FORMATION OF SHEAR TEXTURE IN A5052 SHEET BY SINGLE-ROLL DRIVE WARM ROLLING

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ABSTRACT Large shear deformation was successfully introduced in A5052 aluminum alloy sheet by single-roll drive warm rolling under high friction condition. By 2-pass single-roll drive rolling, shear strain uniformly distributed throughout the thickness. The shear texture of which main components are {111}<110>, {112}<110> and {001}<110> prevailed throughout the thickness, and typical rolling texture could not be observed in any part of thickness. After recrystallization annealing, shear texture became broad and nearly random texture prevailed, though weak shear texture components remained. The average r-value of annealed sheet was about 1.0 which is higher than that of the A5052 sheet fabricated by conventional rolling and annealing. The △r, which is the measure of planar anisotropy, was -0.14 which is also superior to that by conventional process. The single-roll drive rolling is proved to be promising process for fabricating aluminum alloy sheet having excellent formability.

Key words : *aluminum alloy sheet, single-roll drive rolling, shear texture, high r-value*

1. INTRODUCTION

Improvement of formability in sheet forming of aluminum and aluminum alloys which can be accomplished by raising r-value and decreasing planar anisotropy is difficult, since cube texture and R-orientation which are detrimental to sheet formability develop during rolling and annealing of fcc metals[1-3]. It is well known that the well developed <111>//ND texture is effective for improvement of r-value not only of bcc metals but also of fcc metals[4]. However, <111>//ND texture can not be formed in fcc metals by conventional rolling and annealing process. The <111>//ND orientation is one of the main components of texture by shear deformation[5-7]. Accordingly, this orientation will develop in rolled aluminum sheet when shear deformation is superimposed on rolling deformation. It has been reported that shear texture is formed beneath the surface of sheet rolled under high friction condition, whereas the rolling texture prevails in greater part of thickness[8]. Remarkable increase in r-value can not be made in such sheet of fcc metals because of cube and R orientation resulting from typical rolling texture developed in the center layer of the rolled and annealed sheet.

In this study, 2-pass single-roll drive rolling process is proposed for introducing shear deformation throughout the thickness of rolled sheet. Single-roll drive rolling is a kind of asymmetric rolling which can introduce greater amount of shear deformation than conventional symmetric rolling[9]. The variation of texture through the thickness of rolled sheet was measured. The texture and mechanical property of annealed sheet was investigated and feasibility of asymmetric rolling process as a process for improving formability of aluminum and aluminum alloy sheet was proved.

2. EXPERIMENTAL

2.1 Single-roll drive rolling

Procedure of 2-pass single-roll drive rolling proposed in this study is schematically shown in **Fig.1**. Single-roll drive rolling was conducted by conventional rolling mill; one roll was driven by a motor and another roll was allowed to rotate freely by disconnecting from driving shaft. By one pass single-roll drive rolling, large amount of shear deformation was introduced in the driving roll side and smaller shear deformation was introduced in the idle roll side. In the second pass, the sheet was so rolled as to introduce larger shear deformation in the side which was faced to the idle roll in the first pass. After the second pass, almost uniform shear deformation throughout the thickness was introduced in the rolled sheet. In this study, the above mentioned process is called "unidirectional shear rolling".

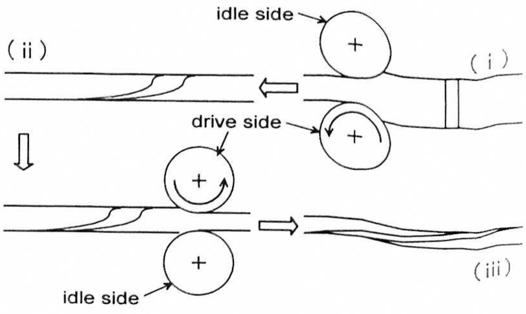


Fig.1 Schematic diagram showing the procedure of single-roll drive rolling. (unidirectional shear rolling)

