A review on stir casting and mechanical behaviour of Al356- Al2O3 for varying percentage of reinforce element.

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ABSTRACT

Aluminium alloys are broadly used in aerospace and automobile industries due to their low density and better mechanical properties, better corrosion resistance and wear, low thermal coefficient of expansion as compared to conventional metals and alloys. One of aluminium alloys is Al 356 alloy found application in High strength airframe and space frame structural parts, machine parts, truck chassis parts, high velocity blowers and impellers. Al 356/Al2O3 composite is a metal matrix composite (MMC) that can be manufactured using stir casting method. With reinforcement of Al2O3 in matrix of alloy the properties of Al356 alloy can be greatly enhanced. A comparison of the mechanical properties and the microstructure of Al 356 alloy with Al356/Al2O3 metal matrix composite containing different percentage by weight of reinforcement were done in present work. The review paper present with the aim keeping in view the gap in the study, which acts as the base of further research.

Keywords*: Stir Casting, Al356/Al2O3, Metal Matrix Composite (MMC).*

I. INTRODUCTION

Industrial technology is growing at very rapid rate and there is increasing need of materials. Conventional monolithic materials have limitations in achieving good combination of strength, stiffness, toughness and density. To overcome these shortcomings and to meet the always increasing demand of modern day technology, composites are most promising materials. Composite materials are those formed by combining two or more materials on a macroscopic scale to form useful third material [3]. Their applications in several demanding fields like automobile, aerospace, defence, sports, electronics, bio-medical and other industrial purposes are becoming essential for the last several decades. Various manufacturing processes e.g. stir casting, ultra-sonic assisted casting, compo-casting, powder metallurgy, liquid infiltration are being utilized for the production of the aluminium matrix composites. These composite materials possess improved physical and mechanical properties e.g. lower density, low coefficient of thermal expansion, good corrosion resistance, high tensile strength, high stiffness, high hardness and wear resistance [1]. A356 alloys naturally have an elastic modulus of about70Gpa which is about one-third of the elastic modulus of the majority kinds of steel and steel alloys[4]. Some automotive companies using MMC for disc brakes also. Honda Company used AMMC for cylinder liners in some of their engines like F20C, F22C and H22A [5]. One of aluminium alloys is Al 356 alloy found application in automobile, aerospace, defence, sports, electronics, bio-medical and other engineering purposes.

II. PROCESSING OF AMC:

Primary process for manufacturing of AMC's at industrial scale can be classified into two main groups.
1) Liquid state processes [3],
a) Stir casting b) Infiltration process c) Reactive processing d) Spray deposition
2) Solid state processes:
a) PM processing b) Diffusion bonding c) Physical vapour deposition.

Table no 1 show the Comparative evaluations of the different techniques used for MMCs fabrication. Among the numbers of fabrication techniques existing for metal matrix composites, stir casting technique is usually accepted as a mainly promising way, at present practiced commercially. Its advantages are simplicity, flexibility and applicability to large quantity production. It allows a conventional composites fabrication route to be used, and therefore minimizes the final cost of the product. Metal matrix composites are usually fabricated by Liquid Metallurgy Route or stir casting technique[10].

Method	Range of shape and size	Metal yield	Range of volume fraction	Damage to reinforcement	Cost
Liquid Metallurgy (Stir casting)	Wide range of shapes; up to 500 kg	Very high, >90%	Up to 0.3	No damage	Least expensive
Squeeze casting	Limited to perform shape	low	Up to 0.45	Severe damage	Moderately expensive
Powder metallurgy	Wide range; restricted size	high		Reinforcement fracture	expensive
Spray casting	Limited shape; large size	medium	0.3-0.7		expensive
Lanxide technique	Limited by pre-form shape; restricted size	-	-	-	expensive

Table 1: Comparative evaluations of the different techniques used for MMCs fabrication [10].

