# "Characterization of Aluminum Based Metal Matrix Composites by Stir Casting Technique"

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## ABSTRACT

*Combining high specific strength with good corrosion resistance, metal matrix composites (MMCs) are materials that are attractive for a large range of engineering applications. The Al based Metal matrix composites (MMC) are an important class of high performance advanced materials with potential engineering applications especially in the area of aerospace, defense and automotive industries. There are several routes available for the fabrication of metal matrix composites such as stir casting, liquid metal infiltration, spray deposition, in silicon carbide powder metallurgy and diffusion bonding. Among these stir casting is the simplest and economical processing route of Al based metal matrix composites In this paper, the relatively low cost stir casting technique is evaluated for use in the production of aluminum alloy MMC's.My present investigation is to fabricate aluminum mono and hybrid metal matrix composites by stir casting technique by introducing different types of reinforcement materials. And also the physical, mechanical characterization of these composite materials and also study of their use in many industrial area.*

**Keyword**: - *aluminum A356, Fly Ash, Silicon Carbide, Stir Casting etc.…*

## 1. INTRODUCTION

The major classifications of engineering materials are metals, polymers, composites and ceramics. The advancement of composites is one of the major innovations in the field of science and engineering. Composites based on metals and their alloys, called as metal matrix composites (MMC). With the increasing demand of general engineering applications in defense, aerospace and general engineering applications, metal matrix composites have become one of the most significant superior materials. MMCs have an edge over polymer matrix composites because of their capability to withstand high temperatures, better transverse mechanical properties, and capability to survive high temperatures, and superior electrical and thermal conductivities and resistance to moisture.

The low density and high specific mechanical properties of aluminum metal matrix composites (MMC) make these alloys one of the most interesting material alternatives for the manufacture of light weight parts for many types of commercial applications. These alloys have wear resistance and strength equal to cast iron, 67% lower density and three times the thermal conductivity. These makes aluminum MMC alloys ideal materials for the manufacture of lightweight automotive and other commercial parts. That is why we have chosen AL A356 as matrix material for our examination.

### 1.1.1 Properties of cast Aluminum A356 alloy

1) Low melting point
2) Good wear resistance
3) Good fluidity
4) Good machinability(in copper containing alloys)
5) Decreased corrosion resistance(in copper containing alloys)
6) High strength
7) High-treatable

### 1.1.2 Applications of cast Aluminum A356 alloy

1) Automotive wheels, axle, and differential housing
2) Automotive cylinder blocks and head, and intake manifold
3) Aircraft fittings, Compressor and pump bodies, Impellers, wave guides
4) Automotive cylinder blocks and head, and intake manifolds

5) Electronic cases
6) Missile bodies, fins, and other structural parts

### 1.2 METAL MATRIX COMPOSITES

A composite material is a material made of two or more physically and/or chemically separate phases. The composite usually has greater characteristics than each of the individual components. Usually the reinforcing component is distributed in the continuous or matrix component. Composites based on the metals and alloy is termed a metal-matrix composite (MMC). In MMCs, the reinforcement usually takes the appearance of short fibers, or continuous fibers, particles. The matrix holds the reinforcement to form the preferred shape and size as the reinforcement improves the mechanical properties of the matrix. The main constitutes of MMC are the matrix and reinforcements.

The interface between reinforcements and matrix plays very important role to find the properties of the composites Interface is the area between the matrix and the reinforcement. It acts a dynamic role in determining the properties of the composite material. The types of interface bonding are physical, mechanical and chemical in nature. Metal composite materials have found application in many areas of daily life for quite some time. Often it is not realized that the application makes use of composite materials. Materials like cast iron with graphite or steel with high carbide content, as well as tungsten carbides, consisting of carbides and metallic binders, also belong to this group of composite materials.

## 2. ALUMINUM A356

Aluminum alloy A356.0 is a 7% Si, 0.3% Mg alloy with 0.2 Fe (max) and 0.10 Zn (max). The “A” in front of an alloy designation denotes a higher purity version of the chemical composition. The alloys have very well Casting and machining characteristics. They are used in the heat-treated condition. Corrosion resistance is excellent and it has very good weld ability characteristics

### 2.1 REINFORCEMENT PARTICLES

The reinforcements are the next phase materials which are added to the matrix alloys. It usually improves strength, stiffness, creep and wear resistance properties of the composites. The option of reinforcements always depends on the end property requirements of composite or part to be manufacture. Various types of reinforcements used are Sic, Al2O3, fly ash, graphite, rice husk etc. Reinforcements for metal matrix composites have a manifold demand profile, which is determined by production and processing and by the matrix system of the composite material. The following demands are generally applicable for:-

Low density
Mechanical compatibility (a thermal expansion coefficient which is low but adapted to the matrix)
Chemical compatibility
Thermal stability
High Young’s modulus
High compression and tensile strength
Good process ability
Economic efficiency

### 2.2 Silicon Carbide

Silicon carbide is a superb abrasive and has been produced and made into grinding wheels and other abrasive products for over one hundred years. It is used in abrasives, refractories, ceramics, and in a number of high-performance applications.

