Anisotropy of the magnetic losses components in semi-processed electrical steels

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Abstract

Making use of magnetic losses separation techniques, it is shown that most of the anisotropy of the total magnetic losses of semi-processed steels with different grain sizes is concentrated in the high induction region of the quasi-static hysteresis loop.

keywords: electrical steels; losses separation; hysteresis losses;

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Grain size and crystallographic texture are known to affect the magnetic losses of electrical steels [1]. The effects of grain size on hysteresis and anomalous losses have been well described [2], but the effect of texture is less understood, due to difficulties in describing texture with few parameters. It is also difficult to isolate the effects of grain size from those of texture, as the processing variables that affect grain size also introduce texture changes [3]. The investigation of magnetic properties anisotropy in electrical steel laminations is a way to evaluate texture effects at each grain size.

A low-carbon 0.5%Si steel was hot and cold rolled to about 0.55mm thickness, annealed to average grain size of 13μm, subjected to different cold rolling elongations, from 0 to 17%, and recrystallized at a decarburizing annealing at 760°C for 2h. Six samples with grain sizes from 13 to 360μm were produced. Core loss and B_{50} measurements at 60Hz were performed separately in the rolling (RD) and transverse directions (TD). Table 1 results indicate that recrystallization after cold rolling increased B_{50} values in the rolling direction, and decreased them at the tranverse direction. This behavior can be related to the reinforcement of the (110)[001] texture component [4], confirmed by ODF measurements on the samples with grain sizes of 13 and 48μm. Samples with larger grain size presented statistical limitations for the use of ODF analysis.

Table 1. Effect of cold rolling elongation on final grain size and Induction at 5000 A/m (B_{50}) in the Rolling (RD) and Transverse (TD) direction of annealed samples.

elongation	%	0	17	13	11	7	4
G.S.	(μm)	13	48	104	125	163	360
B_{50} (RD)	(T)	1.75	1.75	1.75	1.75	1.77	1.71
B_{50} (TD)	(T)	1.75	1.70	1.68	1.68	1.68	1.67

The effect of grain size and anisotropy on the losses components can be seen in Figure 1. Quasi-static hysteresis loss decreases and anomalous loss increases when grain size is increased, except in the 13μm sample, where anomalous loss is high, for unknown reason. The parasitic loss component is not shown, as it is constant at about 1,9 W/kg. It is shown that the anisotropy of total magnetic losses can be attributed to the anisotropy of hysteresis loss, as the anomalous component shows very little anisotropy. Hysteresis loss at transverse direction is 12 to 36% higher than in the rolling direction.

