Investigation of Ageing Parameters on Properties of AL/ALBITE MMCs

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***Abstract*— *The objective of the work was to investigate effect of an accelerated aging on properties of Al6061/albite metal matrix composites(MMCs) such as age hardening, electric resistivity and micro-structural behavior. The samples were aging at 32, 80, 180, and 320°C for 0.01 to 100 hours. The peak of the hardness and the resistivity values of the MMCs increase with increasing reinforcements and ageing temperatures due to ageing precipitation significantly accelerated because of addition of reinforcement. The nucleation process influences dislocation density and it reduces the activation energy for precipitation hence the faster and higher precipitation was observed in MMCs. Changes in the properties of the composites during aging have been demonstrated on the basis of microstructural alterations during ageing.*

***Keywords*— Metal Matrix composites, Microstructure, TEM, Heat treatment.**

I. INTRODUCTION

Recently the aluminum metal matrix composites (MMCs) got more interest in research due to promising in age hardening considerably higher speed than that of parent material[1]. The hardening of MMCs is due to the enhancement of dislocation density around the ceramic particles. The development of dislocation is due to different in thermal expansion properties between matrix and particles. The addition of higher reinforcements help to the diffusion in solute atoms hence it leads to higher rate precipitation process [2-3]. The quenching / cooling temperature from melting temperature to room temperature plays significant role in formation of nucleation vacancy within the matrix materials. [4-5]. The higher nucleation vacancy promotes the creation of Guinier-Preston (GP) zone such as Al-Mg-Si and Mg-Al alloy.[6]

Transmission electron microscopy (TEM) studies have proved the existence of dislocation due to heterogeneous nucleation which leads to increase the strength of the Al MMCs [7]. Many research work showed that precipitation reaction in some Al MMCs in both theoretical and experimentally and they suggested that only matrix dislocation enhances the precipitation growth [8].

The purpose of the present study was to study the effect of artificial aging on the microstructure, hardness and electrical resistance Al/albite of the MMCs as functions of aging temperature, aging time and reinforcement content. Differential scanning calorimetry (DSC), EDS test, and TEM investigation have been undertaken to observe the effect of reinforcement on the decomposition and precipitation kinetics of the matrix alloy.

II. EXPERIMENTAL STUDIES

In this study Al6061 alloy used for matrix materials (chemical composition given in Table 1) and albite of 30-50 µm particles were used as reinforcement. The albite content varies from 0 to 20% by weight were introduce into the Al molten liquid with appropriate stirring process. The all composition of Al /albite MMCs were fabricated by liquid metallurgical technique. The prepared specimens were subjected to various methods of heat treatment such as solution ageing for 24 hour at 520 °C immediately quenched in to ice cold water, stabling at lab temperature for two days then artificial ageing at different temperature for different duration.

Table 1 Chemical Composition of Al6061

Component	Wt. %
Al	94.8-98.6
Mg	0.8-1.2
Si	0.4-0.8
Cr	0.04-.4
Mn	Max 0.15
Cu	0.15-0.4

The aged and non-aged specimens polished as per standard procedure then they are subjected to optical micro-graphical studies after Keller's reagents. After polishing specimens were subjected to micro hardness with the load of 1N. Care was taken to avoid making an indentation directly on a reinforcing particle which otherwise would cause a great scatter in the hardness value.

The electrical resistivity of metals /MMCs is usually very small (~ µΩ-cm). The electrical properties (resistance) were

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measured for all composite specimens using four probe methods. This method was used in the present work, the current and voltage leads were separated so that the contact resistance is not included in the voltage circuit. In the present work, a constant current from a Keithley 228A voltage / current source, The electrical resistance was calculated using ohm's law and knowing the dimensions of the specimen, the electrical resistivity of the materials was determined.

The differential scanning calorimetry studies conducted between room temperature to 600°C it gives heat flow as a function of temperature for the base alloy and the MMCs was studied. The rate of heating was 10°C / min. and the reference sample was indium. The phase transformations during aging were analyzed by EDS.

