# Experimental Investigation and Analysis of Corrosion and Hardness using Aluminium Composites

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**Abstract -Composite materials play a vital role at the present modern industrial sectors. Preparations of metal-matrix composites are light weighted, high strength, extremely hard materials which were useful for every industrious area like aerospace, motor vehicle industries, mechanical tools manufacturing industries due to its advantageous properties like light in weight, flexibility, hardness, simplicity and easily applicable and so on. At the centre of research and growth of these sectors this paper emphasizes the production of metal-matrix Al-SiC composites using the stir-casting method and prepared sample of varying percentile compositions of SiCp –10% with aluminium. Presently these samples are tested under the hardness test, corrosion test and SEM analysis. Evaluation of the corrosion resistance of aluminum alloy matrix/ 10% silicon carbide reinforced composite in various media has been carried out. The result of the work lead to the following conclusions: the composite can be used in an environment containing sodium chloride since the corrosion rate falls within the recommended corrosion range of 1-200 mmpy for usefully resistant materials, The weight loss, the percentage weight loss, and the corrosion rate expressed in mmpy all agree with the physical appearance of the specimens after the exposure time of the test, and the monitored pH of the solution also agreed with the test results.**

**Keywords: Stir casting method, hardness test, corrosion test, micro structural analysis**

## I. INTRODUCTION

Metal matrix composites possess significantly improved properties including high strength, damping capacity, wear resistance and corrosion resistant compared to unreinforced alloys. There has been an increasing composite containing low density and low cost reinforcements. Aluminum alloys are quite attractive due to their low density, their capability to be strengthened by preparation, their good corrosion resistance, high thermal and electrical conductivity and their damping capacity.

## II. OBJECTIVE

From the review it was found there is wide opportunity to reduce the research gap in the field of metal matrix composites. Therefore, in this work attempt has been to fulfill the research gaps. The objective of this work is
1. To fabricate aluminum based metal matrix composite with different composition of silicon carbide using stir casting process.
2. To investigate various mechanical properties of specimen material by conducting various tests like hardness test.
3. To study the effect of silicon carbide reinforcement on mechanical properties.
4. To compare the mechanical properties of various compositions of silicon carbide.
5. To evaluate or investigate the corrosion behaviour of aluminium alloy metal matrix composite reinforced with silicon carbide in a environment which include sodium chloride solution.

## III. EQUIPMENTS USED

### *3.1. STIR CASTING SETUP*

A Self fabricated mechanical stirrer was used to perform stir casting. The equipment was fabricated by keeping the major factors as variable speed, temperature resistance, and load résistance. Portability and cost.

*MAJOR COMPONENTS:*

- DC Motor
- Speed controller (VARIAC)
- Stirrer blade

Fig 3.1 stir casting machine

Fig 3.1.1 stir casting container

*3.2 .HARDNESS TESTING MACHINE*

The hardness of the casted specimen was tested using Brinell Hardness Tester. The Brinell hardness is found by identifying the amount of indentation of the indenter ball in the material when a constant amount of load is applied. The result is given in HB or BHN unit.

Fig 3.2 Hardness testing machine

*SPECIFICATION:*

| Contents | Specification |
|---|---|
| Range | Upto 650 HBW |
| Ball size | 5mm,10mm |
| Load range | 750kg,1000kg,3000 kg |
| Uncertainty | ± 2% |

*3.3 SCANNING ELECTRON MICROSCOPE SPECIFICATION*

Fig 3.3 Scanning electron microscope

*3.4. CORROSION TESTING BY SALT SPRAY TEST*

The salt spray test is a standardized test method used to check corrosion resistance of coated samples. Salt spray test is an accelerated corrosion test that produces a corrosive attack to the coated samples in order to predict its suitability in use as a protective finish. The appearance of corrosion products (oxides) is evaluated after a period of time. Test duration depends on the corrosion resistance of the coating; the more corrosion resistant the coating is, the longer the period in testing without showing signs of corrosion. Salt spray testing is popular because it is cheap, quick, well standardized and reasonably repeatable. There is, however, only a weak correlation between the duration in salt spray test and the expected life of a coating (especially on hot dip galvanized steel where drying cycles are important for durability), since corrosion is a very complicated process and can be influenced by many external factors. Nevertheless, salt spray test is widely used in the industrial sector for the evaluation of corrosion resistance of finished surfaces or parts.


