The 6th International Symposium on East Asian Resources Recycling Technology
October 23 - 25, 2001, Gyeongju (慶州), Korea
ISBN: 89-952527-0-7 93530

Recycling Technology of Aluminum UBC To Can Body Sheets

Cha-Yong Lim and Seuk-Bong Kang

Department of Materials Engineering
Korea Institute of Machinery and Materials
Sangnam-dong 66, Changwon, 641-010, Korea

Abstract

The materials processing factors such as remelting and casting, heat treatment and microstructure, sheet rolling and can body forming in the aluminum can-to-can recycling procedure have been investigated. Aluminum used beverage can(UBC) was remelted together with virgin aluminum. The ceramic filter was used during casting to remove large impurities. As-cast microstructure was composed of large intermetallic compound (mainly β-phase) distributed in the aluminum matrix. By heat treatment, β-phase was transformed to α-phase which was also formed from Mg_2Si particles. The heat treated ingots were hot-rolled at 480°C and cold-rolled to thin sheets. Can making from this thin sheets was successful and earing was measured after can making. There was a critical cold reduction rate for minimum earing. Some cracks were initiated from the impurity particles which was not removed during filtering.

Keywords: Aluminum UBC, Recycling, Microstructure, Can making, Earing.

1. Introduction

In the worldwide nearly 200 billon cans are produced each year [2]. This is about two million tons of can-stock sheet. UBC are collected in a variety of ways [3]. After collection, the bales of cans are broken up in a shredder into small pieces. These shredded cans are then conveyed into a de-lacquering oven to remove the paint and moisture. The hot shredded pieces are pressed into billets which is usually used for raw materials for can body alloy or melted and casted into secondary ingots.

As the production of can body sheet is highly competitive, the production details are not freely available. The sheet currently used for can making is rolled from DC-cast ingots. After scalping, the ingots are homogenized at temperatures above 550°C and soaked for a carefully controlled period.

Recycling of aluminum UBC into can body materials is very important in modern high consumption society. This is the way to reduce waste and energy needed for the production of virgin aluminum. But, there are several problems in the aluminum can-to-can recycling process. The basic metallurgical steps involved in the recycling aluminum UBC are melting, casting, homogenization treatment, hot rolling, annealing and cold rolling, can forming. In each step, the control of microstructure is very important for the optimization of mechanical properties [4-6]. In this study, therefore, the basic metallurgical factors such as microstructure and can forming properties are studied in recycled aluminum UBC.

2. Experimental Procedure

2.1 Materials preparation

Secondary ingots(chemical composition was given in Table 1) made by shredded UBC were melted in the SiC crucible together with virgin aluminum with different mixing ratio. Alloying elements needed to make A3004 were added in the form of mother alloys. After degassing treatment, the molten aluminum was poured into rectangular mold that cast sheet ingots with ceramic filter used to remove large impurities. Fig.1 shows the casting equipment used in this study. The chemical compositions of alloys investigated were listed in Table 2. N2 sample is made of the mixture of 20% secondary ingot and 80% virgin aluminum. N3~N6 cotain 30~60% secondary ingot, respectively.

Table 1. Chemical composition of secondary ingot.

Si	Fe	Cu	Mn	Mg	Al
0.53	0.46	0.22	0.87	1.36	Rem.

Table 2. Chemical compositions of tested alloys

	Si	Fe	Cu	Mn	Mg	Zn	Al
N2	0.25	0.57	0.15	0.91	1.16	0.02	Bal
N3	0.35	0.60	0.17	0.92	1.17	0.03	〃
N4	0.43	0.56	0.16	0.90	1.07	0.04	〃
N5	0.52	0.50	0.15	0.90	0.96	0.05	〃
N6	0.62	0.60	0.14	0.95	0.94	0.06	〃

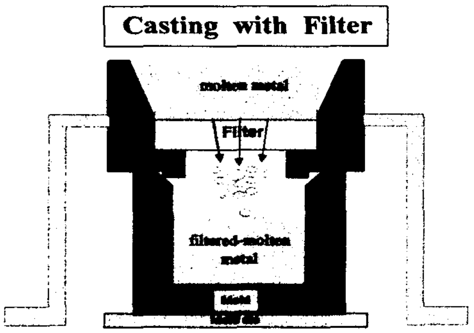


Fig. 1 Casting equipment with filter.

