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Inhomogeneity of Hot Rolling Texture in Cu/Nb Added Ultra Low Carbon Steels

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Abstract The texture and microstructure in Cu/Nb added ultra low carbon steels through the different thickness layer were studied after hot rolling. It was found that the two ultra low carbon steels all show the inhomogeneity of hot rolling texture and the Cu-added ultra low carbon steel was far more inhomogeneous than Nb-added one. In the center layer, the strong α fibre, γ fibre textures and the shear textures including {001}<110>, {111}<112> were founded. Near the surface, the α fibre texture and the orientation texture caused by a typical plane-strain deformation condition of bcc metals were observed.

Key words Inhomogeneity, Microstructure, Texture, Cu/ Nb added ultra low carbon steel, Hot rolling.

1. Introduction

Recently, the newly developed ULC (ultra low carbon) steel is expected to be applied in a wide range of automotive parts.[1)] For the application of the ULC steel, reliability of mechanical properties and the good formability are important. Such properties are related to the texture and microstructure of materials. It is well known that the texture may be inhomogeneous along the sheet thickness due to the inhomogeneity of the deformation during rolling and the non-uniformity of the recrystallization that occurs during the heat treatment.[2)] This inhomogeneity influences the mechanical property and formability of materials.

In this paper, the two hot rolled ULC steels were investigated. One was based on Cu and the other was based on Nb. The Nb-added ULC steel has good formability and non-aging feature 3).However the availability of Nb was restricted by its price and weldability effect. But for Cu-added ultra low carbon steel, C content was controlled in the range of ppm (< 30 ppm) itself without the help of the carbide forming elements such as Nb and Ti. The price of Cu is low and Cu-added ULC steel appears excellent bake hardening behavior and non-aging effect.[4)] The aim of this paper is to understand the inhomogeneity behaviors of the hot rolled texture in the two ultra low carbon steel through the different layers.

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2. Experimental procedure

The chemical composition for the experimental ULC steels is listed in Table 1. The 30 mm thick slab was hot rolled down to 3.2 mm. Finish rolling was carried out at 920°C followed by coiling at 650°C. The microstructures and textures through the different thickness layers were investigated. The reduction process was carried out by the milling machine. The observed position was described by the parameter P which was defined by the equation:

$$P = \Delta t / t_0$$

where t is the distance from the surface, and t_0 the sheet thickness. Five positions with P values of 0, 1/4, 1/2, 3/4, and 1 were selected. Samples were polished and etched with the nital for optical microscopy. The pole figure {110}, {200}, {211} were measured by Co Kα radiation and the orientation distribution function (ODF) is calculated by using the progression extension.

3. Result and discussion

3.1 Microstructure

The optical micrographs of steel 1and steel 2 are taken at different thickness layers, i.e. surface (P = 0), quarter (P = 1/4), center (P = 1/2), three quarter (P = 3/4) and opposite surface (P = 1) (Fig. 1). The two steels show the equiaxed grain microstructure through the different layers. The grains at the surface and opposite surface layers are the finest. This may be due to the grain boundary thermal grooving. In the quarter and three

Table 1. Chemical composition of the experimental ULC steels (wt.%)

Steel	C	Mn	P	S	B	Cu	N	Nb
1	0.0025	0.10	0.06	0.0090	0.001	0.09	0.0021	-
2	0.0025	0.10	0.06	0.0082	0.001	-	0.0022	0.008

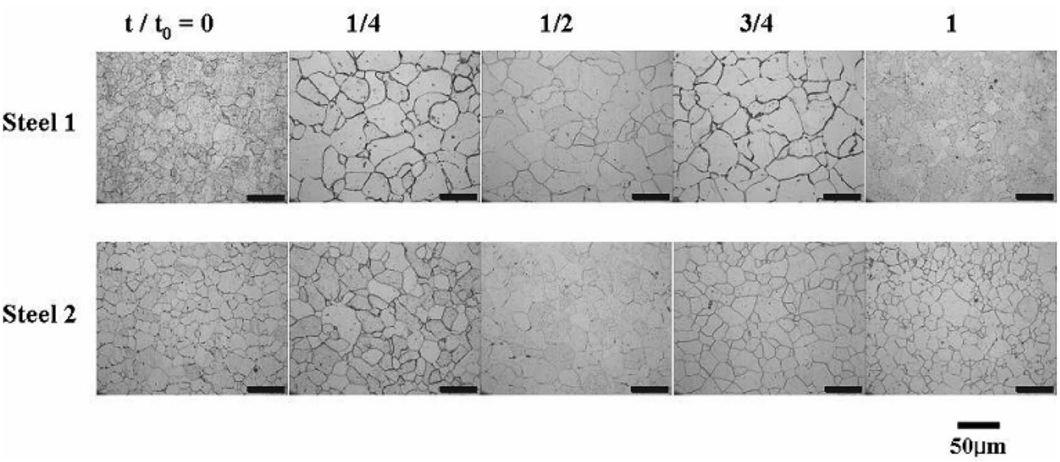

Fig. 1. Optical micrographs of the hot rolled steels.

quarter layers the grains become large. Close to the center layer, the grains become small again. And in the center layer the grain sizes are the most homogenous. Fig. 2. shows the average grain sizes at various layers for two steels. The maximum average grain size appears at the quarter and three quarter layers. For steel 2 the change of average grain sizes through the different layers exists but not so obvious. From the general changes of the microstructure through the different thickness layer, the inhomogeneity degree in the Cu added hot rolled ULC steel are more obvious than in the Nb added ultra low carbon steel. This was explained in terms of the precipitates effect in hindering the grain growth. Because Cu precipitates have low solvus the precipitate effect of Cu-added ultra low carbon steel in hindering the grain growth is smaller than that of Nb-added ultra low carbon steel.

