Effect of Natural Ageing on the Artificial Ageing Response of an Al-Mg-Si-Cu Alloy

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1 Introduction

Al-Mg-Si-Cu heat treatable alloys show a significant hardening response during artificial ageing, but this hardening response is also strongly influenced by the degree of natural ageing after solution treatment. Since storage at room temperature can not be avoided in factories, an understanding of how natural ageing affects the artificial ageing response is of great interest from both fundamental scientific and industrial perspectives. An Al-Mg-Si-Cu alloy based on the AA6022 specification with an additional 0.3 wt% Cu was chosen in this study.

2 Experimental

The alloy was cast, homogenised, and hot and cold rolled to 1.0 mm thick sheets. Small pieces were solution treated at 550°C for 30 min and quenched into water at room temperature.

Samples were analysed before and after artificial ageing in an oil bath at 170°C, following natural ageing intervals of:
2 min, 6 min, 18 min, 60 min, 3 hrs, 12 hrs, 24 hrs, 3 days, 7 days and 21days

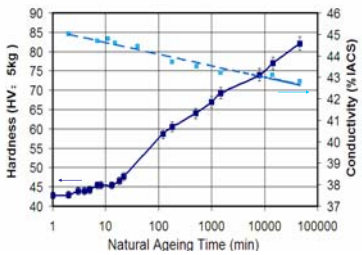
Table1 : Composition of the studied alloy (wt%)

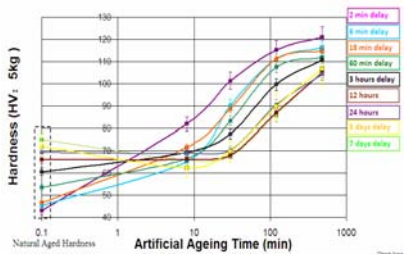
Si	Mg	Cu	Fe	Mn	Cr	Zn	Ti
1.07	0.48	0.29	0.12	0.06	0.08	0.19	0.01

Analysis Methods:

- Hardness, tensile and electrical conductivity testing
- Transmission electron microscopy (TEM)
- 3-dimensional atom probe (3DAP) analysis

3 Results





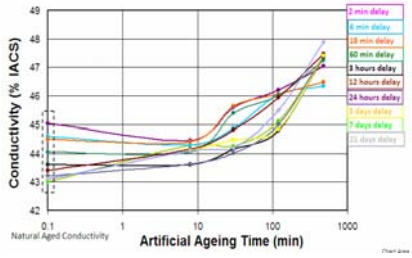


Fig 1: Effect of natural ageing on the hardness and electrical conductivity. *Fig 2*: Effect of natural ageing time on the hardness during ageing at 170ºC. *Fig 3*: Effect of natural ageing time on the electrical conductivity during ageing at 170ºC.

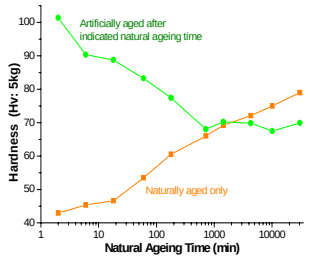


Fig 4: Effect of natural ageing on the hardness with and without artificial ageing for 30 minutes at 170ºC.

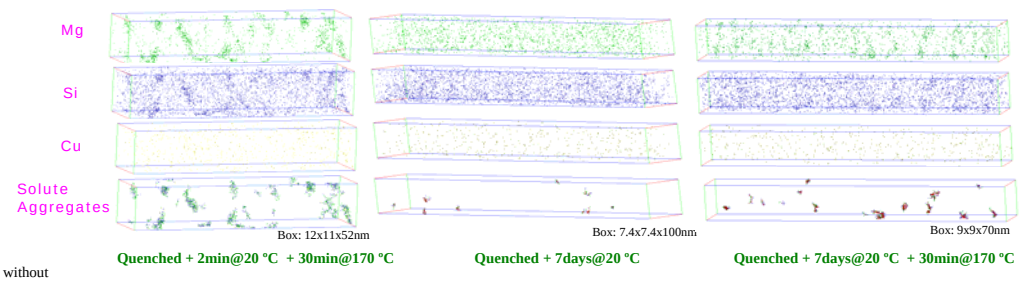


Fig 5: 3DAP elemental maps in different conditions , showing Mg, Si and Cu atom distributions, and corresponding maps of solute aggregates resolved using particle analysis parameters of D = 0.5 nm, L = 0.5 nm, S = 0.5 nm and N = 10 atoms (including Al atoms in the aggregates).

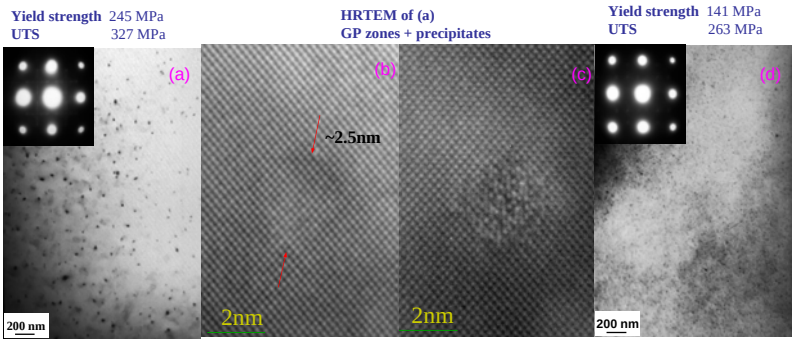


Fig 6: TEM observations in different conditions: (a) (b) (c) Quenched + 2min@20 ºC + 30min@170 ºC, showing GP zones and β'' precipitates; (d) Quenched + 7days@20 ºC + 30min@170 ºC, showing mainly GP zones.

3DAP results show significant changes in the cluster density, average size and distribution after different natural ageing and artificial ageing treatments.

Table 2: Selected cluster analysis in different ageing conditions

Ageing conditions	Quenched + 2min@20 ºC + 30min@170 ºC	Quenched + 7days@20 ºC	Quenched + 7days@20 ºC + 30min@170 ºC
Cluster density (clusters/m^3)	4.7×10^{24}	1.5×10^{24}	3.0×10^{24}
Cluster size: average number of solute atoms (Standard Deviation)	153 (153)	24 (7)	50 (40)
Mg:Si ratio in clusters	1.07	0.85	0.87

4 Conclusion

- The initial hardening behaviour of the alloy is influenced significantly by the degree of clustering of Mg, Si and Cu solute atoms.
- The artificial ageing response is greatest in samples aged immediately after quenching, and decreases very rapidly within several hours of natural ageing.
- TEM shows both GP zones and β" in the quenched and immediately aged condition. The presence of β" increases the strength significantly, but natural ageing before ageing inhibits β" formation.
- 3DAP results show large solute aggregates in the quenched and immediately aged condition with an average size three times larger than when aged after 7 days of natural ageing. Ageing for 30 min at 170ºC after natural ageing for 7 days caused both the cluster density and the average cluster size to double.