2.2 Heat treatment and microstructure

The ingots were heat treated at the temperature of 615°C for 10hrs for the homogenization of second phase (β-phase). Homogenized inogts of 23mm thickness were hot rolled to 4mm at 480°C. Some of hot rolled sheets were annealed, then final cold rolled. Others were first cold rolled after hot rolling, intermediate annealed, then final cold rolled. The working flow was shown in Fig. 2. In each step, the microstructure was analyzed by OM, SEM, and TEM.

3. Results and Discussion

3.1 Microstructure

The compositions of tested can body alloys are such that a number of different phases, derived from the solidification process and a number of solid state transformations, are in equilibrium at the different temperature ranges. Fig. 3 shows the optical microstructure image of as-cast condition of N2~N6 alloys. There are many intermetallic compounds within the dendrite formed during casting. The density of intermetallic compounds increased with increasing the amount of secondary ingot. The optical and transmission electron images of N4 alloy with heat treatment were given in Fig. 4. As-cast microstructure was composed of large β(Al_6(Fe, Mn)) and small Mg_2Si phases within the aluminum matrix. α-phase($Al_{12}(Fe,Mn)_3Si$) is also observed. β-phase was mainly observed on the grain boundary of as-cast condition. Precipitation free zone(PFZ) was also observed. Fine Mg_2Si precipitates were distributed within the grain. The quantity of this Mg_2Si precipitates increased with increasing the Si content. By heat treatment of 400°C for 5hrs, Mg element of Mg_2Si dissolves and only Si element exists(Figure 4(e)). The Si element released was played as a nucleation site of α-phase. Namely, undissolved Si reacts with β-phase to form the α-phase. All phases were transformed to α-phase after heat treatment at 595°C for 20hrs.

