



Effects of multiple-step thermal ageing treatment on the hardness characteristics of A356.0-type Al–Si–Mg alloy

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ABSTRACT

The work outlined the hardness characteristics of thermally aged high chromium sodium modified A356.0-type Al–Si–Mg alloy using the multiple-step thermal ageing treatment (MSTAT) approach. This novel approach consists of double thermal ageing (DTAT) and single thermal ageing treatment (STAT). The investigation also includes the development of a new temperature-compensated-time parameter, P , for the studied alloy at different ageing temperatures and time considered. The results obtained in the DTAT developed for the A356.0-type Al–Si–Mg alloy showed an improvement in the precipitation hardening (PH) ability and hardness characteristics as compared to the convectional STAT temper. The observations were evidenced from the X-ray diffractometry (XRD) pattern indicating the possible strengthening phases. Equally, the hardness behavior was correlated with the microstructures using optical microscope (OPM) and scanning electron microscope equipped with energy dispersive spectroscopy (SEM-EDS).

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1. Introduction

Aluminium alloys consisting of the Al–Si systems are widely used in the automobile field, since they show excellent fluidity and castability, high-strength to density ratio, good corrosion resistance, better mechanical properties or combination of these properties [1–10]. Magnesium is the main solid solution strengthener to Al–Si alloy (to form Al–Si–Mg alloys) and its addition leads to increase in response to precipitation hardening which in turn results in higher yield strength in these alloys [11–14]. A356 alloys is a group of Al–Si–Mg and their increase in strength is by precipitation of Mg_2Si in aluminium matrix as reported by several authors [1,4,15–22]. This precipitation sequence and reactions have long been reported and accepted [8,15–17,23–30] as;



However, Zander and Sandstrom [15] define the sequence as;

SSS $\rightarrow$ clusters of Mg and Si atoms $\rightarrow$ spherical $GP_{zones} \rightarrow$ needle shaped coherent $\beta''(MgSi) \rightarrow$ rodlike semi-coherent $\beta'(Mg_{1.7}Si) \rightarrow$ semi-coherent β -plates (also called β') $\rightarrow$ non-coherent β -plates (Mg_2Si). Different techniques, particularly TEM and XRD techniques have been used to elucidate the precipitation sequence of the alloy system Al–Si–Mg from SSS. The use of TEM for this was reported by Erhad [29] with the following sequence;



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This alloy; however have the disadvantage of low elastic module and precipitation hardening ability in the T6 temper condition [1]. Method(s) for improving this treatment becomes necessary. Although in one of our paper, we have developed a step-quenching-ageing treatment for the A356-type Al–Si–Mg alloy to further enhance its hardness [31], and equally exist, several reports on DTAT of aluminium alloys as a means of improving both the strength/hardness and SCC resistance [32–50]. Controversy as to the role DTAT (T7) temper plays in relation to enhancement of the hardness and stress corrosion cracking (SCC) resistance exist. Some authors [11,36,39,50] termed the T7 temper condition as an over-aged temper, while other [29,32,33,38,40,51,52] reported the treatment to be a double-step or triple step [43] ageing process that brings about improved hardness and SCC resistance. This shows a diverse opinion on the dominant roles of T7 temper in aluminium alloys. In this work, a multiple-step thermal ageing treatment consisting of STAT-T6 and DTAT-T7 have been developed for A356-type Al–Si–Mg alloy along with its temperature-compensated-time parameter, P .

2. Experimental methods

The A356 alloy used was prepared according to the method described elsewhere [53]. The chemical composition can be found in Table 1. The eutectics silicon particles were modified with elemental sodium (0.01%). The alloy was subjected to STAT-T6 and DTAT-T7 heat treatment consisting of solution heat treatment (SHT) at 540 °C for 1 h, water quenched followed by an artificial ageing; DTAT and STAT with varying ageing temperatures of 150 °C,