Fig 3.4 Salt spray chamber

## IV. EXPERIMENTAL METHODOLOGY

The processing of Aluminum Silicon carbide metal matrix composite involves various step by step processes. Each and every step was planned in the aspect of safety, accuracy and cost.

*4.1. EXPERIMENTAL PROCEDURE*

- PREPARATION OF ALUMINIUM METAL MOLT
- CLEANING OF THE METAL MOLT
- SILICON CARBIDE ADDING:
- AGITATING THE MOLT
- CASTING POURING

- COOLING THE CASTING
- REMOVAL OF RUNNER & RISER
- MACHINING PROCESS
- TESTING THE SPECIMEN

### *4.2. MATERIAL SELECTION*

LM 13 alloy is used for pulleys (sheaves), for pistons for all types of diesel and petrol engines, and for other engine parts operating at elevated temperatures. It has the advantage of good resistance to wear, good bearing properties and a low coefficient of thermal expansion.

*CHEMICAL COMPOSITION of LM13 ALUMINIUM GRADE*

| MATERIAL | % OF COMPOSITION |
|---|---|
| Copper | 0.7-1.5 |
| Magnesium | 0.8-1.5 |
| Iron | 1.0 max |
| Silicon | 10.0-13.0 |
| Manganese | 0.5 max |
| Nickel | 1.5 max |
| Zinc | 0.1 max |
| Lead | 0.1 max |
| Tin | 0.1 max |
| Titanium | 0.2 max |
| Aluminium | Remainder |

*MECHANICAL PROPERTIES:*

| **Properties** | **Sand cast** | **Chill cast** |
|---|---|---|
| 0.2% Proof Stress ($N/mm^2$) | 160-190 | 270-300 |
| Tensile Stress ($N/mm^2$) | 170-200 | 280-310 |
| Elongation (%) | 0.5 | 1 |
| Impact Resistance Izod (Nm) | - | 1.4 |
| Brinell Hardness | 100-150 | 100-150 |
| Endurance Limit ($5x10^7$ cycles; $N/mm^2$) | 85 | 100 |
| modulus of Elasticity ($x10^3$ $N/mm^2$) | 73 | 73 |
| Shear Strength ($N/mm^2$) | - | 190 |
| Density ($g/cm^3$) | 2.7 | 2.7 |

*Typical Properties:*

| | |
|---|---|
| Density, g/cm$^3$ | 2.95 - 3.00 |
| Thermal Conductivity, W/m•K | 170 – 200 |
| Thermal Expansion Coefficient, E-6 K$^{-1}$ | from 6.5 to 9.5 |
| Electrical Resistivity, mW•cm | 30 – 50 |
| Bending Strength, MPa | 350 – 500 |
| Elastic Modulus, GPa | 200 – 230 |

## V. EXPERIMENTAL PROCEDURE

### *5.1 PREPARATION OF ALUMINIUM METAL MOLT*

The pure ingots of Aluminum (LM-13) were taken and they are melted in furnace. The furnace is of oil type and the ingots got melted in the burning of the furnace. The ingots gets into a liquid state at the temperature of 650-750* C

5.1 Preparation of aluminium metal molt

### *5.2. CLEANING OF THE METAL MOLT*

The molten molt has some impurities present in it, so it must be removed. The molten molt is treated with the powder of "Kavaral & Degasser" in the furnace and the heating is continued for few minutes.The impurities present in it will float at the top of the molt. These impurities will form as ash and gets separated from the molt.

5.2 Cleaning of the metal molt

### *5.3 SILICON CARBIDE ADDING*

The purified molt is now ready for treating with the silicon carbide. The silicon carbide powder of 224 meshes is now added to the molt in furnace. The temperature is not reduced, so the silicon carbide would mix with the molt easily.

*5.4 AGITATING THE MOLT*

During the agitation process the materials will mix properly .The molt is mechanically stirred to mix the silicon carbide with the metal. The mixing is done for about 1-2 minutes. The mechanically made stirrer is used to stir the molt.

5.4 Agitating the molt

*5.5 CASTING POURING*

The die is prepared for pouring the molt. There preliminary works must be done before pouring the casting. The die is made up of sand by placing a pattern. Since the molt is about 700*C the molt starts burst, this produces blow holes and other improper casting. The die must be filled with a lubricating material to avoid sticking of the casting to the die. The vent for gas release is kept to avoid blow hole formation inside the casting.

