepest descent method and Gauss-Newton method.

After identification process, the complex hysteresis morphological behaviour is reproduced using the parameters set which are defined via Levenberg Marquard Algorithms. The results show good agreement between measurements and model (see Figure 1).

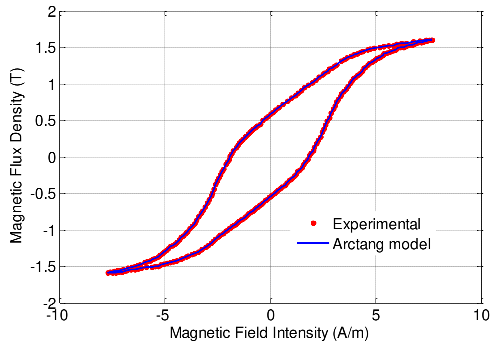

Figure 1 : Major loop after plastic deformation

This study introduces an enhanced hysteresis model based on a modified arctangent function, grounded in the effective field formalism. The model parameters were optimized using the Levenberg-Marquardt algorithm. By applying this approach, the researchers accurately reproduced the hysteresis loops of plastically deformed materials subjected to varying excitation fields. The simulations not only faithfully captured the shape of the hysteresis loops but also demonstrated good agreement with experimental data, validating the robustness of the proposed model.

References

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