Technology and Innovation for Sustainable Development Conference (TISD2008)
Faculty of Engineering, Khon Kaen University, Thailand
28-29 January 2008

Thermoelectric power studies on solution heat treated aluminum alloy grade 6063

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Abstract
In this work the non-destructive testing for aluminum 6063 during coherent precipitation period are performed by using Seebeck coefficient. The results show that Seebeck effect has a very strong link with the vicker hardness, which is the representative of strength.
Keywords: Seebeck, Thermoelectric, Aluminium 6063, Solution heat treatment

1. Introduction
Aluminium alloy 6063 is commonly used in the manufacture of furniture, windows, doors, etc. It is commonly used in architectural extrusion form. The main strengthening mechanism of this aluminium relies on the precipitation of Mg_2Si at the submicroscopic level. For T6 temper, the metal is solutionized at 520°C for 2 hours and quenched. Subsequently, it is aged at 180°C for 8 hours, according to ASM guidance. There are many phenomena occurring during aging period. Its strength is affected by the presence of Mg_2Si in various forms. After solutioning, magnesium and silicon becomes solute in aluminium, so-called solid solution. When the age hardening begins, magnesium and silicon start to come out of solid solution and precipitate as Mg_2Si. The precipitate at the early stage are perfectly coherent with aluminium matrix (fig.1). If the metal is still under high temperature, Mg_2Si precipitate will become partially coherent and , eventually, incoherent with the matrix. Fully coherency is very favorable to achieve high strength for the metal under solution heat treatment.

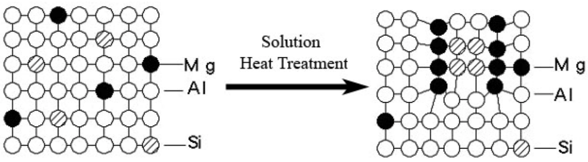

Fig.1. This illustration shows the solid solution becomes fully coherent precipitate of Mg_2Si via solution heat treatment process.

One of the techniques used to investigate the full coherency period is tensile testing, which is a destructive testing method. Hardness is also a very versatile option due to no need for excessively tiresome specimen preparation. However, dimples that occurs from the hardness testing make this technique also destructive testing.

Thermoelectric power (TEP) technique was brought in to investigate the coherent precipitation period. This technique does not alter the samples and has been reported in several articles for successful investigation of several phenomena that happened during experiments. The principle of TEP is based on the Seebeck effect. If one end of a sample is at the cold side (T) and the other end is at the hot side (T+ΔT), a voltage (V) is generated across the hot and cold sides. Seebeck coefficient (S) or thermoelectric power (TEP) is given by :

$$S = \frac{V}{\Delta T} \tag{1}$$

TEP can be affected by several ways. The alloying elements in solid solution and coherent precipitation create new scattering centers for electrons and phonons and, eventually, lower TEP [1]. For noncoherent precipitation, there is no evidence of TEP reduction. Dislocation introduced by cold-rolling can lower TEP. Recovery and recrystallization, which obliterate dislocation, will increase TEP [2],[3],[4].

In this article, aluminium 6063 is under investigation during solution heat treatment period by using TEP measurement and hardness testing.

2. Experimental procedure
The study was carried out on an extruded aluminium 6063. The chemical composition of the studied steel in wt% is as follows: 98.6% Al, 0.5% Si, 0.5% Mg, 0.3% Fe, 0.1% for the remaining. Samples ($1.9 \times 1.9 \times 5$ cm^3) were solutionized at 520°C for 2 hours and quenched. Subsequently, they were aged at 180°C for 12 hours and quenched. Samples were collected from the furnace in every hour. After aging,

samples had surfaces peeled off for a few millimeters to remove the area that the oxidation of magnesium was supposed to occur during experiments. TEP measurements were performed by using the instrument assembled in the laboratory. The diagram of the instrument are shown as in fig.2.

