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The Effect of Process Parameter on Metal Matrix Composite (Al+4%Cu+5%Sic) By Stir Casting

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ABSTRACT

During the last two decades, metal matrix composites (MMCs) have emerged as an important class of materials for structural, wear, thermal, transportation and electrical applications. Metal matrix composites (MMCs) possess significantly improved properties including high specific strength; specific modulus, damping capacity and good wear resistance compared to unreinforced alloys. There are several techniques to produce composites, such as liquid state, solid state and semi-solid state production route. Among the entire liquid state production route stir casting route are simplest and cheapest. The aim of our project is to produce a composite with cheap and simple production route i.e. stir casting method. We have chosen 5% SiC as the reinforcement material and balanced Al + 4% Cu as matrix phase. In this thesis, the grit sizes of SiC have been changed 400, 600 and 800 mesh and tried to observe that the effect of grit sizes of SiC on mechanical properties with vary pouring temperatures 700, 725 and 750˚C.

The best value of BHN, Impact and UTS has been obtained at optimum pouring temperature 725˚C. The pouring rate kept constant at 2.5cm/s for all composites. The mechanical properties as hardness, impact and tensile strength were enhanced with increasing grit size (400, 600 and 800 mesh) of reinforcement SiC particles. Using SPSS 17.0.

Keywords:- Metal Matrix Composites MMC’s, Cu, Silicon Carbide SiC, SPSS, Stir, Pouring Temperature, UTM, Hardness.

I. INTRODUCTION

An alternative to conventional alloys are metal matrix composites (MMC’s), which have a high specific modulus, good wear resistance and a tailorable coefficient of thermal expansion. A major drawback to these MMC’s is high cost. 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. Like their polymer matrix counterparts, these composites are often produced by combining two pre-existing constituents (e.g. a metal and a ceramic fibre). Processes commonly used include powder metallurgy, diffusion bonding, liquid phase sintering, and squeeze-infiltration and stir casting.

[Schwartz 1984] gives a working definition of composite materials as: “A composite material is a material’s system composed of a mixture or combination of two or more macro-constituents differing in form and/or material Composition and that they are essentially insoluble in each other”.The increase in strength of composites due to smaller reinforcement particle size has been reported by many authors. Statistically, larger flaws and more defects are more likely to exist in larger particles and, therefore, will deteriorate the strength of composites when compared with the composites containing smaller particles.

The smaller grain size in the composites containing smaller reinforcement particles can also contribute to the increase in strength. The mechanical properties such as hardness, impact and strength is increase when grit size of reinforcement of SiC particle increase.

II. CHEMICAL COMPOSITION

Metal matrix composites (Al+4%Cu+5%SiC)

Literature Review:

Singla et al., [2009] in his study a modest attempt has been made to develop aluminium based silicon carbide particulate MMCs with an objective to develop a conventional low cost method of producing MMCs and to obtain homogenous dispersion of ceramic material.

Pradeep et al., [2011] in this paper it was aimed to present the research findings of Al6063–SiC particulate metal matrix composites prepared by liquid metallurgy route (stir casting technique). The amount of reinforcement were varied from 0 to 9 wt. %. The SiC particulates were dispersed the in steps of 3 into the Al6063 alloy.***Aqida et al., [2004]*** Porosity in cast metal matrix composite (MMC) has been known as a defect affecting the enhancement of strength, particularly in particle-reinforced MMC. ***Jit N. et al., [2011]*** studied on (A384.1)1-x[(SiC)]x composite containing 0.0%, 0.10%, 0.15% and 0.20% SiC with particle size 0.220 µm were fabricated by modified stir casting technique. The addition of SiC in A.384.1, Al Alloy was found to increase mechanical properties such as hardness, proof stress and ultimate tensile strength with respect to unreinforced Al Alloy.

Behera R. et al., [2011] this paper aims to investigate the solidification behaviour and the forgeability of Aluminium alloy (LM6)-SiC particles composites at different section of three-stepped composite castings.***Kumar G. et al., (2011)*** Aluminium Metal Matrix Composites (MMCs) sought over other conventional materials in the field of aerospace, automotive and marine applications owing to their excellent improved properties. ***Nadaliman G., et al., (2007)*** the investigation studies the effect of pouring temperature and rates the mechanical properties of Aluminium casting. The castings were produced at different pouring temperature and speeds. The speed range is 2.0 cm/sec to 16.0 cm/sec while the temperature range for investigation is 680°C to 750°C.

