

Experimental Investigation on Mechanical Properties of MMC at Optimum SiC Mixture

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Abstract:

There are several technical challenges existing for today's casting technology. Achieving a uniform distribution of reinforcement within the matrix is one such challenge, which affects directly on the properties and quality of composite material.

In the present study a modest attempt would be made to develop Aluminum based Silicon Carbide (AlSiC) with an objective to develop a conventional low cost method of producing Metal Matrix Composites (MMCs)..Two step-mixing method of stir casting technique has been proposed and subsequent property analysis has been made to develop the composite. Aluminium (98.41%) and SiC (360-grade) have been chosen as matrix and reinforcement material respectively. Experiments are planned for conducting varying weight fraction of SiC (in the steps of 5%)while keeping all other parameters like furnace temperatures, stirring speed & total mass of material mixture constant.

The results were evaluated by Brinell Hardness Test, Charpy Impact Test (including micro-structure) and Corrosion Test. The trend of hardness and impact strength with increase in weight percentage of SiC were observed and recommendation made for the potential applications accordingly. By this experimental analysis, it is observed that 25% SiC with Aluminium is the optimum mixture for the Metal Matrix Composites.

Keywords: Aluminum Alloy, Hardness, Impact Strength, MMC (Metal Matrix Composites), SiC (Silicon Carbide/ Carborundum)

Introduction:

A composite material is a material consisting of two or more physically and/or chemically distinct phases. The composite generally has superior characteristics than those of each of the individual components. Usually the reinforcing component is distributed in the continuous or matrix component.

When the matrix is a metal, the composite is termed a metal-matrix composite (MMC). In MMCs, the reinforcement usually takes the form of particles, whiskers, short fibers, or continuous fibers.

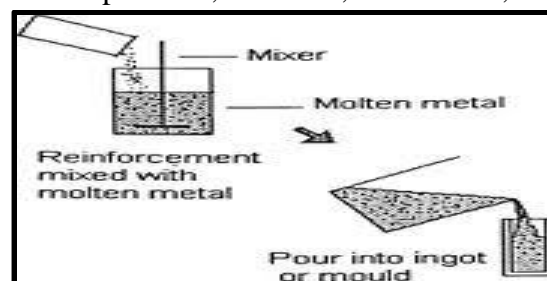


Figure 1: Preparation of Metal Matrix Composite

Composite are materials in which two phases are combined, usually with strong interfaces between the base metal and reinforcement. They usually consist of a continuous phase called the matrix and discontinuous phase in the form of fibers, whiskers or particles called the reinforcement. Considerable interest in composites have been generated in the past because many of their properties can be described by a combination of the individual properties of the constituent phases and the volume fraction in the mixture. Composite materials are gaining wide spread acceptance due to their characteristics of (MMCs) is due to the relation of structure to properties such as specific stiffness or specific strength. Like all composites,

Aluminium Matrix Composites are not a single material but a family of materials whose stiffness, density and thermal and electrical properties can be tailored. Composites materials are high stiffness and high strength, low density, high temperature stability, high electrical and thermal conductivity, adjustable coefficient of thermal expansion, corrosion resistance, improved wear resistance etc. the matrix holds the reinforcement to form the desired shape while the reinforcement improves the overall mechanical properties of the matrix. When designed properly, the new combined material exhibits better strength than would each individual material.

Problem definition

Metal Matrix Composite materials can be produced by many different techniques. The focus of the selection of suitable Process Engineering is the desired type, quantity and distribution of the reinforcement components (particles and fibers), the matrix alloy and the application.

By altering the manufacturing method, the processing and the finishing, as well as by the form of the reinforcement components it is possible to obtain different characteristic profiles, for the same composition and amounts of the components.

The problem for the proposed work is to evolve a development process for the best mix of the alloying elements for AlSiC for deriving optimal mechanical properties for a given hardness and impact strength of the material.

Objectives

The reinforcement of metals can have many different objectives. The reinforcement of light metals opens up the possibility of application of these materials in areas where weight reduction has first priority. The precondition here is the improvement of the component properties. The development objectives for light metal composite materials are:

- Increase in yield strength and tensile strength at room temperature and above while maintaining the minimum ductility or rather toughness.
- Increase in creep resistance at higher temperatures compared to conventional alloys
- Increase in fatigue strength, especially at higher temperatures

Methodology: For our case, the physical experimentation has been carried out under specified input conditions at the foundry; the details of which are given below.

