New retrogression and reaging process for high strength and high stress corrosion resistance 7050 aluminum alloys

Manabu Nakai and Takehiko Eto

Aluminum & Copper Research Section, KOBE STEEL, LTD.
5-5,Takatsukadai 1-chome, Nishi-ku, Kobe, 651-2271, JAPAN

ABSTRACT New retrogression and reaging process for 7050 aluminum alloys, having the yield strength of 600MPa and stress corrosion resistance equal to 7050-T74, has been developed. New Process is combined higher aging and reaging temperature and lower reversion temperature. These treatments brought out wider spacing in grain boundary precipitates (η phase) and denser GP zones and η'phase precipitation to improve the properties as mentioned above.

Keywords: RRA, SCC, exfoliation corrosion, retrogression

1.INTRODUCTION

Stress corrosion resistance of high strength 7000 series aluminum alloys have been improved through overaging treatments such as the T76, T74 and T73 temper. These tempers improve the corrosion resistance but decrease the yield strength simultaneously. Cina1) developed the retrogression and reaging (RRA) treatment as a heat treatment to improve SCC resistance while maintaining high strength. It was put to practical use at long last through application to 7055 as T77 temper2). The SCC resistance of 7055-T77 is not efficient to be between that of 7150-T61 and 7150-T773), which restricts its application only to the compression-dominated structures3). Concerning the RRA treatment, therefore, there is still room for improvement in the combination strength and corrosion resistance.

In the present study, the effects of conditions of aging, reversion and reaging on the precipitates in the matrix and grain boundary precipitates of 7050, 7075 and 7055 were investigated to improve the combination the strength and SCC resistance of high strength 7000 series aluminum alloys.

2.THE COMCEPT OF NEW RRA PROCESS

From the viewpoint of process-microstructure-properties, Fig.1 shows the key technology to obtain the alloys having high corrosion resistance combined with high strength. The first, wider η phase spacing along grain boundaries improve corrosion resistance due to the suppression of their continuance. The second, suitable η'phase precipitates is controlled to reduce the corrosion potential difference between η', [illegible] phase, and the matrix[4]. High-density GP zones in the matrix produce high strength. To realize the microstructure mentioned above, a new RRA treatment (New Process different from the conventional RRA treatment developed by Cina. (Cina Process) was introduced.

3.EXPERIMENTAL

Table1 shows the three chemical compositions of specimens. These alloy Ingots (¢ 150mm) were homogenized at 450℃ for 24hrs, then extruded at 420℃ into the size of 20t x 120w mm (extrusion ratio : 7.5) at 420℃. The specimens were solution heated at 475℃ for 30 minutes, quenched in water to RRA treatment. After the RRA treatments, the strength, electrical conductivity (%IACS), resistance to SCC, and resistance to exfoliation corrosion of specimens were examined. The SCC resistance was evaluated according to ASTM G47. The measurement of the resistance to exfoliation corrosion was done in accordance with ASTM G34.

Table 1 Chemical compositions of Specimens (mass%)

	Si	Fe	Cu	Mg	Zn	Cr	Zr	Ti
7050	0.04	0.08	2.1	2.3	5.9	<0.01	0.12	0.02
7075	0.04	0.12	1.5	2.3	5.8	0.19	0.01	0.03
7055	0.04	0.09	2.0	2.2	6.9	<0.01	0.12	0.02

4. RESULTS

Fig.2 shows the influence of the reversion conditions the conductivity and yield strength after the RRA treatment. The RRA treatment applied here included two methods : New Process (130℃ x 12hrs ⇒ 180℃ ⇒ 130℃ x 12hrs) and Cina Process (120℃ x 24hrs ⇒ 200℃ ⇒ 120℃ x 24hrs). In Cina Process where the reversion temperature is set at the high temperature of 200℃, the yield strength of the alloys increases up to a maximum by a short time reversion for 10 minutes and then rapidly decreases with increasing reversion time. The conductivity at which the maximum yield strength is obtained is as low as 32 IACS% for any of the 7050, 7075 and 7055 alloy. This phenomenon implies that it may be difficult to achieve better high corrosion resistance combined with high strength by Cina Process. On the other hand, in New Process where the reversion temperature is set at the low temperature of 180℃, the conductivity of any of the 7050, 7075 and 7055 alloy shifts to higher conductivity. Moreover, the yield strength is not inferior as compared to the case of Cina Process. The reversion time when the maximum yield strength is obtained shifts from 10 minutes of Cina Process to 120-150 minutes. This implies that New Process can be put to practical use. These facts suggest that high strength and high corrosion resistance may be obtained at the same time by applying New Process to the 7050, 7075 and 7055 alloy.

