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Research Article

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Investigation of the Effect of Solution Hardening on Mechanical Properties of Al 7075–SiC Metal Matrix Composite

Sumathy Muniamuthu[1], Bharani Chandar J.[2] and Deepak N. J.[3]

[1]Asso.Professor, Department of Mechanical Engineering, Vel tech, Chennai
[2]Assistant Professor, Department of Mechanical Engineering, Vel tech, Chennai
[3]JRF, Department of Mechanical Engineering, Vel tech, Chennai

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ABSTRACT

Metal Matrix Composite (MMC) are most vital invention in the field of material processing due to their flexibility in the mechanical properties such as tensile, impact and hardness by modifying the reinforcement weight fraction to the matrix and the desirable property can be obtained by just changing the reinforcement material where as the property is extinct to the matrix metal. Solution hardening is widely used hardening process for non ferrous alloys and sometimes to ferrous alloys to improve the hardness and it is very effective in improving the hardness of the aluminum based alloys and it is widely accepted as one the hardness improvement process.

Keywords: MMC, Solution hardening, aluminium alloy, reinforcement and mechanical properties.

INTRODUCTION

Metal matrix composite: Since the early 1960s, there is demand for new and improved engineering materials with advancement of modern technology interest in the areas of aerospace, automotive industries had forced a rapid development of Metal Matrix Composite [10]. Metal Matrix Composite is a part of composite materials which has metal as the matrix or base metal and particularly selected reinforcement material for the desired property required for the particular application. The composite generally has superior characteristics than those of each individual component are distributed in the continuous or matrix component [4]. A composite material is a material consists of two or more physically and chemically distinct phases [1]. In composites, materials are combined in such a way as to enable us to make better use of their parent material while minimizing to some extent the effects of their deficiencies. The simple term ‘composites’ gives indication of the combinations of two or more material in order to improve the properties. Following figure explains the composite in a simplest manner.

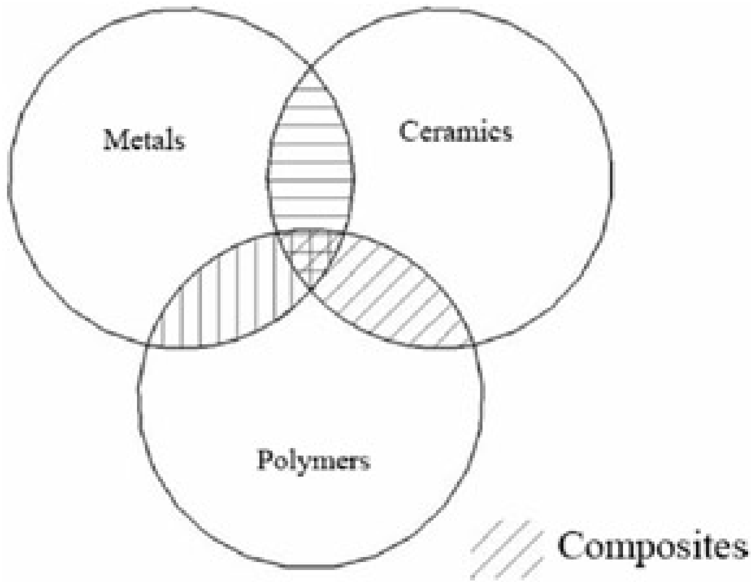

Figure 1 Composite Materials

Solution Hardening: Solution hardening / precipitation hardening / age hardening is commonly used to process aluminum alloys and other in ferrous metals for commercial use. The examples are aluminum-copper, copper-beryllium, copper-tin, magnesium-aluminum and some ferrous alloys. The strength and hardness of some metal alloys may be enhanced by the formation of extremely small uniformly dispersed particles of a second phase within the original phase matrix; this must be accomplished by appropriate heat treatment. The process is called solution hardening / precipitation hardening / age hardening which involve three distinct steps: solution treatment to minimize segregation in the alloy, quenching to create a supersaturated solid solution and aging to facilitate the formation of coherent precipitates which strengthen the alloy by interfering with dislocation movement.

Steps in Solution Heat Treatment

Solution Treatment or Solutionizing is the first step in the precipitation-hardening process where the alloy is heated above the solvus temperature and soaked there until a homogeneous solid solution (α) is produced. The θ precipitates are dissolved in this step and any segregation present in the original alloy is reduced.

Quenching is the second step where the solid α is rapidly cooled forming a supersaturated solid solution of α_{SS} which contains excess copper and is not an equilibrium structure. The atoms do not have time to diffuse to potential nucleation sites and thus θ precipitates do not form.

