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EFFECT OF HOT ROLLING REDUCTION ON MICROSTRUCTURES AND TEXTURES OF GRAIN ORIENTED SILICON STEEL

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The effect of hot rolling reduction on microstructures and textures of grain oriented silicon steel was studied by optical microscopy (OM), zeiss ultra 55 Scanning electron microscope (SEM) and Electron backscatter diffraction (EBSD) technique respectively. The results indicate that the effect of hot rolling reduction on grain size of hot rolled and normalized sheets in surface layer is great, while the effect on grain size of primary recrystallized grain is little. The shear zone thickens with the finishing reduction decreases, moreover strong {111}<112> and {110}<001> textures can be obtained in hot rolled sheets. Combined with the previous research conclusions, it can be found that the rolling process of oriented silicon steel is contributed to the formation of texture, while the recrystallization process reduces the sharpness of the texture.

Keywords: grain oriented silicon steel; hot rolling; reduction; microstructure; texture

INTRODUCTION

Grain oriented silicon steel is an important soft magnetic alloy material which is widely used in electric power and electron industry. The typical texture is {110}<001> texture which is beneficial to improve the magnetic induction of grain oriented silicon steel. Therefore, the purpose of preparing oriented silicon steel is to obtain sharp {110}<001> texture mainly through hot rolling, normalizing, cold rolling and annealing processes[1-3]. At present, a large number of studies on grain oriented silicon steel has focused on cold rolling and recrystallization in order to clarify the growth mechanism of {110}<001> oriented grains during secondary recrystallization, while the research on hot rolling is less[4-6]. Consequently, it is very important to develop new grade grain oriented silicon steel that clarify the evolution of microstructure and texture under different hot rolling processes. The effect of hot rolling temperature on microstructures and textures was studied in previous research[7], and the effect of hot reduction was studied in this paper.

EXPERIMENTAL MATERIALS AND METHODS

Grain oriented silicon steel was selected as the experimental material with main components of 0,053 % C, 3,18 % Si, 0,115 % Mn, 0,028 % Alsol and 0,05 % Sn. Continuous cast slab was rolled to 50 mm and 40 mm thickness on roughing mill espectively, and then the intermediate billets were rolled to 2,3 mm thickness on the finishing mill. Then the hot rolled sheets were designated as low 50-sample and 40-sample separately. Subsequently, the hot rolled sheets were cooled at the same cooling rate of 35 °C/s in order to study the effect of finishiing reduction on microstructures and textures of grain oriented silicon steel. The microstructure was observed by using optical microscopy technique. The crystallographic orientation measurement was carried out on the lateral section of the samples using an HKL-EBSD system, and the image field was the region of 1/2 thickness beneath the surface of hot rolled and normalized sheets. The precipitates in hot rolled sheets were observed by zeiss ultra 55 Scanning electron microscope.

MICROSTRUCTURE ANALYSIS

Figure 1 shows the microstructures of the hot rolled sheets. It can be recognized that the grain size of the surface layer decreases, while the grain size of the center layer changes little with the decrease of the finishing reduction. The reason is that the surface layer microstructure of hot rolled sheets is significantly affected by reduction. The decrease of the reduction reduces deformation energy storage of the sheet surface, and leads to the lower driving force of recovery and recrystallization, which resulting in smaller dynamic recrystallization grains in the surface layer of hot rolled sheets. Taking grain size less than or equal to 10 μm as the statistical standard of recrystallized grain, the recrystallized

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grain size ratio of 50-sample is 35 – 44 %, while that of 40-sample is 32 – 34 %. It shows that more dynamic recrystallization grains can be obtained under the large finishing reduction.

