

The Effect of Heat Treatment on Mechanical Properties of ADC12-Sic Metal Matrix Composite: A Review

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Abstract: *In some few recent years the use of metal matrix composite material increases very rapidly due to their high weight to strength ratio, low density, low thermal expansion coefficient, low maintenance and high temperature resistance. Metal matrix composites are widely used in aerospace and automotive engine components. The aluminum alloys are reinforced with Al₂O₃, B₄C and TiC and fabricated by stir casting, centrifugal casting, and powder metallurgy process. In the fabricated metal matrix composites some different tests were conducted to show mechanical properties, micro-structural characterization of materials were also done. When composite subjected to heat treatments then it significantly affect the micro-structural developments of composite causing to relieving of stress. Few researchers presented some good papers on ADC-12 / SiC with and without heat treatment and discussed their results and gave some suggestions about metal matrix composites. Through this paper I have describe the mechanical and micro-structural properties with and without heat treatment.*

Keywords: (ADC-12) aluminum alloys, Silicon carbide (SiC), Stir casting, Heat treatment, and Mechanical properties.

1. Introduction

AL and AL alloy are gaining huge industrial significance because of their good combination of mechanical, physical properties over the base alloys. These properties includes high specific strength, high wear and good stiffness, high temperature strength, good thermal expansion coefficient and improved damping capacity. These properties obtained through addition of alloy elements heat treatment [1].

Microstructure showed uniform distribution of reinforcement in the matrix resulting in improved mechanical properties and wear resistance compared to without reinforced material. Ceramic reinforced alloys were found to have improvement in mechanical properties and wear resistance compared to unreinforced alloy which may be attributed to the uniform distribution and improved bonding of reinforcement (SiC) in the matrix. Aluminium Silicon alloys possess light weight, high specific strength and very good heat transfer ability which make them suitable material to replace components made of ferrous alloys. Aluminium silicon alloys are widely used in most of IC engines such as cylinder heads and Pistons etc. They find applications in aircraft pump parts, aircraft structure, automotive transmission, aircraft fittings, and water cooled cylinder blocks. Both hypoeutectic and hyper-eutectic alloys can be used as useful engine block materials on account of their adequate resistance and high strength to weight ratio[2].

An important feature of the microstructure in the AL metal matrix composite with silicon carbide system is the increased amount of thermal residual stresses, compared to without reinforced alloys, which are developed due to mismatch in thermal expansion coefficients of matrix and reinforcement phases. Introduction of the reinforcement plays a key role in

both the mechanical and thermal aging behaviour of the metal matrix composite (MMCS) material. Micro compositional changes which occur during the thermo-mechanical forming process of these materials can make substantial changes in mechanical properties such as ductility, toughness and stress corrosion resistance etc. Particulate reinforced composites are not homogeneous materials so the bulk material properties not only are sensitive to the constituent properties but strongly depend on the properties of interface. Strength of particulate reinforced composites depends on the size of the particles, spacing between interparticle, and the volume fraction of the reinforcement. In the case of particulate reinforced aluminium composites, microstructure and mechanical properties can be altered by thermo-mechanical treatment, and also by varying the reinforcement volume fraction[3]. Also today aluminium silicon carbide used for ideal packing material. ALSIC is an ideal packaging material for today's high power density Si chips. ALSIC's unique set of material properties includes a high thermal conductivity and IC device compatible coefficient of thermal expansion (CTE) that permits direct device attachment for maximum thermal dissipation. The low density material of ALSIC is ideal for weight sensitive applications such as portable devices [5].

2. Materials

2.1 Metal matrix composite:

Aluminium - alloy (ADC12) is selected as matrix alloys for synthesis of AMCs. The Aluminium alloys families are represented by 1XXX, 2XXX, 3XXX and up to 8XXX. The 1xxx series designation concerns unalloyed aluminium materials which are distinguished according to their degree of purity. The 8xxx series designations are for miscellaneous

types of alloys (i.e. Fe alloys) which cannot be grouped in the other families. The 2xxx, 6xxx and 7xxx series are heat-treatable alloys. And the 1xxx, 3xxx and 5xxx series are so called non-heat-treatable alloys; they gain their strength by alloying and work hardening. The first digit gives basic information about the principal alloying elements. Among them Aluminium - alloy (ADC12) is selected because it is heat treatable alloy and it is used for various application.

