ROLLING AND RECRYSTALLIZATION TEXTURES IN Al - HIGH Mg ALLOYS

Makoto KOIZUMI*, Hirosuke INAGAKI and Shirou KOHARA*****

* Graduate student, Shonan Institute of Technology
251 Fujisawa, Tsujidou-Nishikaigan, 1-1-25, Japan

** Department of Mechanical Engineering, Shonan Institute of Technology
251 Fujisawa, Tsujidou-Nishikaigan, 1-1-25, Japan

*** Department of Materials Science and Technology, The Science University of Tokyo
278 Noda, Yamazaki, 2641 Japan

ABSTRACT In order to clarify the effect of Mg on rolling and recrystallization textures in Al more clearly, Al-Mg alloys with high Mg concentrations, i.e., containing Mg in the range between 6 and 9% were cold rolled 95% and recrystallized completely at 350℃. In order to study the effect of Mg on the texture developed during grain growth, cold rolled specimens were also annealed at 450℃. It was found that, in the rolling texture of Al-high Mg alloys, the {112}<111> and {123}<634> orientations were not so strong. This was attributed to frequent shear banding, which was enhanced by Mg addition in grains having these orientations. In the recrystallization textures of these alloys, the {100}<001> orientation was very weak. This correlated quiet well with the decrease in the {112}<111> and {123}<634> orientations in the rolling texture. In the textures developed during grain growth, the {100}<001> orientation was much weaker. The {103}<321> orientation was very strong. The {103}<321> orientation appears to be nucleated at shear bands.

Keywords : *ODF, Mg contents, shear band, recrystallization, grain growth*

1 INTRODUCTION

Mg atoms have an approximately 12% larger atomic radius than Al atoms. For this reason, Mg atoms in solid solution in Al have strong interactions with dislocations and grain boundaries. During rolling deformation, cross slip is strongly suppressed by dislocation-Mg atom interactions. As a result, the development of normal cell structures is difficult in Al - Mg alloys, resulting in the formation of shear bands at high rolling reductions. Rolling textures in Al-Mg alloys are therefore considerably different from those observed in pure Al. In a previous paper[1], the effects of Mg on the development of the cold rolling and recrystallization textures in Al-Mg alloys containing Mg in the range between 0.5 and 5% have been investigated in detail. It has been found that, in the rolling texture, the {112}<111> and {123}<634> rolling texture components are significantly reduced by the addition of Mg above 3%. As to the recrystallization textures which have been observed after complete recrystallization at 300℃, it has been found that the {100}<001> orientation increases remarkably with increasing Mg content up to 3%, and that a further increase in the Mg content results in a significant decrease in the {100}<001> orientation. Since it was expected that such effects of Mg should be more clearly observed in Al-Mg alloys with much higher Mg concentrations, it was tried in the present investigation to study the rolling and recrystallization textures of Al-high Mg alloys containing Mg in the range between 6 and 9%, by using the orientation distribution function analysis. By correlating the results of these texture investigations with those obtained by metallographic analysis, possible mechanisms of texture formation were discussed.

2 EXPERIMENTAL PROCEDURE

Al-high Mg alloys containing Mg in the range between 6 and 9% were melted in an Ar atmosphere. These ingots were homogenized at 450℃ for 1hr, cooled in air, and hot rolled at 350℃ to the thickness of 10 ㎜. After annealing at 450℃ for 1hr followed by air cooling they were cold rolled to 95% reduction in thickness under good lubrication.

