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The Effect of Zr, Misch Metal on Microstructure and Mechanical Properties of A6061 Alloy

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Abstract
Weight reduction of car, air plane, boat is hot issue for conservation of nature and save of fuel. So nowadays the application of light metals is increasing in many industrial parts. Al alloys are very attractive light metal for car and air plane parts. A6061 alloy is strong candidate for auto parts such as bonnet and panel. But the mechanical properties of A6061 alloy are not still satisfied to use auto parts. In this study, 0.05wt% Zr and 0.05wt% misch metal(Mm) were added in A6061 alloy to improve the mechanical properties. The microstructures of the aged specimens at 450K had been observed by OM, TEM. And mechanical properties of the aged specimens are measured by using hardness and tensile test.
Hardness of the as quenched ZM specimen is 60Hv and the peak hardness of two step aged (aged temperature of first step is ambient temperature) ZM specimen is 102Hv, T6 treated Zr and Mm added specimen (ZM) and A6061 specimen are 122Hv and 99.6Hv, respectively.
Tensile strength of the as quenched specimen of ZM is 274MPa and peak strength of two step aged ZM specimen is 337MPa. And the elongations of as quenched specimen and peak aged specimen are 31% and 20%, respectively. Tensile strength and elongation of the peak aged ZM specimen which was practiced T6 treatment is 377MPa and 19%, respectively. And the peak strength of T6 treated A6061 alloy is 360MPa. Therefore, the strength of A6061 was increased by the addition of Zr and Mm.

Keywords: Aging, Misch metal, Al 6061, Strengthening

1. Introduction
Al alloys are suitable for weight reduction of car, air plane and boat. Because, a series of AA6xxx have high strength and elongation as compare with density. But, Al alloys have still lower strength and elongation than steel.
It has been found that addition of Zr in Al alloys are very effective in refining grain of cast ingot and better resistant to coarsening of precipitates due to the formation of thermally stable Al3Zr phases formed during casting [1].And rare earth elements (or Ce rich misch metal) in Al-based alloy can improve many properties such as strength, heat resistance, extrusion behavior and so on [2].
The first purpose of this study is to investigate the co-effect of Zr and misch metal addition on the microstructure and mechanical properties of A6061 alloy. And the second purpose of this study is to investigate the effect of heat treatment (T6 and two step aging) on mechanical property. Microstructures had been investigated by using optical microscope (OM), scanning electron microscope (SEM), transmission electron microscope (TEM) and DSC analysis. Mechanical properties had been measured by Vickers hardness and tensile test .

2. Experimental

2.1 Prepare specimens
The compositions of specimens are shown in Table 1. ZM specimen is Zr and Mm added specimen in A6061. A6061 specimen (named at A specimen) was supplied in a cast billet from ALCAN lnc. The ingots homogenized were deformed by hot and cold rolling to make plate specimens. The ingot was rolled from 15t to 5t (mm) by hot rolling and deformed from 5t to 2t (mm) by cold rolling.

2.2 Heat treatment
T6 heat treated specimen consists of solution heat treatment (SHT) at 808K for 60min and quenching in water, followed by aging at 450K for 3.6~28.8Ks. In the case of two step aging, the specimens were hold for 1,209.6Ks at room temperature after SHT and followed by final aging at 450K for 3.6~28.8Ks.

2.3 Microstructural observation
Microstructure of A6061 billet and rolled specimen were observed using OM. These specimens were etched by using Keller's solution (distilled water: 90mL, HNO_3: 5mL, HCl: 3mL, HF: 2mL). Also, precipitates of the aged specimens were observed by TEM (JEOL JEM-2010) at an accelerating voltage of 200kV. Thin film for TEM specimen was prepared by using twin jet polishing in solution which is 30vol%HNO_3 and 70vol%CH_3OH at 233K.

2.4 Mechanical properties
Hardness was measured by using Vickers hardness tester with 500gf load. Tensile strength (UTS), yield strength (YS) and elongation(EL) were obtained by using universal tensile tester (R&B, Unitech-M). Tensile testing was conducted at a cross-head speed of 1mm/min.