2.2 Experimental procedure

A5052 sheet of 3mm in thickness was homogenized at 560°C for 1.5ks and quenched in water. The 2-pass single-roll drive rolling was conducted with the mill of which roll diameter was 70mm. The 2-pass conventional(symmetric) rolling was also conducted for comparison. Rolling temperature was 260°C. Reduction in each pass was 50% , hence total reduction was 75%. In order to roll in high friction condition without galling, mixture of alumina powder and ethanol was applied to the roll surface. Then roll surface was covered with thin alumina powder layer after evaporating ethanol. The rolled sheet was annealed at 360°C for 1.8ks. Variation of shear strain through the thickness was

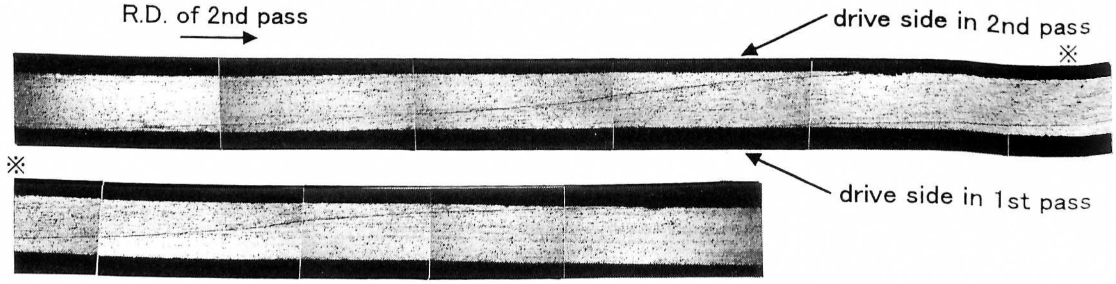


Fig.2 Deformation of embedded cylindrical pin by unidirectional shear rolling.

Fig.3 Deformation of embedded cylindrical pin by conventional rolling.

measured from the deformation of A5052 cylindrical pin by 2-pass rolling which had been embedded in the specimen before rolling with its axis perpendicular to the rolling plane [10]. The {111} pole figure was measured at the various position of the thickness of the sheet after rolling and after annealing by Schulz's reflection and transmission method. The r-value was determined from tension test of which tensile direction was 0°, 45° and 90° from the rolling direction.

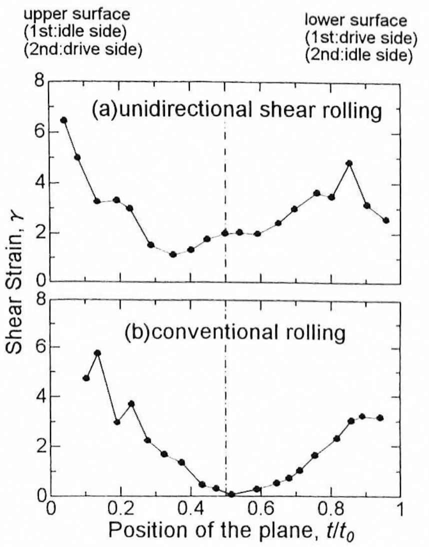


Fig.4 Effect of rolling method on through-the- thickness variation of shear strain.

3. RESULTS AND DISCUSSION

3.1 Deformation by single-roll drive rolling

The deformation of embedded pin by unidirectional shear rolling is shown in **Fig.2**. Lines inclined to the rolling direction is the boundary between sheet and embedded pin. The pin inclines to one direction by shear deformation. The inclination of the pin is almost uniform through the thickness. This indicates that shear deformation is unidirectional and it prevails throughout the thickness. The deformation of pin by conventional rolling is shown in **Fig.3**. The inclination of the pin increases with increasing the distance from the center. At the midthickness, the deformation of the pin by shear deformation is small. **Figure 4** shows the variation of shear strain through the thickness of the sheet measured from the inclination of the pin. In unidirectional shear rolling, definite amount of shear strain is produced throughout the thickness and it increases near the surface. In conventional rolling, shear strain increases near the surface, however it decreases to zero at the midthickness. The 2-pass single-roll drive rolling was proved to promising method to introduce shear strain throughout the thickness of rolled sheet.

