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Evaluation of minor hysteresis loops using Langevin transforms in modified inverse Jiles–Atherton model

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ABSTRACT

In this paper, we present a Langevin transforms model which evaluates accurately minor hysteresis loops for the modified inverse Jiles–Atherton model by using appropriate expressions in order to improve minor hysteresis loops characteristics. The parameters of minor hysteresis loops are then related to the parameters of the major hysteresis loop according to each level of maximal induction by using Langevin transforms expressions. The stochastic optimization method "simulated annealing" is used for the determination of the Langevin transforms coefficients. This model needs only two experimental tests to generate all hysteresis loops. The validity of the Langevin transforms model is justified by comparison of calculated minor hysteresis loops to measured ones and good agreements are obtained with better results than the exponential transforms model (Hamimid et al., 2011 [4]).

1. Introduction

To avoid misestimating of iron losses and to predict accurate iron losses in electromagnetic devices, it requires a precise determination of the minor hysteresis loops in different regions of these devices. Different models have been proposed to represent the hysteresis phenomenon characteristic. Among these models, the Jiles–Atherton (JA) is the widely used one and it has proved its efficiency in many applications [1]. This model is based on physical principles and it can accurately simulate hysteresis loops.

For instance, several important papers have been published in the last years concerning minor hysteresis loops modeling such as [2–11]. The JA model gives accurate results when the maximum flux density is near the saturation (major loop) but it exhibits a certain unphysical behavior for low maximum flux density levels (minor loop) when using the same parameters as determined in the major loop [9].

To overcome this unphysical behavior some researchers suggest a modification of the JA parameters [6,9]. As example in Ref. [6], Leite et al. propose a simple methodology to represent minor hysteresis loops by using additional parameter 'R'. The R parameter can be obtained from experimental set of inner loops. For each induction level a value of R can be obtained by fitting an experimental curve with the modified model. The five other parameters remain the same. In this model the identification of the proposed model parameters can be done by the same way as in the original JA model. Good agreements are obtained with this model but it requires several measurement tests.

In other research studies [9], Miljavec et al. identify for each experimental loop the new five parameters of the JA model. In their calculations of these parameters, they consider that the saturation magnetization varies in each modeled test. But this consideration does not have any physical meaning because the saturation magnetization is constant for each material. To overcome this problem Miljavec et al. propose to modify the reversible parameter 'c' by an adequate exponential function depending on the magnetic field. The result of minor hysteresis loops is quietly improved and the correction paid to the saturation magnetization is insufficient. Furthermore, their model can generate minor hysteresis loops only for existing experimental tests and no else.

In our previous work [4], we have developed an exponential transforms model (ET) which determines the parameters of the modified inverse JA model (MIJA) for minor hysteresis loops by using exponential transforms of major parameters. This model needs only two experimental tests to generate all hysteresis loops with accurate results but this model has not any physical approach.

Alternatively, in this work, we propose a model which has a physical approach; the Langevin transforms model (LT). The LT

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