SCC test and exfoliation corrosion test was made using the specimens processed under the RAA conditions shown in Table 2. The yield strengths of the specimens are approximately 600 N/mm^2. Fig. 3 shows the SCC resistance and the exfoliation corrosion resistance. The SCC resistance of any of the 7050, 7075 and 7055 alloy subjected to New Process is superior to the SCC resistance of that alloy subjected to Cina Process. The exfoliation corrosion resistance also is improved from the rank EB in Cina Process to the rank EA. The SCC stress of the 7050 alloy given the New Process, in particular, is approximately 240 N/mm^2, an excellent SCC resistance equal to the 7050-T74.

5.DISCUSSION

Fig. 4 shows the η phase along grain boundaries in the 7050 and 7055 alloy subjected to the RRA treatment under the conditions shown in Table 2. New Process enlarges the η phase spacing along grain boundaries of 7050 from 300Å to 1000Å, and that of 7055 from 100Å to 300Å. Fig.5 shows the relationship between the η phase spacing along grain boundaries and the SCC stress. The SCC resistance of the 7050 alloy is considerably improved, by widening the η phase spacing. On the contrary, the η phase spacing of the 7055 alloy is winded only to 300Å. Therefore, its SCC resistance is not significantly improved. This is supposedly because the excessive Zn in 7055 precipitates along grain boundaries as continuous η phase, that is at small intervals.

In the New Process, to attain high corrosion resistance by widening the η phase spacing along grain boundaries, the aging and reaging conditions were changed from 120℃ x 24 hrs of Cina Process to 130℃ x 12 hrs, namely the time was shortened and the temperature was raised. The effects of aging time and aging temperature on η phase spacing were investigated on the basis of the assumption that the η phase spacing may be inversely proportional to the diffusion distance of solute atoms (Zn). Fig.6 shows that shortening the aging time is effective to wide the η phase spacing. In the New Process, the aging time is shortened from 24 hours to 12 hours and, at the same time, the aging temperature is increased from 120℃ to 130℃ because if the aging time is shortened without increasing the aging temperature, the density of GP zones inside the grains decreases and thus high strength can not be obtained.

Fig.7 shows η'phase in the matrix the 7050 alloy subjected to the RRA treatment under the conditions shown in Table 3. The size and amount of η'phase of the alloy subjected to New Process with a low reversion temperature are smaller than those of the alloy given Cina Process. The conductivity of both alloys is about 38 IACS%, of the same value. Namely, the total amounts of precipitates of both alloys are equal. This means that more GP zones are formed in the matrix by New Process than by Cina process. Since the yield strength after New Process and Cina Process are approximately 600 N/mm^2 and 550 N/mm^2, respectively, the morphology of precipitates and the yield strength correspond to each other. New Process nucleates high-density GP zones in the matrix to produce high strength of the alloys.

In the New Process, the reversion temperature is lowered from 200℃ of Cina Process to 180℃ in order to attain high SCC resistance combined with high strength. Fig.8 shows the schematic illustrations of precipitation of GP zones and η'phase in the matrix when aged, reversed, and reaged, respectively. In the New Process, GP zones are still existent in large quantities and coexist with η'phase even during reversing treatment on account of the lowered reversion temperature. The total amount of GP-zones including the amount precipitated during reaging treatment is increased remarkably, and a high strength is achieved. On the other hand, in Cina Process, almost all of GP zones dissolve during reversing treatment and the precipitating amount of η'phase is increased. The precipitating amount of GP zones during reaging treatment is decreased. As the result, high strength can not be obtained.

6 .CONCLUSIONS

- The strength and corrosion resistance of any of the 7050, 7075 and 7055 alloy can be improved through the application of New Process in which the reversion temperature is lowered from 200 ℃ to 180 ℃ and the aging and reaging temperature is raised from 120℃ to 130℃. Concerning the 7050 alloy in particular a high yield strength over 600N/mm^2 and a high SCC resistance equal to 7050-T74
- Lowering the reversion temperature decreases the precipitating amount of η'phase during reversion and increases the density of GP zones during reaging treatment, resulting in the increases in strength. Raising the aging and reaging temperature causes the η phase along the grain boundaries to precipitate sparsely and thus causes, resulting in the improvement in SCC resistance.
- The aluminum alloys suitable for RRA treatment is 7050. Even if New Process is applied to 7055, the improvement in the SCC resistance is limited.

6.REFERENCES

[1] B. H. Cina : US. Patent 385684, 24 Dec. 1974.
[2] D. A. Lukasak, and R. M. Hart : Light Metal Age, Oct. (1991), 11.
[3] W. H. Hunt, Jr. and J. T. Staley : Light-Weight Alloys for Aerospace Applications, Ed. by E. W. Lee, C. H. Cina and N. J. Kim, TMS, (1989), 111.
[4] Rajan,K. ,Wallace,W. and Beddoes, J. C. : J. Materilas Science, 17 (1982), 2817.