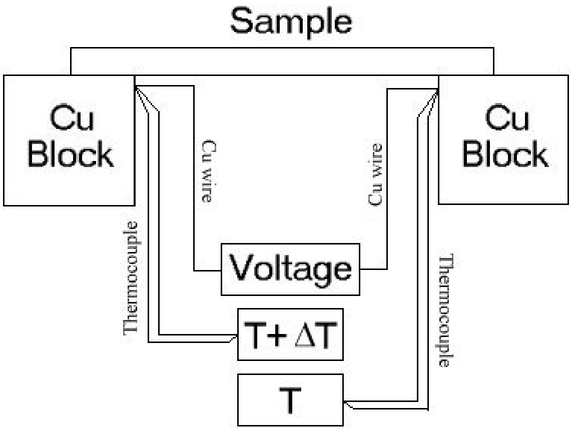

Fig. 2. The diagram of instrument for Seebeck coefficient measurement

A Keithley 2182A nanovoltmeter was deployed for voltage measurement. Temperature DAQ NI9211 was deployed for temperature measurement. Copper were used as a reference material. Therefore, the TEP values reported in this work are relative to pure copper and not the absolute TEP values of the Al6063 samples. The temperature difference between hot and cold junctions is 2°C. TEP(μV/K) was determined by a ratio of measured voltage to temperature difference. Vicker hardness was also performed by using Shimadizal HMV-2000 with load of 100gf and dwell time of 40 second.

3. Results and discussion

Vicker hardness result (fig.3) shows lower hardness at the beginning of experiment. The highest hardness is achieved at aging sample for 8 hours. This period is recommended by ASM for Al6063 solution heat treatment procedure. This can imply that 8-hours-aging period should give superior strength for Al6063 due to Mg_2Si coherent precipitation. It can be noticeable that sample without aging possesses higher hardness than 1-hour-aging and 2-hour-aging. This phenomenon can be explained by the effect of solid solution hardening. After solution treatment, magnesium and silicon atoms are supposed to be soluted in aluminium matrix. Therefore, no-aging sample will be greatly affected by this supersaturated solid solution. However, when aging continues, magnesium and silicon atoms start to come out of aluminium matrix and precipitate as Mg_2Si form. The effect of solid solution strengthening will become diminished.

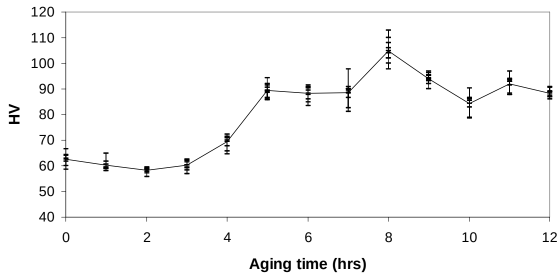

Fig.3. The illustration of vicker hardness test of aged Al6063 at 180°C

Seebeck coefficient measurement of aged samples (Fig.4) shows upward trend from 0 hour to 3 hours. This can be explained by the effect of solid solution to seebeck coefficient. Magnesium and silicon soluting into aluminium matrix causes disturbance to electrons and phonons movement. Therefore, when the aging starts, magnesium and aluminium will come out of aluminium matrix and the disturbance decreases. As a result, TEP will increase. From 4-hours-aging onward, the trend is downward and become minimum at 8-hours- aging. This is caused by Mg_2Si coherent precipitation, which disturbs electrons and phonons movement once again. TEP will decrease after 4-hours-aging. After 8-hours-aging, the trend goes upward again. This can be implied that the effect of coherent precipitation starts to be diminished.

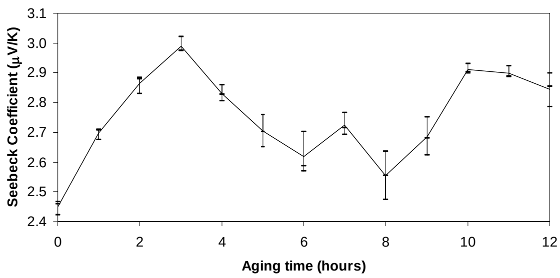

Fig. 4. The illustration of Seebeck coefficient measurement of aged Al6063 at 180°C

4. Conclusion

A technique of non-destructive testing for Al6063 is suggested. Seebeck coefficient result can be seen as conformity with vicker hardness result especially during 8-hours-aging.

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