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► **To cite this version:**

Arnaud Cariou, Afef Kedous-Lebouc, Christian Chillet, Laurent Albert, Sergi Riba. New investigation in Loss Surface model to consider dynamic magnetization's history. 25th Soft Magnetic Materials Conference (SMM'2025), May 2022, Grenoble, France. hal-03676291

HAL Id: hal-03676291

<https://hal.science/hal-03676291>

Submitted on 23 May 2022

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New investigation in Loss Surface model to consider dynamic magnetization's history

Arnaud Cariou^{a,b}, Afef Kedous-Lebouc^b, Christian Chillet^b, Laurent Albert^a, Sergi Riba^a

^aMEA department, IRT Saint-Exupery, B612 3 rue Tarfaya, 31405 Toulouse, France

^bUniv. Grenoble Alpes, CNRS, Grenoble INP*, G2Elab, F-38000 Grenoble, France

This paper presents a new calculation of the dynamic part of the Loss Surface (LS) model to consider the magnetization history. It is to be combined with a static model of hysteresis to estimate iron loss. The analysis of the behavior of various hysteresis loops highlighted the history dependency of the dynamic part of the LS model. An innovative formulation is then proposed to consider the dynamic effects inertia and to construct correctly the practical hysteresis for any applied waveform. The improved model is validated through experimental measurements.

Keywords: hysteresis modeling, Loss Surface model, dynamic magnetic history, experimental validation

1. Introduction

The continuously increase of electric power in airplane urges to improve electrical machines design and, among others, iron loss calculations. Hysteresis models are characterization costly but also more precise. The LS model has been improved recently [1] and can be used properly for iron loss estimation. This paper aims to improve further its accuracy by considering dynamic magnetization history.

2. Dynamic effects and magnetization history

The LS model is based on the magnetic field separation into a static part H_{stat} , depending on the flux density B and the magnetic history $Hist(B)$, and a dynamic part H_{dyn} related to B and its time derivative $D_t B$:

$$H = H_{stat}(B, Hist(B)) + H_{dyn}(B, D_t B) \quad (1)$$

H_{dyn} is determined from a single surface H_{surf} measured under triangular B of B_{max} amplitude and variable frequency. In [2], a little effect between sine and triangular waveforms is observed. Yet, these damping effects are well known and can modify the material behavior as illustrated in [3]. Here, a set of triangular and trapezoidal $B(t)$ has been applied to compare $H_{dyn}(B, D_t B)$. A large difference between $H_{dyn}(tri)$ and $H_{dyn}(trap)$ is observed, especially at reversal points.

3. New time-dependent dynamic hysteresis

A new corrected dynamic surface ($H_{surf,cor}$) is proposed:

$$H_{surf,cor}(t) = \tau \cdot \frac{dH_{surf}(t)}{dt} + H_{surf}(t) \quad (2)$$

With $\tau = \frac{\sigma \cdot \mu_s \cdot e^2}{12}$, σ : the electric conductivity, μ_s : the static magnetic permeability, e : the material thickness.

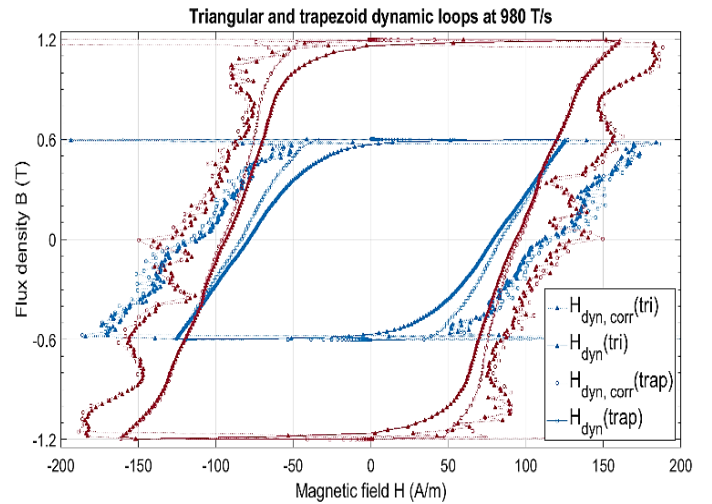


Figure 1 : Measured and corrected H_{dyn} loops at 0.6 and 1.2 T for triangular and trapezoidal B , for $D_t B = 980 T/s$

Fig. 1 compares $B(H_{dyn})$ cycles before and after corrections. It shows that $H_{dyn,corr}(tri)$ and $H_{dyn,corr}(trap)$ overlap and are very similar for both 0.6 and 1.2 T. This result is also confirmed by a theoretical approach involving classical eddy currents.

So, for any $B(t)$ waveform, the time-dependent H_{dyn} is calculated from $H_{surf,cor}$, with τ' being correlated to the static permeability μ'_s linked to $B(t)$ signal:

$$H_{dyn}(t) = \frac{H_{surf,cor}(t) \cdot \frac{\delta t}{\tau'} + H_{dyn}(t-1)}{1 + \frac{\delta t}{\tau'}} \quad (3)$$

This new formulation shows an overall improvement of the hysteresis estimation compared to the previous one. The final paper will illustrate the relevance of this correction for several excitation and its impact on the loss computation while combined with a static Play model [4].

References

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