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Mechanical and Electrical Properties of Aluminium Alloy by Cryorolling Process

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Abstract

The mechanical and electrical properties of aluminium alloy 6061 are reported in this present work. Aluminium alloys were homogenized at 550 ◦C, for 5 hours and cooled in the furnace. The different thickness reductions of 60-90% on homogenized aluminium alloy plates were achieved by cryo-rolling. Later, the as rolled samples were aged by solution treatment at the temperatures of 520 ◦C for 1 hour, water quenched; subsequently aged at 160 ◦C for 8-24 hours and partial aged (not solution treatment) at 160 ◦C for 8-24 hours. Mechanical and electrical properties of samples were investigated. The experimental result showed that the microhardness of cryo-rolled samples were increase with increasing the percentage of the thickness reduction. Moreover, the microhardness of cryo-rolled, aged by solution treatment samples were higher than those of the cryo-rolled and cryo-rolled, partial aged samples. The cryo-rolled alloys subjected to full aged at 160 ◦C for 24 hours exhibited the hardness of 125 HV and electrical conductivity values was 45.76 %IACS and the cryo-rolled alloys subjected to partial aged at 160 ◦C for 20 hours exhibited the hardness of 67 HV and electrical conductivity values was 49.67 %IACS

Keywords: *Aluminium alloys; cryorolling; aging*

1. Introduction

Aluminium alloy 6061 is generally used as medium-strength structural alloys which advantages of good weldability, corrosion resistance and immunity to stress-corrosion cracking [1-2]. The mechanical properties of aluminium alloy 6061 can be improved more by strain hardening. Rolling process is one of strain hardening it can be enhanced refining the grain structure to small grained material.

Ultrafine-grained metals (UFG) and alloys with the grain size less than 1μm display better mechanical

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properties. The ultrafine-grained materials are usually produced by severe plastic deformation (SPD) techniques such as equal channel angular pressing (ECAP), multiple compression, and severe torsional straining [3-11]. Another way, cold rolling process cannot be used to produce UFG alloys due to its high stacking fault energy and the reduced driving force available for recrystallization.

Cryo-rolling has been recognized as a possible way to produce ultrafine grained materials, it requires less plastic deformation when compared to the severe plastic deformation processes at important temperature. That's why, an attempt has been made in the present work to study the effect of cryo-rolling on mechanical and electrical properties of 6061 aluminium alloy.

The objective of the present work is compare effect of aging and partial aging time on mechanical and electrical properties of 6061 of the cryo-rolled alloys

2. Experimental

The 6061 alloy plates (thickness 13.0 mm), with the compositions of 0.67% Si, 1.11% Mg, 0.31% Cu, 0.06% Mn, 0.49% Fe, 0.01% Zn, 0.30% Cr, 0.02% Ti (wt %) for the present work. These plates were homogenization and rolled at liquid nitrogen temperature upto 80% thickness reduction. The samples were dipped in liquid nitrogen for 10 min prior to each roll pass and for 2 min during reducing for 10% the rolling process. In order to study the effect of aging and partial aging time on mechanical and electrical properties of 6061 of the cryo-rolled sample at a thickness reduction of 80% were solution treatment at the temperatures of 520 ∘C for 1 hour, water quenched; subsequently aged at 160 ◦C for 8-28 hours and partial aged (not solution treatment) at 160 ◦C for 8-24 hours.

The vickers micro hardness (200 g load) was measured on the samples. The electrical conductivity was measured on the samples by Foerter (sigma test 2.069) condition of measure is temperature 25 ∘C and frequency 240 kHz.

3. Results and discussion

3.1. Hardness

The hardness values of the homogenized alloys rolled at cryogenic temperature as a function of strain are shown in Fig. 1. The strain corresponds to different percentage of thickness reduction in the samples. The hardness of the cryo-rolled samples has increased from 74 to 88 HV and the effects of aging time on the hardness of Al-Mg-Si alloy compare hardness values of the homogenized alloys rolled at cryogenic temperature at a thickness reduction of 80% were solution treatment at the temperatures of 520 ∘C for 1 hour, water quenched; subsequently aged at 160 ◦C for 8-28 hours and partial aged (not solution treatment) at 160 ◦C for 8-24 hours are shown in Fig. 2.