In a stir casting process, the reinforcing phases (usually in powder form) are distributed into molten magnesium by mechanical stirring. Stir casting of metal matrix composites was initiated in **1968, when *S. Ray*** *[1969]* introduced alumina particles into aluminium melt by stirring molten aluminium alloys containing the ceramic powders. . ***Lloyd (1999)*** reports that vortex mixing technique for the preparation of ceramic particle dispersed aluminium matrix composites was originally developed by ***Surappa & Rohatgi (1981)*** at the Indian Institute of Science.

Reinforcement

The most common reinforcements are silicon carbide (SiC), alumina (Al_2O_3), and graphite. Other carbides such as TiC and B_4C as well as aluminium nitride (AlN) can be used. SiC is of interest because of its relatively high modulus, low density, and its availability in different reinforcement shapes and sizes.

Matrix

According to the aluminium association system, the matrix materials generally employed include pure Al (AA 1000), AlCu (AA 2000), AlMg (AA 5000), AlMgSi (AA 6000), AlZn (AA 7000), and AlLi (AA 8000) *Terry B. [1990]*.

Al-MMC's:

Aluminium alloys are extensively used in aerospace and automobile industries due to their low density and good mechanical properties, better corrosion resistance and wear, low thermal coefficient of expansion as compared to conventional metals and alloys.

One of the major challenge when processing on 4% Cu + 5% SiC with balanced Aluminium Metal Matrix Composites are achieving a homogeneous distribution of reinforcement in the matrix as it has a strong impact on the properties and the quality of the material. Among discontinuous metal matrix composites, stir casting is generally accepted as a particularly promising route, currently practiced commercially. Its advantages lie in its simplicity, flexibility and applicability to large quantity production. It is also attractive because, in principle, it allows a conventional metal processing route to be used, and hence minimizes the final cost of the product.

Experimentation

The effects of input (independent) variables as pouring temperatures (700˚C, 725˚C and 750˚C) and material type's (varying with grit size of SiC particles) on output (dependent) variables as hardness, impact strength and ultimate tensile strength, statistically analysis were performed by using SPSS 17.0.

In a stir casting process, the reinforcing phases (usually in powder form) are distributed into molten magnesium by mechanical stirring. Stir casting of metal matrix composites was initiated in 1968, when *S. Ray [1969]* introduced alumina particles into aluminium melt by stirring molten aluminium alloys containing the ceramic powders. This involves incorporation of ceramic particulate into liquid aluminium melt and allowing the mixture to solidify. Here, the crucial thing is to create good wetting between the particulate reinforcement and the liquid aluminium alloy melt.

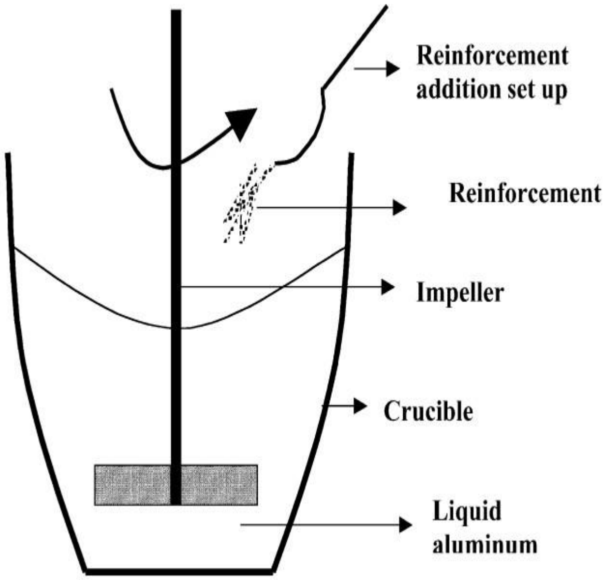


Fig .1 Schematic Diagram of Stir Casting

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.

In preparing metal matrix composites by the stir casting method, there are several factors that need considerable attention, including the difficulty of achieving a uniform distribution of the reinforcement material, wettability between the two main substances, porosity in the cast metal matrix composites, and chemical reactions between the reinforcement material and the matrix alloy.

Methodology

First of all, the balanced aluminium with 4% Cu was melted in a graphite crucible in an open hearth furnace. After automatic mechanical mixing is carried out for about 3 minutes at normal stirring rate 600 rpm and then poured into sand mould with pouring temperature 700˚C, 725˚C and 750˚C respectively.

After that the balanced Al+4%Cu and 5% SiC (400-grit) were took. For this, the base metal Al+4%Cu were preheated at 450˚C for 3 hours in a electrical resistance muffle furnace before and mixing the SiC particles were preheated at 1100˚C for 2 hours in a electrical resistance muffle furnace to remove the moisture and surface oxidized.