Steps involved in Stir Casting:

1.Preparation of the material
2.Placing raw materials in a graphite crucible into a muffler furnace
3.Heating the crucible above the liquids temperature of raw material
4.Stirring is performed to homogenize the temperature and then adding the reinforcement into molten alloy
5.Pouring the molten metal in the mould
6.Withdrawal of the composite from the mould after solidification
7.Sample produced is ready for testing

Figure 2: Flow Chart showing steps involved in Stir Casting

Experimental Procedure:

Aluminum Alloy was melted in a crucible by heating it in a muffle furnace at 800 C for three to four hours. The silicon carbide particles were preheated at 1000 C for one to three hours to make their surfaces oxidized. The furnace was first raised above the liquidus temperature of Aluminium near about 750 C to melt the alloy completely and was cooled down just below the liquidus to keep slurry in Semi solid state

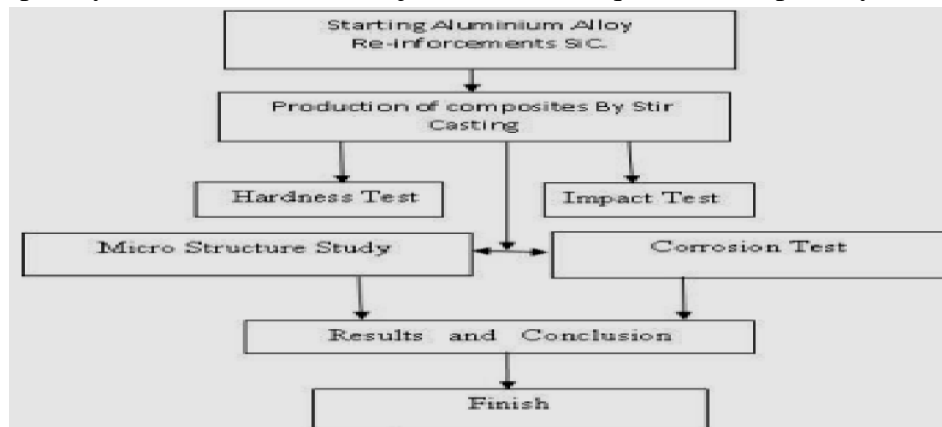


Figure 3: Flow Chart of Methodology

Automatic stirring was carried out with the help radial drilling machine for about 10 minutes at stirring rate of 290 RPM. At this stage, the preheated SiC particles were added manually to the vortex. In the final mixing process the furnace temperature was controlled within 700 ± 10 C. After stirring process the mixture was pour in the other mould to get desired shape.

For Experimental methodology:

Step 1: Preparation of sand mould.

Green sand or Molding sand as it is popularly known is used with binding material to form the cope and the drag or the cores of the mold .

Step 2: Preparation of Specimen of various compositions

The alloying element SiC is mixed proportionately by weight in the ratio of 5%,10%,15%

20%, 25%, 30%.The percentage of alloying element to be used is determined by literature review and history for development of this work. The specimens of above percentage of SiC is shown in Figure 4



Figure 4: Specimens for hardness test of Metal Matrix Composite

Step 3: Machining of specimen for test.

For Charpy/ Izod Impact test, the material needs to be sized as a square section with a notch as specified by the relevant IS standard. The samples for Impact Test are shown in Figure 5.



Figure 5: Specimens for Impact test of Metal Matrix Composite

Step 4: Checking Hardness over 'Hardness testing machine'

Brinell Hardness Test is carried out over 'Llyod' Testing machine. The tested specimens are shown in Figure 6.

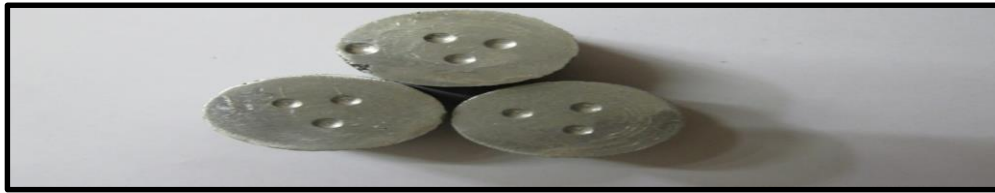


Figure 6: Specimens of hardness tested of Metal Matrix Composite

Step 5: Checking Impact Strength using 'Charpy Impact testing machine'

Test for Impact Strength is carried out using the setup specified for Izod Impact Test.

Step 6: Corrosion Test was carried out by ASTM 262-A Practice B and results are that the corrosion rate of Metal Matrix Composites.

Step 7: Analysis of results.

Various Experiments were conducted on fabricated MMCs samples by varying weight fraction of SiC (5%, 10%, 15%, 20 %, and so on) and size of SiC particles (360 Grade) to analyze the casting performance characteristics of Al/SiC-MMCs.

Trend of hardness and impact strength with increase in weight percentage of SiC were observed and tabulated in Table 1. Also the results are shown graphically in Figure 7. The experiment was conducted by varying weight fraction of SiC (in the steps of 5%) while keeping all other parameters like furnace temperatures, stirring speed & total mass of material mixture constant.

