IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology
ISO 3297:2007 Certified
Vol. 3, Issue 11, November 2016

Development and Characterization of Aluminium LM6 based Matrix using 2% Sic & 2% Al_2O_3

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Abstract: Aluminium based composites with the addition of SiC and Alumina was successfully achieved with stir casting process. It has been observed that stir formed Al alloy LM 6 with SiC/Al_2O_3 reinforced composites is superior to base Al alloy LM 6 in terms of tensile strength, Impact strength and hardness. It has been observed that there is an improvement in the hardness of the developed composite which is due to dispersion of SiC/Al_2O_3 particles. It has been concluded that maximum value of Tensile strength of 238 N/mm2, Impact strength of 7.09 Nm and hardness of 131VHN was obtained by combination of 2% Silicon carbide and 2% of Aluminium oxide when mixed in AMC.

Keywords: AMC, SiC, Al_2O_3, Stir casting.

INTRODUCTION

Materials are so important in the development of human civilization that the historians have identified early periods of civilization by the name of most significantly used material, e.g. Stone Age, Bronze Age. It is obvious that materials have affected and controlling a broad range of human activities through thousands of decades. In general the materials are classified as:

- Metals and Alloys
- Ceramics, Glasses and Glass-ceramics
- Polymers (plastics), Thermoplastics and Thermo sets
- Semiconductors

Metals and Alloys are the inorganic materials composed of one or more metallic elements. They maintain their good strength but are least resistant to corrosion. Ceramics and Glasses are materials consisting of both metallic and non-metallic elements bonded together chemically.. Generally they have high melting points and high chemical stabilities. They have high hardness, high moduli and high temperature strength. But since they are very brittle they cannot be used as good as metals [1].

Polymers are the organic materials which consist of long molecular chains or networks containing carbon. They generally have low densities and low rigidity. Their mechanical properties may vary considerably and generally have a good strength to weight ratio. Semiconductors are covalent in nature. Their electrical properties depend extremely strongly on minute proportions of contaminants. They are usually doped in order to enhance electrical conductivity, examples: silicon (Si), germanium (Ge), and gallium arsenide[2].

Therefore conventional engineering materials are unable to meet this requirement of special properties. Hence there is a great need for materials with special properties with emergence of new technologies, results new class of engineering materials i.e. composites.

A composite material is composed of reinforcement embedded in a matrix. The matrix holds the reinforcement to form the desired shape while the reinforcement improves the overall mechanical properties of the matrix.

CLASSIFICATION OF COMPOSITES

On the basis of matrix material or matrix phase composites are classified as Metal Matrix Composites (MMC), Ceramic Matrix Composites (CMC), Polymer Matrix Composites (PMC).

Metal matrix composites (MMCs), like all composites consist of at least two chemically and physically distinct phases, suitably distributed to provide properties not obtainable with either of the individual phases.

A metal matrix composite (MMC) combines into a single material a metallic base with a reinforcing constituent, which is usually non-metallic and is commonly a ceramic. By definition, MMC’s are produced by means of processes other than conventional metal alloying [3].

METAL MATRIX COMPOSITES

A composite material in which one constituent is a metal or alloy, the other constituent is embedded in this metal matrix and usually serves as reinforcement.

Due to combination of metallic properties with ceramic properties, metal matrix composites show greater shear and compression strength with capabilities to perform at high temperature.

Metal Matrix Composites (MMC's) are considered a group of advanced materials which represent low density, good tensile strength, high modulus of elasticity, low coefficient of thermal expansion, and good wear resistance [4].

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ALUMINIUM METAL MATRIX COMPOSITES (AMMCs)

The most popular types of MMCs are Aluminium alloys reinforcing with ceramic particles. These low-cost composites provide higher strength, stiffness and fatigue resistance with a minimal enhance in density over the base alloy. Aluminium metal matrix composites have attracted increasing attention due to their combined properties such as high specific strength, high stiffness, low thermal expansion coefficient and superior dimensional stability.

LITERATURE REVIEW

Wei et al. [6] studied the effect of macroscopic graphite (Gr) particulates on the damping behavior of commercially pure aluminum (Al). Macroscopic graphite particulate reinforced commercially pure aluminum metal matrix composites (MMCs) were prepared by pressure infiltration process. The damping characterization was conducted on a multifunction internal friction apparatus (MFIFA).
Natrajan et al. [7] studied the wear behavior of aluminium metal matrix composite (Al MMC) sliding against automobile friction material has been compared with the conventional grey cast iron. The grey cast iron disc has been machined from a brake drum of a commercial passenger car. The Al MMC disc has been manufactured by stir casting technique using A356 aluminium alloy and 25% silicon carbide particles and machined to the required size. The friction and the wear behavior of Al MMC, grey cast iron and the semi metallic brake shoe lining have been investigated at different sliding velocities, loads and sliding distances. The worn surfaces and sub-surface regions of MMC, the cast iron and the lining have been analysed using optical micrographs. The investigation showed that the MMCs have considerable higher wear resistance than conventional grey cast iron while sliding against automobile friction material under identical conditions. A gradual reduction of friction coefficient with increase of applied load is observed for both cast iron and Al MMC materials. However, in all the tests it is observed that the friction coefficient of Al MMC is 25% more than the cast iron while sliding under identical conditions. The wear of the lining material has been observed more when sliding against MMC disc because of the ploughing of the lining material by the silicon carbide particles.
Lloyd [8] studied the factors influencing the micro structural, mechanical properties relationship of composites shows the effect of different reinforcement. In this author study different reinforcement effect on different alloy are considered. Conclusions of this paper are elongation of composites decreases as increases percentage of reinforcement and tensile strength are increases. Miracle [9] studied 6092/SiC/17.5p & 2009/SiC/15p-T4 for F16 aircraft Door and body purposes in Air Force Research Laboratory. It can be observed that the densities of composites are higher than that of their base matrix, further the density increases with increased percentage of filler content in the composites.

