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Studies on the effect of delayed aging on the mechanical behaviour of AA 6061 SiC_p composite

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Abstract

Silicon carbide reinforced aluminium is the most notable composite in the family of discontinuously reinforced composites (DRCs). The matrix of this class of composites can be heat treated by solutionizing and aging to modify the microstructure and thereby the mechanical properties. In the present investigation the effect of delayed aging on AA 6061 SiC_p composite is reported. The delay aged specimens were subjected to hardness and fatigue testing. It is observed that the mechanical properties are degraded for a delay of up to 12 h before aging. However for delay of 16 h and beyond, the properties are similar to that of composites exposed to nil (0 h) delay. The experimental results are discussed with respect to the scanning electron micrographs (SEM) of the fatigue failed samples.

Keywords: Metal matrix composite; Solutionizing; Artificial aging; Delayed aging; Hardness; Fatigue

1. Introduction

In recent years there has been considerable interest in the use of metal matrix composites (MMCs) due to their superior properties. Though many desirable mechanical properties are generally obtained with fiber reinforcement, these composites exhibit anisotropic behaviour and are not easily producible by conventional techniques. Nevertheless, MMCs reinforced with particles (DRCs) tend to offer modest enhancement of properties, but are more isotropic and can be processed by conventional routes [1]. Among the DRCs the most common particulate composite system is aluminium reinforced with silicon carbide [2,3]. Generally aluminium is light in weight, which is the foremost requirement in most of the applications and it is less expensive than other light metals, such as titanium and magnesium. Moreover, when a ceramic reinforcement is added to the aluminium matrix the properties are further enhanced thereby making it a prospective material for many lightweight applications [4].

Out of the various conventional processing routes, stir casting technique appears to be a promising route for the mass production of aluminium DRCs with reproducible properties [5]. The as cast composite has very limited usage due to the inherent deficiencies and hence it is subjected to secondary processing [6,7]. The final stage of the production process of composite materials with aluminium alloy matrices usually includes heat treatment process to modify the matrix microstructure by differential precipitation [8,9]. Precipitation process is achieved from the supersaturated solid solution obtained by heating the alloy to a higher temperature followed by quenching and natural aging (at room temperature) or artificial aging (at elevated temperature) [10]. In order to obtain a fine and homogenous distribution of the precipitates, the second phase of the alloy has to be completely dissolved in the solid solution during solutionizing so as to attain super saturation on quenching [11].

Studies by Appendino et al. [12] indicate that the following is the aging sequence for 6061 aluminium alloy and its matrix based DRCs: supersaturated solid solution → clusters of solute atoms and vacancies (primitive GP zones) → needle shaped GP zones → rod shaped, metastable, hexagonal, semi

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Table 1
Nominal composition (wt.%) of matrix alloy AA 6061 employed

Si	0.4–0.8
Fe	<0.7
Cu	0.15–0.41
Mn	0.15
Mg	0.82–1.2
Zn	0.25
Al	Balance

coherent, β phase → stable, incoherent, cubic, Mg_2Si precipitate (β phase). Since 6061 aluminium alloy is susceptible to natural aging, artificial aging of 6061 aluminium alloys and AA 6061 matrix based DRCs is usually carried out immediately after quenching to ensure fine and uniform distribution of precipitates. However, it is commonly observed that in industries unscheduled delays and fluctuations occur during heat treatment processing, i.e. between solutionizing and artificial aging. This leads to a variation in the properties of the composites processed in different batches, which is considered to be critical from the quality control perspective. Hence, in the present work an attempt has been made to record the effect of delayed aging on the properties of stir cast AA 6061 SiC_p composite.

2. Experimental details

Stir cast AA 6061 SiC_p composite was used in the present study. The details of stir casting process are reported in detail elsewhere [2,5,13]. The cast billets were hot extruded in four stages at 693 K from the original diameter of 75–17 mm rods. The composition of the matrix alloy is furnished in Table 1. The optical microstructures of the extruded composite (longitudinal and transverse direction) are shown in Fig. 1.

No evidence of macropores, blowholes and gravity settling of SiC particles in Al matrix is seen. The distribution of SiC particles is fairly uniform though few clustered particles are evidenced at irregular intervals in the transverse direction. The reinforcements are randomly distributed, which can be attributed to the good wettability of Al for SiC particulates. Absence of particle depleted region, agglomeration and porosity indicate good solidification conditions and the suitability of the casting process adopted. The specification and

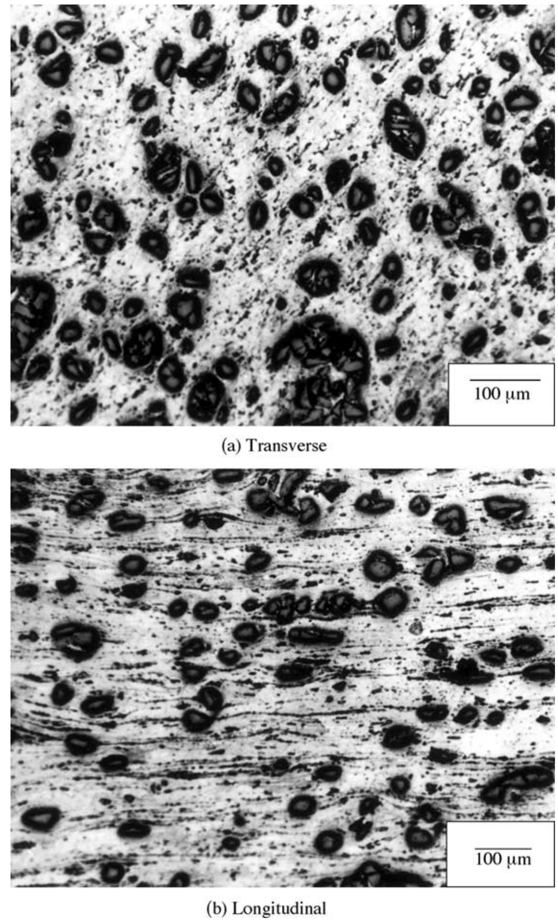

Fig. 1. Optical micro-graph of the extruded composite: (a) transverse and (b) longitudinal.

the mechanical properties of the extruded composite before heat treatment are presented in Table 2.

Usually the effects of aging treatment on DRCs are estimated by hardness tests [14–16]. In the present study in

Table 2
Specification and properties of AA 6061 SiC_p composite

Nominal percentage of reinforcement (wt.%)	20
Average reinforcement particle size (μm)	23
Ultimate tensile strength (MPa)	467–470
(%) Elongation	3.5–4.0
Hardness (BHN)	62

Table 3
Heat treatment schedule of AA 6061 SiC_p composite

Code	Solutionizing details	Quenching medium	Delay before aging (h)	Aging details	Cooling details
F00	803 K/3 h	Water	00	443 K/4 h	Air cooling
F02	803 K/3 h	Water	02	443 K/4 h	Air cooling
F04	803 K/3 h	Water	04	443 K/4 h	Air cooling
F06	803 K/3 h	Water	06	443 K/4 h	Air cooling
F08	803 K/3 h	Water	08	443 K/4 h	Air cooling
F12	803 K/3 h	Water	12	443 K/4 h	Air cooling
F16	803 K/3 h	Water	16	443 K/4 h	Air cooling
F24	803 K/3 h	Water	24	443 K/4 h	Air cooling