### 2.3 Stir casting

Stir Casting is the method of stirring molten metal ‘s used for continuous stirring of particles into molten metal alloy to and instantly pour into the metal mould or sand mould then cooled and allow to solidify. Stir casting is suitable for manufacturing composites only with up to 30% volume fractions of reinforcement. A main problem with the stir casting process is the separation of reinforcing particles which is caused by the settling of the reinforcement particles during the melting and casting processes. The distribution of the particles in the molten matrix depends on the stirring parameters, geometry of the mechanical stirrer, melting temperature, placement of the mechanical stirrer in the melt, and the characteristics of the particles added. In this process, a strong bond between the matrix and reinforcement is achieved by using high processing temperatures, and often, alloying the matrix with an element which can interact with the reinforcement to produce a new phase which improves wetting between the matrix and the reinforcement material.

### 2.4 Objective

Main objective of this project was to synthesize aluminum based mono and hybrid metal matrix composites using SiC, Fly Ash, and (SiC+ Fly Ash) particles as reinforcements using stir casting process and study the effect of different weight percentage on properties of Al based mono and hybrid metal matrix composites.

**Experiments will performed to fabricate MMC**

| A 356 | Sic (wt. %) | Fly Ash (wt %) |
|---|---|---|
| A 356 | 18 | 0 |
| A 356 | 22 | 0 |
| A 356 | 0 | 18 |
| A 356 | 0 | 22 |
| A 356 | 9 | 9 |
| A 356 | 11 | 11 |

## 3. EXPERIMENTAL SETUP

### 3.1 Materials used for experiment

1) Aluminum A356 (Matrix material)
2) Fly-ash (reinforcement material)
3) Silicon carbide (reinforcement material)
4) Magnesium (wetting agent)
5) Foundry flux for molten metal
6) Degasser

### 3.2 List of equipment's used for the experiment

7) Power Hacksaw
8) Weighing Machine
9) Electric Resistance Furnace
10) Crucible (Clay-Graphite)
11) Lifting Tong
12) Pit furnace
13) Lathe Machine
14) Crucible

## 3.3 Properties of materials

| | REINFORCEMENT | | MATRIX ALLOY |
|---|---|---|---|
| | SiC | Fly-ash | A356 |
| Melting point | 2700 | | 557-613 |
| Density (g/cc) | 3.2 | 2.09 | 2.67 |
| Hardness | 2800 | | - |
| Thermal conductivity | 120 | 0.062-035 | 151 |
| Coefficient of thermal Expansion | 4.0 | | 21.5 |
| Specific heat capacity | 750 | | 21.5 |
| Color | Black | | |

**3.4 Magnesium (wetting agent)**

Wettability can be defined as the ability of a liquid to extend on a solid surface, and represents the extent of intimate contact between a liquid and a solid. The problem of a wetting of the ceramic particles by molten metal is one of surface chemistry and surface tension. The chemistry of the particle surface includes any contamination and oxidation must be considered. The composites manufactured by liquid metallurgy techniques show brilliant bonding between the ceramic and the matrix when reactive elements, such as Mg, Ca, Ti, or Zr are added to induce wettability. Usually 1 to 2 wt. % of Mg is added to get optimum wettability

**3.5 Foundry flux for molten aluminum alloy**
**Degassing flux**
Hydrogen, found in the foundry primarily due to the decomposition of water vapour, is soluble in liquid aluminum alloys, but much less so in the solid phase. When aluminum Solidifies, the excess dissolved hydrogen comes out of solution and forms bubbles, from pinhole size to much larger sizes. Metal which has not been degassed before

casting is Susceptible to this type of defect. The hexa-chloro-ethane was used as degassing flux for the molten aluminum. Degassing flux removes hydrogen gas, oxides and other impurities from the melt.