III. STIR CASTING:

Stir casting of metal matrix composites was initiated in 1968, when S. Ray introduced alumina particles into an aluminium melt by stirring molten aluminium alloys containing the ceramic powders [6].

Stir casting is a liquid state method of composite materials fabrication, in which a dispersed phase (ceramic particles, short fibres) is mixed with a molten matrix metal by means of mechanical stirring. The resultant molten alloy, with ceramic particles, can then be used for die casting, permanent mould casting, or sand casting. In preparing metal matrix composites by stir casting method some of the factors that need considerable attention are as follows [3].

1. To achieve uniform distribution of the reinforcement material.
2. To achieve wet ability between the two main substances.
3. To minimize porosity in the cast metal matrix composite.

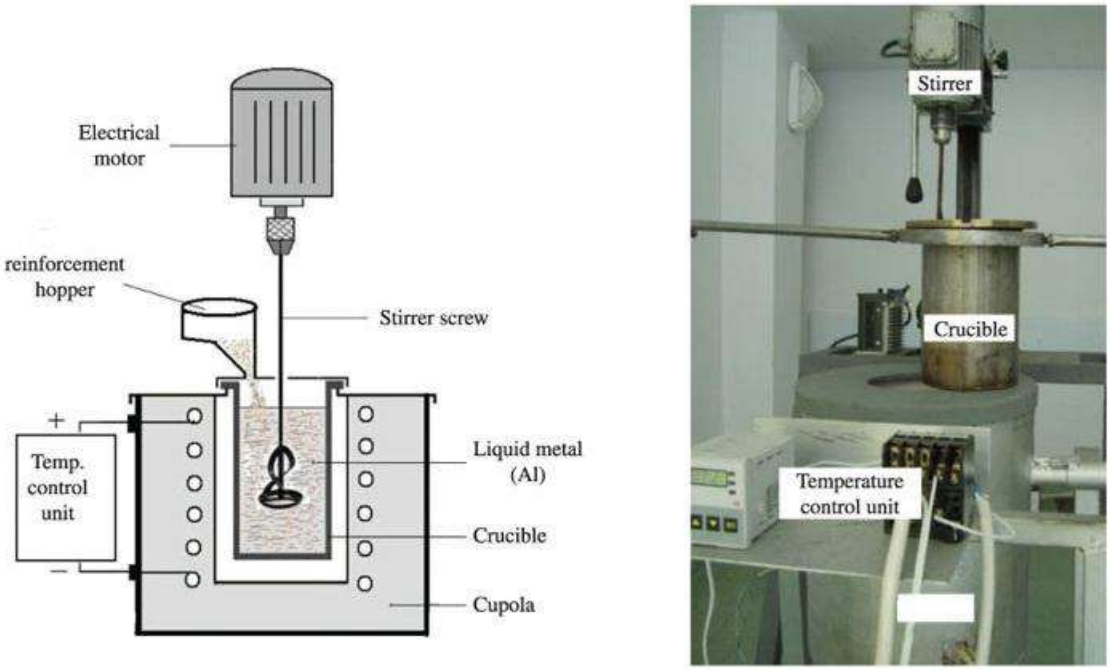

Figure-1: Stir casting furnace setup[10].

IV. PROCESS PARAMETERS:

For manufacturing of composite material by stir casting knowledge of its operating parameter are very essential. As there is various process parameters if they properly controlled can lead to the improved characteristic in composite material. The important process parameters are [3].

1. Stirrer Design.
2. Stirrer Speed.
3. Stirring Temperature.
4. Stirring Time.
5. Preheat temperature of reinforcement.
6. Preheat temperature of mould.
7. Reinforcement feed rate.
8. Stirrer Blades.

1) Stirrer Design:
It is very important parameter in stir casting process which is required for vortex formation. The blade angle and number of blades decides the flow pattern of the liquid metal. The stirrer is immersed till two third depth of molten metal. All these are required for uniform distribution of reinforcement in liquid metal, perfect interface bonding and to avoid clustering.