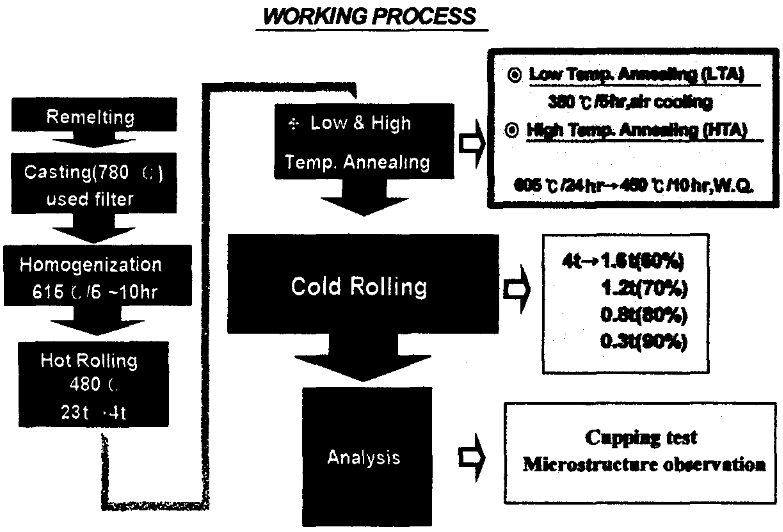


Fig. 2 Working flow of this experiement

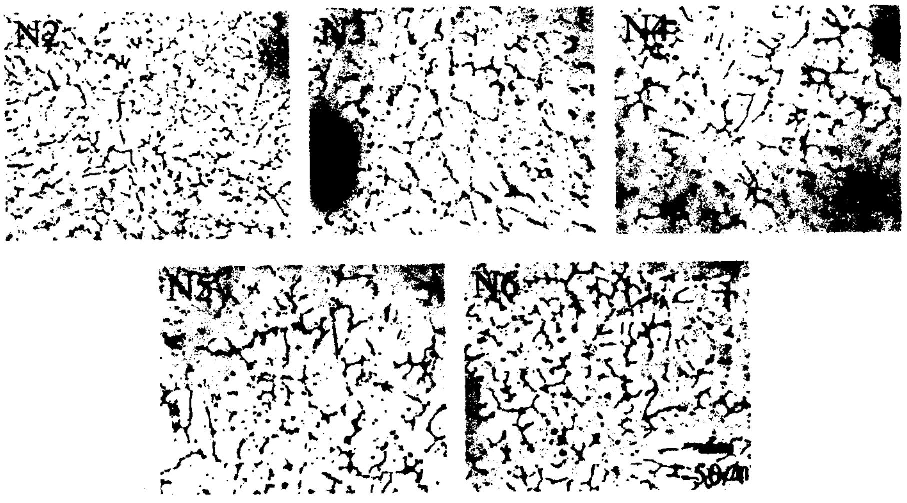


Fig. 3. Optical micrographs of N2~N6 alloys in as-cast condition

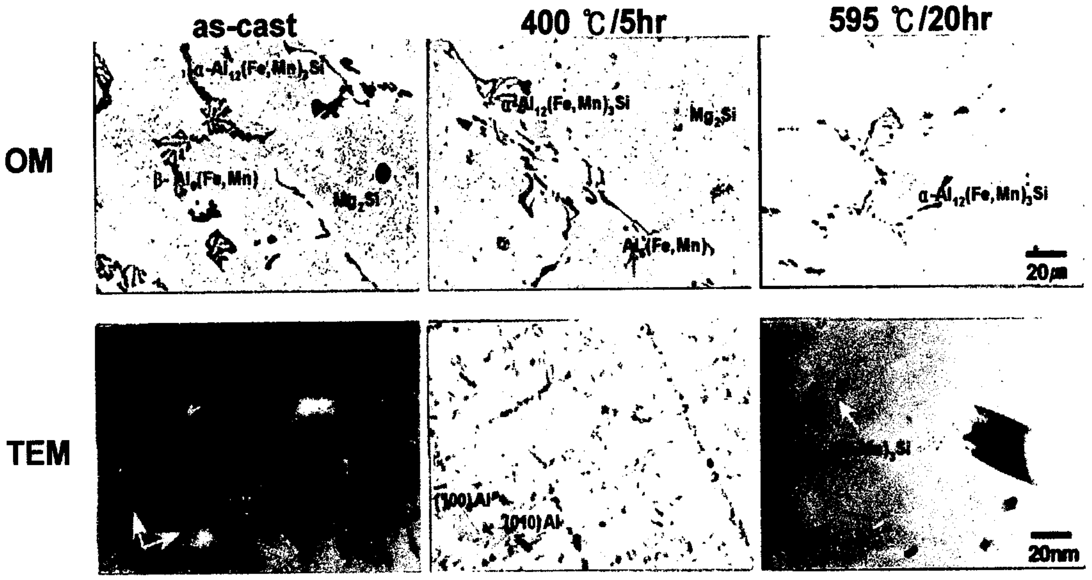


Fig. 4. Optical and TEM micrographs of N4 alloy in as-cast and after heat treatment.
(a) OM(as-cast), (b) OM(400°Cx5hrs), (c) OM(595°Cx20hrs)
(d) TEM(as-cast), (e) TEM(400°Cx5hrs), (f) TEM(595°Cx20hrs)

The thin interdendritic platelets of β are transformed to coarser α-phase particles (5-10μm) and the same phase also nucleates and grows from Mg_2Si particles to form a fine dispersion of precipitates that are ~0.1μm in diameter. The adequate duration and temperature of the homogenization was determined from the mean size of these dispersoids of α-phase as 615°C for 5~10hrs.

3.2 Analysis of impurities

Ceramic filter was used during casting stage in order to remove large impurities. Fig. 5 shows the used filter. 4 points of used filter were analyzed by EDS. Fig. 6 shows the analyzed results. It can be seen that the impurities filtered during is intermetallic compound of Mg, Fe, Cu, Si.

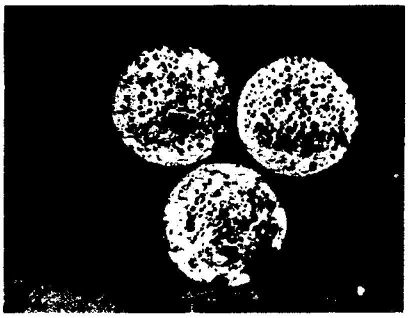
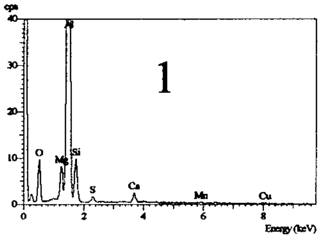
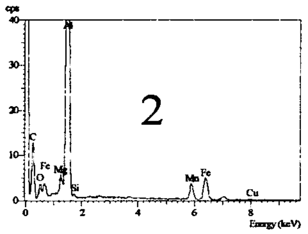
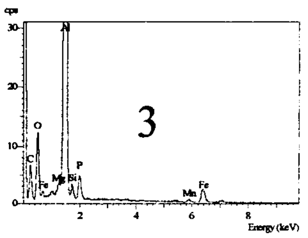