Figure 3.1: Pit Furnace

Figure 3.2: Safety Frame

Figure 3.3: Fly Ash

Figure 3.3: aluminum A536

## 4. ANALYSIS

### 4.1 HARDNESS MEASUREMENT

The below tables show that incorporation of fly ash and silicon carbide particles in Aluminum matrix causes reasonable increase in hardness. The strengthening of the composite can be due to dispersion strengthening as well as due to particle reinforcement. Thus, fly ash and silicon carbide as filler in Al casting reduces cost, decreases density and increase hardness which are needed in various industries like automotive etc.

| COMPOSITE SAMPLES | HARDNESS(BHN) |
|---|---|
| AL-18% Fly Ash | 37.5 |
| AL-22% Fly Ash | 85.5 |

**Table 4.1: 18% And 22% Fly Ash**

| COMPOSITE SAMPLES | HARDNESS(BHN) |
|---|---|
| AL-18% Sic | 83.5 |
| AL-22% Sic | 83.66 |

**Table 4.2: 18% And 22% Sic**

| COMPOSITE SAMPLES | HARDNESS(BHN) |
|---|---|
| AL-18%(FLY ASH+ Sic) | 96.66 |
| AL-22%(FLY ASH+ Sic) | 94.83 |

**Table 4.3: 18% And 22% (Fly Ash+ Sic)**

### 4.2 POROSITY ANALYSIS

The density measurements were carried out to find out the porosity of the produced samples fabricated by stir casting process. The porosity was achieved by the experimental densities of each volume percent Sic, Fly Ash and (Sic + Fly Ash) reinforced composite. The experimental Densities of the samples were evaluated by weighing the each composite sample.

| Metal Matrix Composite | Theoretical Density (g/cm3) | Experimental Density (g/cm3) |
|---|---|---|
| A356 | 2.685 | 2.4 |
| A356 + 18% Sic | 2.7622 | 2.469 |
| A356 + 22% Sic | 2.763 | 2.623 |
| A356 + 18% Fly Ash | 1.9 | 2.480 |
| A356 + 22% Fly Ash | 1.9 | 2.478 |
| A356 + 18% (Sic +Fly Ash) | 2.568 | 2.48 |
| A356 + 22% (Sic +Fly Ash) | 2.74 | 2.45 |

**Table 5.4: Porosity Properties**

### 4.3 TENSILE STRENGTH ANALYSIS

Strength is the maximum stress that a matter can tolerate under external forces without Destruction. For tensile testing of A356/ Sic, A356/ Fly Ash and A356/ Sic/ Fly Ash composite Material, one samples for each percentage of reinforcement have been prepared as per specification which is shown in Figure. According to ASTM E-8 Standard Specification, the diameters of the samples are prepared 12.5 mm and gauge length 60 mm. below table shows the values of tensile strength of samples. The surrounded hard particles in the matrix act as barrier that resists the plastic of composites when it is subjected to strain. This can explain the improvements of the tensile strength and hardness in composites. The presence of hard particle in a soft matrix increases the dislocation density.

**Table 5.5: Tensile Properties**

| Composite Sample | Tensile Strength (MPa) | Elongation (%) |
|---|---|---|
| A356 | 58.011 | 1.7 |
| A356 + 18% Sic | 71.04 | 0 |
| A356 + 22% Sic | 107.54 | 0 |
| A356 + 18% Fly Ash | 118.63 | 0 |
| A356 + 22% Fly Ash | 117.32 | 1.7 |
| A356 + 18% (Sic +Fly Ash) | 91.9 | 0 |
| A356 + 22% (Sic +Fly Ash) | 86.69 | 1.7 |

## 5. CONCLUSIONS

A356/Sic, A356/Fly Ash and A356/Sic/Fly Ash composites at different percentage of reinforcement (18%, 22%) were fabricated at 700º C via stir casting method. By studying the properties of A356, Sic and Fly Ash composites produced by stir casting, the following conclusions can be drawn:-

- Stir casting greatly refines the structure of A356 composites. By increasing the stir casting intensity leads to further grain refinement.
- The percentage porosity of electromagnetic stir casting samples for the reinforcement 18%, 22% are and respectively, very low percentage porosity observed by electromagnetic stirring.
- The tensile strength at 18% and 22% of sic reinforcement are 71.04 MPa and 107.54 and for fly ash reinforcement are 118.63 and 117.32 respectively.
- From the results, hardness of stir casting samples for 18% and 22% of reinforcement are ---- and --- respectively.
- From the study it is concluded that we can use fly ash for the production of composites and can turn industrial waste into industrial wealth. This can also solve the problem of storage and disposal of fly ash.

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