III. OBSERVATION OF PROCESS PARAMETERS

BHN Test

Hardness testing involves a small indenter being forced into the surface of the material being tested under controlled conditions of load and rate of application. The depth or size of the resulting indentation is measured, which in turn is related to a hardness number The Brinell hardness test method consists of indenting the test material with a 5 mm diameter ball subjected to a load of 250 kg. The full load is applied for 1 minute. The diameter of the indentation left in the test material is measured with a low powered microscope. The Brinell harness number is calculated by dividing the load applied by the surface area of the indentation.

The corresponding values of hardness (BHN) were calculated from the standard formula.

$$\mathrm{BHN} = \frac{2P}{\pi D(D - \sqrt{(D^2 - d^2)})}$$

Where,

P = Applied force (kgf),
D = Diameter of indenter (mm)
d = Diameter of indentation (mm)

Impact Strength

In the Izod impact test, the test piece is a cantilever, clamped upright in an anvil, with a V-notch at the level of the top of the clamp. The test piece is hit by a striker carried on a pendulum which is allowed to fall freely from a fixed height. After fracturing the test piece, the height to which the pendulum rises is recorded by a slave friction pointer mounted on the dial, from which the absorbed energy amount is read.

Energy required to break the specimen

(E) = [W × R (Cos β — Cos α) × g] Joule

Where,

W= Weight of hammer in K α =Angle fall in degree.
R=Distances of C.G hammer in β =Angle rise in degree

Tensile Strength

Tensile strength is defined as a stress, which is measured as force per unit area. The ultimate tensile test is the most widely used test to determine the mechanical properties of materials. In this test, a piece of material is pulled until it fractures.

During the test, the specimen elongation and applied load is measured. Strain and stress are calculated from these values, and are used to construct a stress-strain curve. The testing involves taking a sample with a fixed cross-section area, and then pulling it with a controlled, gradually increasing force until the sample changes shape or breaks. The maximum capacity of Determine the Tensile Strength ─

a. Maximum load from the table

b. Tensile strength = Maximum Load / Original Area (N/mm^2)

Problem formulation & Design of Experiment

In the present study a modest attempt has been made to develop aluminium based silicon carbide particulate Metal Matrix Composites with an objective to develop a conventional low cost method of producing MMCs and to obtain homogenous dispersion of ceramic material.

Process Parameters

1. Independent parameters (input) are ─

a. Pouring Temperatures:

- 700˚C,725˚C,750˚C

b. Material Types:

- Balanced Al + 4% Cu,Balanced Al + 4% Cu + 5% SiC (400-grit),Balanced Al + 4% Cu + 5% SiC (600-grit),Balanced Al + 4% Cu + 5% SiC (800-grit)

c. Pouring time constant

d. Pouring rate constant at 2.5 cm/s

2. Dependent parameters (out comes) are ─

Hardness (BHN),Impact strength (Izod),Ultimate tensile strength(UTS)

Fig.2Experimental Set Up

IV. RESULTS

It has been observed that melting and pouring conditions have directly or indirectly effect on mechanical properties of cast materials as hardness, percentage elongation, percentage reduction in diameter, toughness and so on.

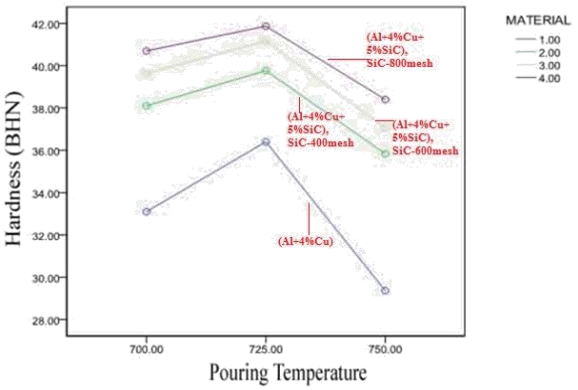
The increase in strength of composites due to smaller reinforcement particle size has been reported by many authors. Statistically, larger flaws and more defects are more likely to exist in larger particles and, therefore, will deteriorate the strength of composites when compared with the composites containing smaller particles. The smaller grain size in the composites containing smaller reinforcement particles can also contribute to the increase in strength. The mechanical properties such as hardness, impact and strength is increase when grit size of reinforcement of SiC particle increase

The effects of input (independent) variables as pouring temperatures (700˚C, 725˚C and 750˚C) and material type's (varying with grit size of SiC particles) on output (dependent) variables as hardness, impact strength and ultimate tensile strength, statistically analysis were performed by using SPSS 17.0. It is clear from below table 4.1, which is extracted by analyzing data as shown in Appendix-I by Multivariable Analysis of Variance (MANOVA) using spss-17.0 software.