Aging is the third step where the supersaturated α, α_{SS}, is heated below the solvus temperature to produce a finely dispersed precipitate. Atoms diffuse only short distances at this aging temperature. Because the supersaturated α is not stable, the extra copper atoms diffuse to numerous nucleation sites and precipitates grow. The formation of a finely dispersed precipitate in the alloy is the objective of the precipitation-hardening process. The fine precipitates in the alloy impede dislocation movement by forcing the dislocations to either cut through the precipitated particles or go around them. By restricting dislocation movement during deformation, the alloy is strengthened. The Figure 2 depicts the micro-structure changes while the alloy is subjected to solution hardening.

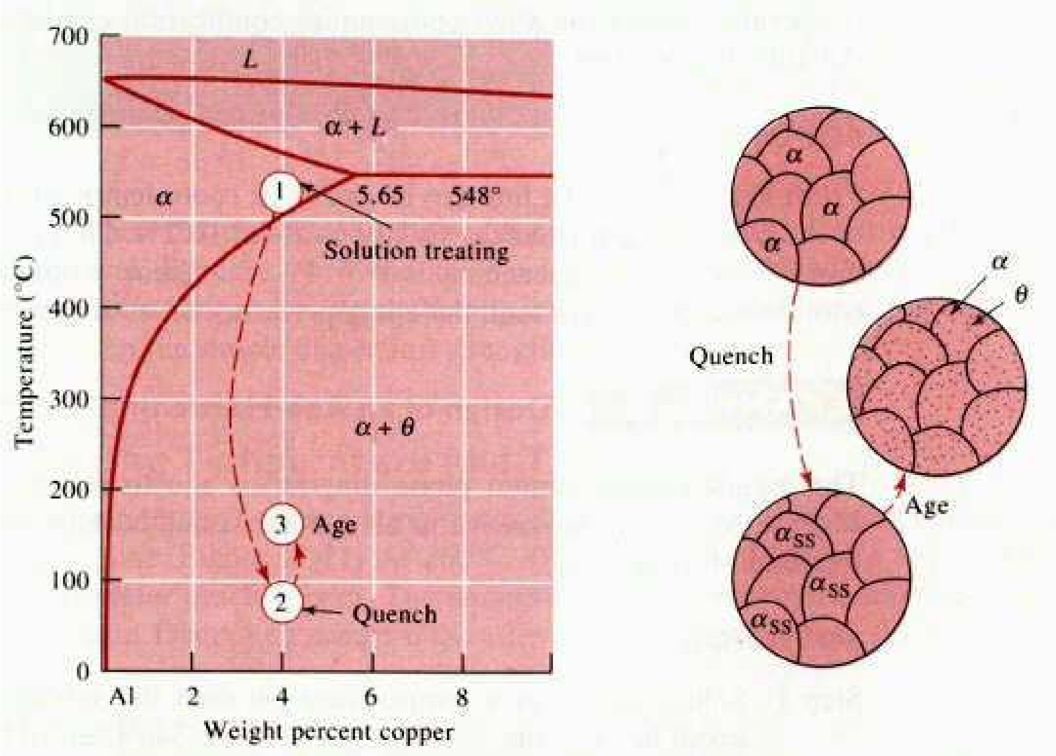

Figure 2 Showing the Three Steps of the Solution Hardening

Effects of Solution Hardening

The most important factors of solution hardening are temperature and the time elapsed for the process (aging duration) and mode of aging (natural or artificial aging). The changes in the properties to the non treated alloy to the solution hardened solution depend upon the changes in the aging temperature and time.

- Solution hardening increases the hardness of the alloy to an acceptable range.
- Relive the internal stress formed during the manufacturing process to some extent.
- Refine the internal structure of the alloy.
- Reduces the ductility of the alloy.
- Reduces the strength of the alloy.

Experimental procedure

The specimen prepared for the investigation of effect solution hardening was prepared with aluminum alloy Al7075 which is commercially available in the markets in many grades, in this study Al7075 T6 grade and silicon carbide of 40-50micron were used. Stir casting methodology is adapted for the processing of the composite.

The following flow chart depicts the steps for processing specimen and solution hardening is as follows.

