Effect of Soaking Time on the Normalizing Annealing Process and Its Influence on Microstructure, Texture, and Magnetic Properties of grain-oriented electrical steel

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Grain-oriented silicon steel hot-rolled samples were normalized at 1000°C for 90/120s, cold-rolled, and annealed. Increased soaking time enhanced Goss fraction, influencing grain size and texture. XRD showed a decrease in {411} and rise in Goss with longer time. ODF revealed Goss-related components post-recrystallization. Longer soaking (120s) resulted in lower core loss.

Keywords: grain-oriented, normalized, texture, core loss.

1. Introduction

The process design must be narrow and sharp to produce grain-oriented silicon steel with low-temperature slab heating technology. The normalized process must balance temperature and soak time to recrystallize the hot-rolled microstructure and precipitation control [1]. From then on, the hot band coil is prepared for cold rolling, producing the shear bands from which the Goss component arises. In this way, this work aims to discuss the effect of soaking time on the magnetic properties of HGO

2. Experimental method

Hot-rolled samples with 2.25 mm thickness were normalized at 1000°C for 90 and 120 seconds. Then, they were cold rolling achieving 0.27 mm, decarburized at 840°C and nitrided. Finally, high heat treatment was carried out at 1200°C. Texture characterization was conducted using a FEI XL-30 Scanning Electron Microscope and a Philips X'Pert X-ray diffractometer. Magnetic properties were measured using an Epstein frame at the Brockhaus MPG200D.

3. Results and discussion

The orientation maps (IPFs) obtained from the annealed sample at 90 and 120 seconds are shown in Figure 1. The effect of soaking time on the sizes of equiaxial recrystallized grains is visible. In the central portion, both samples exhibited elongated grains, where the recovery takes place. Increasing the soaking time, it increased the {001}<110> fraction from 0.048 to 0.052 from 90 to 120 seconds, respectively. The increase in the Goss fraction to 20~25% of the thickness in normalized HGO material has been credited as beneficial to the secondary recrystallization process and ultimately, a source of reduction in magnetic losses [2]

The volume fractions of the main texture components measured by X-ray diffraction on the surface plane show the main difference lies in the fraction of the {411} component, with the sample annealed for 90 seconds being 10% higher. In contrast, the Goss orientation is 14% higher for the sample annealed for 120 seconds.

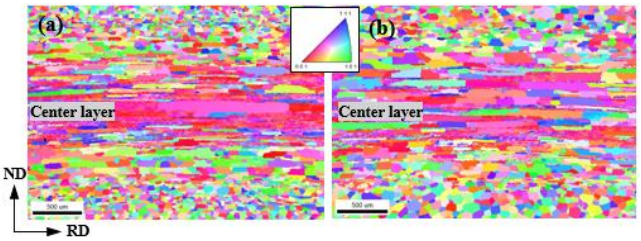

Figure 1: Orientation map (IPF) to microstructure annealed full thickness. (a) 40s of soaking time (b) 120s of soaking time.

The ODF after primary recrystallization at 840°C is shown in Figure 2 (a) and (b). The texture is typical of material after recrystallization and is composed of a strong intensity of the γ-fiber ({111}<112>), {114}<481>, {554}<225> and θ-fiber {001}<210>. The {111}<112> and {554}<225> components are related to Goss due to their higher growth rate due to the rotation of approximately 30º with the common axis <110> [3]

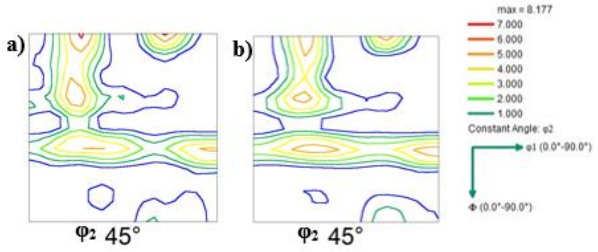

Figure 2: Orientation distribution function (ODF) φ_2 0° and 45° for samples after the first recrystallization. (a) 40s of soaking time (b) 120s of soaking time.

The magnetic properties were 1.926 T (90s) and 1.901 T (120s). The core loss was 10% lower with longer soaking time.

1. References

[1] Xianglong Wang, Li Luo, Wenzhu Li, Journal of Magnetism and Magnetic Materials, 552, (2022) 169210.

[2] Shozaburo N, Kunihide T, Jiro H, Katsuro K, Journal of the Japan Institute of Metals and Materials, (1991), Issue 12, Pages 1392-1399.

[3] Matsuo, M., Sakai, T. & Suga, Y, Metall Trans A 17, (1986) 1313–1322.