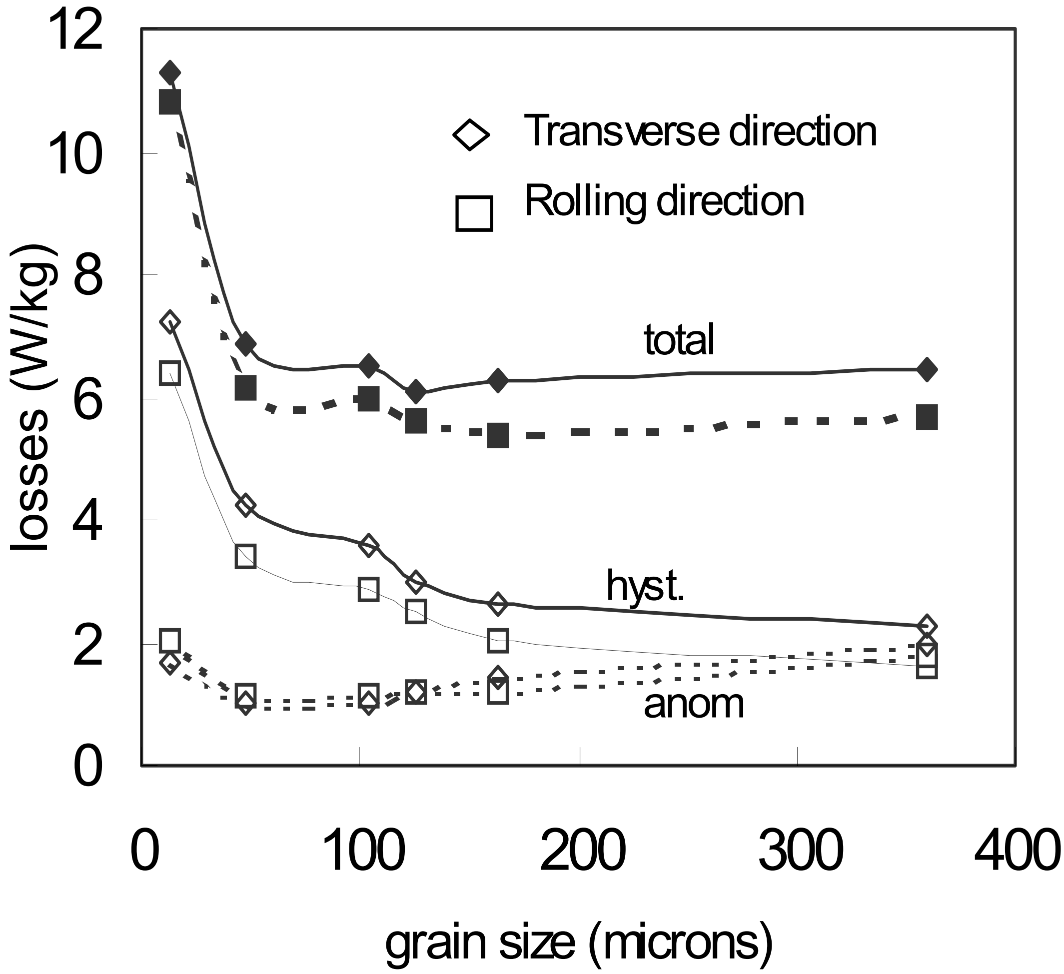

Figure 1. Effect of grain size on Total Losses, Hysteresis Loss and Anomalous Loss at 1.5T 60Hz, for measurements at rolling and transverse directions.

The comparison of the shape of the quasi-static hysteresis curves of samples in RD and TD directions showed that most of the hysteresis area difference lies above the knee of the loop. The knee of the curve is usually associated with a change in magnetization mechanism, suggesting that the hysteresis loss can be separated in two regions. We have chosen the induction value at maximum relative permeability as the border line between the two hysteresis loss components: a low induction (LI) component, calculated by integrating the hysteresis loop area limited by the maximum permeability induction lines (Figure 2), and a high induction (HI) component, which is the difference between the whole hysteresis area and the low induction component.