From the cold rolled sheets, coupons having dimensions of 50(l)×40(w)mm^2 were prepared. They were isothermally annealed at 300℃ up to complete recrystallization. Cold rolled specimens were also isothermally annealed at 450℃ for 30min to investigate the textures developed during grain growth process. These specimens were chemically thinned down to 0.15 ㎜ thickness using NaOH solution. The {111}, {100} and {220} pole figures were determined on these specimens using a Rigaku RINT 2200 diffractometer equipped with a texture goniometer. These measurements were made by using both Decker-Asp-Harker transmission method and Schulz reflection method. Results obtained with these two methods were adjusted at the tilting angle of 45° from the normal direction. These data were stored on a floppy disk, and the orientation distribution functions (ODF) were calculated by the method of Roe up to the 22nd order using an NEC9821/Xe personal computer. Ghost corrections were not made in these calculations. In this paper, only constant ϕ =0°, 25° and 45° section of these functions are given to save space, since all important ideal orientations are located on these sections. Their positions are given in Fig. 1.

Metallographic observations were made on these specimens using an optical microscope. Special attentions were directed to the densities and distributions of shear bands, and nucleation of recrystallized grains at these shear bands.

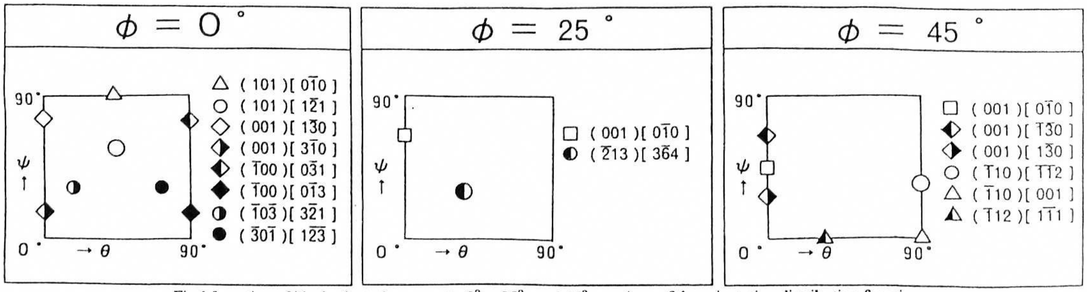

Fig. 1 Location of ideal orientations on ϕ =0°, 25° and 45° sections of the orientation distribution function.

3 RESULTS AND DISCUSSIONS

3.1 Rolling Textures

$\phi=0^\circ$ and 45° sections of orientation distribution functions describing rolling textures of Al-high Mg alloys are shown in Fig. 2.

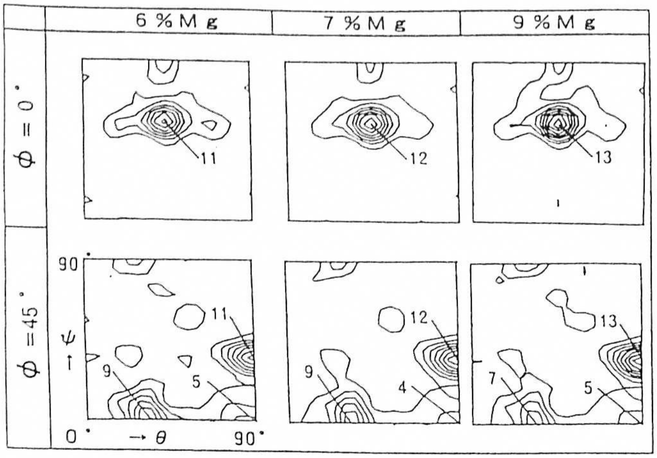

Fig. 2. $\phi=0^\circ$ and 45° sections of orientation distribution function representing textures of Al-6, 7 and 9% Mg alloys cold rolled 95%.

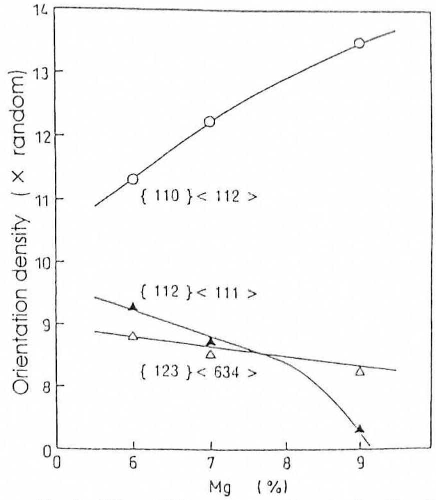

Fig. 3. Effect of Mg content on orientation densities of main rolling texture components. {110}<112>, {112}<111> and {123}<634>.