3. Results and discussion

Fig. 1 shows OM images of as-cast, homogenized, rolled, solution heated treated A and ZM alloys. Zr has formed Al_3Zr with Al during casting, and Al_3Zr precipitate is effective phase of grain refinement [3]. Therefore, the grain of ZM alloy is smaller than A alloy as shown in Fig.1.
Fig. 2 shows the hardness change of A and ZM alloys according to aging time at 450K. ZM alloy is higher hardness than alloy A. This is due to the grain refinement and precipitate of Al_3Zr in ZM alloy by addition of Zr and Mm. By Hall-Petch equation, hardness and strength increased with decreasing grain size [4].

Table 1. The composition of specimens (wt%)

Specimen No.	Mg	Si	Cu	Cr	Zr	Mm	Others(Fe, Mn, Zn, Ti)	Al
A(AA6061)	0.85	0.59	0.19	0.08	-	-	<0.19	Bal.
ZM (added Zr, Mm alloy)	0.85	0.59	0.19	0.08	0.05	0.05	<0.19	Bal.

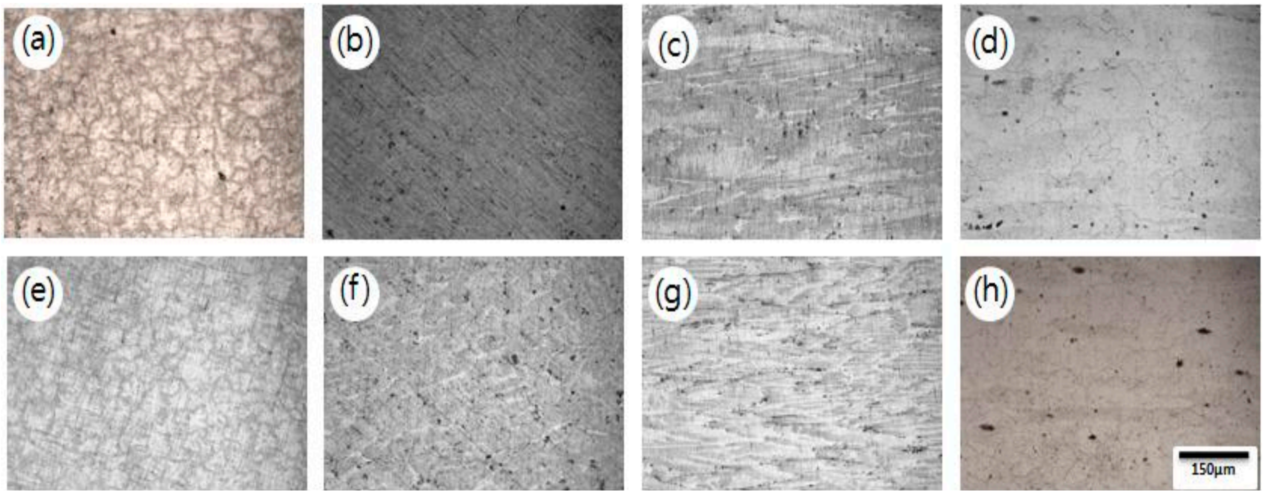

Fig.1 OM images of (a) as-cast, (b) homogenized, (c) rolled, (d) SHT of A alloy(e) as-cast, (f) homogenized, (g) rolled, (h) SHT of ZM alloy.

Fig.3 shows the hardness of ZM alloy according to aging time of two types. The hardness of T6 treatment is higher than two-step aging. Because, cluster I is formed in A 6061 alloy during aging at room-temperature.The cluster I can't make nucleus of β'' -phase [5].Therefore, volume fraction of β'' which is the most strengthening phase of A6061 alloy in two-step aging decreased by preaging treatment at ambient temperature. So pre-aging at ambient temperature before baking (final aging) is not beneficial effect on mechanical property in A 6061 alloy.
Fig. 4 shows tensile strength of the aged ZM alloys at 450K. The UTSand YS of T6 treatment is higher than those of two-step aging. The elongation of two specimens is similar to at 450K for short aging time. But elongation gab between T6 specimen and two-step aged specimen increased with aging time. Because the density of β''-phase in T6 specimen was increased than that of two step aged specimen. However, elongation in over aged specimen increased due to transform from β''-phases to β'-phases.

