ECAP 한 알루미늄 판재의 성형성 연구

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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 was investigated in this study. It was found that the average r-value of the equal channel angular pressed and subsequent heat-treated specimen was 1.7 times higher than that 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 sheets.

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

1. Introduction

During the last decade, considerable effort has been devoted to investigate of the physical and the mechanical properties of pressed bulk materials [1], but there have been few researchers who were interested in the texture evolution of equal channel angular pressed sheet materials [2-5]. Large amount of the shear deformation can be obtained through ECAP process; this method can be applied to obtain shear textures in Al sheets.

In this study, the 1050 Al sheet was pressed 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 pressed and subsequent heat-treated AA 1050 Al sheet.

2. Experimental

Sheets of commercial AA 1050 aluminum alloy were used to obtain a severe deformation by an equal channel angular pressing. 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 process 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 pressed up to 4 times through the channel of ECAP die set. Then the ECAPed samples were annealed, at temperatures of

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100°- 400° C for 1 hour in an air condition chamber, to study the microstructure, hardness, and texture change of the pressed Al sheets. The microstructure of the three side surfaces of the pressed specimens were investigated by using optical microscopy. The Vickers microhardness of the pressed samples was measured by applying a load of 300g. To obtain the information of the texture change in the pressed 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 figures 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 were calculated by equations (1) and (2) respectively.

$$\Delta r = \frac{(r_0 - r_{45}) + (r_{90} - r_{45}) + (r_{90} - r_{135}) + (r_{180} - r_{135})}{4} \quad (1)$$

$$\bar{r} = \frac{r_0 + 2r_{45} + 2r_{90} + 2r_{135} + r_{180}}{8} \quad (2)$$

3. Results and discussion

Fig. 1 shows the variation of hardness which was obtained from the pressed and the annealed Al sheet according to the number of ECAP passes. After first pass, the hardness increased substantially in Fig. 1. The hardness of the first pass pressed 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 increase in annealing temperatures in all the pressed samples. Especially, the hardness decreased slightly at over 100° C/ 1 hour and highly at over 300° C/ 1 hour annealed samples in Fig. 1. The decrease in hardness after annealing is related to the recrystallization of the pressed Al sheets.

Fig. 2 shows the optical micrographs obtained from the side surfaces of the pressed 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 pressed out direction. The degree of shear plastic deformation increases with the increasing the number of ECAP passes and was also related to the increase in hardness.

Fig. 3 shows the (111), (100) and (110) pole figures that were obtained from initial Al sheet, 1 pass, 4 passes, pressed, 4 passes ECAPed at 400° C/ 1 hour subsequent annealed. After 1 ECAP pass, a very strong {001}<100> component changed to another texture through a severe shear deformation from the process. After 4 ECAP passes, {111}//ND component increased and after annealing at 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 data in Fig. 3. For the calculation of from these pole figure ODFs, the sample symmetry used triclinic type in this study.

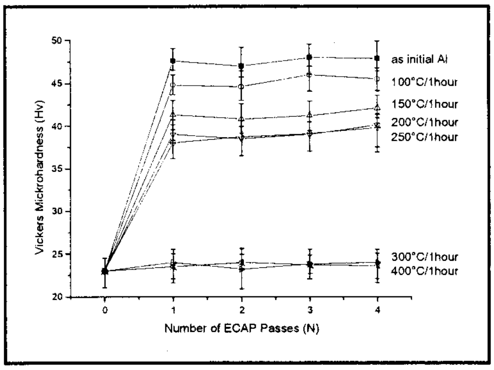

Fig. 1. The variation of hardness obtained from the initial Al, the pressed and the increased subsequent heat-treated Al sheets with the number of ECAP passes

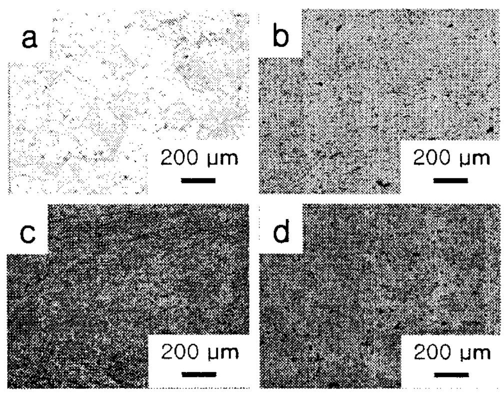

Fig. 2. Optical micrographs obtained from the side surfaces of Al sheet; (a) initial Al sheet, and (b) 1 pass, (c) 4 passes, (d) 4 passes and heat treated at 400°C/ 1 hour

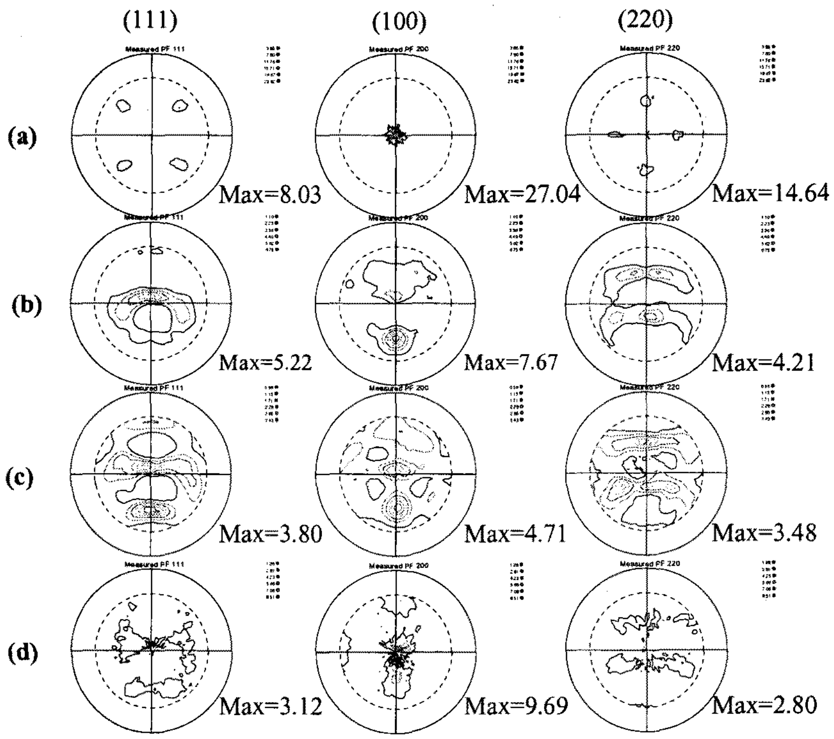

Fig. 3. (111), (100) and (110) pole figures from the 1/4 depth thickness of surface; (a) initial Al sheet, (b) 1 pass ECAPed, (c) 4 passes ECAPed with C type, (d) 4 passes ECAPed with C type and annealed Al sheet at 400°C/1 hour

Table 1. The variation of r-value, $\bar{r}$, and $|\Delta r|$ of the ECAPed using A and C types and subsequent annealed 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

4. Conclusion

1. The hardness of 1 pass pressed 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 pressed and heat-treated Al sheet is 1.7 times higher than that of the initial Al sheets. The increase of average r-value are related to

decrease {001}<100> component, and to increase {111}<112>, {111}<110>, and {123}<634> components after pressed and subsequent heat treated condition.

4. The Δr-value of the pressed 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.

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6. Conclusion

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