5.5. Casting pouring

*5.6 COOLING THE CASTING*

The casting from the die is removed. The casting will be too hot as its super heated, so the casting must be cooled in order to avoid the oxidation process. The casting is cooled by the quenching process. This process includes the rapid cooling of the casting by treating with the water. The casting is immersed in a bath containing water to remove the heat and to get a solid form of the casting.

5.6 cooling the casting

*5.7 REMOVAL OF RUNNER & RISER*

The die must have the runner and riser. The runner is provided to pour the molt into the die. The riser is provided to make the molt fill in the die completely and the overflow takes place in other end. These runner and riser are removed by machining process.

*5.8 MACHINING PROCESS*

The Machining process is done in order to remove the excess and unwanted material. The machining process includes all the lathe works. The casting is machined to the desired shape. This process includes surface finish, surface grinding, facing, turning operations.

*5.9 TESTING THE SPECIMEN*

After the machining process the final product is our specimen. The specimen is used for the tests. The test is conducted to find the properties of the specimen manufactured. In this work, hardness test, surface roughness, sliding wear test and corrosion testing of such nickel composite coatings are carried out. The effect of particle size and number of particles suspended in the plating solution on the concentration of co-deposited particles is reported. The commonly done tests are as follows.

- Scanning Electron Microscope (SEM) test
- Brinell hardness test
- Corrosion test
- Material Composition test

VI. 6. TESTING OF SPECIMEN

*6.1 HARDNESS TEST*

Hardness is the property of a material to resist permanent indentation. Because there are several methods of measuring hardness, the hardness of a material is always specified in terms of the particular test that was used to measure this property. Rockwell, Vickers, or Brinell are some of the methods of testing. Brinell hardness testing is the most common method for hardness testing. In Brinell tests, a hard, spherical indenter is forced into the surface of the metal to be tested. The diameter of the hardened steel (or tungsten carbide) indenter is ranges from 5-10mm. Standard loads range between 500 and 3000 Kg; during a test, the load is maintained constant for a specified time (between 10 and 30 seconds). Here we used 5mm indenter ball diameter of the hardened steel, the 750 Kg load is maintained constant for a 10 seconds. Then indentation on the specimen is measured by hand microscope. The Brinell hardness test shall be carried out over Brinell hardness tester. Two samples of Al/Sic- MMC's for different sizes and weight fraction of SiC particles shall be prepared. After test and hardness value on dial, the Brinell hardness values with reference to scale HRB shall be taken for all samples and shown by graphs.

*6.2 CORROSION TEST -WEIGHT LOSS METHOD*

The corrosion resistance of aluminium alloy matrix composite reinforced with SiC particulates has been evaluated in critical media. Water and the atmosphere have been excluded in the evaluation because aluminium has been known to exhibit a very high resistance to these media: any evaluation in these media will require a very long time for meaningful result or data to be generated.

*Weight loss and corrosion rate*

The weight loss was calculated by finding the difference between the initial and final weight of each coupons after each immersion period as given in equation (1) and the corrosion rates were calculated in millimetre per year as given in equation (2).

$$\boxed{W = W_i - W_f \text{---------------} (1)}$$

Where,

$W_i$ = initial weight (kg),
$W_f$ = final weight (kg).

$$CPR\ (mmpy) = 8600W/(D\times A\times t) \quad \text{------------}(2)$$

where,

W is the weight loss (mg) after exposure time t (h),
D is density of metal ($g/cm^3$) and
A is the area of the specimen ($cm^2$) and
T is time of exposure in hours.

*6.3 MICRO STRUCTURAL ANALYSIS OF ALUMINIUM AND ALUMINIUM-SIC COMPOSITES:*

*Microstructure analysis by scanning electron microscope*

The scanning electron microscope (SEM) uses a focused beam of high-energy electrons to generate a variety of signals at the surface of solid specimens. The signals that derive from electron-sample interactions reveal information about the sample including external morphology (texture), chemical composition, and crystalline structure and orientation of materials making up the sample. In most applications, data are collected over a selected area of the surface of the sample, and a 2-dimensional image is generated that displays spatial variations in these properties. Areas ranging from approximately 1 cm to 5 microns in width can be imaged in a scanning mode using conventional SEM techniques (magnification ranging from 20X to approximately 30,000X, spatial resolution of 50 to 100 nm).The SEM is also capable of performing analyses of selected point locations on the sample; this approach is especially useful in qualitatively or semi-quantitatively determining chemical compositions (using EDS), crystalline structure, and crystal orientations (using EBSD). The design and function of the SEM is very similar to the EPMA and considerable overlap in capabilities exists between the two instruments.