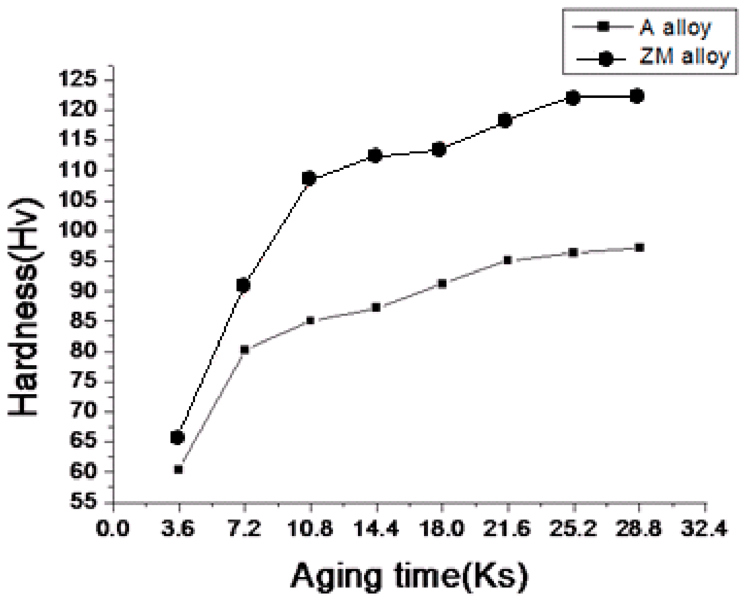

Fig.2 Hardness changes of the aged A and ZM alloys vs aging time at 450K (T6 treatment).

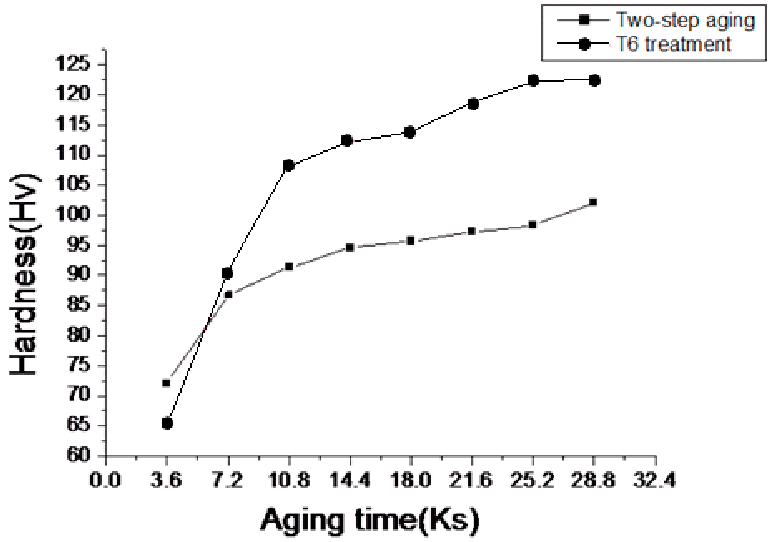

Fig.3 Hardness changes of the T6 and two-step aged ZM alloy vs artificial aging time at 450K.

Fig.5 shows TEM images of the aged A and ZM alloys for 3.6Ks at 450K. All specimens showed very few precipitates. However, precipitate density of two-step aged ZM alloy are less than that of another specimen. This result is attributed to form cluster I at room temperature.

Fig. 6 shows TEM images of the aged A and ZM alloys for 28.8Ks at 450K. The density of precipitate in T6 treated A alloy was observed similar to ZM alloys. Therefore, the precipitate of β''-phase was few affected hardness and strength. The size and density of β''-phase between two step aged ZM and A alloy were similar.

