

Article Info

Received: 02 Apr 2016 | Revised Submission: 20 May 2016 | Accepted: 28 May 2016 | Available Online: 15 Oct 2016

Precipitation Hardening Parameters Effects on Mechanical Properties of Extruded AA2014 Based Metal Matrix Composite

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ABSTRACT

Heat treatment of aluminium alloys are affected by means of precipitation hardening comprising the following steps: solutionizing, quenching and aging at room temperature (natural aging) or at elevated temperature (artificial aging). Nevertheless, during precipitation hardening of aluminium matrix-based discontinuously reinforced composites, in the solutionizing stage, the matrix alloy is modified quite significantly due to the occurrence of dislocations. The main problem faced in the heat treatment process is the selection of optimum combination of precipitation of hardening parameters for achieving the required mechanical and tribological properties of composites.

Keywords: *Solutionizing Temperature; Solutionizing Time; Aging Temperature; Aging Time.*

1.0 Introduction

Metal-matrix composites are used in advanced structural, electronic, automotive, aerospace, wear applications and thermal management [1]. The advantage of metal matrix composites is their adapted physical, mechanical and thermal properties with low density, high abrasion, high thermal conductivity, high specific strength, high specific modulus, and wear resistance [2, 3].

The ever-increasing demand for low cost reinforcement encouraged the interest towards production and utilization of using by-products from industry as reinforcement since they are readily available or are naturally renewable at affordable cost. Al alloys are widely used in aerospace, automobile and electronic industries due to their excellent wear and corrosion resistance, low density, low coefficient of thermal expansion, good strength and castability. The common microstructure of hypereutectic Al- alloys is composed of primary silicon particles. The high strength and wear resistance of these alloys are attributed to the presence of hard silicon particles [6]. The forming based semi-solid phase has attracted great attention as a new technology since it complemented the

shortcomings of the current forming processes. The morphology of the primary phase of semi-solid metals plays a very important role in the quality control of semi-solid process. Electromagnetic stirring is a forming process which fills the mold cavity through injecting cylinder with semi-solid slurry after uniformly transformed dendritic microstructure formed during solidification process to spherical primary-Al phase particles and distributing it into eutectic phase, by strongly stirring the melt at the initial stage of solidification. The electromagnetic stirring needs to be a good substitute system of mechanical stirring to avoid alloy contamination and damage of stirrer. The rheology forming is controlled by grain and solid fraction using the electro-magnetic stirring system. This study sets up the experimental data applicable to control the particle grain size of the resulting materials to be produced by electromagnetic stirring to investigate the relation between the properties of A356 alloy such as primary-Al phase particle sizes, their distribution, and spherical structure and electromagnetic stirring current and time [7]. The preparation of raw material slugs within the mushy zone, which is the key technology of semisolid metal processing, is an issue of great

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importance. In semisolid metal processes for Al alloys, it is desired that the structure be non-dendritic and contain minimal or no entrapped eutectic. The traditional EMS (Electromagnetic stirring) process mainly works in the mushy zone of the alloy, i.e., supercooled + EMS. There are two hypotheses to explain the formation mechanism of non-dendrites, that is, mechanical fragmentation and the root remelting of the dendrite arms. The homogenization of the temperature and constituents caused by the forced convection during stirring can prompt the nucleation of the primary α -Al phase and restrain the growth of dendrites. The combination of light weight, environmental resistance and useful mechanical properties such as modulus, strength, toughness and impact resistance has made aluminium alloys well suited for use as matrix materials.

In AA2014/eggshell metal matrix composite, very little study has been done to logically examine the mechanisms of atom redistribution in the precipitation hardening process and the effect of a variety of natural ageing times on the mechanical properties at the end of artificial ageing process.

