Dynamic magnetic hysteresis modeling based on improved parametric magneto-dynamic model

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Background

Transformers, motors and other electrical equipment are widely used under high frequency conditions, and soft magnetic materials are an important part of such equipment. Therefore, the research on the characteristics of soft magnetic materials is of great significance for the optimal design of electrical equipment. As the important characteristics of soft magnetic materials, magnetization and loss characteristics need to be carefully studied.

Objectives

☞ Aiming at the problem caused by the nonuniform distribution of internal magnetic field of magnetic materials at high frequency, an improved parametric magneto-dynamic (IPMD) model based on physical significance is proposed.

☞ In order to improve the accuracy of iron loss calculation and dynamic hysteresis loop simulation, IPMD model is coupled with different hysteresis loop models. Considering simplicity and accuracy, the Tellinen(TLN) model is selected.

The Tellinen hysteresis model

In order to accurately apply the IPMD model, the nonlinear relationship between magnetic field intensity and magnetic flux density must be considered. Therefore, it is very important to adopt an appropriate hysteresis model. Considering the accuracy and simplicity of the model, the TLN model is selected.

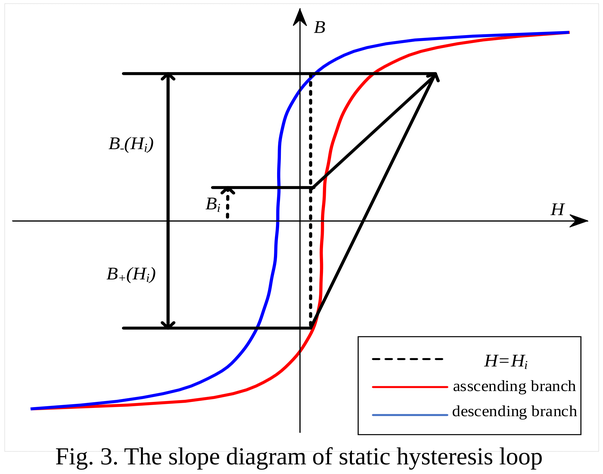


Fig. 3. The slope diagram of static hysteresis loop

Schematic diagram of measurement system

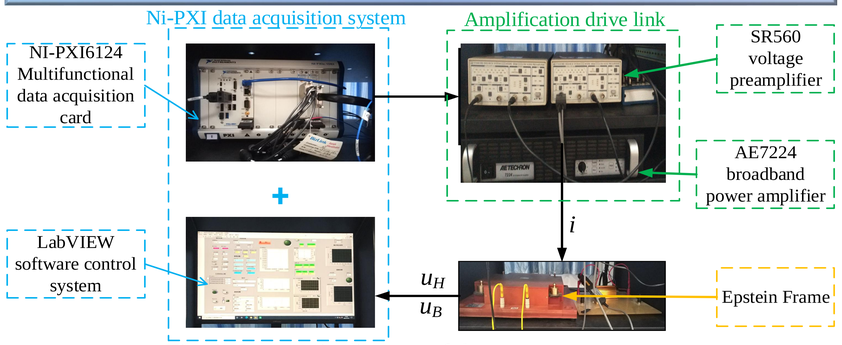


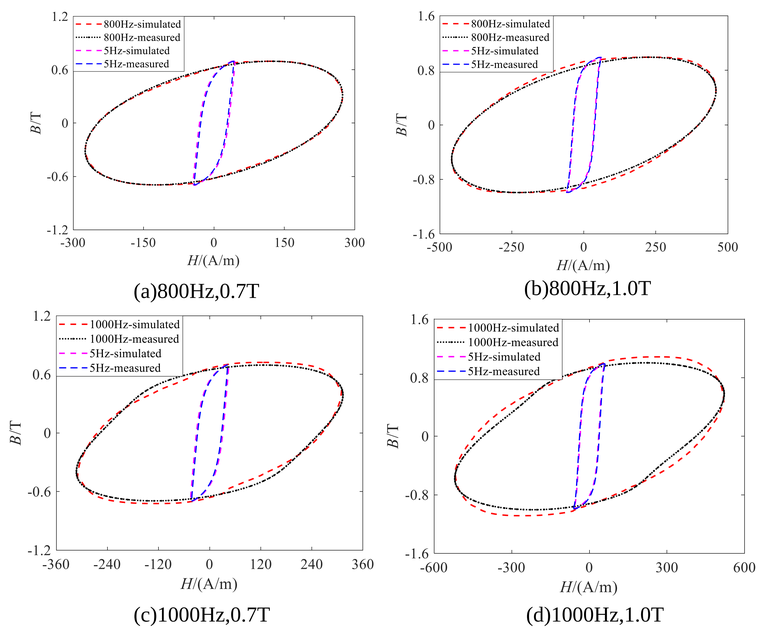
Fig. 1. Schematic diagram of the measurement system