III. RESULTS AND DISCUSSION

3.1. Microstructure

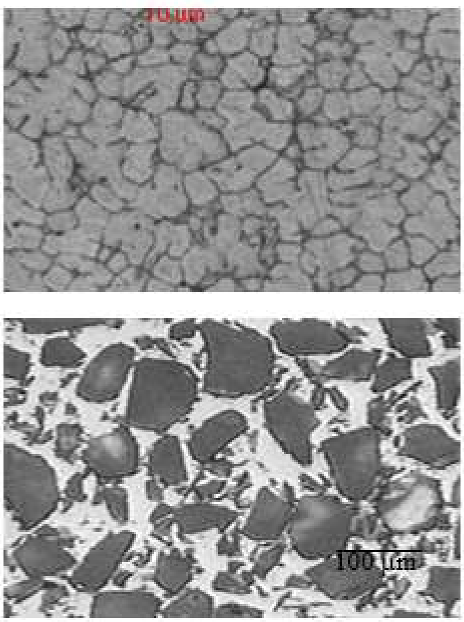

Fig.1: Microstructure of Al and Al/15%albite MMCs

MMCs properties can be determined based on their microstructure as well as distribution of reinforcement. Fig. 1 shows the albite distribution within the Al MMCs. The observation show that the particle uniform distribution and their size vary from 30 to 50 µm. As cast microstructure of MMCs show that the grain size is larger than that of Al/albite MMCs. The nucleation generally starts at colder particle due to temperature gradient between the particles and molten metal. The grain boundaries grow outwards from the reinforcement and caused to solute enrichment. The higher density metal ring is observed between matrix and reinforcement. But there is not gap is seen between them hence the particle is well bonded with matrix alloy.

3.2. Microhardness results

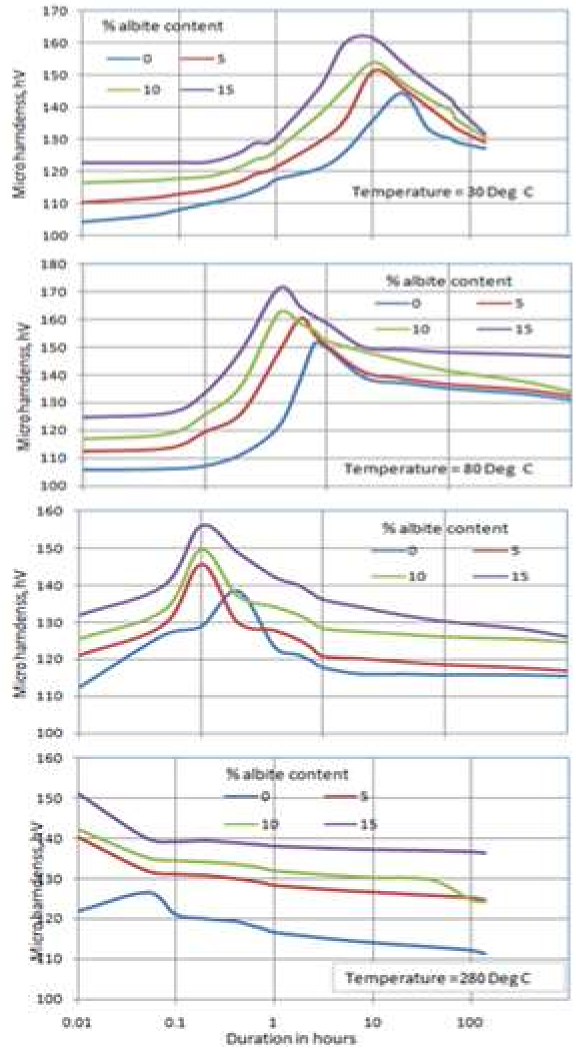

Fig. 2: Vickers microhardness curves of Al alloy and its composites obtained on aging at various temperatures.

The variation of micro-hardness as a function of aging time and aging temperature for the unreinforced as well as albite particulate reinforced Al6061 alloy MMCs is shown in Fig. 2. The plots indicate that in all the cases except at an aging temperature of 320°C, the hardness value initially increases with the increase in aging time. It continuously increased until it reaches the maximum values then it stable and finally decrease marginally with ageing time. The addition of albite has resulted in an increase in the hardness of the MMCs. Increasing hardness of MMCs due to dislocation density and difference in thermal properties of alloy and reinforcement.

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However, there is no significant difference in the hardness values of the composites and the matrix alloy for long aging duration. This dislocation density greatly influence on ageing precipitation during heat treatment. But as the MMCs overage, the dislocation becomes diluted within the matrix alloy hence the slight decrease in hardness during the overage conditions. The MMCs are generally faster reaction in both ageing and over aging hence the peak shift to left side. The maximum hardness peak temperature decreased with increasing albite addition due to faster reactions. In other hand higher aging temperature the aging reaction is faster (more precipitation) hence the shifting of maximum peak towards left in the graph. The peak is not seen at 320 °C ageing temperature for both matrix and reinforcement. This explains the shifting of the hardness peak towards lower aging time as the aging temperature increases. At a higher aging temperature of 320°C, peak is not observed since it must have been already achieved by the time the first observation was recorded.

3.3. Electrical resistivity results

The variation of electrical resistivity with aging time at 32, 80, 180 and 320°C for the Al6061matrix alloy and Al6061/albite particulate reinforced MMCs is shown in Fig. 3. It is observed that at all aging temperatures the overall variation of electrical resistivity with aging time may be categorized into three different stages. The resistivity initially sharply increased, then it maintained constant vales with ageing time and lastly the values sharply decreased with time. There is small difference could be seen in resistivity change between the Al and Al /albite composites. But the resistivity of composites slightly higher than that of the Al alloy. But at centre region of graph for the Al/albite composites are found to be smaller in length compared to matrix materials. In other case the resistivity of Al/albite composites showed drastically decreased at the higher ageing duration.

