The effect of continuous deformation behaviors on texture formation in magnesium alloy

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Abstract. In previous study, it was investigated texture formation behavior of high temperature compression test in various AZ magnesium alloy. These authors investigated AZ31, AZ61, AZ80 and AZ91 magnesium alloy of compression test at temperature 673K to 723K, a strain rate of $5.0 \times 10^{-2} \text{s}^{-1}$, and a strain -0.4 to -1. It was found two characteristics of texture formation behaviour – 1) the basal texture was increase with solute concentration increasing, 2) the main texture component developed depending on deformation conditions. However, additional experiment was needed to clarify why the development of these texture occur. Therefore, this study investigated the mechanism of texture development behaviors in the AZ91 magnesium alloy with three different types initial textures during high-temperature plane strain compression deformation. This compression test conditions were temperature of 673K to 723K, and a strain rate of $5.0 \times 10^{-4} \text{s}^{-1}$, with up to a strain -1.0. After compression test, the specimens were immediately quenched in water. The texture measurement was conducted by the Schulz reflection method using Cu Kα radiation and EBSD. As a result, in all specimens, fiber texture was formed at located at a position 25° away from (0001) texture. In addition, changes in the main component occurred depending on the temperature and the initial texture.

1. Introduction
The magnesium and its alloys is a lightweight material that has attracted attention because it has great synergy when used in transportation and portable devices. The AZ91 magnesium alloy, a type of magnesium alloy, has favourable mechanical properties that can be used as a structural material [1]. However, magnesium and its alloys has poor formability at room temperature, due to having the hexagonal crystal structure. Due to this limited slip system, there is a poor formability and high solute AZ91 alloy is mostly used as a casting material [2,7]. Therefore, it is necessary to understand the texture control in order to improve poor formability, and is important to understand the mechanism of texture formation in AZ91 magnesium alloy.

In previous study, these authors investigated the behavior formation of texture in AZ31, AZ61, AZ80, AZ91 magnesium alloys during high temperature compression test at various deformation conditions. It was found that two characteristic of texture formation behaviors occur. First, the basal texture was increasing with solute concentration increase. Second, the main texture component developed depending on deformation conditions. They reported that texture formation of magnesium alloy was affected by dynamic recrystallization [1-3]. However, there is no enough to clarify study on the texture formation behaviors of AZ91 alloy.
Therefore, in this study, texture formation behavior of AZ91 magnesium alloy was investigated by plane strain compression tests under the various initial texture and deformation conditions.

2. Experimental procedure

The base materials used a cast AZ91 ingot with Mg-8.77%Al-0.74%Zn wt% chemical composition. The ingot rolled at 673K with rolling reduction of 30%. Specimens were machined out three type of specimens as shown in Figure 1. Figure 1 shows the geometric arrangement of the specimens and RD means the direction in which the specimen extension in plane strain compression. Each specimen is rotated 90 degrees in TD or RD direction. After machining, the specimen is annealed at 723K for 1h for producing homogeneous microstructure. Figure 2 shows axis densities of three types of specimens before deformation. The pole densities are projected onto the compression plane. Mean axis density is used as a unit to draw the contour lines. In case of specimens A, the {0001} pole densities are distributed at the periphery of the pole figure. The (0001) pole densities in specimen B and C are distributed on the great circle 90º from TD and RD, respectively.

Plane strain compression tests were carried out at temperature 673K and 723K, and a strain rate of 5.0×10^{-4}s^{-1} with an up to strain of -1.0. After compression test, the specimens were immediately quenched in water. The microstructure is observed the mid-plane after mechanical polishing and electropolishing. Texture measurements were conducted by the Schulz reflection method using Cu Kα.

Figure 1. The geometry of specimens [2].

Figure 2. {10\overline{1}0} pole figures showing the crystallographic characteristics of the three types of specimens before deformation. (a), (b) and (c) show the specimens of A, B and C, respectively. The pole densities are projected onto the compression plane. Mean axis density is used as a unit to draw the contour lines.
radiation and EBSD. The texture evaluation through five pole figures of \{0001\}, \{10\overline{1}0\}, \{10\overline{1}1\}, \{10\overline{1}2\}, \{11\overline{2}0\}. Based on these five pole figures the ODF (Crystal Orientation Distribution Function) was determined by the Dahms and Bunge method [4]. Electron Backscatter Diffraction (EBSD) measurements were performed after the electrolytic polishing.