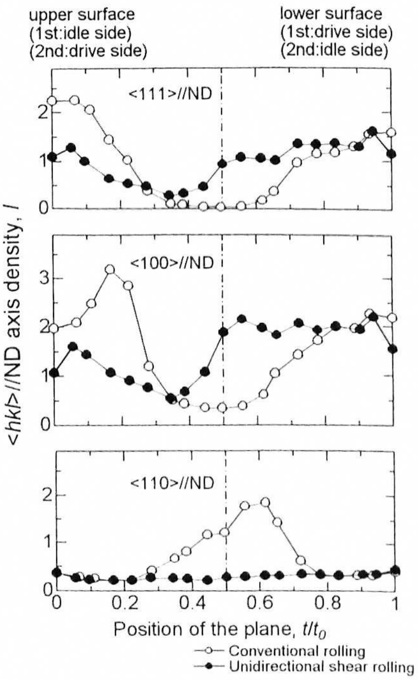


Fig.5 Effect of rolling method on through-the-thickness variation of preferred orientation.

3.2 Texture variation through the thickness

Figure 5 shows through-the-thickness variation of <*hkl*>//ND axis density determined from relative intensities of X-ray reflections from (*hkl*) planes parallel to the surface of the sheet rolled by single-roll drive rolling and conventional rolling. In unidirectional shear rolling, <111>//ND axis density increases near the surface and the smallest value is about 0.3, which corresponds to the variation of shear strain. In conventional rolling, <111>//ND axis density becomes almost zero around the midthickness where shear strain is very small. The <100>//ND axis density varies in the similar manner as the <111>//ND axis density. The <110>//ND axis density, which is the main component of rolling texture of fcc metals, increases at the center of the thickness of conventionally rolled sheet. It has a very small value and does not vary through the thickness of the unidirectionally shear rolled sheet. The {111} pole figures measured at various position through the thickness of the unidirectional shear rolled sheet is shown in **Fig.6**. From the drive side in the 2nd pass to the idle side, the position of strong pole intensity were seen near {111}<110>, {112}<110> and {001}<110> orientations which are main components of shear texture. The peaks of (111) pole intensity rotates about 10° around TD axis toward rolling direction. Components of conventional rolling texture are not detected. The sheet having shear texture throughout the thickness could be fabricated by single-roll drive rolling. The intensity of near {001}<110> orientation is stronger than other orientations at the midthickness. The change of texture through the half thickness of conventionally rolled sheet is given in **Fig.7**. At the surface and a quarter from the surface, where shear deformation was introduced, shear texture develops. At the center of the thickness, {123}<634> and {124}<112> orientations which are known as typical rolling texture of fcc metals develop. The intensity of {001}<110> is stronger than other orientations at a quarter from the surface, which is similar to the center of the unidirectionally shear rolled sheet. It seems that the relative intensity of {001}<110> to the other components of shear texture increases with decreasing shear strain.