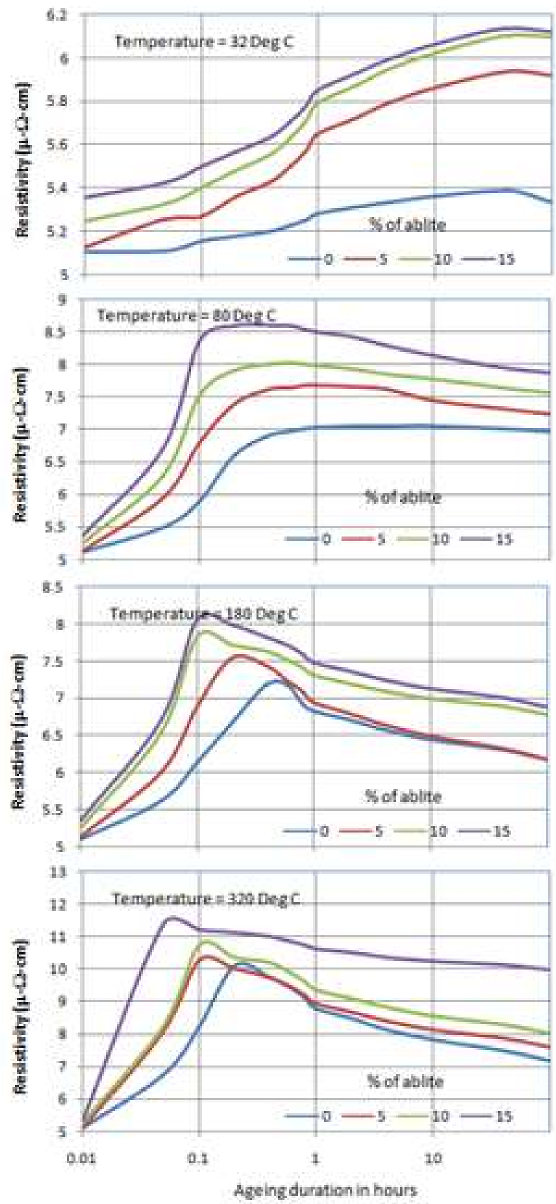

Fig. 3: Electrical resistivity curves of Al alloy and its composites obtained on aging at various temperatures.

3.4. DSC studies

The DSC thermograms of both Al alloy and Al/albite MMCs are plotted in Fig. 4. The all curves show that a unique exothermic peak with respect to their nature of precipitation process during ageing but endothermic peak their dissolution process. The peak precipitation temperature of composites depends upon the percentage of albite content. The temperature decreased with albite content due to accelerate the precipitation kinetics.

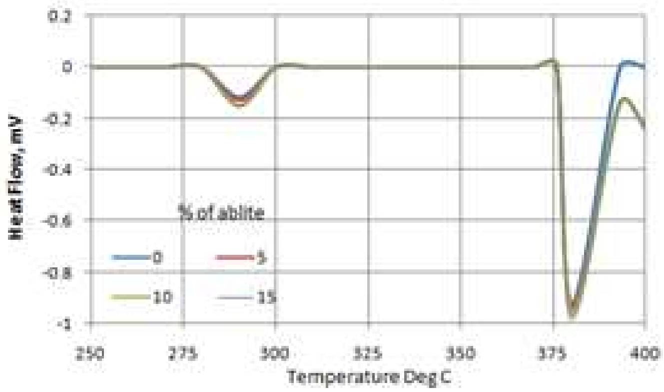

Fig.4: The result of the differential scanning calorimetry for the Al alloy and Al/albite composites

Previous works [9-11] on Al6061 alloys has provided some proof for precipitation concentration obtained by higher temperature as well as quenching rate. The precipitation process starts at 180 °C and their shape generally needle and it is Metaphase [12]. At higher temperature the enhancing the ageing time and clustering process which leads to finer precipitation. The precipitation chemical composition is β-Mg2Si which is main cause for higher hardness. The hardness is mainly depends on the arrangement and size of precipitation. Precipitate β-Mg2Si was small quantity could be seen in the Al/albite composites but evenly distribution could be seen in the aged matrix alloy.

IV. CONCLUSION

1. On quenching Al6061 alloys into cold water at 0°C after heat treatment, both precipitation and cellular reaction has been found to occur.
2. The hardness of both Al alloy and its composites sharply increased at beginning and reaches maximum peak then they decrease due to their dislocation density.
3. The similar trend was observed for electrical resistivity for both matrix alloy and composites but the property depends on phase transformation factors.
4. The maximum temperature decreased with addition of reinforcement due to reinforce particles acts as a nucleation sites.
5. In summary, the annealing temperature at 523 °C for 24h followed by aging at 180°C are recommended for Al/albite composites on the based on their temperature.

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