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

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The effect of hot rolling temperature 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 show that being hot rolled at 1 152 °C and 1 227 °C respectively, the effect of hot rolling temperature on microstructures of hot rolled and normalized sheets is little, and there is only a small difference in grain size between the samples. Secondary recrystallization is difficult to occur in the medium temperature sample due to the lack of sufficient inhibitors in the sample. The major deformed texture component in center region of hot rolled sheets is {114}<481> which has obviously heredity, and it is more sharp in low temperature sample.

Keywords: grain oriented silicon steel, hot rolling, sheet, texture; microstructure

INTRODUCTION

Grain oriented silicon steel is an important soft magnetic alloy material used as transformer core. Its magnetic induction intensity is determined by the orientation and sharpness of {110}<001> texture. It is reported that the type, size and number of inhibitor have an important effect on the formation of sharp {110}<001> texture during the secondary recrystallization [1,2]. The production process of grain oriented silicon steel is divided into high heating temperature technology and low heating temperature technology according to the type of inhibitor [3,4]. At present, the development trends of the grain oriented silicon steel is to reduce heating temperature [5,6]. Consequently, it is important to produce grain oriented silicon steel with low heating temperature that research the evolution of microstructure and texture of grain oriented silicon steel at different temperature. In this paper, the effect of hot rolling temperature on microstructure and texture of grain oriented silicon steel was studied.

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, of which the main inhibitor was AlN. Continuous cast slab was hot rolled to 2,3 mm thick after heating at 1 152 °C and 1 227 °C respectively, and then the hot rolled sheets were designated as low temperature sample (L-sample) and medium temperature sample (M-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 hot rolling temperature 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 electron backscattered diffraction 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 (SEM).

MICROSTRUCTURE ANALYSIS

Figure 1 shows the microstructures of the hot rolled sheets. It can be recognized that the microstructure is composed of ferrite and pearlite, and dynamic recrystallization grains can be found in the surface layer and the center layer of the samples. According to the statistical results, the average surface and center grain size of the L-sample is 16,63 μm and 11,73 μm respectively, while that of the M-sample is 24,47 μm and 21,87 μm respectively. And the reason is that the high rolling temperature leads to the grain coarsening. Taking grain size less than or equal to 10 μm as the statistical standard of recrystallized grain, the recrystallized grain size ratio of L-sample is 36 – 42 %, while that of M-sample is 18 – 42 %. It

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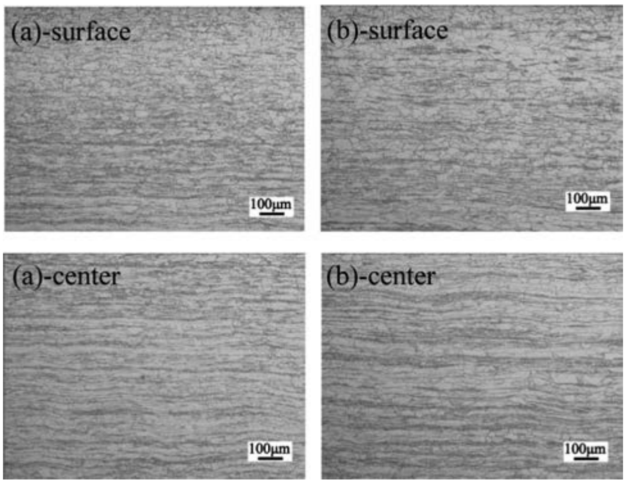

Figure 1 Microstructures of hot rolled sheets
(a) L-sample; (b) M-sample

shows that more dynamic recrystallization grains can be obtained at the low hot rolling temperature.

Figure 2 indicates the microstructures 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. According to the statistical results, the average surface and center grain size of the L-sample is 40,57 μm and 10,79 μm respectively, while that of the M-sample is 49,62 μm and 16,86 μm respectively. It is shown that surface grains are coarsened obviously, while the center grains size has no distinct change after normalization. This is due to that the center recovered structures of the hot rolled samples are difficult to recrystallize during normalization. The effect of hot rolling temperature on microstructures of hot rolled and normalized grain oriented silicon steel sheets is little at the medium and low hot rolling temperature in conclusion.

Figure 3 shows the macrostructures of finished products. Secondary recrystallized structures can be seen in L-sample, while a large number of fine grain structures can be seen in M-sample. It is due to that the number of inhibitors is little in M-sample, as shown in