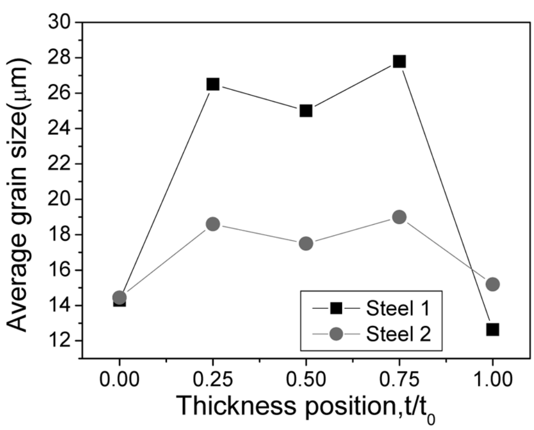

Fig. 2. Average grain sizes of the hot rolled steels.

3.2 Texture

Fig. 3 shows the skeleton lines of á fibre (<110>//RD) and γ fibre (<111>// ND) for two steels at the different thickness layers. Two steels revealed a bit different trend. For steel 1 at the surface the {225}<110>, {223}<110> and {332}<110> appear as the main texture components with the high orientation density. The orientation densities

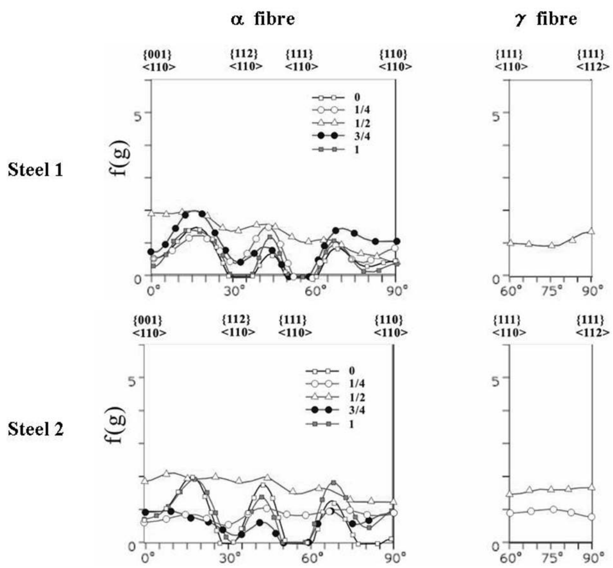

Fig. 3. The α, and γ fibre skeleton lines of the hot rolled steels.

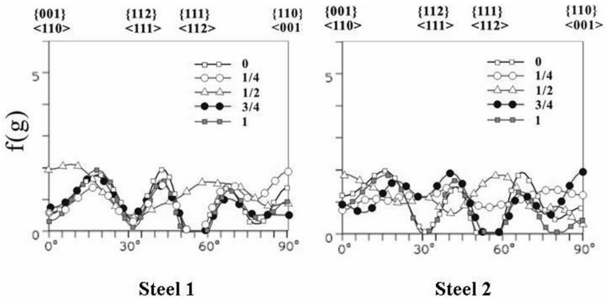

Fig. 4. The ε fibre skeleton lines of the hot rolled steels.

of these components were higher at quarter and three quarter layers to the surface. Close to center layer the α fibre and γ fibre are all developed well. Especially, the γ fibre appears strong. For steel 2 the changes of the texture at surface and center layers were similar to steel 1. But at the quarter layer the {225}<110>, {223}<110> and {332}<110> components degraded and the γ fibre began to appear. As mentioned above, for steel 2 at the quarter layer the texture transition occurred but for steel 1 the transition is not evident. It is concluded that the distribution of texture through the different layers is inhomogeneous and the trend of the texture change is different for steel 1 and steel 2.

In the same manner the changes of orientation densities along the ε fibre (<110>//TD) were somewhat different in two steels. The ODFs of ε fibre for two steels is shown in Fig. 4. Despite texture inhomogeneity from the surface to the center layer, two steels revealed a common characteristic as follows. In the surface, $\Phi = 15^o$ orientation, $\Phi=42.5^o$ orientation and $\Phi = 70^o$ orientation are dominant. On the other hand, in the center layer, {001}<110> orientation shows the maximum peak and {111}<112> with a relatively strong orientation density were formed. Similarly, for steel 2 at the quarter layer the texture transition occurred but for steel 1 the transition did not appear. This is due to the Cu precipitate effect in hindering the grain growth. It can be seen that the texture in the surface layer mainly comprises orientations caused by a typical plane-strain deformation condition of bcc metals. Near the center, in contrast, typical shear textures are observed. Such textural distribution may be strongly related to the shear strain distribution caused by milling.[5)]

4. Conclusions

The present study examined the texture and microstructure of the Cu/Nb added ultra low carbon steels during hot rolling. The microstructure inhomogeneity of two steels was found through the different layers and the inhomogeneity degree in the Cu added ultra low carbon steel is more obvious than in the Nb added ultra low carbon steel. This is due to the Cu precipitates effect in hindering the grain growth. And in the center layer the grains are fine and homogenous relatively. The texture inhomogeneity was observed through different layers for two steels. Though two steels revealed a bit different trend, it can be seen that the texture in the surface layer mainly comprises orientations caused by plane-strain deformation condition and in the center typical shear textures related to the shear strain distribution caused by milling are observed. For steel 2 at the quarter layer the texture transition occurred but for steel 1 the transition did not appear.

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