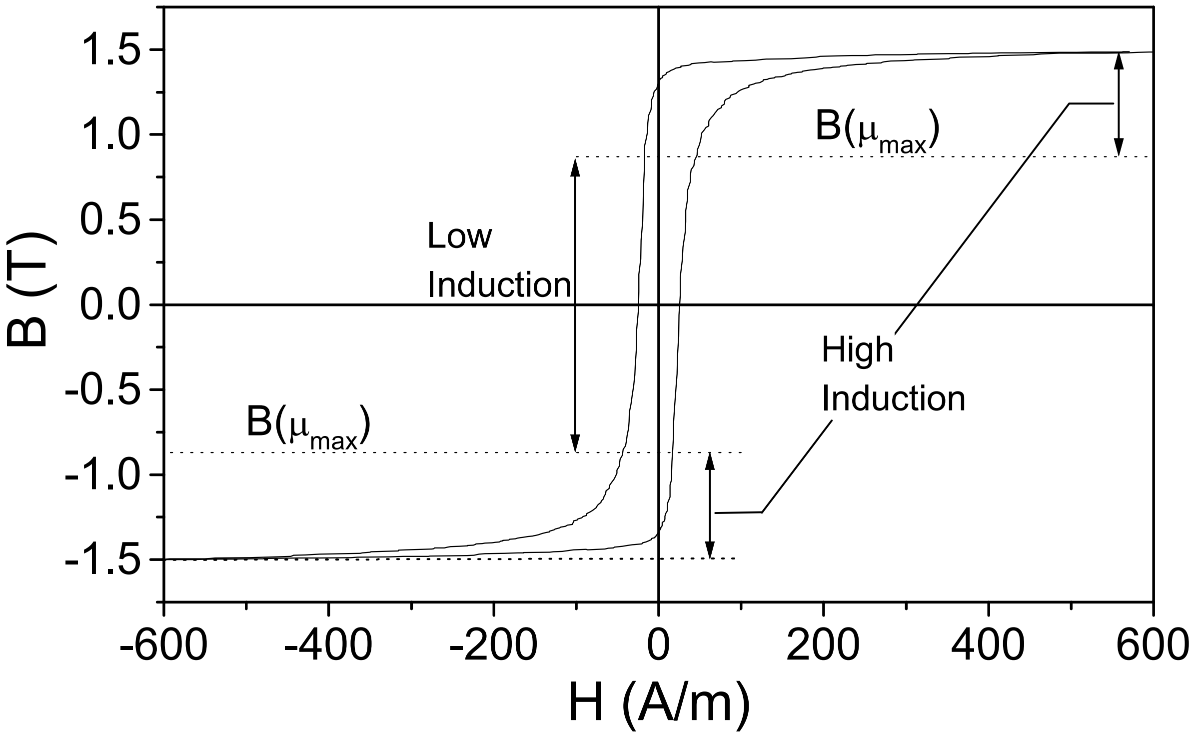

Figure 2. Hysteresis loop of the 360μm grain size sample, rolling direction, showing the regions of the Low Induction and High Induction loss components.

Figure 3 shows the effect of grain size on both hysteresis components, in the rolling and transverse direction. It is shown that the LI component is much more sensitive to grain size, and the anisotropy of the HI component is much larger, indicating a much stronger texture dependence on the latter. Domain annihilation and domain nucleation are the most probable sources of irreversible magnetization changes in that region [5].

It can be concluded that, as the value of the HI component is larger than the LI component at the optimal grain size for total losses, around 150μm, texture improvements should have an important role in future developments of non-oriented electrical steels with lower total losses.

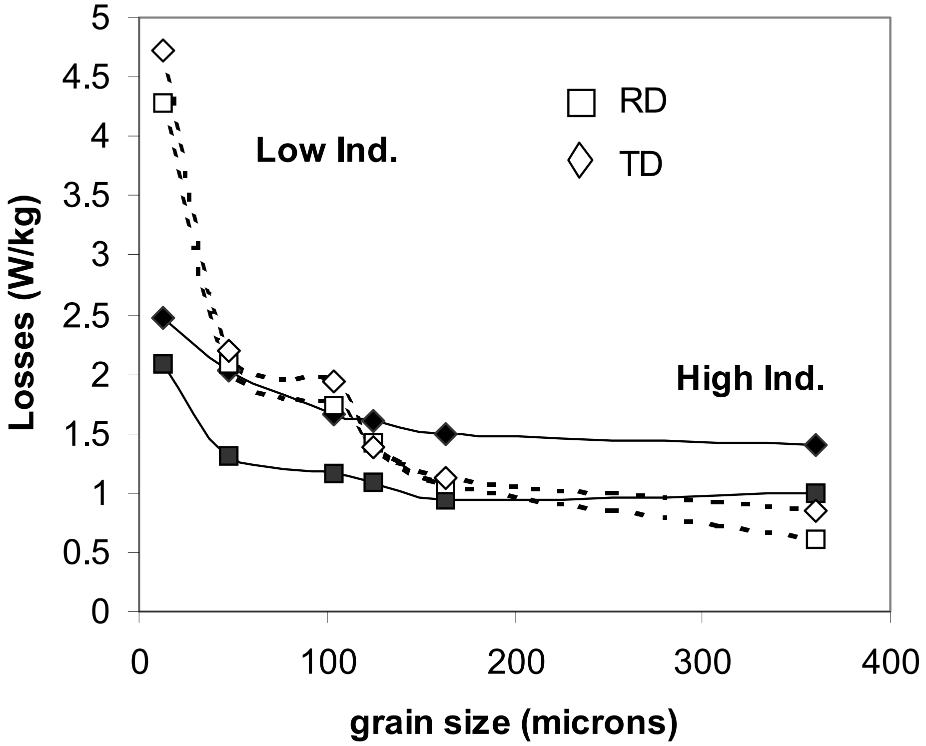

Figure 3. Effect of grain size on the losses in the Low Induction component (dotted line) and in the High Induction component (full line).

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