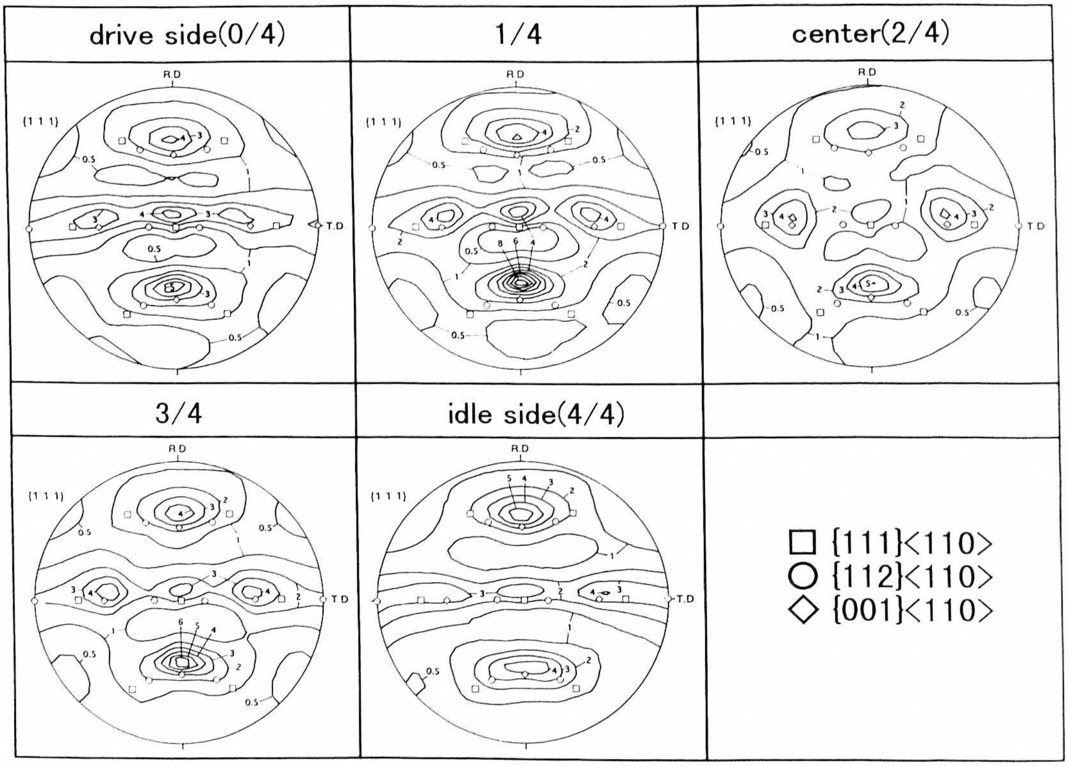
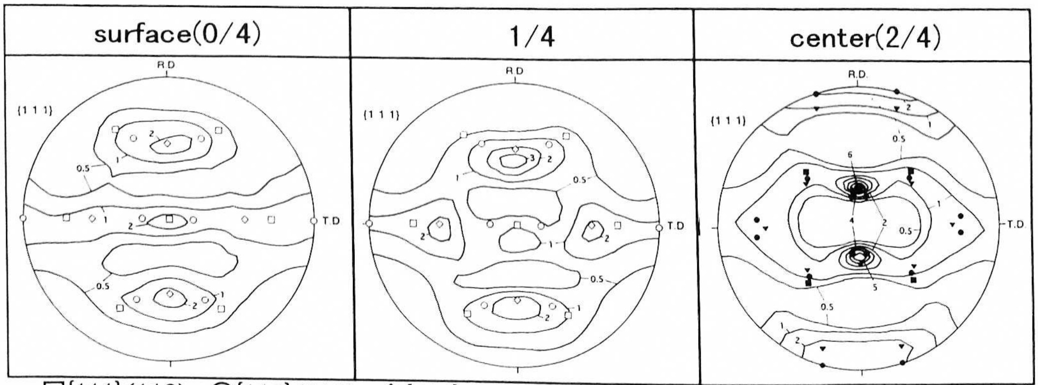
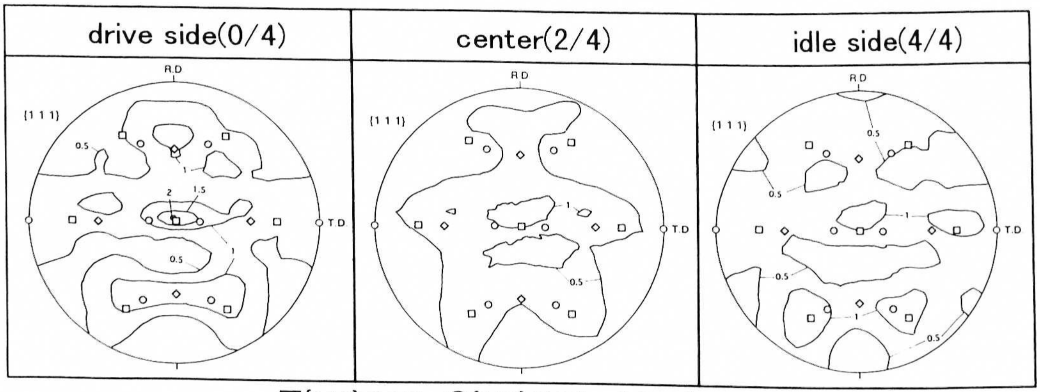


Fig.6 Variation of {111} pole figure through the thickness of the unidirectionally shear rolled sheet.


surface(0/4) | 1/4 | center(2/4)