Fig.5 Used ceramic filter







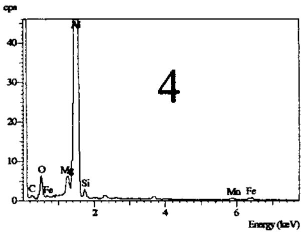


Fig.6 EDS results of used filter

3.3 Can forming and earing

The homogenized ingots were scalped and hot rolling at 480°C from 23mm to 4mm. Intermediate annealing after hot rolling was conducted in low temperature(LTA, 350°Cx5hrs, AC) and high temperature(HTA, 605°Cx24hr → 450°Cx10hrs, WQ) to release the stored energy. There were no recrystallized grains after low temperature annealing. Only precipitation takes place. The cold rolled sheets with different reduction rate of 60, 70, 80% were obtained by rolling of the of the heat treated sheet at room temperature.

Efficient use of the blank sheet for can making process requires that the cup and can should be deep drawn and ironed isotropically. Unfortunately the strong textures are introduced during sheet making and these casuse the the generation of ears. Fig. 7 shows the successfull deep-drawn cup and cracked cup. 4-fold earing was made by cupping. The type of texture was explained previously[7].

Cracking takes place during cupping process in some parts of the sheets. Fig. 8 shows the results of analysis of cracked part of the cup by EDS and SEM. Cracked part were divided into three area. Area A was sound part and the dimple fracture surface was obtained. Coarse Fe particle was detected in the intermediate region of A and B. Brittle fracture surface was caused due to the coarse Fe particle. Impurities such as Cr, Ca, Si compounds were observed on B area. Fig. 9 show two EDS results of B area.

Although the earing which means metal loss depends on the mechanical parameters of can making such as lubrication, blank hold pressure, and alighment, its degree can be reduced by control of the texture components developed during thermomechanical process.(hot rolling, intermediate annealing, and cold rolling)