Table 1: Strength Properties of MMC at Various SiC mixture

%SiC	Hardness (HRC)	Impact Strength (J)
0	31.8	11.67
5	38.33	21.67
10	41.4	25.2
15	42.4	26.33
20	43.8	31.33
25	45.8	36.33
30	42.6	31.89

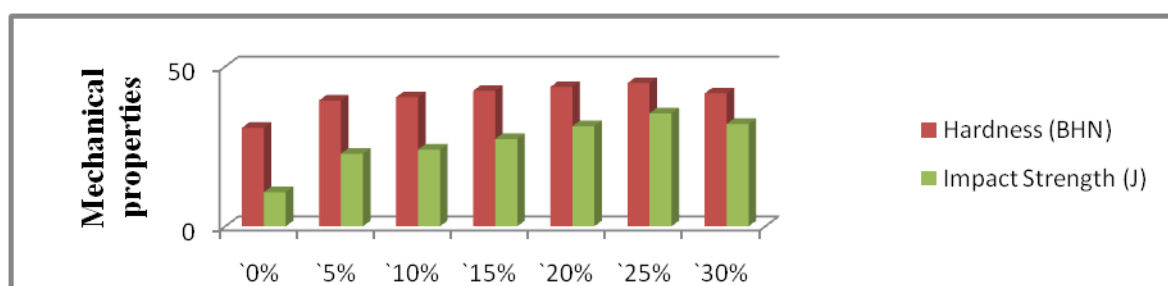


Figure 7: Mechanical Properties vs. % SiC Graph

From the above Figure 7, 25% SiC is the best mixture. But to confirm this, we took a trial for 23%, 24%, 26% and 27% SiC. The results are shown in Table 1.

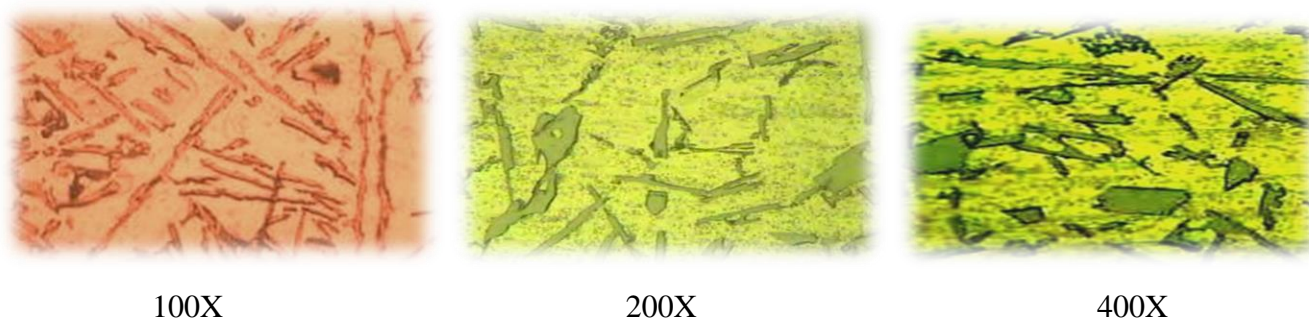
Table 2: Strength Properties of MMC at Optimum SiC Mixture:

SiC (%)	Hardness (HRC)	Impact Strength (J)
23	42.79	31.68
24	44.78	32.85
25	45.86	36.33
26	44.50	35.89
27	42.16	33.12

Since the results show a favorable mechanical strength for the specimens at 25%SiC, this value needs to be studied with peripheral values for securing the best results. For this purpose, experiments are proposed for 23%, 24%, 26% & 27% SiC.

Microstructure:

Microstructure study was carried out for specimen of 25% SiC in Aluminum. Microstructure study shows the dispersion of SiC in Aluminum at different 100X, 200X and 400X Magnification.



Conclusion

The experimental study reveals following conclusions:

(a) Hardness (BHN) and Density (gm/cc) increases with the increase in reinforced particulate size (360 Grade) and weight fraction (5%, 10%, 15%, and 20%) of SiC particles. Maximum Hardness (BHN) = 44.8 and Maximum Density (gm/cm^3) = 2.828gm/cm^3 has been obtained at 25% weight fraction of 360 Grade size of SiC particles as shown in Table 1 and Figure 7.

(b) Impact Strength (NM) decreases with the increase in reinforced particulate size (360 Grade) and increases with the increase in weight fraction (5%, 10%, 15%, and 20%) of SiC particles. Maximum Impact Strength = 35.33 N-m has been obtained at 25 % weight fraction of 360 Grade size of SiC particles as shown in Table 2.

(c) Microstructure: Optical Homogenous dispersion of 25% SiC particles in the Al matrix shown in figure.

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