한국소성가공학회 2001년도 춘계학술대회 논문집 pp.176~179

Groove Pressing 한 Aluminum 3003 판재의 집합조직 및 미세조직의 변화

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Texture and Microstructure in Aluminum 3003 Sheet During Groove Pressing

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Abstract

A simple cold pressing procedure which allows shear deformations on sheet metals is proposed by designing dies with grooves and applied to aluminum 3003 sheets. Shear deformation led to the formation of preferred orientation along <100>//RD, and the effect of initial textures on the formation of shear textures was also studied. Rectangular shaped dislocation cells formed in the deformed microstructure and boundaries of dislocation cells gradually rounded with the increased plastic strain. Upon subsequent annealing textures inherited deformation textures. Recrystallized grains consisted of a large number of fully recovered subgrains with well defined boundaries which persisted even after annealing at a higher temperature.

Key Words : Aluminum 3003 sheet, Groove Pressing Deformation(GPD), Texture, Microstructure, Extended Recovery, Discontinuous Recrystallization

1. Introduction

Shear deformation on bulk metallic materials has been widely studied, since shear strain can be imposed on the material without change in external dimension of the deformed samples. The degree of work hardening increases with repeatedly imposed plastic shear strain in materials. The equal channel angular pressing (ECAP) is one of the promising procedures which impose repeated shear strain on bulk metallic material[(1)~(5)]. Works on the development of microstructure and changes in mechanical properties during various equal channel angular processes have been recently reported in various metallic materials. However, application of ECAP on sheet materials is in the meanwhile limited because of its complicated tooling[(6)].

In the present work, a simple cold pressing method

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[7] which may allow the shear deformation on sheet metals is proposed and applied to aluminum 3003 sheets. In order to obtain the shear deformation without thickness reduction of the sheet, the shape of the groove of pressing dies was properly designed.

2. Experimental Procedure

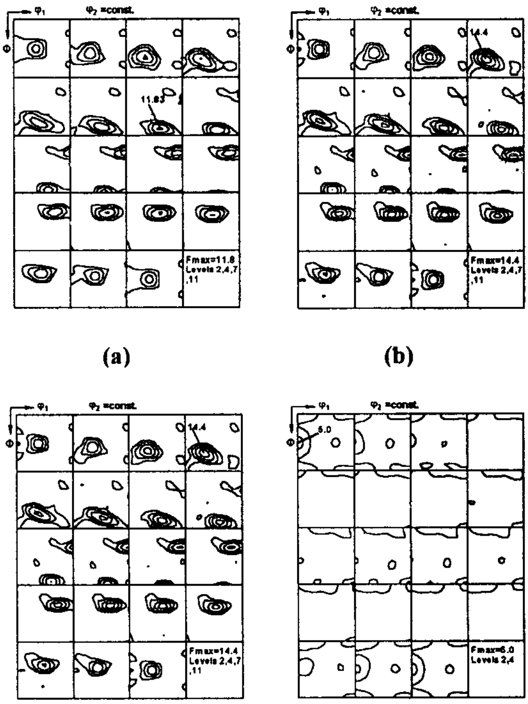
In the present study, a hot band with a thickness of 6.1mm of the commercial Al-alloy AA3003 (Al-4.5%Mg-0.8%Mn) was used. The as-received material had a fully recovered microstructure with very diffusing grain boundaries and displayed strong texture gradients throughout the thickness of which a nearly random initial texture at the surface layer and the typical cold rolling texture (preferred orientation along the β-fiber) of Al-sheets were observed. Prior to the groove pressing deformation (GPD), two initial specimens were produced by different thermomechanical treatments: The hot band was first cold rolled to a thickness reduction of 50%. Subsequently, an initial specimen was produced by annealing at 300℃ for 2h which gave rise to a fully recovered sample with the β-fiber texture (B-specimen) and another initial specimen was prepared by anneal at 350℃ for 1h which gave rise to a fully recrystallized sample with the Cube texture (C-specmen).

The crystallographic textures of the sheets were determined in the sheet center by measuring pole figures, and from three incomplete pole figures, the three-dimensional orientation distribution functions (ODF) $f(g)$ were calculated.

3. Results and Discussion

The as-received hot band had a recovered/recrystallized microstructure with very diffuse grain boundaries. Whereas the surface of the hot band displayed a very weak texture, the texture of in the center layer (Fig. 1*a*) comprised the typical rolling texture of Al-sheets that is characterized by the so-called β-fiber running from the copper-orientation over the S-orientation to the brass-orientation through the orientation space.

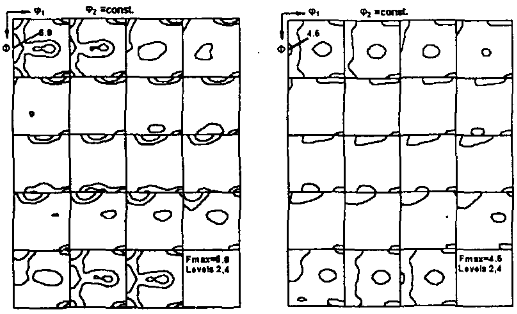
Cold Rolling of 50% resulted in an increase of preferred orientations along the β-fiber. The texture of the B-specimen (Fig. 1c) consisted of the Cube-{001}<100>, the Goss- {011}<100> and the P-orientation {011}<122>.