Table 2 RRA treatments and Material Properties.

	RRA treatments	YS,N/mm^2	%IACS
7050 New. Process	130℃x12hrs⇒180℃x 90min⇒130℃x12hrs	600	38
Cina Process	120℃x24hrs⇒200℃x 15min⇒120℃x24hrs	605	34
7055 New. Process	130℃x12hrs⇒180℃x120min⇒130℃x12hrs	600	38
Cina Process	120℃x24hrs⇒200℃x. 15min⇒120℃x24hrs	605	34

Table 3 RRA treatments and Material Properties.

	RRA treatments	YS,N/mm^2	%IACS
7050 New. Process	130℃x12hrs⇒180℃x 90min⇒130℃x12hrs	600	38
Cina Process	120℃x24hrs⇒200℃x 30min⇒120℃x24hrs	550	38

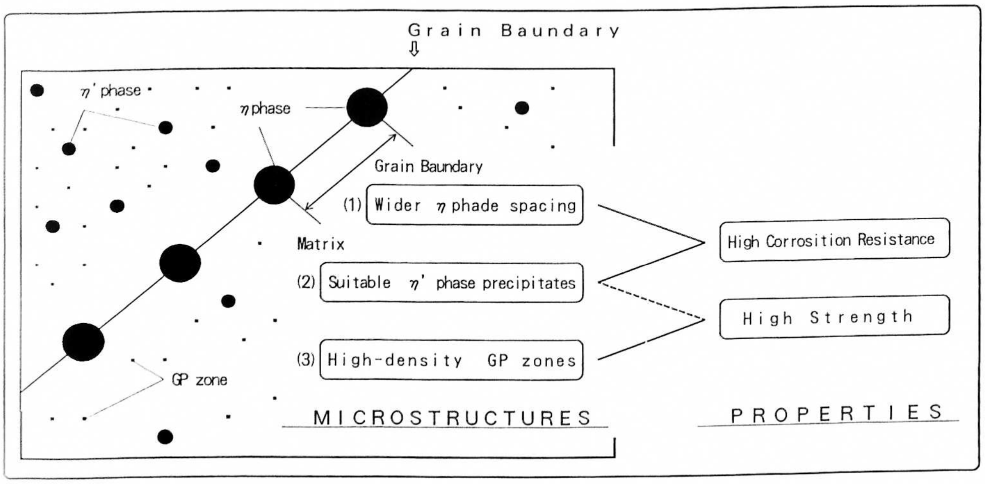

Fig. 1 The Concept of New Process.

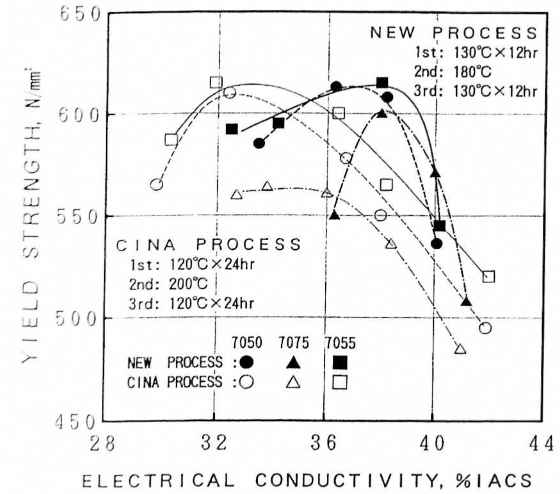

Fig. 2 Yield Strength and electical conductivity for New Process vs. Cina Process.

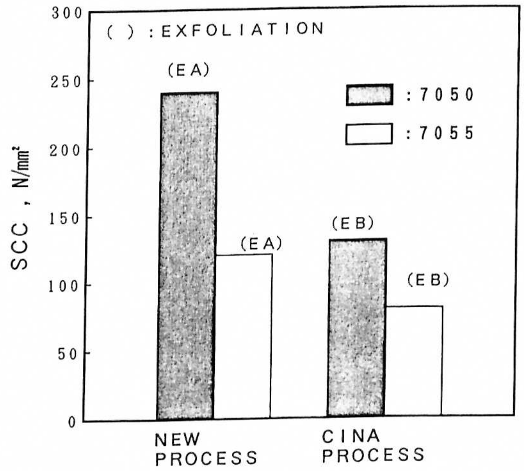

Fig. 3 SCC resistance and exfoliatioin corrosion resistance improvements of New Process comprared to Cina Process.

