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Improvement of Textures in Aluminum Alloy Sheets by Asymmetric Warm Rolling

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Abstract

To improve the formability of aluminum alloy sheets, the texture control by the asymmetric warm rolling has been studied. Shear texture which is similar to rolling texture of low carbon steel was developed by asymmetric warm rolling with different roll velocities. After recrystallization annealing, a small amount of {111}//ND orientation suitable for deep drawing was observed. The Lankford value which indicates formability was a little higher than that of conventionally processed aluminum alloy sheets.

1. Introduction

The discharge of carbon dioxide (CO_2) gas is reduced by weight reduction of automobiles using aluminum alloy sheets instead of steel sheets. However the formability of aluminum alloy sheets for autobodies is inferior to that of low carbon steel. It is recognized that Lankford value (r-value) is seem to be one of the indicator of formability especially deep drawing. The r-value is strongly depended on the preferred orientations of the texture of the sheets [1].

The rolling texture of FCC metals such as aluminum alloy is typically characterized by the β-fiber, through copper orientation (Cu:{112}<111>), S orientation (S:{123}<634>) to brass orientation (Bs:{011}<211>), and the recrystallized texture mainly consists of cube orientation (Cube:{001}<100>). On the other hand, the rolling texture of BCC metals such as low carbon steel is typically characterized by the α-fiber, through {001}<110>, {112}<110} to {111}<110>, and the recrystallization texture consists of the γ-fiber {111}//ND. It is well known that the plastic anisotropy and formability of sheets are closely associated with crystallographic texture, and γ-fiber gives rise to high r-value and good deep drawability.

However γ-fiber cannot be observed by conventionally cold rolled and recrystallized aluminum alloy sheets, thus the formability is inferior to steel.

In the previous studies, a {111}//ND texture could be observed in recrystallized aluminum alloy sheets by introducing shear texture [2-5]. Kamijo and Fukutomi also showed that the

{111}//ND texture could be observed in surface layer of warm rolled Al-Mg alloy sheets at 523K to 573K, and the r-value was improved [6].

In the present study, formation of shear texture by asymmetric warm rolling and the {111}//ND texture after recrystallization annealing were examined as a possible strategy to improve the formability of aluminum alloy sheets.

2. Experimental

AA6061 and AA5182 alloys were DC cast and hot rolled to 5mm thick. The chemical compositions are shown in Table 1.

Table 1: Chemical compositions of AA6061 and AA5182 (wt%).

	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
AA6061	0.63	0.29	0.33	0.04	0.93	0.16	0.02	0.03	Bal.
AA5182	0.09	0.21	0.04	0.35	4.50	0.04	0.01	0.02	Bal.

The asymmetric warm rolling mill was designed with each roll independently driven by two motors, and rolls were heated by cartridge heaters inserted in rolls. The asymmetric warm rolling was carried out 5mm to 1mm at 473K to 523K, both sheets and rolls were heated. The asymmetric ratio was varied from 120% to 200%. The recrystallization solution treatment was carried out in salt bath at 803K for 30sec followed by then water quenching. As rolled and after solution treated specimens were tensile tested along 0, 45, 90degree to the rolling direction. The r-value was measured at 7.5% plastic strain. The shear strain was measured by the gradient of pre-inserted aluminum wire after asymmetric rolling, and calculated following equations.

equivalent strain $$\varepsilon = \frac{2}{\sqrt{3}}\phi \quad \ln \frac{1}{1-r} \qquad (1)$$

shear strain $$\gamma = 2\sqrt{\phi^2 - 1} \quad \ln \frac{1}{1-r} \qquad (2)$$

$$r = 1 - H_1 / H_0 \qquad (3)$$

$$\phi = \sqrt{1 + \left\{ 1 + \frac{(1-r)^2}{r(2-r)} \tan\theta \right\}^2} \qquad (4)$$

Where H_1 and H_2 are thickness before and after rolling, θ is the gradient of aluminum wire.

The texture analysis was carried out by X-ray refraction at upper and lower surface, and center of thickness layers of the sheet. The orientation distribution functions (ODFs) were calculated from {111}, {200}, {220} incomplete pole figures by the series expansion method according to Bunge (l_{max}=22) with ghost correction.

3. Experimental Results

Figure 1 shows the wire gradient of AA6061 alloy after asymmetric warm rolling at 523K with various asymmetric ratios. Increasing the asymmetric ratio, the shear strain calculated from the wire gradient became larger. The shear strain also depended on rolling temperature and deformation resistance of alloy, as can be seen in Figure 2.

