Microstructure and Magnetic Properties of Grain-oriented Electrical Steel by Continuous Annealing under Stress Treatment

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During the final high-temperature batch annealing of grain-oriented electrical steel, abnormal grain growth of {110}<001> Goss grains occurs. A few Goss grains grow selectively at the expense of many other primary recrystallized grains, which are related to the magnetic properties of the final product. This study aims to explore the possibility of reducing manufacturing costs for producing grain-oriented electrical steel by using continuous annealing within 10 minutes instead of long batch annealing. To shorten the incubation period of abnormal grain growth during high-temperature annealing, pre-straining in tension and temper rolling were applied to specimens prior to annealing. Depending on the annealing conditions and pre-strains, the abnormal grain growth of Goss or non-Goss oriented grains evolved within 10 minutes. Microstructure, texture, and magnetic properties under pre-strain annealing conditions were investigated and discussed in this study.

Keywords: Grain-oriented electrical steel; abnormal grain growth; continuous annealing; pre-strain annealing

1. Introduction

During the final high-temperature batch annealing of grain-oriented electrical steel, abnormal grain growth of {110}<001> Goss grains occurs. A few Goss grains grow selectively at the expense of many other primary recrystallized grains, which are related to the magnetic properties of the final product. This study aims to explore the possibility of reducing manufacturing costs for producing grain-oriented electrical steel by using continuous annealing within 10 minutes instead of long batch annealing. The kinetics of abnormal grain growth of Goss texture can be significantly accelerated by strain induced boundary migration(SIBM) mechanism [1,2] In this study, to shorten the incubation period of abnormal grain growth during high-temperature annealing, pre-straining in tension and temper rolling were applied to specimens before annealing.

2. Results and discussion

Figure 1(a) and 1(b) show the microstructure and texture of samples without pre-strain after annealing at 1050℃ for 10 minutes. The sample without pre-strain has unchanged microstructure and texture after annealing for 10 minutes. The normal grain growth was still inhibited by second-phase particles. The nearly similar primary recrystallized texture ({411}<148> and{111}<112>) were still remained after annealing for 10 minutes. A few Goss-oriented (within tolerance angles of 15°) grains were investigated with an area fraction of 1.4% and no size advantage.

Figure 1(c) and (d) show the microstructure and texture of samples with pre-stretching and annealing at 1050℃ for 10 minutes. On the other hand the microstructure and texture of the pre-stretched sample have significantly changed after annealing for 10 minutes. Obvious abnormal grain growth occured in the pre-stretched sample at 1050℃. EBSD analysis shows both Goss-oriented grain and non Goss-oriented grain grew abnormally to sizes exceeding ~2mm after annealing for 10 minutes. Near goss-oriented grain, which had a low misorientation angle of 13.4° from the exact Goss orientation, grew abnormally. Additionally, some non-Goss oriented grains in Fig. 1(c) (bottom-left side), which were significantly deviated from the Goss orientation, grew abnormally to a size as large as the Goss-oriented grains after annealing for 10 minutes. Regardless of the orientation of the abnormally grown grains, many remaining island grains were observed inside the abnormally grown grains and mostly had low misorientation angle less than 15° with them. [3]

We observed that abnormally grown grains had the Non-Goss orientations, as well as near Goss orientation in pre-stretched sample after annealing for 10 minutes. The reason why diffused Goss-oriented grains grew abnormally annealing under stress condition will be in discussed in detail.

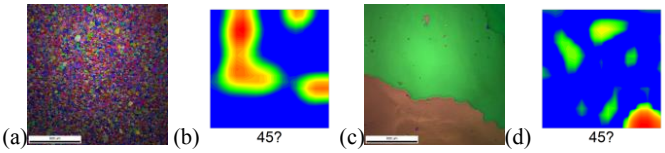

Figure 1: samples after annealing at 1050℃ for 10 min
(a) EBSD IPF map and (b) ODF diagrams (φ_2 = 45° section) of samples without pre-strain (c) EBSD IPF map and (d) ODF diagrams (φ_2 = 45° section) of samples with pre-stretched

References

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