3. Results and discussion

3.1. Behavior of deformation

Figure 3 shows true stress – true strain curves for deformation at temperature of 723K with a strain rate of 5.0x10^{-4}s^{-1} up to a strain of -0.4. The flow stress decrease with increasing of temperature.
3.2. Behavior of microstructure and texture formation

Figure 4 shows the grain structure maps observed by EBSD measurements for specimen A before and after deformation – (a) before deformation and (b) at 723K with a strain rate of 5.0x10^{-4}s^{-1} up to a strain of -1.0. The light grey grains are within 15° from (0001) (compression plane) and the dark grey grains are range from 15° to 30° from (0001) (compression plane). Figure 4 (a) and (b) have the same magnification. Black lines express the grain boundaries with a misorientation higher than 15°.

Figure 4 (a) shows that the most of equiaxed grains formed, and these grains indicated light and dark grey. This means that the basal texture was formed before deformation as shown the pole figure of initial texture in Figure 2(a). Also, two types of grey grain show similar fraction. However, with increasing of the strain, the mean grain size gradually increase and the grains with dark grey continuously increase as shown in Figure 4. (b). Although the experiment results of different kinds of specimens are not shown here, specimen B and C were also has same texture formation behaviors.

Figure 5 is the inverse pole figure showing the density distribution of compression axis after deformation at strain rate of 5.0x10^{-4}s^{-1}. (a) 673K, ε = -1.0, (b) 673K, ε = -1.0, (c) 673K, ε = -1.0, (d) 723K, ε = -1.0 (e) 723K, ε = -1.0, (f) 723K, ε = -1.0, respectively. The mean axis density is used as a unit. The value of the maximum axis density and its position are shown at the bottom of the inverse pole figure. The position of maximum axis density is written in (α, β) form. α is the angle from (0001), and β is rotation angle around [0001] from the [0001]-[10\bar{1}0] line to the position of the maximum axis density.

In this study, three kinds of specimens show different texture before deformation. The values of maximum axis densities and its position change with increasing of strain and their positions are α angle 20~25° from (0001) (compression plane) at a true strain of 1.0. This result shows that basal texture was
not developed at deformation condition of this study unlike previous study [2]. This means that texture formation behavior changes depending on the initial texture.

In order to investigate the quantitative variation of texture formation behaviour after deformation, the relationship between maximum axis density and misorientation from (0001) is shown in Figure 6. The horizontal axis in Figure 6 is α angle from inverse pole figure, and the vertical axis is maximum axis density of each β angles which means rotation angle around [0001] from the [0001]–[1010] line.

With increasing strain, the position of maximum axis densities in α angle 20–25° gradually increases. After the deformation up to a strain of 1.0, maximum axis densities at α angle 20–25° show higher than any other α angle in specimens A and C. These results show that axis densities after deformation more developed when axis densities exist at α angle 20–25° before deformation. That is, this means that formation and development of texture after deformation is affected by initial texture. Also, it could confirmed that the maximum axis density in three kinds of specimens continuously moves into α angle 20–25° and the maximum axis density at α angle 20–25° highly increases with increasing of strain. From these results, it is considered that texture formation behavior is affected by continuous deformation and grain growth and the deformed texture is stable orientation for deformation of this study.

4. Conclusions

![Figure 6](image)

**Figure 6.** Compared main component α of Fraction A, B and C specimens to before and after deformation. The one bar means the 10 degree unit of average.
This study investigated the texture formation behavior of AZ91 magnesium alloy with different initial texture during plane strain compression at high temperature. The investigations for microstructure and texture gave the following results.

1) Regardless of initial texture, the fiber texture is formed at located at a position 20–25° away from (0001) after the deformation.
2) With increasing of strain, the fiber texture is formed and developed at a position 20–25° away from (0001). Texture formation behavior in this study is affected by continuous deformation and grain growth.

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