It is seen that, in these alloys with high Mg concentrations, the {110}<112> orientation is very strong (see $\phi=0^\circ$ sections). It increased remarkably with increasing Mg content. The {112}<111> orientation, on the other hand, is rather weak in these alloys (see $\phi=45^\circ$ sections). It decreased with increasing Mg content. These features are more quatitativery illustrated in Fig. 3, in which orientation densities of these orientations and the {123}<634> orientation are plotted against Mg content. A remarkable features of rolling textures in Al-high Mg alloys were thus the development of the strong {110}<112> Brass type component. On the other hand, the {112}<111> and the {123}<634> orientations are generally weak and continuously decreased with increasing Mg content. The effect of Mg on the formation of shear bands was investigated by using a SEM. It was found that high densities of shear bands are formed in these alloys. In comparison with the shear bands formed in Al-Mg alloys containing Mg less than 5% [2], their densities were much higher. The fact that the development {112}<111> rolling texture component is strongly suppressed by the Mg addition may be explained in term of shear banding and its orientation dependence[3, 4 and 5]. It has been reported that shear bands are formed only in grains having orientations which are located between {112}<111> and {123}<634> orientations along the ß fiber[4]. Through the formation of shear bands, the {112}<111> orientation becomes unstable, so that it is induced to rotated about the transverse direction [4, 5, 6 and 7]. Therefore the {112}<111> orientation rotates about the <110> axes lying parallel to the transverse direction toward the {110}<001> orientation. The {110}<001> orientation further rotates about the <110> axes lying parallel to the normal direction toward the {110}<112> orientations. Due to this mechanism the development of the {112}<111> orientation may be therefore suppressed and the formation of the {110}<112> orientation may be enhanced in the rolling textures of these alloys.

3.2 Recrystallization Textures

ϕ =0° and 25 ° sections of the recrystallization textures observed in Al-high Mg alloys after complete recrystallization are illustrated in Fig. 4.

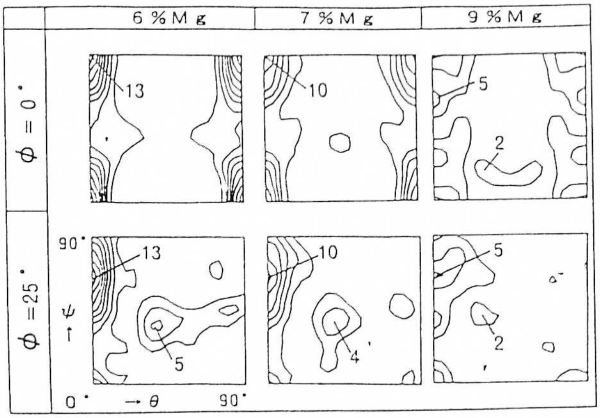

Fig. 4 ϕ =0 ° and 25 ° sections of orientation distribution function representing textures of Al-6, 7 and 9% Mg alloys cold rolled 95% and annealed at 350 ℃ up to complete recrystallization.

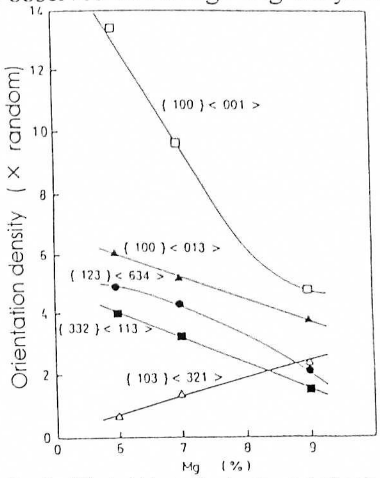

Fig. 5 Effect of Mg on the development of main recrystallization texture components. {100}<001>, {100}<013>, {123}<634> {332}<113> and {103}<321>

