Effect of re-austenitization on the transformation texture inheritance

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Abstract. Bainitic-martensitic microstructures produced by direct quenching austenite subjected to different degrees of pancaking have been re-austenitized and quenched to fully martensitic structures in order to investigate the effect of prior texture on the final martensite texture. Three different prior austenite pancaking states varying from convex-like to highly pancaked were investigated using an ultrahigh-strength strip steel hot rolled with various finish rolling temperatures followed by direct quenching. Microstructures were characterized using FESEM and transformation texture analysed using FESEM-EBSD at the strip surface, quarter-thickness and mid-thickness positions. The results show that an increase in rolling reduction below the non-recrystallization temperature increases the intensities of ~{554}<225>α and ~{112}<110>α texture components in the ferrite along the strip mid-thickness and of the ~{112}<111>α component at the surface. The re-austenitization of the materials at 910°C for 30 min led to an inheritance of the same components from the parent specimens, but also increased the intensity of {001}<110>α, {110}<110>α and {011}<100>α components.

1. Introduction

Texture is known to influence the mechanical properties of steels [1-3]. It also well established that hot rolling parameters have a pronounced effect on the transformation textures of ultrahigh-strength steels [1-4]. Furthermore, in hot-rolled accelerated cooled or quenched steels, a memory effect has been observed by the variant selection of the Kurdjumov-Sachs (K-S) orientation relationship during the phase transformation, i.e. the original texture is partly retained after re-austenitization and cooling [4-6]. However, the effect of the degree of deformation in the non-recrystallization regime of austenite on the transformation texture inherence at different depths in the thickness direction is not widely covered. The aim of the present paper is to report the effects of total reduction in the non-recrystallization regime (Rtot) on the transformation texture of an ultrahigh-strength low-alloyed steel when quenched from as-rolled and re-austenitized material.

2. Experimental

In these experiments, 210 mm thick continuously cast slabs were thermomechanically rolled to a final strip thickness of 6 mm and direct quenched to room temperature at a rate of ~50-70 °C/s to produce three different austenite morphologies. The chemical composition of the steel was 0.1C-0.2Si-1.1Mn-1.2Cr-0.15Mo-0.03Ti-0.002B (wt.%). For comparison purposes, direct quenched material was also re-austenitized at 910 °C for 30 min and water quenched to room temperature at ~50-70 °C/s. The six investigated materials are given in Table 1.

Table 1. Investigated materials and austenite morphologies.

| As-rolled                          | Re-austenitized         |
|------------------------------------|-------------------------|
| 1Conv (Convex-like austenite)      | 1ReA (Equiaxed austenite) |
| 2Panc (Pancaked austenite)         | 2ReA (Equiaxed austenite) |
| 3HiPanc (Highly pancaked austenite)| 3ReA (Equiaxed austenite) |

General characterization of the transformation microstructures was performed with the aid of both a VK-X200, Keyence laser scanning microscope (LSCM) and a Sigma, Zeiss field
emission scanning electron microscope (FESEM) using picric acid and nital etching. Electron backscatter diffraction (EBSD) measurements and analyses were performed using the EDAX-OIM acquisition and analysis software. The FESEM for the EBSD measurements were made at 15 kV with a step size of 0.10 µm. Prior austenite grain sizes (PAGS) were measured as described in Ref. [7].

3. Results and discussion

3.1. Austenite morphologies

The austenite morphologies of the specimenss are shown in Figure 1. In the as-rolled specimens 1Conv, 2Panc and 3HiPanc prior austenite grain size (PAGS) were 9.6 µm, 8.1 µm and 8.0 µm and total reduction in the non-recrystallization regime (Rtot) were ~38%, ~52% and ~66%, respectively. In the re-austenitized specimens (1ReA, 2ReA and 3ReA) austenite morphologies were equiaxed and average PAGS were ~13.3 µm. The degree of Rtot did not affect the uniformity or magnitude of the PAGS. A typical re-austenized specimen is shown in Figure 1d.

![Figure 1](image)

Figure 1. Prior austenite grain boundaries in 1Conv (a), 2Panc (b), 3HiPanc (c) and 1ReA (d).

