Effect of cold rolling reduction on magnetic and mechanical properties of a 3.3% Si non-grain oriented electrical steel

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The effect of cold rolling reduction rate on the magnetic and mechanical properties of non-grain oriented electrical steel (NGOES) with 3.3 wt% Si was evaluated. Transfer bar samples were submitted in a laboratory to hot rolling for the thicknesses of 2.5, 2.1, 1.5 and 1.2 mm at 1000 °C, hot band annealed at 1000 °C, cold rolled to 0.50 and 0.25 mm and final annealed at 940 °C. As expected, the results demonstrated that magnetic polarization (J_{50}) and yield strength ($Rp_{0.2}$) presented antagonistic behavior, where at the lowest rate of cold reduction, the material showed the highest polarization and the lowest yield strength, due to the strong influence of the η/γ fibers ratio and final grain size on these properties. The cold rolling reduction which obtains the best balance between magnetic properties (core loss at 1T/400Hz and J_{50}) and mechanical properties (yield strength $Rp_{0.2}$) is 66.7 % for 0.50 mm and 83.3 % for 0.25 mm, both cases for the same hot band thickness of 1.50 mm.

Keywords: Non-grain oriented electrical steel; magnetic properties; mechanical properties; texture; cold rolling reduction rate.

1. Introduction

Although many studies were carried out to determine the best magnetic properties for NGOES such as [1] [2], there are few that focus on identifying the optimum cold rolling reduction rate that balances both mechanical and magnetic properties. With the growing emphasis on environmental protection and the reduction of CO_2 emissions, there is increasing market demand for electric vehicles (EVs) and hybrid electric vehicles (HEVs) with high-efficiency motors [3]. This demand calls for electrical steels with low core losses at medium frequencies, high magnetic polarization (J_{50}), and improved mechanical properties [4]. Therefore, the present study aims to investigate the best trade-off between mechanical and magnetic properties in 0.50 mm and 0.25 mm NGOES with 3.3% Si, by varying the cold rolling reduction rate from 50% to 90%.

2. Experimental Method

Transfer bar samples of NGOES 3.3%Si were reheated at 1150°C, hot rolled at 1000 °C to thickness of 1.00 mm , 1.50 mm, 2.00 mm, and 2.50 mm thick and then cooled to 500°C to simulate coiling. Thereafter, the samples were hot band annealed at 1000 °C, cold rolled to 0.25 mm and 0.50 mm and final annealed at 940 °C. Magnetic measurements were carried out using a Brockhaus single sheet tester MPG200D, mechanical properties were measured on an Instron 5583 tensile test machine, texture analysis was performed via X-ray diffraction using a Philips X'Pert X-ray diffractometer and the grain size was measured using DMRM Leica optical microscope.

3. Results and Discussion

Since the yield strength did not show significant variation across the cold rolling reduction for 0.5 mm, an optimum point that maximized J_{50} and minimized W1T/400hz was observed at a cold reduction rate of 66.7%, i.e., hot band of 1.5mm as shown in Figure 1-a. On the other hand, the lowest cold rolling reduction rate for 0.25mm presented the highest value of J_{50}, the lowest core loss at 1T/400Hz but also the minimum Rp0.2, as shown in Figure 1-b. These results demonstrated the strong influence of texture on J50, since the cold reduction affects the material's texture [5]. However, taking into account the the DIN EN 10303:2016-02 table D-1 [13] where the minimum yield strength (RP0.2) is 390MPa, we considered the optimal balance between mechanical and magnetic properties for 0.25mm to be at 83.3%, i.e., also a hot band of 1.5mm.

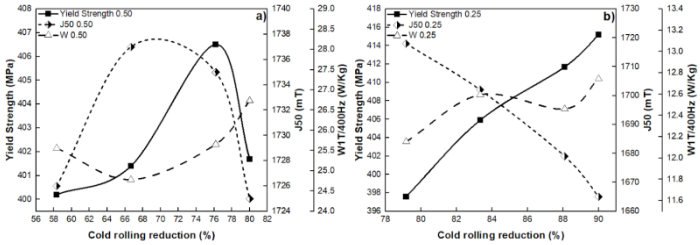

Figure 1: Relationship between yield strength, magnetic polarization (J_{50}), and core loss (W) as functions of cold rolling reduction after final annealing for: a) 0.50 mm (left) and b) 0.25 mm (right).

References

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