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ECAP한 Al 판재의 판재성형성

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Formability of ECAPed Al Alloy Sheet

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Abstract

Ultra-fine grained and high hardened Al sheet was obtained by Equal channel angular pressing (ECAP). During this process the microstructure, the hardness and the texture of AA 1050 Al alloy sheet are changed by a severe shear deformation. The plastic strain ratio after the ECAP and subsequent heat-treatment condition has been investigated in this study. It was found that the average r-value of the ECAPed and subsequent heat-treated specimen was 1.7 times higher than those of the initial Al sheet. This could be attributed to the various texture formations through the ECAP and subsequent heat-treatment of AA 1050 Aluminum alloy sheet.

Key Words : Equal channel angular pressing (ECAP), Severe shear deformation, Texture, Microstructure, Plastic strain ratio, R-value, Formability, Earing

1. 서 론

During the last decade, considerable efforts have been devoted to investigate of the physical and the mechanical properties of ECAPed bulk materials[1]. But there have been few researchers that were interested in the texture evolution of ECAPed sheet materials [2-5]. In the present investigation, the 1050 Al sheet was ECAPed to investigate the effects of the severe shear deformation that was induced by the ECAP on the change of microstructure, hardness and texture. This study investigated also the change of average r-value (r - value), and Δr-value that obtained from the measured plastic strain ratio (r-value) data to get the formability and earing height in the ECAPed and subsequent heat-treated AA 1050 Al sheet.

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2. 실험 방법

Sheet of commercial AA 1050 aluminum alloy was used to obtain a severe deformation by an Equal Channel Angular Pressing (ECAP). The sheet samples, with dimensions of 35mm x 15mm x 2 mm, were cut out from a rolled sheet along the rolling direction. Then these plates were annealed at 550 ° C for 2 hours to homogenize the initial grain size through thickness (named initial Al sheet). The ECAP was performed in a die with an oblique angle (Φ) of 90° and a curvature angle (Ψ) of 20° at room temperature and at a constant speed of 2 mm/sec using route C (sample was rotated 180° about the sample axis between passes). The initial Al sheets were passed up to 4 passes through the channel of ECAP die set. After the ECAP and subsequent heat-treatment, to study the microstructure, hardness, and texture change of the ECAPed Al sheets, and the samples were annealed at the temperature of 100°- 400° C for 1 hour in an air condition. The microstructure of the three side surfaces of the ECAPed specimens were investigated by using an optical microscopy. The Vickers microhardness of the ECAPed samples was measured by applying a load of 300g. To obtain the information of the texture change in the ECAPed samples, the incomplete pole figures of (111), (200), and (220) at 1/4 depth thickness from the surface for each sample were measured by using an X-ray texture goniometer. The orientation distribution functions (ODFs, f(g)) were calculated from the three incomplete pole figure data using the series expansion method studied by Bunge [6]. It was tensile tested to obtain the r-value along the angles of 0°, 45°, 90°(180°), and 135° to ECAP direction. The average r-value ($\bar{r}$ -value), and Δr-value that obtained from the measured r-value data.

3. 결과 및 토의

Fig. 1 shows the variation of hardness which was obtained from the ECAPed and the annealed Al sheet according to the number of ECAP passes. After 1 pass, the hardness increases highly in Fig. 1. The hardness of the 1 pass ECAPed Al sheet is over about two times higher than that of the initial Al sheet. The hardness of the heat-treated Al sheet decreases with an increasing of annealing temperature in all the ECAPed samples. Especially, the hardness was decreased slightly at over 100° C/ 1 hour and highly at over 300° C/ 1 hour annealed samples in Fig. 1. The decreasing in hardness after annealing is related to the recrystallization of the ECAPed Al sheets.

Fig. 2 shows the optical micrographs that were obtained from the side surfaces of the ECAPed and the annealed Al sheets. The grain of initial Al sheet exhibited an equi-axial, uniform, and coarse structure. The grains were elongated, having an angle of 15 – 30

degrees to the ECAPed out direction. The degree of shear plastic deformation increases with the increasing the number of ECAP passes and was also related to the increasing in hardness.

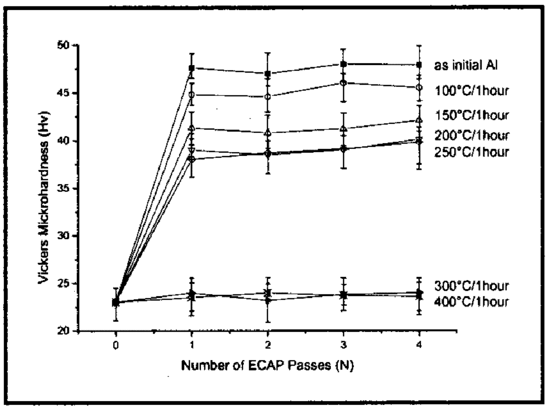

Fig. 1 The variation of hardness obtained from the initial Al, and the ECAPed and subsequent heat-treated Al sheets as the number of ECAP passes