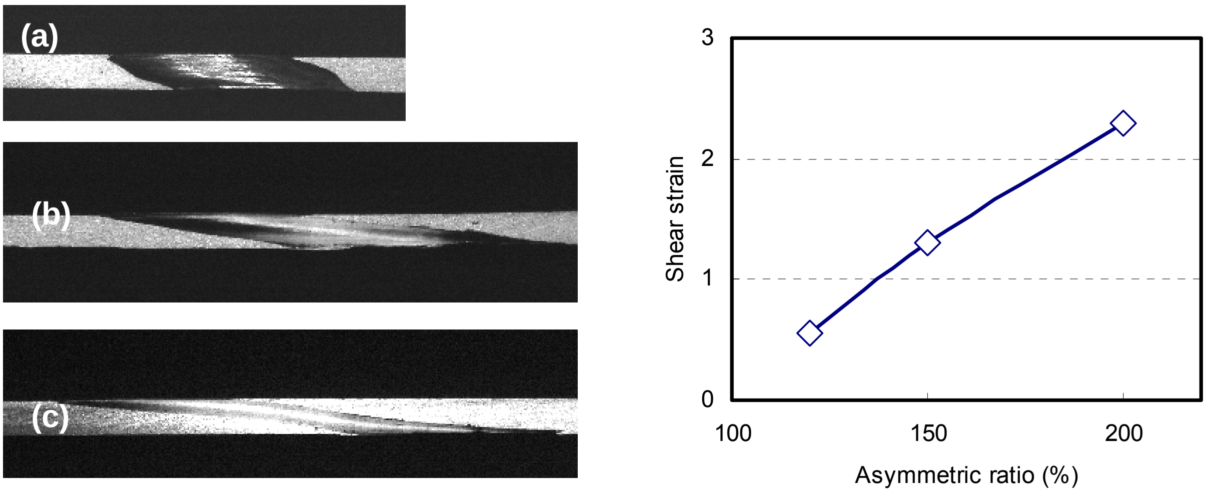

Figure 1: Wire gradient and shear strain of AA6061 after asymmetric warm rolling at 523Kwith asymmetric ratio (a) 120% (b) 150% (c) 200%.

Figure 3 shows the ODFs of asymmetric warm rolled AA6061 and AA5182 at 523K with asymmetric ratio of 200%, comparing with that of conventional cold rolling process. The ODFs of conventionally cold rolled specimen consisted from the β-fiber, and after recrystallization a strong accumulation of cube texture {001}<100> could be seen. On the other hand, the ODFs of asymmetric warm rolled AA5182 and AA6061 specimens comprise from {001}<110>, {112}<110> to {111}<110> fiber texture which was similar to cold rolling texture of low carbon steel. Moreover the β-fiber components has seldom be seen. However the ODFs of recrystallization texture of asymmetric warm rolling became randomised, and desirable strong accumulation of {111}//ND could not be seen, dissimilar to low carbon steel. Cube texture was not present, and a small amount of {111}<112> orientation was developed. Further in AA5182 alloy sheets, nearly Bs orientation {011}<211> was newly developed during recrystallization.

Figure 4 shows the orientation densities of as asymmetric warm rolled at 523K with asymmetric ratio of 200%, and that of after recrystallization. The shear texture which corresponding α-fiber of BCC metals (Figure 4(a)) was eliminated by recrystallization, and the {111}<112> orientation which corresponding γ-fiber of BCC metals (Figure 4(b)) slightly increased in both AA6061 and AA5182 alloys. The accumulation of the {111} <112> orientation was larger in AA5182 while the shear strain was lower than AA6061.

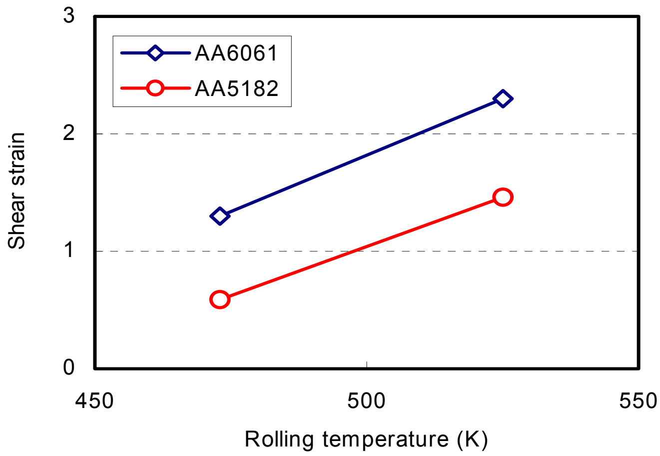

Figure 2: Effect of rolling temperature on shear strain. (Asymmetric ratio:200%).