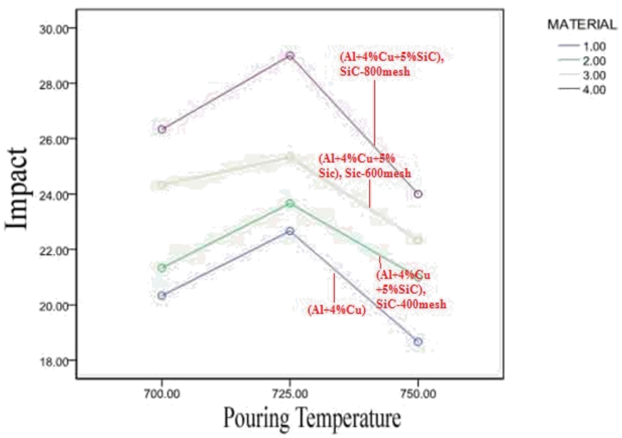
Sl.No.	Material Types	Pouring Temperatures	Hardness (BHN)	Impact Strength (Joule)	UTS (N/mm^2)
1	1	700	34.3	20	130
2	1	700	33	20	129
3	1	700	32	21	128
4	1	725	35.7	23	134
5	1	725	37	22	135
6	1	725	36.5	23	137
7	1	750	27.4	19	125
8	1	750	31.8	18	123
9	1	750	28.9	19	122
10	2	700	38.3	21	147
11	2	700	37.4	22	146
12	2	700	38.6	21	145
13	2	725	40.2	24	153
1	2	725	39.2	24	154

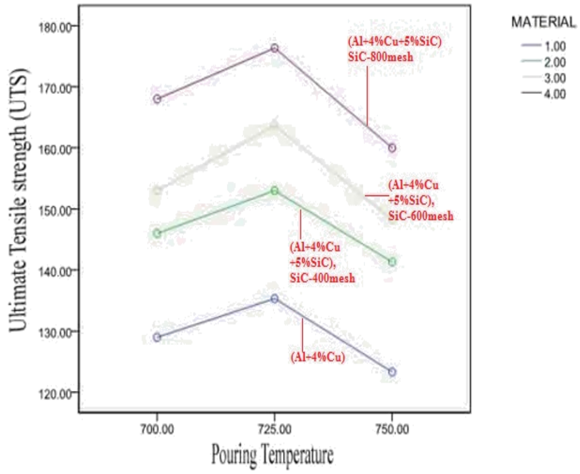
4					
15	2	725	39.9	23	152
16	2	750	36.8	20	141
17	2	750	35.9	21	143
18	2	750	34.8	22	140

Effect of pouring temp. on BHN



The impact is increases initially for all composites with pouring temperature at 700°C. It latter attained its maximum value of all material types at pouring temperature 725°C. After that it falls sharply at the pouring temperature 750°C. From the figure, it can be observed that the impact of the composite material-2 (Al + 4% Cu + 5% SiC) is higher than the base matrix material-1 (Al + 4% Cu). Thereafter, the increasing impact with increasing the grit sizes of SiC particles. The maximum impact attained when the reinforcement was 800-grit at pouring temperature 725° C.





Variation in the UTS with Different Pouring Temperature

V. CONCLUSION

The significant conclusions of the studies carried out on balanced (Al + 4% Cu + 5% SiC) composites are as follows.

- Cast balanced (Al + 4% Cu + 5% SiC) composites were prepared successfully using liquid metallurgy techniques (stir rout).
- Hardness of the composites found increased with increased grit size of SiC.
- Impact (Izod) of the composites found increased with increased grit size of SiC.
- The tensile strength of the composites found increased with increased grit size of SiC.

- The pouring temperature at 725°C which gave the best optimum value of hardness, impact strength and ultimate tensile strength. When the pouring rate kept constant at 2.5 cm/s for all composites.

VI. SCOPE FOR FUTURE WORK

- We only consider three grit sizes (400, 600, and 800); chances may be that with further reduction in grit size mechanical properties of composite may decline.
- We added only 5% SiC, however with further addition of SiC particles mechanical properties may improved as investigated by *Singla M. (2009)* for Al and SiC casting.
- Wear resistance may be the parameter which defines the hardness and abrasive property of composite is the scope for future work.
- Experiments are performed on open hearth furnace chances of inclusion and blow holes may measure.

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