Orientation densities of the {100}<001>, {100}<013> and {103}<321> orientations determined on ϕ =0° section and orientation densities of {123}<634> orientation determined on ϕ =25° section were plotted in Fig. 5 as a function of the Mg content. The {100}<001> orientation was strong in the specimen containing 6% Mg. However, it decreased significantly with increasing Mg content. Such decreases of the {100}<001> recrystallization texture component may be explained in terms of shear banding which has occurred during cold rolling. According to Engler and Lücke[7], {100}<001> recrystallized grains are nucleated at transition bands in deformed grains having orientations in the range between {112}<111> and {123}<634> along the ß fiber. The development of the {100}<001> recrystallization texture component is therefore strongly dependent on the volume fraction of the deformed matrix having these orientations. Since shear banding reduces the volume fraction of the deformed matrix having these orientations, Fig. 3, the development of the {100}<001> recrystallization texture component should be more strongly suppressed in alloys with higher Mg content in which shear banding occurrs more extensively during cold rolling. Also the {100}<013>, {123}<634> and {332}<113> orientations decreased with increasing Mg content and the recrystallization texture tended to be random. The {103}<321> orientation which is supposed to be nucleated at shear bands[6, 7 and 9], on the other hand, increased in fact with increasing Mg content. In Fig. 5, also orientation densities of the {332}<113> orientation is given in the figure, since it is known that the {332}<113> recrystallization texture component develops remarkably in specimens having strong {110}<112> rolling texture component. The {332}<113> orientation, however, decreased with increasing Mg content. In the recrystallized specimens of Al-high Mg alloys, ß-phase particles could be observed with an optical microscope. The number of ß-phase particles was significantly increased with increasing Mg content. These particles may strongly suppress the development of the normal recrystallization textures. This may be the reason why the recrystallization texture in the Al-9% Mg alloy was random.

3.3 Texture development during grain growth

By annealing at 450°C for 30min, extensive grain growth was allowed to occur in these Al-high Mg alloys. ϕ=0° and 45° sections describing textures of these specimens are illustrated in Fig. 6.

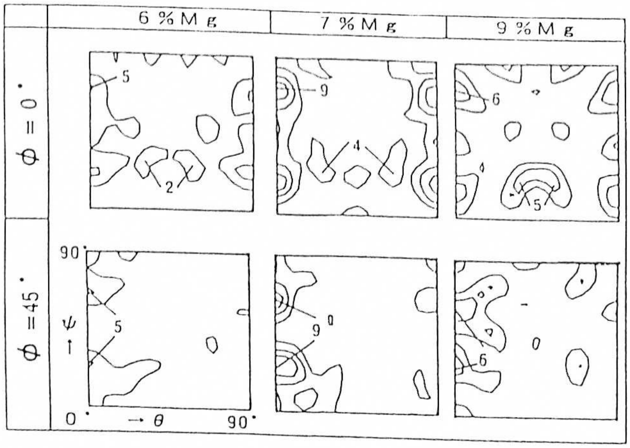

Fig. 6 ϕ=0° and 45° sections of orientation distribution function representing textures of Al-6, 7 and 9% Mg alloys cold rolled 95% and annealed at 450 °C to enhance grain growth.

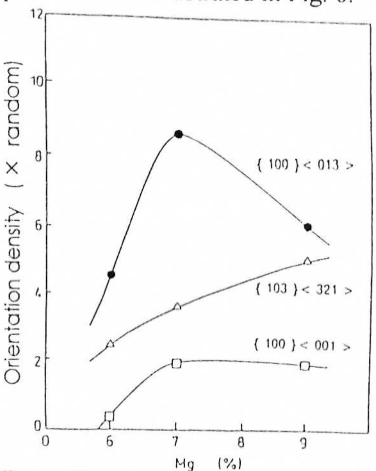

Fig. 7 Effect of Mg on the development of main texture component during grain growth {100}<001>, {100}<013> and {103}<321>.