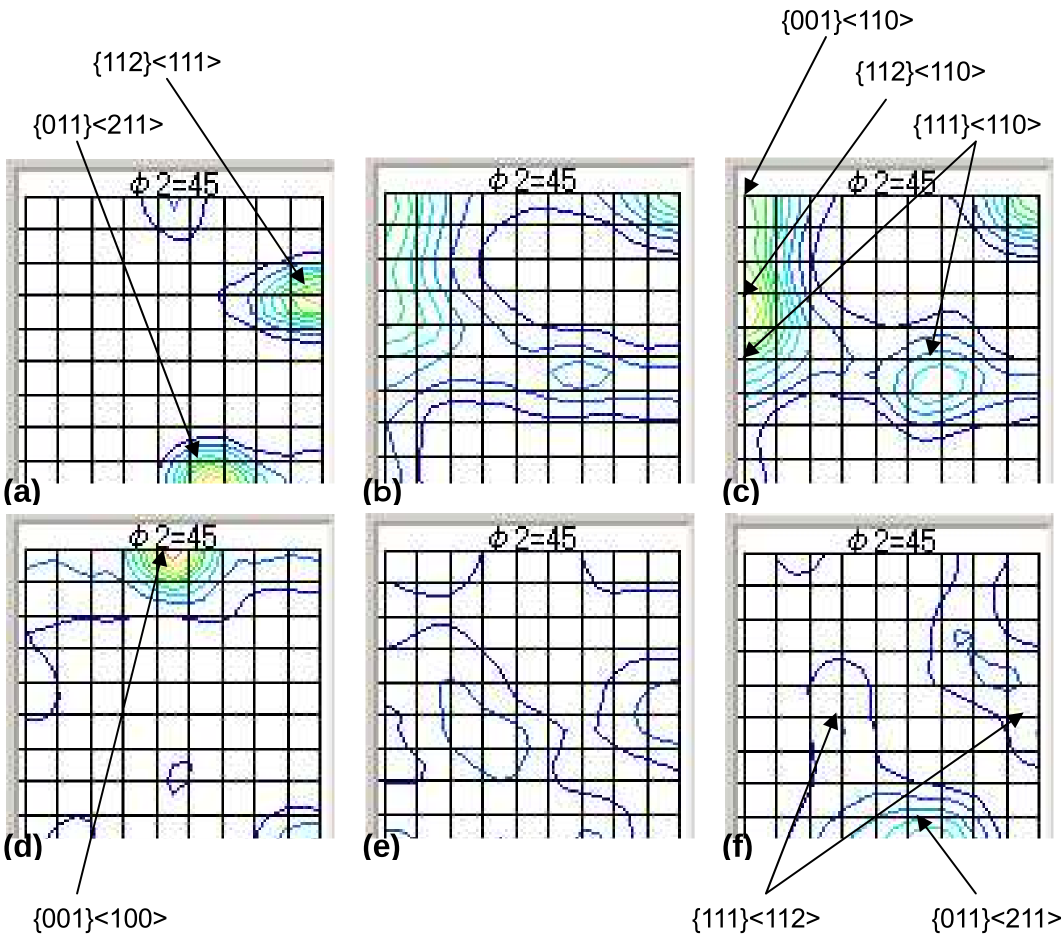

Figure 3: The ODFs of ψ2=45degree section of conventional cold rolled and asymmetric warm rolled specimen. (a) to (c):as rolled, (d) to (f):after recrystallization, (a)(d): conventional AA6061, (b)(e): asymmetric AA6061, (c)(f): asymmetric AA5182.

Figure 5 shows the anisotropy of the r-value of asymmetric warm rolled AA6061 and AA5182 at 523K asymmetric ratio of 200%, comparing with that of conventional cold rolling process. The 45degree r-value of as asymmetric warm rolled specimen was very high, and the average r-value was about 1.3. However the r-value of the recrystallized specimen was almost same in any directions and the average r-value was about 0.8. Comparing with conventional cold rolled and recrystallized specimen, the r-value of asymmetric warm rolled specimen was slightly higher.