STIR CASTING PROCESS

Stir casting is a liquid state process which is used to fabricate MMCs conveniently. To prepare AMCs, aluminium matrix is completely melted and ceramic particles are added into molten metal in a vortex created by using a mechanical stirrer [10]. This method is most economical to fabricate composites with particulates fibers [11]. The following figure 1 shows the basic layout of stir casting setup which contains a furnace, crucible, a motor which can be operated at variable speeds, a stirrer attached to motor which stirs the molten metal in crucible.

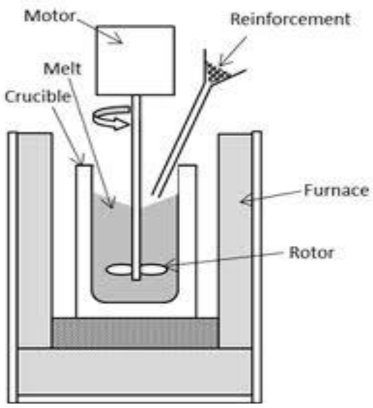

Fig. 1 A Stir casting setup

MATRIX MATERIAL

For the preparation of AMC the matrix Aluminium alloy LM6 is used as matrix for manufacturing of composite.
Reinforcement: Silicon carbide and Alumina was used as a reinforcement material.

SETUP AND EXPERIMENTATION

Pit Furnace was used to heat the material to desired temperatures. A pit furnace in historical usage is a furnace in which the subject material is isolated from the fuel and all of the products of combustion including gases and flying ash. For the preparation of AMC, Aluminium Alloy was melted in a Graphite crucible by heating it in a pit furnace at 780°C for four hours. The silicon carbide particles and Alumina particles were preheated at 1100°C respectively for three hours to make their surfaces oxidized.


Fig. 2 Stirring Process

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The furnace temperature was first raised above the liquidus temperature of Aluminium up to 750°C to melt the Al alloy completely. Stirring was carried out with the help of machine for about 15 minutes at stirring rate of 250 RPM.

At this stage, the preheated SiC particles and Alumina particles were added manually to the vortex then again whole mixture was stirred so that uniform composition may be achieved. In this experiment SiC and Alumina particles of 100 micron size were used.

TABLE I SAMPLES WITH ALL PARAMETERS

Sample No.	Coppmposition
K1	Pure (LM6)
K2	Aluminium (LM6)+ 2% (SiC)
K3	Aluminium (LM6) + 2% (Al_2O_3)
K4	Aluminium (LM6) + 2% (SiC) + 2% (Al_2O_3)

CHARPY IMPACT TEST RESULTS

The Charpy impact test was performed on the Impact testing machine. This result is shown in the figure 1.2, in the form of bar chart with all process parameters.

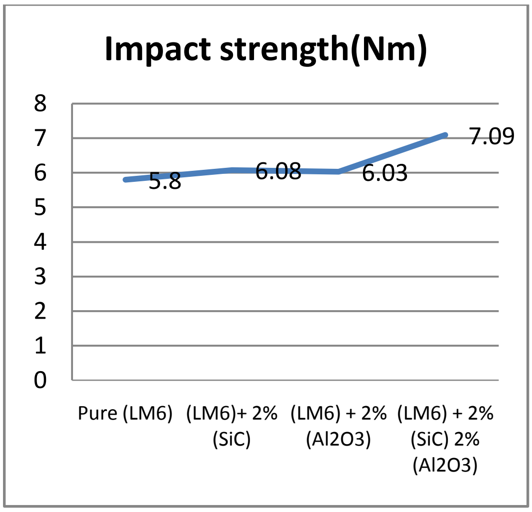

Fig.3 Impact strength results at different compositions of reinforcement

Graph shows that with the increase in SiC & Al2O3 constituent Impact strength increases as compared to base metal. It is observed from figure that for a given percentage of SiC and Al_2O_3, higher value of impact strength is obtained with SiC.

The increase is nominal which gives an indication that further increase in reinforcement may not have any considerable effect in impact strength. This increase and further saturation may be due to the complete dispersion of SiC and Al_2O_3 into matrix and strong interfacial bonding between Aluminium alloy LM6, SiC and Al_2O_3.