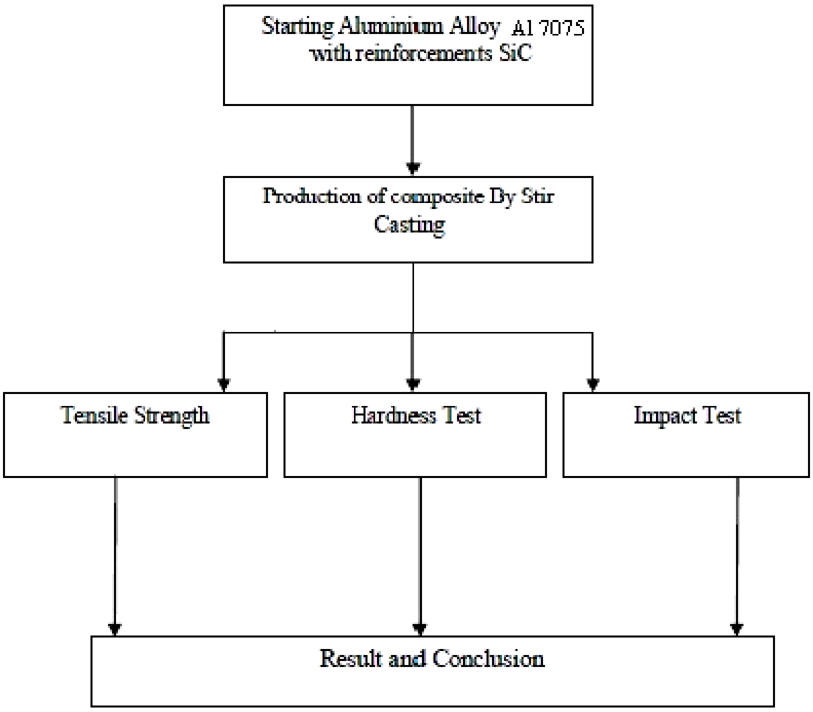

Figure 3 Flow Chart

Methodology

Material Processing: There is a variety of manufacturing processes available for discontinuous metal matrix composites; stir casting is generally accepted as a particularly promising route, currently practiced commercially. In general stir casting of MMCs involves producing a melt of the selected matrix material, followed by introducing reinforcement material into the melt, obtaining a suitable dispersion through stirring. Its advantages lie in its simplicity, flexibility and applicability to large quantity production, It is also attractive because, in principle this method suitable for engineering application in terms of production capacity and cost efficiency [8]. A stir casting method is one of the most competitive methods for fabricating SiC particle reinforced aluminum matrix composites because of its low cost with competitive quality.

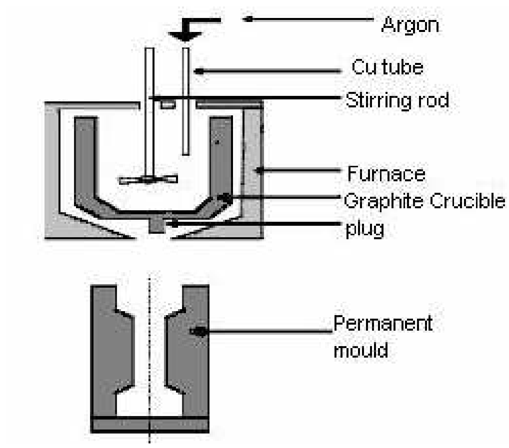

Figure 4 Schematic Diagram of Experimental Stir Casting Setup

Initially the aluminum alloy in billet form is cleaned manually to remove the dust and other foreign particles then the aluminum billet are weighed to determine the weight fraction of the reinforcement used. Experiments carried out for a wide range of particle weight percentage varying from 2% to 8% in steps of 2%[1].The reinforcement particles are measured with respect to the aluminum alloy used. After the measurements are completed the stir casting setup is prepared for the process.

The parameter for the processing of the aluminum stir casting is selected by the following literature review.

Aluminum alloy 6061 was melted in a crucible by heating in a muffle furnace at 800˚C for three to four hours. The alumina particles were preheated to 1000˚C to 900˚C respectively for one to three hours at the same time to make their surface oxidized. The furnace temperature was first raised above the liquidus temperature of the aluminum near about 750˚C to melt the Al alloy completely and was then cooled down just below the liquidus to keep the slurry in semisolid state. Automatic stirring was carried out with the help of radial drilling for about 10 minutes at the stirring rate of 290 RPM. At this stage the preheated alumina particles were added manually to the vortex. In the final mixing processes the furnace temperature was controlled within 700±10˚C. After stirring process the mixture was then pour in the other mould to get desired shape of specimen was shared by Ajay singh et al by their experiment[2]. Balanced aluminium alloy with copper were melted in graphite crucibles. At the same time the SiC particulate was preheated in a muffle furnace set at 1100°C for approximately 2 hour to remove surface impurities and assist in the adsorption of gases. The ceramic particles were then poured slowly and continuously into the molten metal and the melt was continuously stirred at 600 rpm was said by Shubham mathur and Alok barnawal by their study [9].

The vortex method is one of the better known approaches used to create and maintain a good distribution of the reinforcement material in the matrix alloy. In this method, after the matrix material is melted, it is stirred vigorously to form the vortex at the surface of the melt, and ht reinforcement material is then introduced at the side of the vortex was said by Srinivasa Reddy et al by their inference by experiment [11].