The chemical compositions of aluminium alloy was analysed using glow discharge spectrometer which is shown in the Table 1.

Some good Characteristics of Composite Materials

- 1) Symmetry: Tensorial nature of material properties.
- 2) Hierarchy: Stacking of individual structural units
- 3) Heterogeneity: Non-uniformity of the chemical or physical structure.
- 4) Anisotropy: Direction dependence of the physical properties.

2.2 Reinforcement

SIC can be used as reinforcement in the form of particulates or fibre to improve the properties of the composites. The SIC particles, used as reinforcement in the aluminium matrix for synthesizing the composites. It increases the yield strength and overall strength, and modulus of elasticity of the composites. SIC shows the high structural stability and strength retention even at temperature above 10000C. The various properties of SIC particles are shown in table 2.

Silicon carbide (SIC) is an interesting material that has found application in a variety of industries. The some good applications of this material are its use as an abrasive material and use as a wide band gap semiconductor for high power and high temperature electronic devices. The high hardness of this material, led to its use in machining tools and in other structural applications.

Function of reinforcement:

1. Contribute desired properties.
2. Load carrying.
3. Transfer the strength to matrix.

3. Stir Casting or Compo Casting

On the basis of the reinforcement the fabrication techniques can vary considerably. Some of the techniques for the development of the composites are stir casting method, powder metallurgy, plasma spraying and squeeze casting etc. This is the simplest and most commercially used techniques known as stir casting method. This is also called as the vortex technique. In this technique the introduction of the pre-treated ceramic particles into the vortex of molten alloy created by the rotating impeller. Ceramic particles and ingot grade aluminium are mixed and melted. The melt is stirred slightly above the melting point temperature. Stir casting offers better matrix-particle bonding due to stirring action of particles into the melts. Homogeneous mixing and good wetting can be obtained by selecting appropriate processing parameters like stirring speed, time, and temperature of molten metal, preheating temperature of mould and also uniform feed rate of particles.

4. Heat Treatment

Heat treatment is the process of heating and cooling to achieve desired physical and mechanical properties through modification of their crystalline structure of the materials. Temperature, length of time, and rate of cooling after heat treatment will all impact properties dramatically. Most common reasons to heat treat include increasing strength, increasing hardness, increasing toughness, improving ductility and increase in corrosive resistance.

It is an important operation in the manufacturing process of many machine parts. The objective here is to select the heat treatment cycle that produces the most favourable precipitate size and also distribution pattern. Heat treatment of metal matrix composites (MMCS) has an additional aspect to consider; the particles introduced into the matrix may alter the alloy's surface characteristics and increase the surface energies. The specimens of Al-Si-SiC composite were heat treated in a programmable furnace to compare the properties in aged and as cast condition. There were three stages involved in the heat treatment.

- 1) Solutionising: The specimens were heated to a temperature of $490 \pm 50^\circ\text{C}$ for 8 hours until the alloy solute elements are completely dissolved in the Al solid solution.
- 2) Quenching: the solution treated specimens were rapidly cooled into oil to prevent the precipitation of the solute elements and to obtain a super saturated solid solution and
- 3) Artificial aging: To improve the strength and hardness of the material the specimens were reheated to $135^\circ\text{C}/150^\circ\text{C}/175^\circ\text{C}/200^\circ\text{C}/240^\circ\text{C}$ for 6 hours each and then allowed to cool in the still air.