To verify the accuracy of the model proposed, it is necessary to measure the hysteresis loop of silicon steel laminations at different frequencies。The one-dimensional magnetic measurement system is established according to the standard "IEC60404-2", as shown in Fig.1. The parameters of silicon steel lamination are shown in Table I.

TABLE I. Parameters of silicon steel laminations

Type	Length(mm)	Width(mm)	Thickness(mm)	Density(kg/m^3)
50JN470	300	30	0.5	7650

Dynamic hysteresis loop simulation



(a)800Hz,0.7T (b)800Hz,1.0T

(c)1000Hz,0.7T (d)1000Hz,1.0T

Fig. 4. Comparison between simulated and measured hysteresis loops

The improved parametric magnetodynamic model

Based on the fact that the length l_{Si} and width w_{Si} of silicon steel lamination are much larger than its thickness d, the electromagnetic phenomenon in silicon steel lamination is one-dimensional approximate. Combined with the characteristics of magnetic field distribution in the lamination at high frequency, the IPMD model divides half of the silicon steel lamination into N slices nonuniformly by appropriately reducing the outer slice thickness and increasing the inner slice thickness.

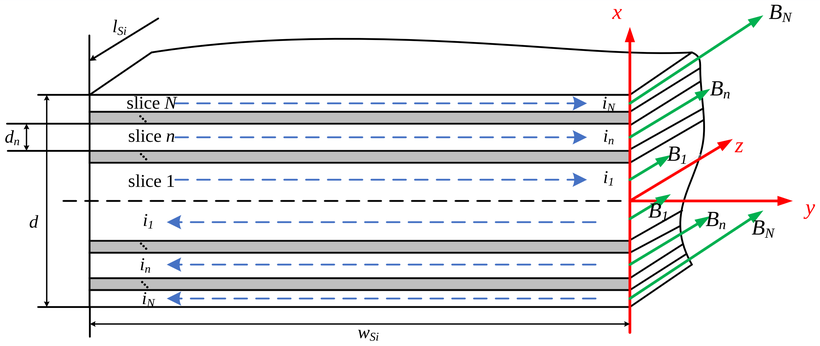
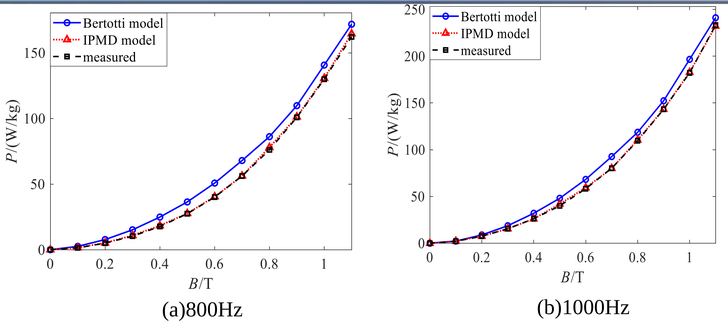


Fig. 2. The partial schematic diagram of silicon steel lamination

Loss calculation



(a)800Hz (b)1000Hz

Fig.5. Comparison of measured and calculated iron losses at different frequencies

Summary

In this paper, the IPMD model considering the nonuniform magnetic field distribution in silicon steel lamination is proposed, which can accurately simulate the dynamic hysteresis loop in a wide range. The model can also be used to calculate the iron loss at high frequency. This method is of great significance to the study of magnetization and loss characteristics of soft magnetic materials.