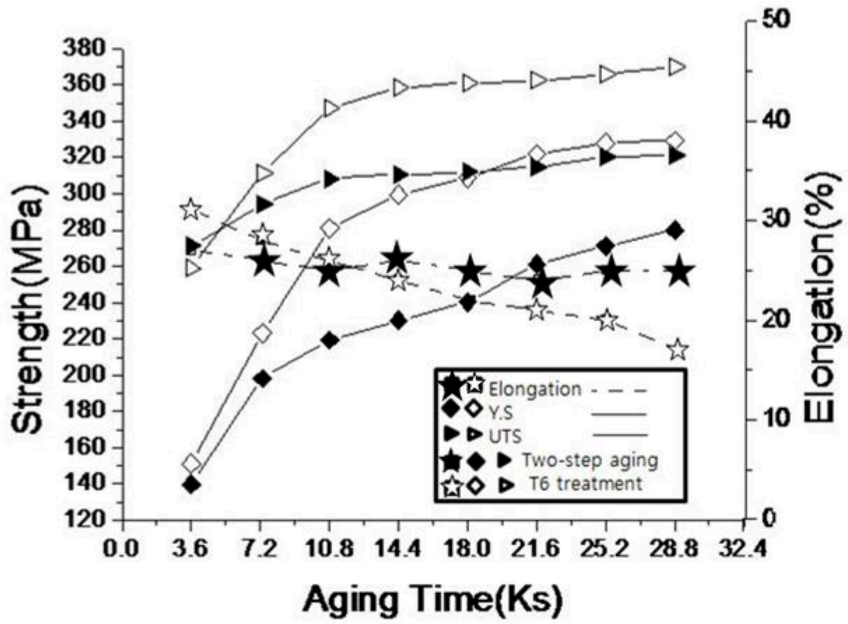

Fig.4 Tensile properties of the aged ZM alloys at 450K.

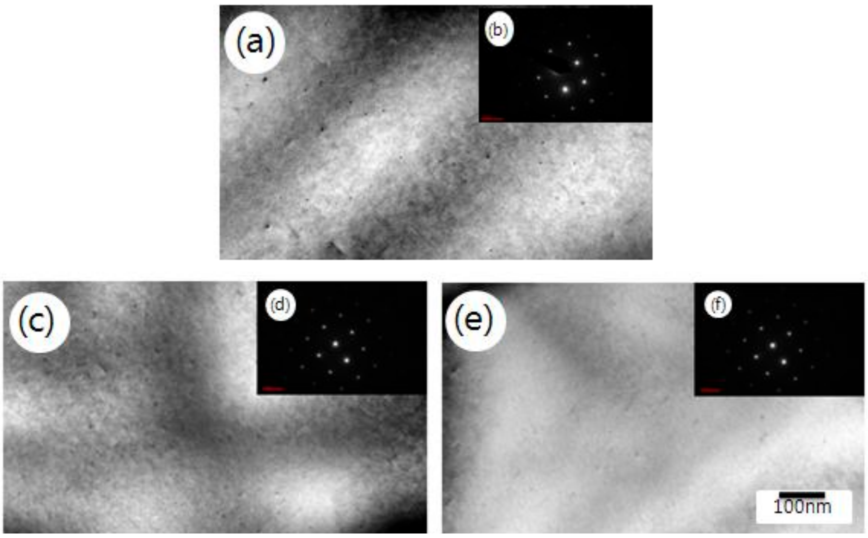

Fig. 5 TEM images of the aged A alloy for 3.6Ks (a) BFI, (b) SADP and aged ZM alloy for 3.6Ks (c) BFI, (d) SADP , two-step aged ZM alloy for 3.6Ks ,(e) BFI, (f) SADP (aged at 450K).

Fig.7 shows DSC curves of A and ZM alloys. The β'' and β' phase of ZM alloy is more early precipitaed than that of A alloy. And cluster II also can preciptate easily. However, the effect of Zr and Mm addition on the mechanical properties is not considerable. Because quantity of β'' and β' phases is similar in peak aged (aged for 28.9Ks) specimens between A and ZM as shown in Fig.6.

4. Conclusions

1. The hardness and strength were improved by the addition of Zr, Mm in AA6061 alloy due to grain refinement.
2. Two-step aged A and ZM specimens show lower mechanical properties than those of T6 treated specimens.
3. The effect of Zr and Mm addition on precipitation behavior is not considerable because the distribution and size of β'' and β' phases are similar.