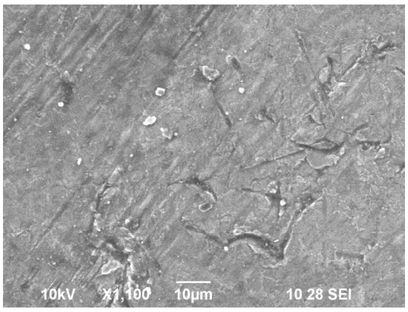


Fig6.3.1 Sample of Al

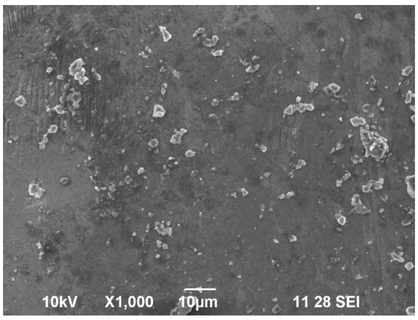


Fig6.3.2.Sample of Al +SiC

## VII. RESULTS AND DISCUSSION

A detailed study was undertaken to pool-up the existing literature on Aluminium based MMCs and efforts were put to understand the basic needs of the growing Composite industry. This includes various aspects such as Characterization, fabrication, testing, analysis and correlation between microstructure and the properties obtained. The conclusions drawn from this study are

- Pure aluminium matrix is preferred to various alloy matrices due to the high temperature stability of the aluminium as compared with aluminium alloys. Lower working temperature's in case of alloy matrices is attributed to lower stability of the alloy matrix and coarsening of the grains. In addition, the load transfer in case of pure aluminum matrix is more effective due to the clean interface.
- There exists a wide range of database in the literature for different types of reinforcements in Aluminum Metal Matrix Composites.
- There are varieties of techniques available for production of metal matrix composite. Each having its own merits and demerits. In particular, some are far more expensive than others. The manufacturer generally prefers the lowest cost route. Therefore, stir-casting technique represents a substantial proportion of the MMCs in commercial sectors today. Thus the priority of this work will be to prepare MMC using silicon carbide as reinforcement material and to study its characteristics.
- From the hardness test we can find that the hardness of aluminum –silicon carbide composite is more than aluminum alloy.

| CONTENTS | SAMPLE-1 | SAMPLE-2 |
|---|---|---|
| SAMPLE ID | ALUMINIUM LM-13 | ALUMINIUM LM-13 + SiC |
| HARDNESS VALUE | 121 BHN | 124 BHN |
| INDENTOR | 5.0 mm BALL | 5.0 mm BALL |
| LOAD APPLIED | 250 Kgf | 250 Kgf |

- From the corrosion test we can find that the corrosion rate of aluminium –silicon carbide composite is less than aluminium alloy.

| CONTENTS | SAMPLE -1 | SAMPLE-2 |
|---|---|---|
| ITEM DESCRIPTION | ALUMINIUM LM-13 | ALUMINIUM LM-13+SiC |
| DURATION OF TEST | 24 Hrs | 24 Hrs |
| SPECIFIC GRAVITY | 1.028 to 1.0413 | 1.028 to 1.0413 |
| TEMPERATURE | 35 | 35 |
| METHOD OF TEST | SALT SPRAY TEST | SALT SPRAY TEST |

**Weight loss and corrosion rate**

| MATERIAL | IMMERSION TIME(day) | AREA (cm2) | DENSITY (g/cm3) | WEIGHT LOSS (g) | TIME (hr) | CORROSION RATE mm/yr |
|---|---|---|---|---|---|---|
| **Al** | 1 | 66 | 2.7 | 5 | 24 | 0.0115 |
| **Al+SiC** | 1 | 66 | 2.95 | 3 | 24 | 0.0063 |

- From the SEM analysis the microstructure of pure aluminium and aluminium silicon carbide is analysed.

## VIII. CONCLUSION

From that investigation and analysis of the Characteristics of composite materials (Al-SiC) is improved by following as,

- The hardness of the material has been improved to a notable value.
- The corrosion behaviour of aluminium alloy / 10 % silicon carbide reinforced particulate composite in severe environments have been evaluated, the media are 5 weight percent NaCl solution.
- The weight loss, the percentage weight loss, and the corrosion rate expressed in mmpy all agree with the physical appearance of the specimens after the exposure time of the test.

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