ULTIMATE TENSILE STRENGTH

Tensile test is used to assess the mechanical behaviour of the composites and matrix alloy. Ultimate tensile strength (UTS), often shortened to tensile strength (TS) or ultimate strength, is the maximum stress that a material can withstand while being stretched or pulled before necking, which is when the specimen's cross-section starts to significantly contract. The samples for the tensile test were cut from the composite blanks with power hacksaw followed by the cutting on the shaper machine.

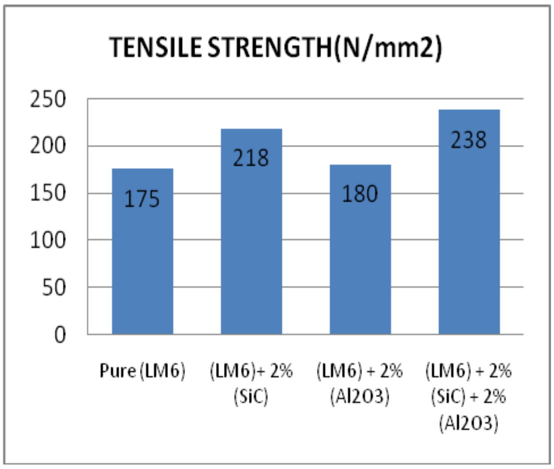

Fig. 4 Ultimate tensile strength results at different compositions of reinforcement

In results ultimate tensile test base metal had 175 N/mm^2 but when added the 2 % of silicon carbide in base metal it increases the tensile strength 218 N/mm^2 . Plot showing comparative tensile strengths with vary % of SiC & Al_2O_3 along with parent (base) metal. The experimental results shows that the Ultimate tensile strength of the cast MMCs produced are somewhat higher than that of the non-reinforced LM6 alloy. It shows that with increase in reinforcement wt. %, ultimate tensile strength increases. The results also predict that the value of Ultimate tensile strength is increasing gradually with addition of reinforcements particles. This happens may be due to uniform dispersion of SiC & Alumina in during fabrication of composites.

VICKER'S HARDNESS TEST RESULTS

A Vicker's hardness tester was used for the hardness measurement. The specimens were prepared are metallographic finished with different grades of emery paper and subsequently polished with alumina. The hardness of composite samples was measured at 10 kgf load for 20 seconds for 25 to 30 times repeatedly on a sample. The result of Vicker's hardness test for LM6 without reinforcement and the wt. % variation of different reinforcements SiC/ Al2O3 and Al alloy LM6 are shown in Fig 5.
In Vicker's hardness test results, base metal had 110 VHN. But when added the 2 % of silicon carbide in base metal it

DOI 10.17148/IARJSET.2016.31133

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increases the tensile strength 120 VHN. But when added the 2 % of Aluminium oxide in base metal it increases the hardness to 122 VHN. The combined Vicker's hardness of 2% Aluminium oxide and silicon carbide was 131 VHN. The experimental data shows the hardness of the cast metal matrix composites increase proportionally by increasing the weight percentage of SiC and Al_2O_3 particles in the casting.

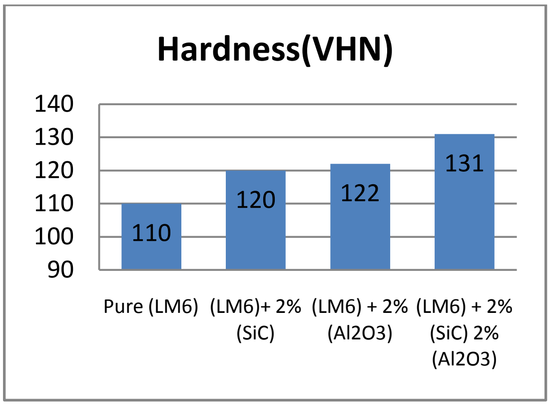

Fig. 5 Hardness results at different compositions of reinforcement

From the graphs it is clear that, as the reinforcement percentage increases the micro hardness also increases. The reason for this may be either the proper mixing due to high viscosity of molten composites or good interfacial bonding between the particle– matrix interfaces.

CONCLUSION & REMARKS

In the present investigation, different experimental techniques were used to characterize some physical and mechanical properties of Stir casted Aluminium alloy LM6 and its composites containing different weight fractions of SiC and Alumina particles.

- Aluminium based composites with the addition of SiC and Alumina was successfully achieved with stir casting process. It has been observed that stir formed Al alloy LM 6 with SiC/Al_2O_3 reinforced composites is superior to base Al alloy LM 6 in terms of tensile strength, Impact strength and Hardness.
- It has been observed that there is an improvement in the hardness of the developed composite which may be due to dispersion of SiC/Al_2O_3 particles.
- It has been concluded that maximum value of Tensile strength of 238 N/mm^2, Impact strength of 7.09 Nm and hardness of 131VHN was obtained by combination of 2% Silicon carbide and 2% of Aluminium oxide when mixed in AMC.

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