2) Stirrer Speed:
Stirring speed is an important parameter to promote binding between matrix and reinforcement i.e. wettability. Stirring speed decides formation of vortex which is responsible for dispersion of particulates in liquid metal. In our project stirring speed is 300 rpm.

3) Stirring temperature:
Aluminium melts around 650°C, at this temperature semisolid stage of melt is present. Particle distribution depends on change in viscosity. The viscosity of matrix is mainly influenced by the processing temperature. The viscosity of liquid is decreased by increasing processing temperature with increasing holding time for stirring which also promote binding between matrix and reinforcement.Good wettability is obtained by keeping temperature at 800°C.

4) Stirring Time:
As stirring promote uniform distribution of reinforcement partials and interface bond between matrix and reinforcement, stirring time plays a vital role in stir casting method. Less stirring leads to non-uniform distribution of particles and excess stirring forms clustering of particles at some places. Stirring time is 5 minutes in our case.

5) Preheat temperature of reinforcement:
Casting process of AMC's is difficult due to very low wettability of alumina particles and agglomeration phenomenon which results in non-uniform distribution and poor mechanical properties. Reinforcement is heated to 500°C for 40 minutes. It removes moisture as well as gases present in reinforcement.

6) Preheat temperature of mould:
Porosity is the major problem in casting. In order to avoid porosity preheating of mould is good solution. It helps in removing the entrapped gases from the slurry to go into the mould. It also enhances the mechanical properties of the cast AMC. Mould is heated to 500°C for one hour.

7) Reinforcement feed rate:
Non-uniform feed rate promotes clustering of particles at some places which causes the porosity defect and inclusion defect, so to have a good quality of casting the feed rate of powder particles must be uniform. The flow rate of reinforcements measured is 0.5 gram per second.

8) Stirrer Blades:
The blade angle and number of blades are prominent factor which decides the flow pattern of the liquid metal at the time of stirring. The blade with angle 45° & 60° will give the uniform distribution. The number of blade should be 3-4. Blade should be 20mm above the bottom of the crucible. Blade pattern drastically affect the flow pattern. Stirrer blades play an important role in creating vortex of the molten matrix. This vortex formation ensures boding characteristic of matrix and reinforcement[3].

Figure 2 : Stirrer Blades[8].

V. Materials Chemical Composition & properties:

Table no 2 shows the chemical composition of Al356&Al359. Al 356 aluminium alloy which acts as matrix was used in pure form. MMCs in general consist of at least two components, namely matrix and the reinforcement. The matrix is usually an alloy, and the reinforcement is usually a ceramic.

Sr.no.	Element	Wt% Al356	Wt% Al359
1	Cu	0.20	0.2
2	Mg	0.25-0.45	0.5-0.7
3	Mn	0.10	0.10
4	Si	6.5 - 7.5	8.5-9.5
5	Fe	0.20	0.20
6	Zn	0.10	0.10
7	Ti	0.20	0.20
8	Al	Balance	Remaining

Table 2: Comparative evaluations of Chemical Composition of Al 356&Al 359[2,12].

1. Table No.3 shows mechanical properties of aluminium Al356.

Property	Tensile Strength (MPa)	Hardness (BHN)	Toughness (Joule)	Fatigue Strength (1×10^7 MPa)	Endurance Limit	Modulus of Elasticity	Shear Strength
Al 356	230	75	6	120	56	71	120

Table 3: Mechanical Properties Al356 Alloy [2].

2. Table No.4 shows thermal properties of Al 356.

Property	Latent Heat of Fusion	Specific Heat	Liquidus Temperature	Solidus Temperature
Value for Al 356	389kJ/kg	963 J/kg	615ºC	555ºC

Table 4: Thermal Properties Al356 Alloy[2].