(a) (b) (c) (d)

Fig. 1 Textures before groove pressing. (a) hot band, (b) 50% cold rolled, (c) B-specimen, (d) C-specimen

Fig. 2 shows the evolution of texture during GPD. As mentioned earlier, the initial texture of the B-specimen comprised the strong β-fiber orientations. After two times of the GPD, the β-fiber orientations still persisted, the overall orientation density along the β-fiber decreased. The texture was entirely changed only after 4 times of the GP, i.e. the Bs- and S-orientation weakened in a large extend and the Cu-orientation completely disappeared. This implies that the β-fiber orientations stable at the strain state during rolling are unstable at the strain state during groove pressing. The texture of the 4 times pressed sample is characterized by preferred orientations with <001> parallel to the RD and {110} parallel to the ND. Increasing number of the GPD, whereas the intensities of the {110}//ND orientations diminished, the orientations along {001}//RD did not further develop but rather remained as preferred orientations.



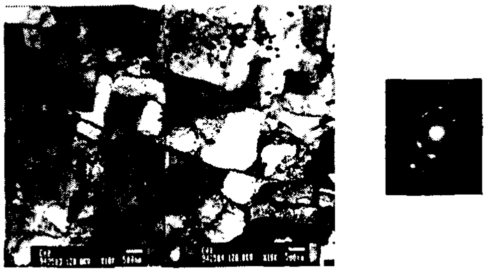
(a) (b)

Fig. 2 Textures after 4 times of GPD (a) B-specimen, (b) C-specimen

A typical recrystallization texture of Al alloy with dispersoids was found in the initial C-specimen. In contrast to the B-specimen, The RSD did not give rise to a drastic change in preferred orientations of the B-specimen. The texture after 2 and 4 times of the GPD was quit similar to the initial texture and the maximum orientation density $f(g)$ was found at the Goss-Orientation. With increasing deformation, the overall orientation intensity slightly decreases and the maximum moved to (0° ,20° ,0°) after 8 times pressing.

The TEM micrographs of the groove pressed specimens observed from the cross sections (RD-sections). The typical deformed microstructure is shown in Fig. 3. Difference in the microstructure and texture of the initial specimen did not give rise to a pronounced difference in the deformed microstructure. After the GPD, the microstructure of the B- and C-specimen was comprised with nearly rectangular shaped dislocation cells having an average size of 1.5 ㎛ (Fig. 3*a* and *b*). Although a striking orientation contrast among dislocation cells was found in the TEM micrographs, it was revealed by SADP (selected area diffraction pattern) that the orientation difference between neighboring dislocation cells was commonly ranged from 3° to 6° inside of a grain.

(a)



(b) (C)

Fig. 3 TEM micrographs of the groove pressed specimens (RD section). (a) B-specimen after 8times pressing, (b) C-specimen after 8 times pressings, (c) SADP of (b)

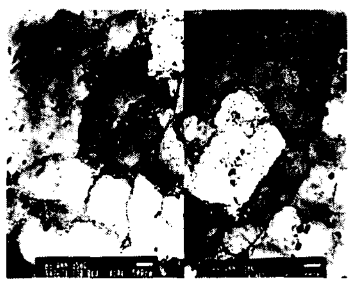


Fig. 4 TEM micrographs of the groove pressed and annealed B-specimen (RD section)

An example of annealed TEM microstructure in Fig. 4 shows the 8 times shear deformed B-sample after annealing at 350℃. Compare to the deformed microstructure, boundaries of dislocation cells become sharper and inside of cells is nearly free from dislocations. Although annealing processes quit prevailed throughout the microstructure, subgrains earlier formed during the GPD persisted and the misorientation across the boundary of subgrains still existed. Thus, annealing of the GPD specimen gave rise to the formation of characteristic recovered/recrystallized grains comprising a large number of fully recovered subgrains.

The annealing texture of the RSD specimens indeed resembled the deformed texture. Annealing textures of the C-specimen as a function of increasing shear deformation. Interestingly, annealing at 350℃ for 1h gave rise to a marked change in neither position nor intensity of preferred orientations. It was noted that the deformation textures were also scarcely changed upon annealing even at 400℃.

Parallel to the GPD experiment, as a reference of the typical plastic deformation on metallic sheets, cold rolling and recrystallization annealing on both the B- and C-specimens were performed. Cold rolling of AA 3003 led to the formation of the typical rolling texture that is characterized by the so-called β-fiber. With the increase in reduction degree, the β-fiber orientations gradually increased. The TEM microstructure can be characterized by an array of strongly elongated dislocation cells, which are commonly referred to as microbands. In the longitudinal sections(TD-sections) these microbandsare inclined by ±30 to 35° to the RD. After annealing of the cold rolled specimens the well-known cube recrystallization textures developed which were characterized by preferred cube orientations.

4. Conclusion

(1) The β-fiber orientations stable at the strain state during rolling are unstable at the strain state during groove pressing.

(2) During GPD orientation along <001>//RD developed as preferred orientations.

(3) In the normally cold rolled specimen, the normal discontinuous recrystallzation took place. However, in the groove pressed specimen, an extended recovery (a continuous recrystallization) took place.

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