Orientation densities of the {100}<001>, {100}<013> and {103}<321> orientations determined on these sections were plotted in Fig. 7 as a function of the Mg content. In these specimens, the {100}<001> orientation was very weak. The {100}<013> orientation was strong and increased remarkably with the increasing amount of Mg. At the Mg content above 7%, however, the {100}<013> orientation decreased appreciably with increasing Mg content. The {103}<321> orientation, on the other hand, increased with increasing Mg content. In a previous investigation[8], the effects of both the annealing temperature and the Mg content on the development of the annealing textures of high purity Al and Al-Mg alloys containing Mg up to 5% have been investigated in detail. It was found that, in high purity Al, the {100}<001> orientation increased remarkably by annealing at higher temperatures and that, in Al-Mg alloys, the development of the {100}<001> orientation is strongly suppressed. Lücke and co-workers[6, 7 and 9] have reported that the recrystallization texture is strongly dependent on the annealing temperature. At lower annealing temperatures, the main orientation of the texture is {100}<001>. But, at higher annealing temperatures near 500°C, the {100}<001> orientation is weak and orientations such as {103}<321> and {110}<001> develop remarkably. They suggested that the {110}<001> and {103}<321> recrystallization texture components are nucleated at shear bands at higher annealing temperatures. The specimens used in the present investigation were isothermally annealed at 450°C for 30min after 95% cold rolling. In these cold-rolled sheets, shear bands are developed remarkably with increasing Mg content. Therefore, the {103}<321> orientation may have been developed remarkably during this annealing. The texture in the Al-9% Mg alloy was rather random. This may be because the texture established at the complete recrystallization was already random, Fig. 5.

4 CONCLUSION

(1) In the rolling texture of Al-high Mg alloys, the addition of Mg strongly suppresses the development of the ß-fiber texture components lying in the range between {112}<111> and {123}<634>. This may be ascribed to frequent shear banding which is induced in grains of these orientations by Mg atom. As a result of such shear banding, the {110}<112> component is strong in the rolling texture of Al-high Mg alloys.

(2) In the recrystallization textures of Al-high Mg alloys, the {100}<001> orientation is weak and decreased appreciably with the increasing Mg content. This decrease correlates quite well with the decrease in the {112}<111> and {123}<634> component in the rolling texture.

(3) In the texture developed during grain growth in Al-high Mg alloys, the {100}<001> orientation is very weak. Also the {100}<013> orientation becomes weak at the Mg content above 7%. The {103}<321> orientation, on the other hand, increases with increasing Mg content. This increase is correlated with the development of shear bands during cold rolling. The {103}<321> orientation appears to be nucleated at shear bands.

REFERENCES

[1] M. Koizumi, H. Inagaki and S. Kohara : Z. Metallkde. 88(1997)576.
[2] H. Inagaki and S.Kohara : Z. Metallkde. 88(1997)570.
[3] K. Morii, H. Mecking and Y. Nakayama : Acta metall. 33(1985)379.
[4] O. Engler, C. Renoux and G. Gottstein : Proc. 3rd InS. Conf. on Al Alloys, ed by L. Arenberg et al., The Norwegian Inst. Technology, 2(1992)203.
[5] P. Wagner, O. Engler and K. Lücke : Acta metall. mater. 43(1995)3799.
[6] K. Lücke and O. Engler : Mater. Sci. Techn. 6(1990)1113.
[7] O. Engler and K. Lücke : Scripta metall. 27(1992)1527.
[8] M. Koizumi, H. Okudaira and H. Inagaki : submitted to Z. Metallkd.
[9] P. Wagner, O. Engler and K. Lücke : Textures and Microstructure. 14-18(1991)927.