□{111}<110> O{112}<110> ◇{001}<110> ■{001}<100> ●{123}<634> ▼{124}<112>

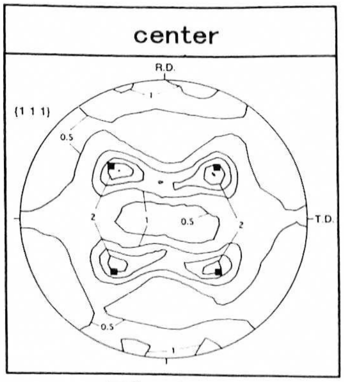
Fig.7 Variation of {111} pole figure through the thickness of the conventionally rolled sheet.


drive side(0/4) | center(2/4) | idle side(4/4)

□{111}<110> O{112}<110> ◇{001}<110>

Fig.8 Variation of {111} pole figure through the thickness of the sheet annealed at 360 °C foe 1.8ks after unidirectional shear rolling

Texture variation through the thickness of the sheet annealed at 360°C for 1.8ks after unidirectional shear rolling is shown in **Fig.8**. Throughout the thickness, weak shear components remains after recrystallization. Texture spread around shear components is very large and pole intensity is smaller than that of rolled sheet. **Figure 9** shows texture measured at the center of the thickness of the sheet annealed after conventional rolling. Typical recrystallization texture of fcc metals including {001}<100> orientation is observed. At the surface and a quarter from the surface, similar textures to those in unidirectionally shear rolled and annealed sheet were observed. Through-the-thickness texture gradient remained


center

■{001}<100>

Fig.9 {111} pole figure measured at the center of the sheet annealed at 360 °C foe 1.8ks after conventional rolling.

after completion of recrystallization of the conventionally rolled sheet.

Table 1 r-values of unidirectionally shear rolled and conventionally rolled sheets.

tensile direction from R.D.	0°	45°	90°	$\bar{r}$	Δr
unidirectional shear rolling	0.94	1.08	0.94	1.01	−0.14
conventional rolling	0.48	0.74	0.48	0.61	−0.26

3.3 r-values

The r-values of annealed sheets after shear rolling and conventional rolling are listed in Table 1. The average r-value equal to unity and planar anisotropy Δr of −0.14 is achieved in the sheet annealed after unidirectional shear rolling. These values are much superior to the conventionally rolled and annealed sheet. The mechanical property of shear rolled and annealed sheet is almost isotropic because of nearly random texture developed throughout the thickness. The conventionally rolled and annealed sheet had a layer of cube texture which might result in lower r-value and larger anisotropy.

4. CONCLUSIONS

1) The shear strain larger than 1.0 was introduced throughout the thickness of the sheet by unidirectional shear rolling using single roll drive mill.
2) The shear texture developed throughout the thickness of unidirectionally shear rolled sheet.
3) The sheet annealed after unidirectional shear rolling had broad texture spreading around shear components. This orientation develops throughout the thickness and cube texture did not observed at any part of thickness.
4) The average r-value equal to unity and planar anisotropy Δr of −0.14, which are much superior to the sheet fabricated by conventional process, are achieved in the sheet annealed after unidirectional shear rolling.
5) It is proved that the 2-pases single-roll drive rolling is promising method for fabricating aluminum alloy sheet with excellent formability.

REFERENCES

[1] P.A.Beck and H.Hu: Trans.AIME, 194(1952), 83
[2] F.J.Humphreys and M.Hatherly: Recrystallization and Related Annealing Phenomena, Pergamon(1995), 393
[3] O.Engler, H.E.Vatne and E.Nes: Mater. Sci. and Eng. Ser.A, A205(1996), 187
[4] P.H.Lequeu and J.J.Jonas: Metall. Trans., A, 19A(1988), 105
[5] I.L.Dillamore and W.T.Roberts: J. Inst. Metals, 92(1963), 193
[6] W.Truszkowski, J.Król and B.Major: Metall. Trans., A, 11A(1980), 749
[7] T.Sakai, Y.Saito and K.Kato: Trans. ISIJ, 27(1987), 520
[8] T.Sakai, Y.Saito, M.Matsuo and K.Kawasaki: ISIJ Int., 31(1991), 86
[9] J.Hu, K.Ikeda and T.Murakami: J. Japan Inst. Metals, 60(1996), 1130
[10] T.Sakai, Y.Saito, K.Hirano and K.Kato: Trans. ISIJ, 28(1988), 1028