Correlation of grain size and sheet thickness on the excess loss of non-grain oriented electrical steel

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Excess loss was analysed in non-oriented electrical steel (NOES) sheets with 2.4% and 3.3% Si by weight, in six thicknesses and various grain sizes. This work aims to show the correlation between grain size and thickness in excess loss. For this, excess losses were evaluated at frequencies from three to 2000 Hz. As a result, it was concluded that the effect of grain size is greater with increasing sheet thickness.

Keywords: excess loss, grain size, thickness

1. Introduction

Manufacturing electric motors that operate in higher frequency ranges has driven the development of optimized electrical steels. Therefore, studies are focused on the components of total energy loss per cycle (W_t) most affected by the increase in frequency. Excess loss (W_{exc}) is influenced by the frequency $f^{0.5}$ and is obtained by subtracting the hysteresis loss (W_h) and the classical eddy-current loss (W_{cl}) from the total loss (W_t), as shown in Equation 1[1].

$$W_{exc}(f) = W_t - (W_h + W_{cl}) \quad \text{[J/m³]} \quad \text{Equation 1}$$

Research have indicated that the variables grain size and thickness act on excess loss. Bertotti [2] concluded that the effect of grain size (GS) was linear with excess loss and Campos [3] indicated a parabolic effect for thickness (e) in excess loss. Thus, the focus of this work is to establish the effects of grain size and thickness on excess loss.

2. Results and discussion

The excess loss obtained in different sheet thicknesses, grain sizes, two silicon contents, and frequency range used was from three to 2000 Hz. Figure 1 shows the excess losses in three thicknesses at a frequency of 400 Hz and various grain sizes in 3.3% Si electrical steels. It can be seen that the excess loss has a linear behavior in relation to the grain size.
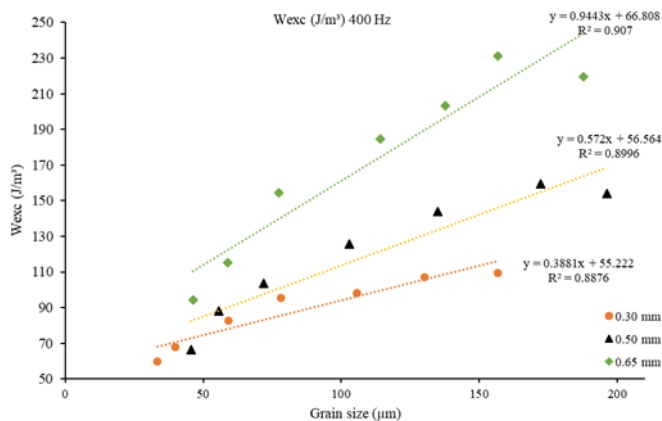

Figure 1: Excess loss in 3.3% Si electrical steels at a frequency of 400 Hz. Skin effect correction was used for the calculation of excess loss.

The effect of thickness on excess loss is seen in Figure 2,

where the excitation frequency is 400 Hz and a range of grain sizes has been established. The figure shows that thickness has a parabolic effect on excess loss and increasing silicon content results in decreasing loss.
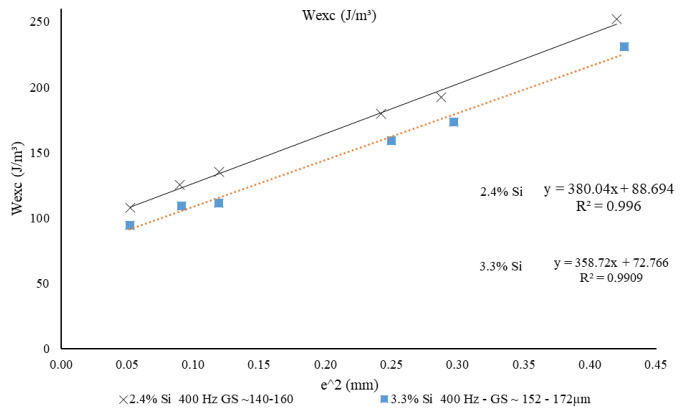

Figure 2: Excess loss as a function of the square of the thickness and in a range of grain size (µm). At a frequency of 400 Hz at 1 Tesla of induction.

It concluded that excess losses are affected linearly by grain size and parabolically by sheet thickness. Furthermore, it is observed that increasing silicon content leads to a reduction in excess loss and the effect of grain size is greater at higher thicknesses.

References

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