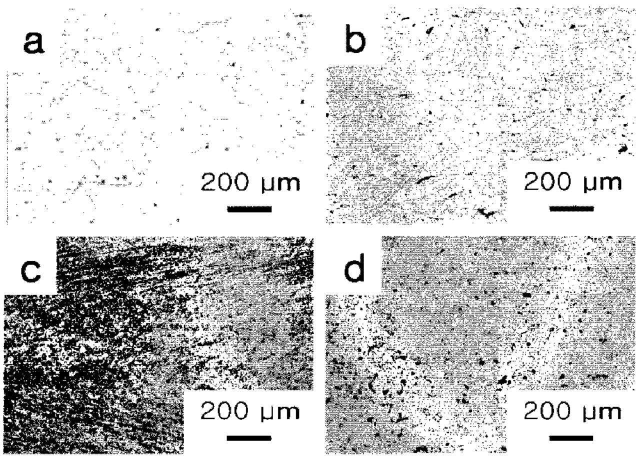

Fig.2.Optical micrographs obtained from the side surfaces of Al sheet; (a) initial Al sheet, and (b) 1 passes, (c) 4 passes, (d) 4 passes and heat treated at 400 ° C/ 1 hour.

Fig. 3 shows the (111) pole figures that were obtained from initial Al sheet, 2 passes, 3 passes, 4 passes ECAPed, 4 passes ECAPed and at 300° C/ 1 hour subsequent annealed, and 4 passes ECAPed and at 400° C/ 1 hour subsequent annealed Al sheets. After 2 passes ECAP, a very strong {001}<100> component changed to another texture through a

severe shear deformation from the ECAP. After 4 passes ECAP, {111}//ND component is increased and after annealing at 300° C, and 400° C / 1 hour, {111}//ND component is decreased in Fig. 3. In order to do a convenient analysis of the pole figures and a calculation of ODFs is needed from these pole figure data in Fig. 3. For the calculation of ODFs, the sample

Table 1. The variation of r-value, $\bar{r}$, and $|\Delta r|$ of the ECAPed and subsequent heat-treated Al sheets

Conditions of samples	r-value					$\bar{r}$	$\|\Delta r\|$
	0°	45°	90°	135°	180°		
Initial specimen (550°C/2 hrs)	0.946	0.285	1.1	0.293	1.1	0.502	0.773
4 passes and heat treated (300°C /1 hr)	0.557	0.914	0.662	0.943	0.662	0.801	0.292
4 passes and heat treated (400°C /1 hr)	0.614	1.03	0.67	1.084	0.67	0.859	0.396

symmetry used triclinic type in this study.

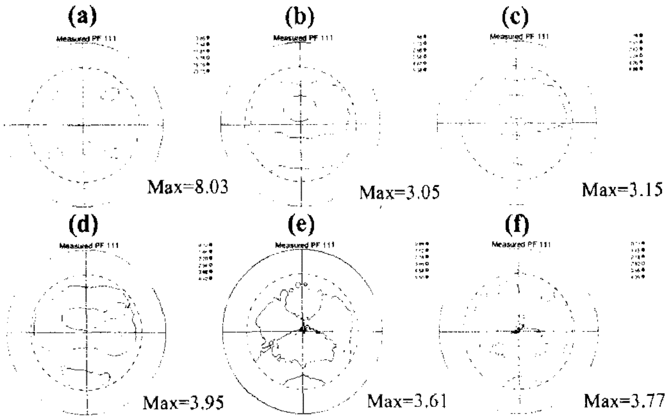

Fig. 3. (111) pole figures; (a) initial Al sheet, (b) 2 passes ECAPed, (c) 3 passes ECAPed, (d) 4 passes ECAPed, (e) 4 passes ECAPed and annealed at 300°C/1Hr, (f) 4 passes ECAPed and annealed at 400°C/1Hr

결 론

1. The hardness of 1 pass ECAPed Al sheet is about 2 times higher than that of the initial Al sheet.
2. {001}<100> component decreases remarkably after 1 pass ECAP, the <111> // ND shear component and {110}<111> are increased after 1 pass ECAP, and {123}<634>, and {012}<021> components are increased after the ECAP and subsequent heat-treatment at 400 C for 1 hour.
3. The average r-value ($\bar{r}$-value) of the ECAPed and heat-treated Al sheet is 1.7 times higher than that of the initial Al sheets. The increasing of average r-value are related to decrease {001}<100> component, and to increase {111}<112>, {111}<110>, and {123}<634> components after ECAPed and subsequent heat treated condition.
4. The Δr-value of the ECAPed and subsequent heat-treated Al sheet is lower than that of the initial Al sheet. This result may be also related to the formation of the various types of texture components.

감사의 글

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