An enhancement of hardness in the cryo-rolled Al–Mg-Si alloys could be directly attributed to the higher dislocation density and the formation of sub microcrystalline structures, which occurs during severe plastic deformation. It can be explained based on the mechanism that dynamic recovery was effectively suppressed during cryo-rolling leading to a higher dislocation density [6-7]. The ultrafine-grained microstructures formed during cryo-rolling of Al–Mg-Si alloy obeys the Hall-Petch effect [1, 14 -15] to substantiate the improved hardness observed in the present work. With the formation of ultrafine grains in the cryo-rolled alloys, hardness would increase due to the restricted mobility of dislocation imposed by higher dislocation density.

The effects of aging time on the hardness of Al-Mg-Si alloy. The hardness increased from time to time, at the same temperature. The hardness of the GP Zone is greater than the super saturated solid solution. And the phase θ” and θ’ can affect the mechanical properties such as hardness, etc. On the-other hand, the hardness decreases during the phase θ (over-aged) was aged for long times. It can be concluded that the hardness depends on the microstructure of the precipitate.

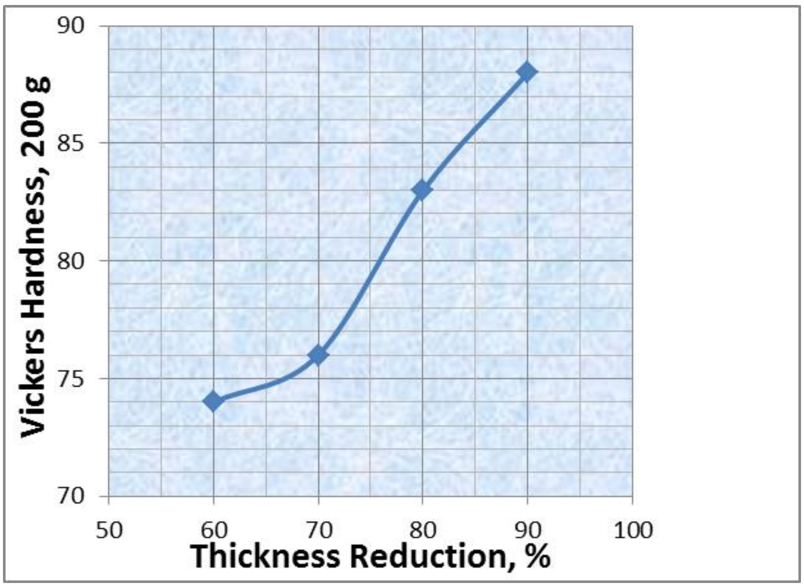


Fig. 1.The hardness values of the homogenized alloys rolled at cryogenic temperature

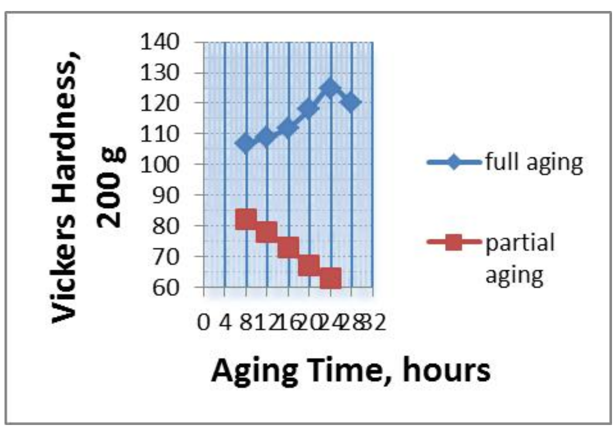


Fig. 2. The compare hardness values of full aged and partial aged

3.2. Electrical conductivity

The electrical conductivity value of the homogenized alloys rolled at cryogenic temperature is shown in table 1. It is shown that the value has not different from 49 %IACS for the cryo-rolled samples difference % thickness reduction. it showed a relatively same electrical conductivity value. An enhancement of electrical conductivity of the Al–Mg-Si alloy not upon cryo-rolling treatment. [7,12-14].