Among the Al-Cu-Mg casting alloys, AA2014 cast aluminium alloy is a commercially accepted casting alloy. It is generally used in aircraft structures, especially wing and fuselage structures under tension. It is also used in high temperature applications such as in automobile engines and in other rotating and reciprocating parts such as piston, drive shafts, brake- rotors and in other structural parts which require light weight and high strength materials. The 2014 alloy is heat treatable in the cast condition and exhibits the highest strength to weight ratio. The chemical and mechanical properties of AA2014 alloy are given in Table 1 and Table 2 respectively [6].

2.0 Literature review

Review of heat treatment and its Process Parameters for the Metal Matrix Fabrication are given in Table 1.

Table 1: Chemical Composition of AA2014

Si	Fe	Cu	Mn	Mg	Zn	Ti	Ni	Cr	Al
0.5-0.9	0.5	3.9 – 5.0	0.4-1.2	0.2-0.8	0.25	0.2	0.1	0.1	Balance

Table 2: Measured Properties of AA2014 Alloy

Melting point	6400C
Density (g/cm ³)	2.8
Tensile Strength (MPa)	185
Hardness (BHN)	60
Toughness (Joule)	12
Ductility (percentage elongation)	13
Fatigue Strength (MPa) for 1 x 10 ⁷ cycles	90

Table 1: Review of Heat Treatment and its Process Parameters

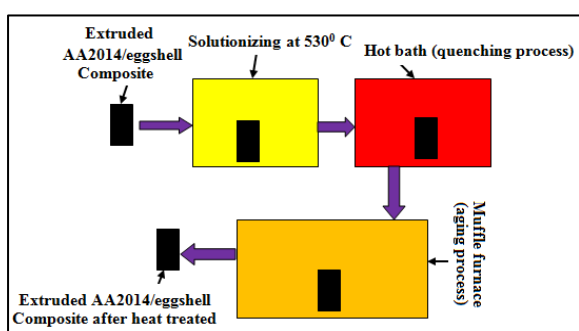
	(2012)	mm×60 mm×20 mm are (480 °C, 30 min) and (480 °C, 90 min), respectively.
18	Choong do Lee (2013)	Heat treatment with solutionizing and aging treatment times of 6 h at 540 °C and 16 h at 160 °C, respectively, was proposed as the optimal conditions.
20	E.M. Elgallad et al. (2014)	1. Solution treatment at 530 °C for 5 h dissolved the first three phases into the solid solution and consequently improved the mechanical properties of the alloy. 2. By utilizing the appropriate aging temperature and time, different combinations of strength and ductility could be obtained
19	Shashi shekhar et al. (2014)	Aging behaviour was studied as a function of time and temperature and corresponding microstructure as well as fractographs of tensile tested specimens was recorded.

3.0 Precipitation Hardening Process

Fabrication of metal matrix composite used in this study was fabricated by electromagnetic stir casting technique, details given elsewhere [7].

Precipitation hardening is a heat treatment technique used to increase the yield strength as well as other properties of composites. The process of precipitation hardening is actually a three step sequence. The orders of involved heat treatment process were solutionizing, hot bath quenching, aging and air-cooling as shown in Figure 1. The first step is known as solution treatment which is used to remove the room-temperature structure and redissolves any existing precipitate. Solutionizing process was done at a temperature of 5300 C for certain range of time period and then quenched in a hot bath about 700C to keep away from warping of composite specimens. If the composite were slow cooled, the second – phase precipitate would nucleate and material would revert back to a structure similar to equilibrium. To prevent this from happening, the solutionized composites are quenched from their solution treatment temperature. Without delay (not more than 15 seconds), artificially aging was carried out in a muffle furnace for certain range of temperature and time.

Fig. 1: Schematic Diagram of Precipitation Hardening Process



4.0 Conclusions

The following conclusions can be drawn from the analysis:-

- 1 Composites can be heat treated by solutionizing and aging to modify the microstructure and thereby the mechanical properties.

- 2 By utilizing the appropriate aging temperature and time, different combinations of strength and ductility could be obtained.

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