VII. Fabrication of Al-a356Alloy With Al2O3

Stir casting method was used to prepare MMC. Amount of aluminium (Al 356) alloy and alumina (Al2O3) particles in desired quantity to produce composites having 5, 10, 15, and 20 volume percent alumina were evaluated using charge calculations. Reinforcement material (alumina) was first preheated at a temperature of 2500C for 5 minutes to improve wet ability with matrix forming alloy. The Furnace temperature was set to about maximum 700-750oC in order to minimize the chemical reaction between the substances. Melting of A356 ingots were performed at a temperature of 750oc and the liquid alloy was then allowed to cool in the furnace to a semi solid state at a temperature of about 6000C. Reinforcement particles (pre-heated) were added to the molten alloy and stirring performed speed of 650 rpm for 10 minutes to reach mushy state. The composite slurry was then superheated to 7200C and a second stirring performed to ensure uniform distribution of alumina particles using a mechanical stirrer was done. Four samples of composite with different percentage of alumina particles were cast into prepared sand moulds [2].

Figure 3: Raw material :- (A)Al2O3 Granules[1] and (B) Al-a356 Granules[1].

VIII. Results and Discussion

1. Tensile test

Test specimens were prepared according to (ASTM E8-04) standards. The heat treated and aged specimen was loaded in Universal Testing Machine until the failure of the specimen occurs. Tests were conducted on composites of different combinations of reinforcing materials and ultimate tensile strength was measured. Simultaneous readings of load and elongation are taken at uniform intervals of load. Uniaxial tensile test is conducted on the fabricated specimen to obtain information regarding the behaviour of a given material under gradually increasing stress strain conditions [7].

Figure 5: Universal Testing Machine [1]

2. Hardness test

Hardness test was carried out using Brinell hardness tester. Hanumanthe Gowda and P. Rajendra Prasad had studied the specimens of 20 mm thickness were machined from as-cast, single aged and double aged with strain and without strain of various compositions mentioned. Steel ball of 2.5 mm diameter and 60 Kgf load was used. The test was carried out at three different locations and the average value was taken as the hardness of the composite [7]. There are two aluminium composite sample, one with 5% reinforcement and other with 10% reinforcement of alumina with aluminium alloy a356 alloy matrix[1].

Figure 6: Brinell Hardness Testing Machine[1]

IX. Conclusion

By reviewing the literature on the aluminium metal matrix reinforced materials, Gyanendra Singh, Akash Singh was observed that reinforcement of the variety of ceramic particulate have been studied in details. Even the tribological and wear properties with various types of reinforcement material, e. g. Al2O3, SiC, TiB2, graphite have been discussed in a review article. The interest in natural mineral reinforced composite materials is rapidly growing both in terms of their industrial applications and fundamental research. They are renewable, cheap, completely or partially recyclable, and biodegradable. Natural minerals like garnet, zircon, rutile, sillimanite etc. can be used as the reinforcement of composites. Their availability, renewability, low density, and price as well as satisfactory mechanical properties make them an attractive ecological alternative to others ceramics used for the manufacturing of composites . The literature review reveals that comparatively less work has been done on the reinforcement of Al matrix with minerals. Moreover, in the published articles, the tribological studies of the mineral reinforced composites with the variation of particles size and amount of reinforcement have not been studied in a systematic manner. The wear characteristics at high temperatures and also under the high applied loads need to be explored for high temperature structural applications. Limited work has been done on rutile reinforced aluminium matrix composites [1].

To bridge this gap it is planned to study the wear properties of Al alloy reinforced with rutile mineral in various concentrations 5%, 10%, 15% and 20wt.% and with the variation of different particle sizes with fine sized particles (50-75μm) and coarse sized particles (106-125μm). Tribological behaviour of the samples has been studied under different loading conditions varying from 9.8N to 49.0N and under various temperatures ranging from 50oC to 300oC. Micro structural analysis of the prepared samples and the worn surfaces and debris has helped in determining the type of wear mechanism responsible for the loss of material during the dry sliding[1].

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