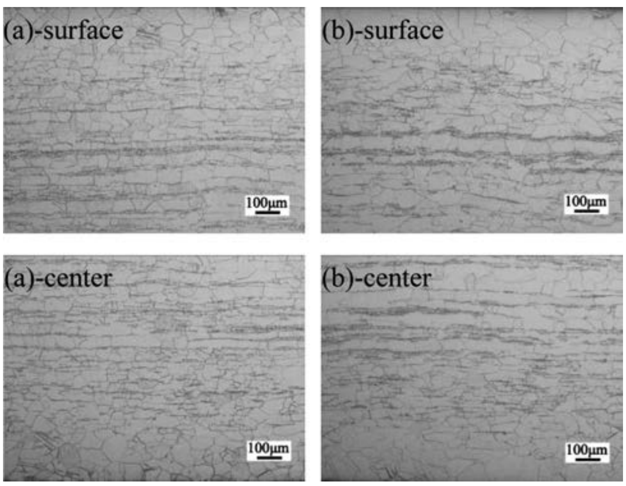

Figure 2 Microstructures of normalized sheets
(a) L-sample; (b) M-sample

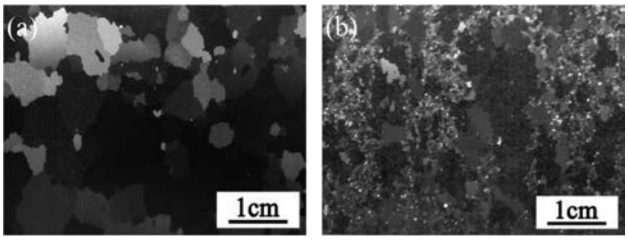

Figure 3 Macrostructures of finished products
(a) L-sample; (b) M-sample

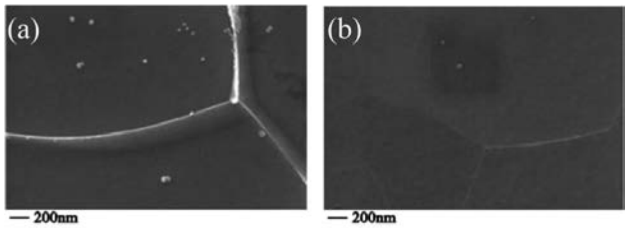

Figure 4 Precipitation of hot rolled sheets
(a) L-sample; (b) M-sample

Figure 4. The reason is that a large number of AlN particles dissolve in M-sample during hot rolling, whereas the peak temperature of AlN particle precipitation is lower than the finishing temperature, which cause that the more dissolved AlN particles are too late to precipitate in the M-samples.

TEXTURE ANALYSIS

Figure 5 shows the EBSD orientation maps of the hot rolled sheets. The texture components of hot rolled sheets are mainly {110}<001>, {110}<112>, {111}<110>, {111}<112>, {114}<481> and {100}<011>. The shear surface region of the M-sample is thicker, while the deformed center region of the L-sample is thicker. More {110}<001> oriented grains can be found in surface layer of M-sample, and more {114}<481> oriented grains can be found in center layer of L-sample.

Figure 6 indicates the EBSD orientation maps of the normalized sheets. It can be seen that the texture characteristic of normalized sheets is similar to that of hot rolled sheets, and it is merely that the intensity of the α-fiber <110> texture is slightly reduced. The {114}<481> texture in the L-sample is sharper and the magnetic property is better than that in M-sample. The

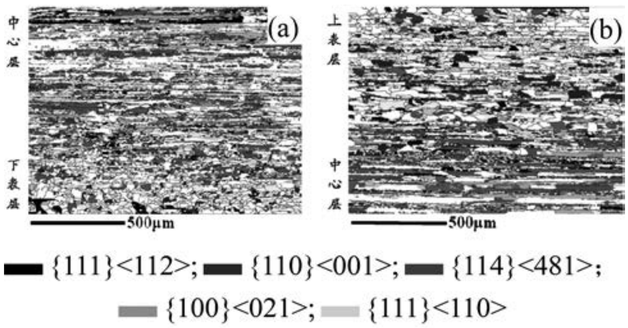

Figure 5 EBSD orientation maps of hot rolled sheets
(a) L-sample; (b) M-sample

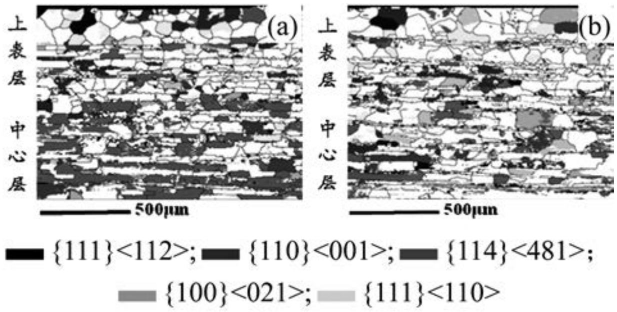

Figure 6 EBSD orientation maps of normalized sheets
(a) L-sample; (b) M-sample

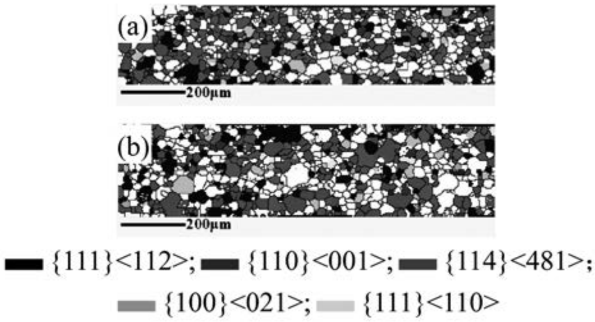

Figure 7 EBSD orientation maps of decarburized strips
(a) L-sample; (b) M-sample

shear region is thicker and the intensity of {110}<001> texture is reduced in M-sample.

Finally, the EBSD orientation maps of the decarburized strips are shown in Figure 7. The texture components of decarburized annealed strips are mainly {100}<021>, {114}<481> and γ-fiber texture. This texture feature shows obvious inheritance from center region textures of hot rolled sheets. It can be seen that the texture components of the samples are similar, but the intensity and relative quantity are different. The difference of the samples is mainly the grain size, of which the M-sample is larger. Therefore, the hot rolling temperature mainly affects the grain size of decarburized strips, but has little effect on the texture components.

CONCLUSIONS

The grain oriented silicon steel is hot rolled at 1 152 °C and 1 227 °C respectively, and the conclusions are as follows:

The effect of hot rolling temperature on microstructures of hot rolled and normalized sheets is little, and there is only a small difference in grain size between the samples.

Secondary recrystallization is difficult to occur in the M-sample due to the lack of sufficient inhibitors in the sample.

The major deformed texture component in center region of hot rolled sheets is {114}<481> which has obviously heredity, and it is more sharp in L-sample.

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