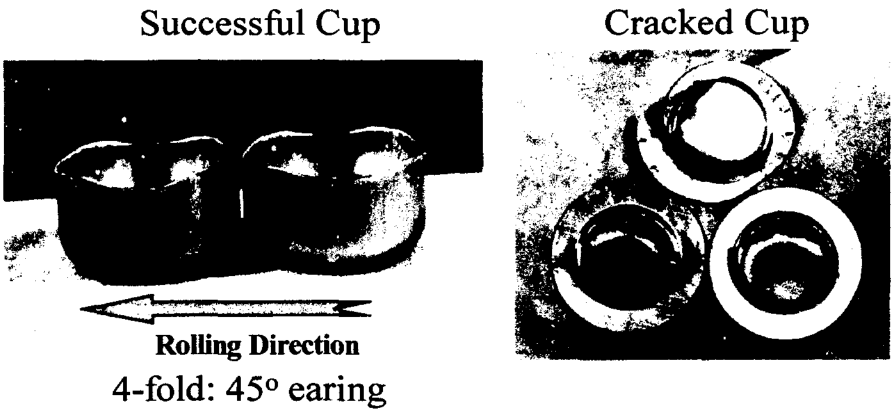


Fig. 7 Deep-drawn cup and cracked cup

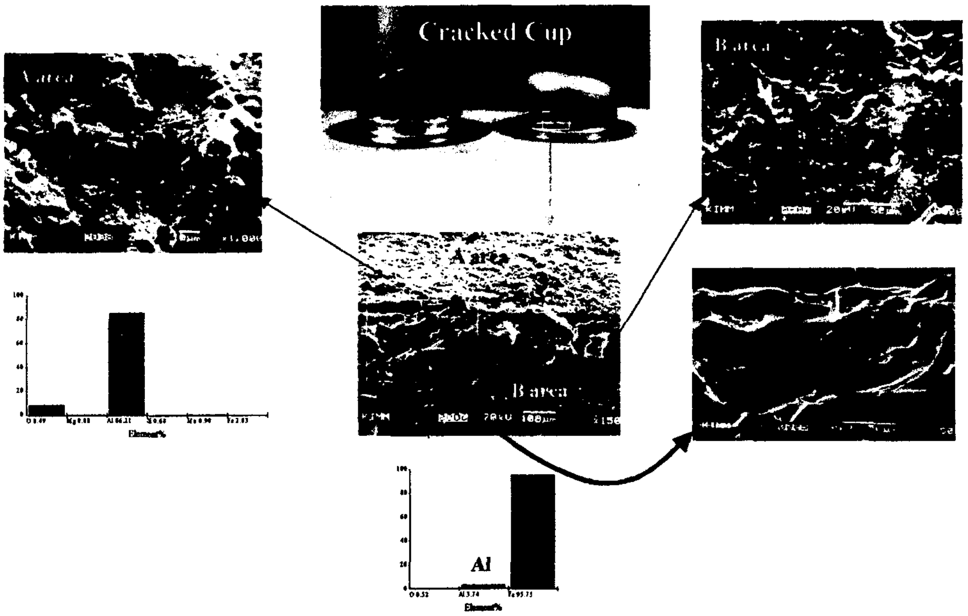


Fig. 8 Analysis of cracked cup by EDS and SEM

Fig. 9 EDS results of B area

Fig. 10 shows the earing rate of 5 can alloys as a function of cold rolling rate. Intermediate annealing after hot rolling was conducted inat low temperature(LAT process, upper figure) and high temperature(HAT process, lower figure). The earing rate increases with increasing the contents of secondary inpots. The earing rate has miminum value at 70% cold reduction rate(critical reduction rate) for both intermediate annealing process. This is due to the balance of deformation and recrystallization textures. The adequate ratio of these two textures is one to one.[7] For further increase of cold reduction rate, earing rate increased becasue of the increased deformation texture component.

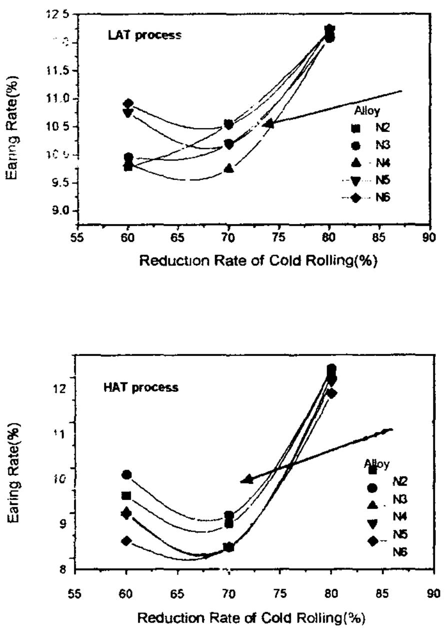


Fig.10. Earing rate with cold rolling.

4. Conclusions

The following conclusions could be drawn from the above experimental results. Ceramic filter was very helpfut to remove the large impurities. In aluminum can to can recycling, the second phase particles made in the solidification stage due to the impurity elements(Fe, Si) must be controlled by heat treatment. The recommended heat treatment condition was 615°C for 5-10hrs. Furthermore, the texture developed during thermomechanical processing stage should be adjusted to minimize the ears of can. The adequate ratio of deformation texture and recrystallization texture is one to one.

Can making from this thin sheets was successful and earing was measured after can making. There was a critical cold reduction rate for minimum earing. Some cracks were initiated from the impurity particles which was not removed during filtering.

5. References

[1] F. J. Humphreys and M. Hatherly, "Recrystallization and Related Annealing Phenomena", (1995), *Pergamon*, 393.

[2] http://www.alumi-can.or.jp/, (Aluminum Can Recycling Association), (1998)

[3] http://recyclemetal.com/aluminum.ht

[4] H. S. Ko, S. B. Kang, H. W. Kim and O. N. Yoon: J. Kor. Inst. Met. & Mater., **35** (1997), 664.

[5] P. A. Hollinshead and T. Sheppard: Metall. Trans. A, **20A** (1989), 1495.

[6] Ph. Lequeu and J. J. Jonas: Metall. Trans. A, **19** (1988), 107.

[7] C.Y. Lim, H.S. Ko, and S.B. Kang, "Materials study in aluminum can-to-can recycling process", Proceedings of Fifth International Symposium on East Asian Recycling Technology, June 15-17, 1999, Tsukuba, Japan, (1999) 47.