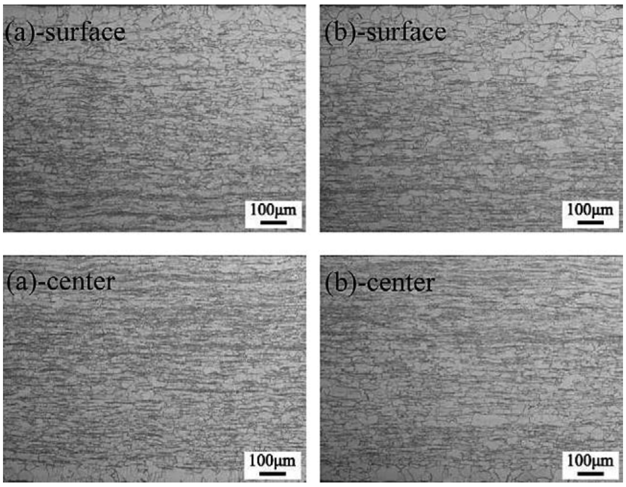

Figure 1 Microstructures of hot rolled sheets
(a) 50-sample; (b) 40-sample

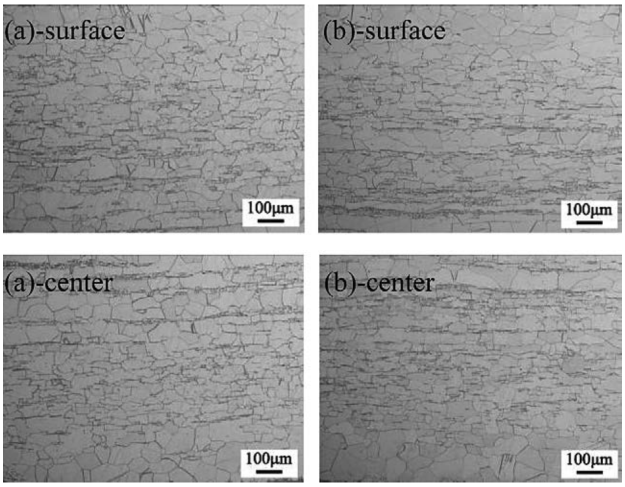

Figure 2 Microstructures of normalized sheets
(a) 50-sample; (b) 40-sample

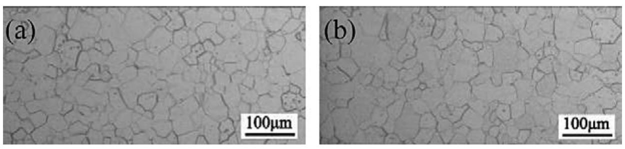

Figure 3 Microstructures of decarburized strips
(a) 50-sample; (b) 40-sample

Figure 2 indicates the microstructures of the normalized sheets. It is exhibited that the samples inherit the banded structure characteristic of hot rolled sheets and the thermally deformed structures recrystallize after normalizing. The recrystallization can be seen in surface layer obviously, while recovery and recrystallization as well as the grain growth can be found in center layer. According to the statistical results, the average surface and center grain size of the 50-sample is 40,58 μm and 15,96 μm respectively, while that of the 40-sample is 40,48 μm and 19,68 μm respectively. It is shown that center grains are coarsened obviously, while the surface grains size has no distinct change with the decrease of the finishing reduction after normalization.

Figure 3 shows the microstructures of decarburized strips. It can be recognized that the finishing reduction has little effect on grain size and homogeneity of primary recrystallized grain. According to the statistical results, the grain size difference between the two samples is about 0,2~0,8 μm, while the standard deviation difference is about 1μm.

TEXTURE ANALYSIS

Figure 4 shows the EBSD orientation maps of the hot rolled sheets. It can be seen that shear textures such as {110}<001> and {110}<112> are the main texture components in surface layer of the samples, while the main texture components of center layer are deformation textures such as α fibre texture <110>, {111}<112> and {114}<481>. Specifically, the shear surface region of the 40-sample is thicker, and more {110}<001> oriented grains can be found in surface layer. Moreover, the strong {100}<011> texture is formed in center layer of 40-sample due to the small finishing reduction.