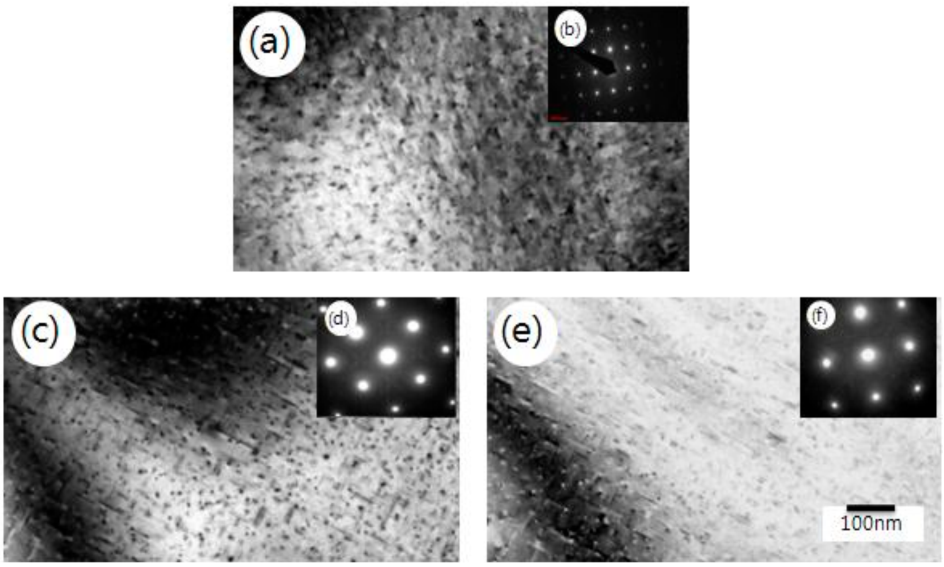

Fig. 6 TEM images of the aged A alloy for 28.8Ks (a) BFI, (b) SADP and aged ZM alloy for 28.8Ks (c) BFI, (d) SADP, two-step aged ZM alloy for 28.8Ks (e) BFI (f) SADP. (aged at 450K)

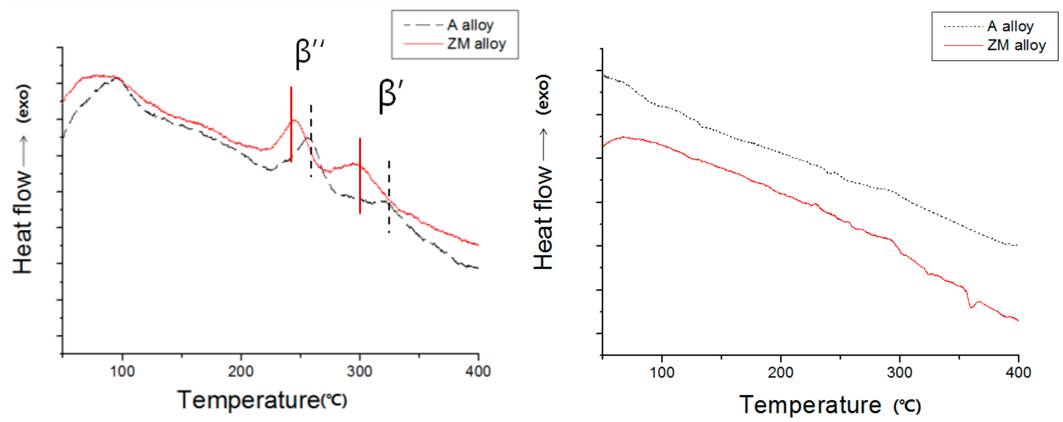

Fig. 7 DSC curves of A and ZM alloys observed in the temperature range from R.T. to 673K (a) as-quenched alloys (b) aged for 28.8Ks at 450K.

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References

[1] V. G. Davydov, T. D. Rostova, V. V. Zakharov, Yu. A. Filatov, and V. I. Yelagin, Mater. Sci. Eng. A, 280, (2000) 30.
[2] Yuyong Chen, Qingchun Li, Zhuling Jiang, J. the Less Common Met. , 110, Issues 1-2, (1985) 175-178.
[3] Jiang Li Ning , Da Ming Jiang, Mater. Sci. Eng. A, 452–453, (2007) 552–557.
[4] William A. Counts , Michael V. Braginsky, Corbett C. Battaile, Elizabeth A. Holm, Inter. J. Plasticity, 24, (2008) 1243–1263.
[5] A. Serizawa, S. Hirosawa, and T. Sato, Metall. Mater. Trans. A, 39A, (2008) 243-251.