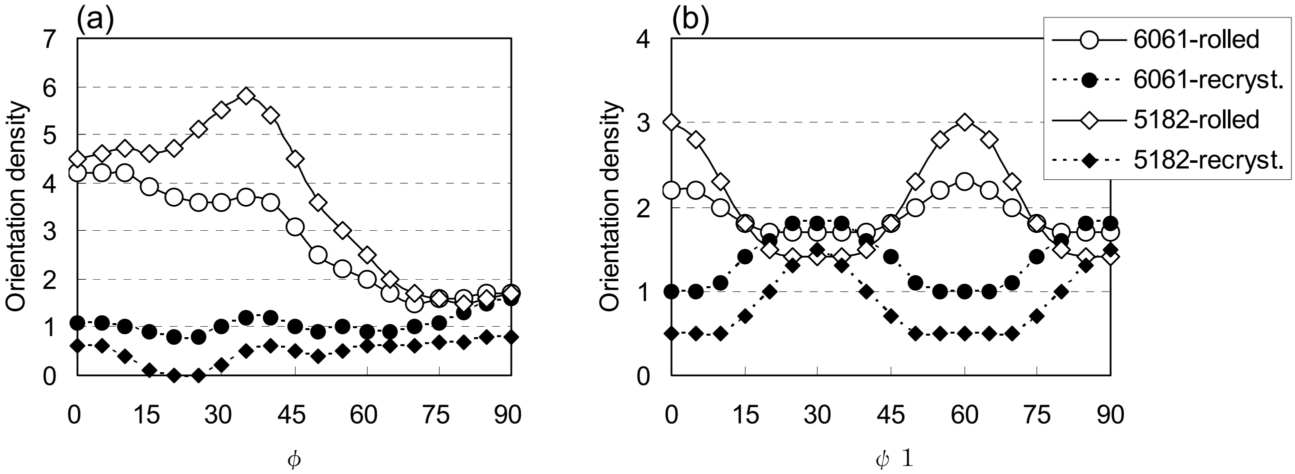

Figure 4: Orientation densities of asymmetric warm rolled at 523K with asymmetric ratio of 200% and recrystallized specimens. (a) ψ2=45degree ψ1=0degree (b) ψ2=45degree Φ=55degree.

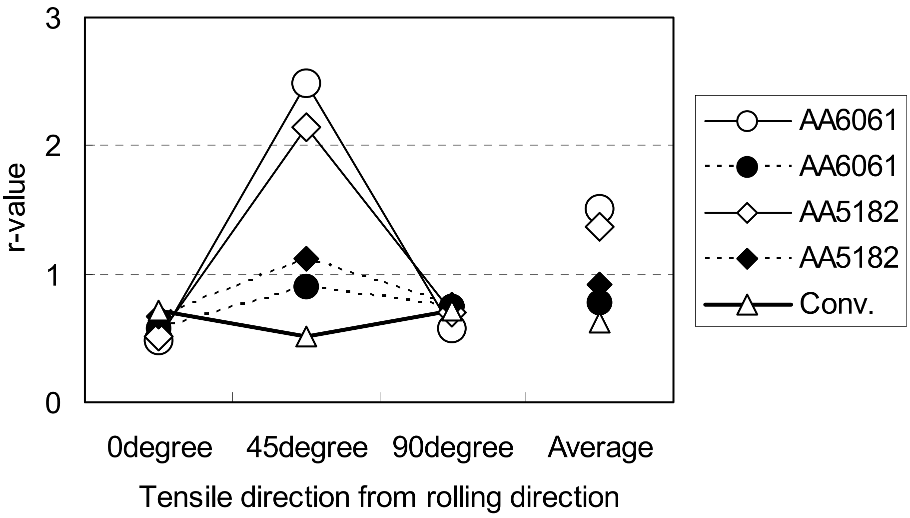

Figure 5: r-value of asymmetric warm rolled at 523K with asymmetric ratio of 200% and recrystallized specimens.

5. Conclusions

Strong shear texture could be obtained by asymmetric warm rolling in AA6061 and AA5182 aluminum alloy sheets. The shear texture was similar to the cold rolling texture of low carbon steel. After recrystallization solution treatment, the texture became randomised and only a small amount of {111}//ND orientation could be observed. The Lankford value of asymmetric warm rolled and solution treated specimen slightly increased comparing with that of conventional cold rolling process.

Acknowledgment

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