Density of the particle is one of the important factors determining the distribution of the particles in molten metal. Particles having higher density then molten metal can settle at the bottom of the bath slowly and lower density can segregate at the top. During subsequent pouring of the composite melt, the particle content may vary from one casting from one region to another was said by Ajay singh et al in their study [2].

From detailed literature review the following parameters and composite processing are selected and followed for the this study, initially after cleaning the aluminium alloy billet surface the furnace temperature was raised to 850˚C and maintained for one hour to remove the moisture content in the boron nitrate coat given in inner side of the graphite crucible, simultaneously the reinforcement Silicon Carbide is preheated to 1000˚C in a muffle furnace. After the removal of the moisture content the alloy billet were melted to form liquid alloy and then the liquidus alloy is lowered to 750˚C to form a slurry in form of semisolid to facilitate uniform dispersion of the reinforcement in the matrix. And then after attaining the temperature Silicon Carbide was poured to the vortex formed due to the continuous automatic stirring at 600RPM the stirring after the inclusion of the reinforcement is carried for 15 minutes.

After the uniform dispersion of reinforcement with the matrix, the liquid composite was allowed to flow in to the die through the crucible bottom pouring arrangement controlled by pneumatic control circuit. Figure below shows the experiment setup.

Figure 5 a) stir cast setup **b) stirring unit**

Solution Hardening: The solution hardening of the prepared specimens were carried as follows, the prepared specimen was first raised above the re crystallization temperature of the aluminum alloy(450±30˚C) and maintained for 8hrs and then the hot specimen is quenched in chilled water and then the chilled specimen is reheated to 180˚C for 2 hrs.

RESULT AND DISCUSSION

Tensile test: The tensile specimens for the testing from the prepared composite materials are prepared by as per the ASTM standards (ASTM E8/E8M-2009). The machine used for testing of the composite is UT 100 – Sans China. As the solution hardening on aluminum metal matrix has a negative effect on the material as mentioned above. A negative effect on the tensile strength was inferred with related to pure Al7075. As the negative effect of the solution hardening on the tensile property of the composite there is an increase in rapid improve in brittleness of the composite was noticed.

Impact Test: The Charpy impact test procedure was carried to determine the impact strength of the composite material. The test was carried as per the standards (ISO 148-01-2009). Hence there is an improvement of brittleness in the composite material in this mechanical test also we inferred a negative effect of solution hardening.

Hardness test: The hardness test was carried on the Vickers hardness testing machine to ASTM E384-2011 standards under the HV5kg scale and the values for the noted down in a tabulation. By the result obtained from the testing clearly shows a increase in a hardness of the composites and with respect to the increase in the weight percentage of the reinforcement with the matrix material.

Table 1 hardness chart

Weight %	HV number
2%	66.77
4%	68.77
6%	70.67
8%	81.73

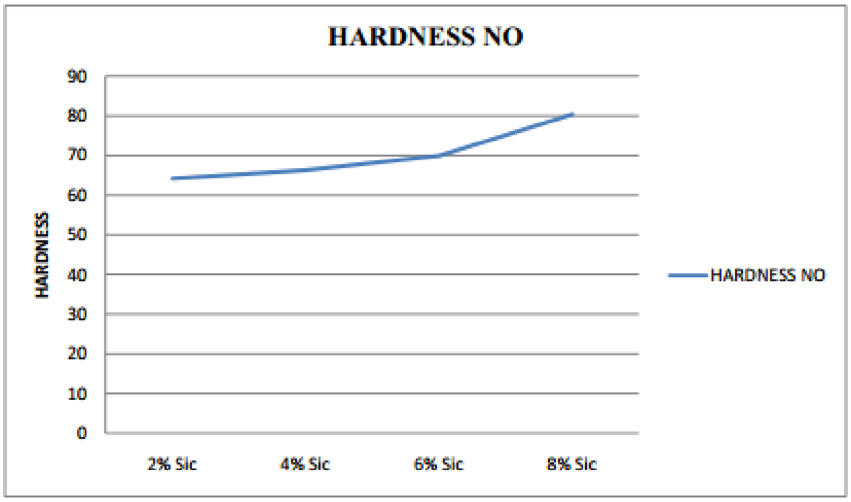

Figure 6 Graph weight % Vs HV number

CONCLUSION

By the experimental results it is clear there is a positive effect of solution hardening on the prepared composite materials is experienced by the reduction in the ductility of the composites material as compared to the parent material and increase in the brittleness of the composite material as compared to the parent material. Hence we need a further more detailed study on the process parameters for the solution hardening to obtain the optimum result with unaffected tensile and impact properties.

It is good to study the dispersion of the reinforcement to micro level and testing may also be carried to micro level to determine the best result. It is advisable to reduce the range between the composite weight fraction to determine the better result.

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