3.2. Transformation texture

The orientations of importance in the present materials are found in the $\phi_2=45^\circ$ section of Figure 2. Transformation textures were determined at the sheet subsurfaces, ¼-thicknesses and mid-thicknesses in as-rolled and re-austenitized specimens. Only surface and mid-thickness ODF sections are shown in Figure 3 (as-rolled) and Figure 4 (re-austenitized) as no difference was found between the ¼-thickness and mid-thickness specimens.

In the strip subsurface layer, increasing Rtot from 38% to 66% decreases the intensity of the $\{001\}<110>_\gamma$ component, indicating that austenite recrystallization was no longer taking place at this location during rolling due to surface cooling. Concurrently, the $\sim\{112\}<111>_\gamma$ and $\sim\{110\}<111>_\gamma-\{110\}<112>_\gamma$ components increase in intensity quite significantly, Figures 3a, 3c, and 3e. Wittridge and Jonas [8] have reported, in the $\gamma$-to-$\alpha$ transformation, the shear components $\{111\}<211>_\gamma$ and $\{112\}<110>_\gamma$ lead to the formation of the shear components
\{112\}<111>\alpha, \{110\}<112>\alpha, and \{110\}<111>\alpha\), respectively. The high intensities of the bcc shear components indicate that the partially ferritic surface has been extensively deformed by shear.

In the specimen 1Conv, the strongest centerline texture component was the \{001\}<110>\alpha, Figure 3b. This component is generally formed by the transformation of the fcc cube component (\{001\}<001>\gamma), indicating that the centers of the plates had undergone recrystallization prior to transformation. In specimens 2Panc and 3HiPanc, the effect of increasing \(R_{tot}\) led to a decrease in the intensity of the \{001\}<110>\alpha component and to a significant increase in the intensities of the \sim\{554\}<225>\alpha, \sim\{112\}<110>\alpha, and \sim\{112\}<131>\alpha components, Figures 3c and 3f. The latter are formed by transformation from the fcc Cu (\{112\}<111>\gamma), Br (\{110\}<112>\gamma) and Goss (\{110\}<001>\gamma) rolling components, indicating that considerable “pancaking” had in fact taken place.

At the surface, the re-austenitized specimens contained the same texture components as the as-rolled starting materials, but with weaker intensities. Re-austenitizing 3HiPanc led to a decrease in \(f(g)\) from 15 to 3 in the texture component close to \{112\}<111>\alpha, Figures 3e and 4e. After Ray and Jonas [1], decreased texture caused from the multiplicity of variants on transformation. Also at the centerline \{112\}<131>\alpha and \{554\}<225>\alpha components are inherited reason of K-S orientation relation from the starting material, but specimen 2ReA contained significant intensities of \{110\}<110>\alpha, \{011\}<100>\alpha components and specimen 3ReA \{001\}<110>\alpha component, Figures 4d and 4f, respectively. Ray et al. [4] have been reported that the recrystallized austenite form a strong cube component \{001\}<001>\gamma and its, twin \{122\}<212>\alpha, which can derive the \{001\}<110>\alpha, \{110\}<110>\alpha and \{011\}<100>\alpha components in the phase transformation. These results indicate that intense texture in as-rolled material can intensify the texture in subsequently re-austenitized and quenched material.

In the future, re-austenitization followed by quenching can be used to study the effect of texture on strength and toughness without the uncertainties introduced by variations in chemistry, grain structure and inclusion content for example, because the chemical composition and prior austenite condition are the same in the each specimen (1ReA, 2ReA and 3ReA).

Figure 2. Important orientations of the bcc structure in the \(\phi_2=45^\circ\) section.
4. Summary

The effects of total reduction the non-recrystallization regime (R_{tot}) on the transformation texture of an ultrahigh-strength low-alloyed steel has been investigated. The observations can be summarized as follows:

1. The as-rolled direct quenched condition consisted mainly of auto-tempered martensite and lower bainite while the re-austenitized and quenched material was fully martensitic.

2. An increase in R_{tot} strengthens the intensities of the \{554\}<225>\_\alpha\ and \{112\}<110>\_\alpha\ texture components at the 1/4- and mid-thickesses and the shear texture \{112\}<111>\_\alpha\ at the strip surface.

3. Re-austenitized specimens contained the same texture components as the as-rolled starting materials, but in weaker intensities. Texture components \{001\}<110>\_\alpha, \{110\}<110>\_\alpha\ and \{011\}<100>\_\alpha\ were dominant at the mid-thickness.

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