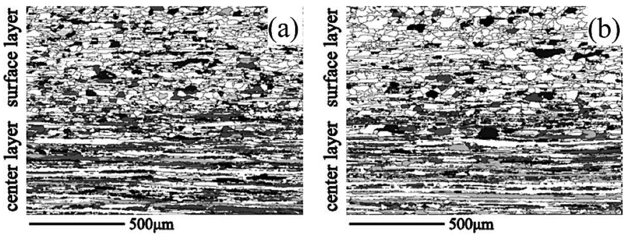

Figure 4 EBSD orientation maps of hot rolled sheets
(a) 50-sample; (b) 40-sample
{111}<112>; {110}<001>; {114}<481>;
{100}<011>; {110}<112>

Figure 5 indicates the EBSD orientation maps of the normalized sheets. It can be seen that the surface layer is consisted of coarse recrystallized grains, and the center layer is consisted of the recovered and recrystallized grains. The texture components is basically in accordance with that of which the hot rolled sheets after normalizing, but the sharpness decrease significantly, furthermore the {114}<481> and {110}<001> are dominant textures. Compared with the 50-sample, more {110}<001> oriented grains can be seen in surface layer but less {114}<481> oriented grains can be seen in center layer of 40-sample.

The EBSD orientation maps of the decarburized strips are shown in Figure 6. It is demonstrated that the recrystallized structure is fine and uniform after decarburizing and nitriding. The grain size of primary recrystallized grains decreases from 21,73 μm in 50-sample to 20,30 μm in 40-sample with the decrease of the finishing reduction. It can be found that the texture components of decarburized annealed strips are mainly

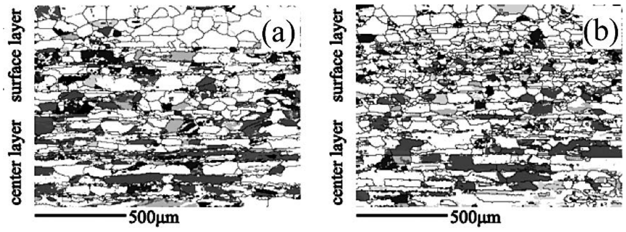

Figure 5 EBSD orientation maps of normalized sheets
(a) 50-sample; (b) 40-sample
{111}<112>; {110}<001>; {114}<481>;
{100}<011>; {110}<112>

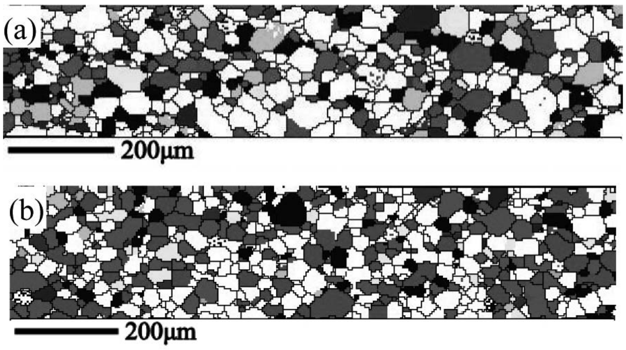

Figure 6 EBSD orientation maps of decarburized strips
(a) 50-sample; (b) 40-sample
{111}<112>; {110}<001>; {114}<481>;
{111}<110>; {110}<112>

{114}<481> and γ fiber texture <112>. This texture feature shows obvious inheritance from center region textures of hot rolled sheets. The texture components of the samples are similar, but the intensity and relative quantity are different.

CONCLUSIONS

The grain oriented silicon steel is hot rolled under different finishing reduction, and the conclusions are as follows:

The effect of hot rolling reduction on grain size of hot rolled and normalized sheets in surface layer is great, while the effect on grain size of primary recrystallized grain is little.

The texture component of normalized sheets is in accordance with that of the hot rolled sheets. The sharpness of texture is weak after hot rolling and normalizing, but it is strong after cold rolling and decarburizing.

The shear zone thickens with the finishing reduction decreases, moreover strong {111}<112> and {110} <001> textures can be obtained in hot rolled sheets.

Acknowledgements

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Note: The responsible translator for English is Yuan Yuan Shao, University of Science and Technology Liaoning, Anshan, China