Table 1: Chemical composition of ADC 12 alloy

Element	ADC-12
Si	10.29
Mn	0.12
Mg	0.47
Cu	1.98
Fe	0.75
Ni	0.80
Al	Rest

Table 2: Properties of SIC reinforcement

Particle	SIC
Elastic modulus (GPa)	420 – 450
Density (gm/cc)	3.2
Coefficient of thermal expansion (k^{-1})	4.3×10^{-6}
Specific heat ($\text{Kg}^{-1} \text{k}^{-1}$)	840
Thermal conductivity (Wm-K^{-1})	10-40 at 1100°C
Poisson ratio	0.17

4.1 Comparison of mechanical properties and micro structural properties before and after heat treatment

Here is the comparison of mechanical and microstructural properties of the aluminium alloy with the silicon carbide before and after heat treatment. What I had got from the some research journals. After doing the literature review the study shows the following conclusions:

4.2 Mechanical And Micro-Structural Properties Before Heat Treatment

- 1) Tensile strength of composite increases for 10% SIC composite but remains equal to alloy in 15% SIC composite.
- 2) Compressive strength of composites decreases with increase in SIC concentration.
- 3) Hardness of the composites increases with increase in SIC concentration.
- 4) Impact strength of composites decreases with increase in SIC concentration.
- 5) The wear rate increases with increase in sliding distance and applied pressure for all the materials.
- 6) The coefficient of friction varies in the range of 0.07 to 0.13 for alloy and the composites.
- 7) The seizure pressure is more for composites as compared to base alloy.
- 8) The seizure temperature increases with increase in SIC concentration.
- 9) The wear coefficient of alloy lies in the range of 10-3 which signifies that type of wear is severe wear whereas in case of composites it is in the range of 10- 4 which signifies that type of wear is mild or oxidational.
- 10) The microstructure of alloy shows aluminium dendrites and plate shaped eutectic silicon. Microstructure of composites shows uniform distribution of SIC particles in the base alloy with good interface bonding between the matrix alloy and the SIC particle. Usually the spacing between the dendrites is in the range of 4-5 microns hence the chance of entrapment of SIC particle in the interdendritic region does not arise. In fact the SIC particles are pushed by the Aluminium dendrites and the particles are found along with the eutectic liquid.

4.3 Mechanical and Micro-Structural Properties After Heat Treatment:

- 1) Microstructure indicates uniform distribution of ceramics in the matrix resulting in good bonding of the particulates.
- 2) Heat treatment does not affect the stress – strain behaviour of the metal matrix composites.
- 3) After heat treatment the material gets the desired properties like strength, hardness, ductility etc.
- 4) The impact strength increases initially with aging temperature and thereafter it remains almost constant with increase in aging temperature.
- 5) There is an improvement of nearly 36% in the tensile strength at peak age temperature (aged at 175 C) as compared to as cast composite because of formation of coherent precipitates.
- 6) There is nearly 50 % improvement on proof stress value due to heat treatment.
- 7) There is nearly 40% improvement on hardness due to heat treatment. The reason being a good interface between the SIC and aluminium matrix which always give rise to higher hardness value.
- 8) Heat treated aluminium composite matrix shows distribution of SIC particles in the heat treated Aluminium silicon matrix. A higher magnification micrograph shows the interphase of SIC particles and Aluminium matrix. The spherical shaped eutectic silicon

can be seen at the interphase. Clearly shows a higher magnification micrograph depicting the interphase of SIC particles and heat treated ADC12 alloy matrix. The spherical shaped eutectic silicon can be seen at the interphase. So it improves the microstructural properties of the aluminium matrix composite particulate with silicon carbide.

5. Conclusion

The mechanical and structural properties are very important from the design point of view. And the desired properties are very important to make our design safe. Because in designing there are so many factor which are unknown to us, so to compensate it we take factor of safety because we want my design safe. So in this paper I have discussed the effect of heat treatment on the metal matrix composites which is widely used in the industries.

Strength is very important properties from the design point of view. And we have seen that there is a good improvement in the strength of metal matrix composites after heat treatment. We have seen that the mechanical and structural properties are improved after the heat treatment. And the improvement is desirable to use this analysis for designing a component. It reduces the internal residual stresses also.

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