The effect of aging times on the electrical conductivity compare during full aged and partial aged investigate the effect of precipitate on the aging behavior. The variation of electrical conductivity value with aging times show in table 2. In that value of full aging approximate during 43-47 %IACS with increasing the aging times and value of partial aging approximate during 48-50 %IACS with increasing the aging times.

The effects of aging time on the electrical conductivity of Al-Mg-Si alloy. The electrical conductivity values not different from time to time, at the same temperature. The electrical conductivity of the GP Zone is as same as the super saturated solid solution. And the phase θ” and θ’ cannot affect the electrical properties

Table 1. The electrical conductivity value of the homogenized alloys rolled at cryogenic temperature

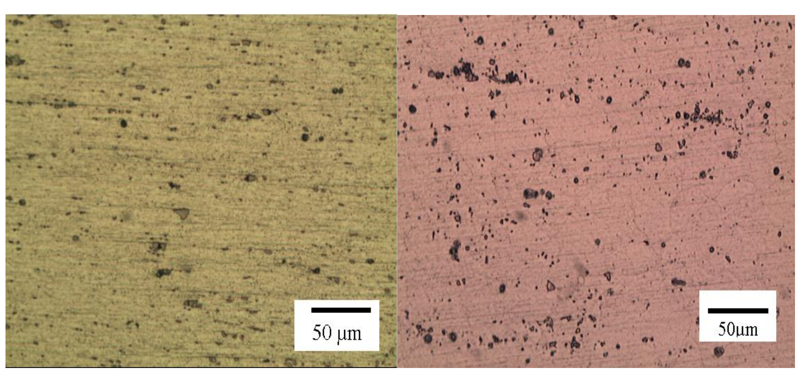
% thickness reduction	% IACS
60	49.19
70	49.81
80	49.14
90	49.62
Homogenization sample	49.42

Table 2. The variation of electrical conductivity value with aging times

Time (Hours)	% IACS	
	Full aging	Partial aging
8	44.10	48.94
12	46.67	49.06
16	44.46	49.01
20	46.41	49.67
24	45.76	49.54
28	43.74	-

3.3. Microstructure

The microstructure of the Al–Mg-Si alloys cryo-rolled at 80 % of thickness reduction full aging at 160 ◦C 24 hours and full aging at 160 ◦C 28 hours (over aging) shown in Fig. 3. The precipitate size increasing 3 µm up to 8 µm after increasing aging time at 24 hours to 28 hours respectively. A continuous increase in precipitate size in the cryo-rolled and full aging samples, in the present work, may be due to the chemical contain and work hardening, which occur during aging of the samples as reported in the literature [3-11].



3a 3b

Fig.3. The optical microstructure of Al–Mg-Si alloys cryo-rolled at 80 % of thickness reduction samples.

(3a) full aging at 160 ◦C 24 hours, (3b) full aging at 160 ◦C 28 hours (over aging)

4. Conclusions

From this investigation on the effect of cryo-rolling and aging time on mechanical and electrical properties of 6061 Al alloy, the following conclusions can be made

1. The cryo-rolling was more effective on enhancing hardness of the 6061 Al alloy that increase than those of the alloy rolled at room temperature [15] with the same reduction ratio, mainly due to the suppression of dynamic recovery during deformation at cryogenic temperature.
2. The electrical properties of the alloy cryo-rolled and aged at 160 ◦C for 8-28 hours and partial aged at 160 ◦C for 8-24 hours were attribute to the good conductivity as same as homogenization sample.

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