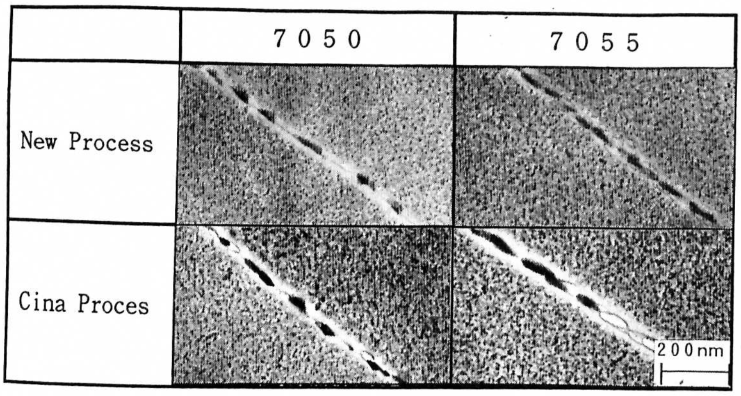

Fig. 4 TEM showing η phase along grain boundar

(A)New Process-7050
(B)New Process-7055
(C)Cina Process-7050
(D)Cina Process-7055

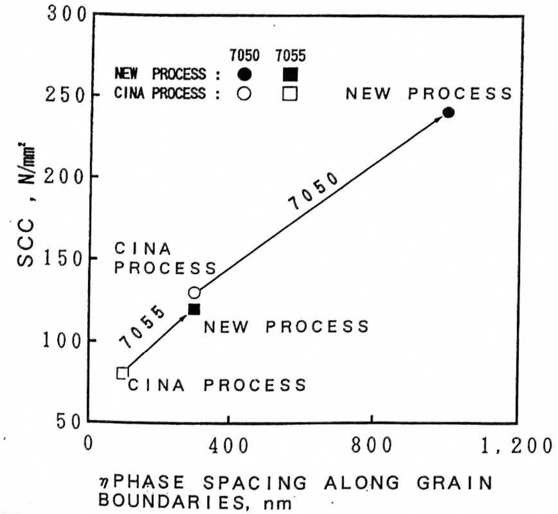

Fig. 5 SCC resistance vs η phase along grain boundarie for New Process-7050, 7055, Cina Process-7050, 7055.

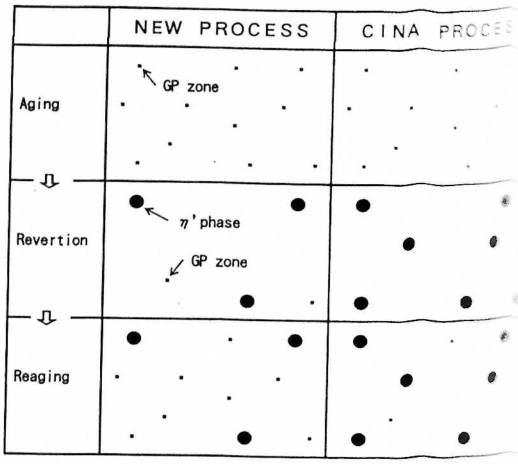

Fig. 6 Effect of aging time and temperatur on iso η phase spacing along grain baundar curves.

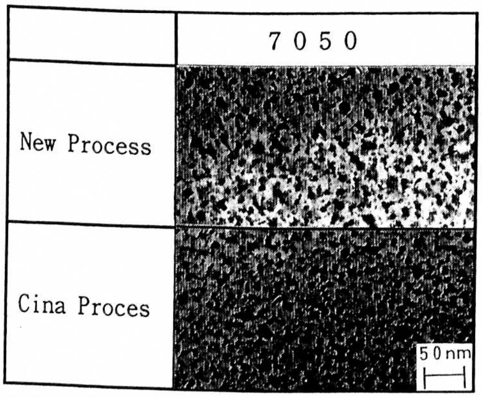

Fig. 7 TEM showing η'phase in the (A)New Process-7050 and (B) Cina Process-7050.

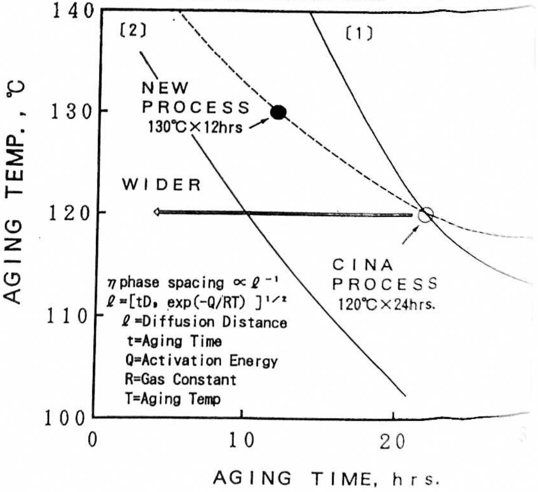

Fig. 8 Influence of aging and reaging con tions on diffusion disance of Zn.