Study of Properties of Al LM-25/SiC fabricated by using Stir Casting Method and Wear Analysis by RSM

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Abstract—Aluminum MMC's are widely used in various applications because of their higher mechanical and physical properties when compared with their base Al alloy. This paper focuses on the change in mechanical properties of various Al/SiC composites fabricated by using stir casting method. Effect of SiC reinforcement in different Al alloys on mechanical properties like hardness, tensile strength, wear test, percentage elongation, residual stress measurements are discussed in detail. For this purpose various reinforcement of SiC with 0,4,8 percent weight and different particle sizes are considered along with Al alloys. Variations in process parameters of stir casting are also made and taken into consideration.

Keywords—Al/SiC, Al LM-25, Hardness, MMCs, Tensile Strength, Wear Resistance, Response Surface Methodology.

I. INTRODUCTION

A metal matrix composite (MMC) is a composite material with a mixture of two or more constituent parts, one being a metal, other material may be a different metal such as a ceramic or organic compound. If three materials are present, it is called as hybrid composite. The unique characteristics of the composite materials for the specific requirements make these materials more popular in a variety of applications like aerospace, automotive and structural components, resulting in savings of material and energy. Metal matrix composites (MMCS) have become an important class of materials for structural, wear, thermal, transportation and electrical applications. This is due to their ability to exhibit superior strength-to-weight and strength-to-cost ratio when compared to equivalent monolithic commercial alloys. The strength of the composites depends on the amount, arrangement and type of reinforcement in the resin. Aluminium-based particulate reinforced metal matrix composite has high class of performance material for which it is used in aerospace, automobile, chemical and transportation industries because of its improved strength, high elastic modulus and increased wear resistance over conventional base alloy. To improve different properties of the main material, such as wear resistance, hardness, fatigue resistance, friction coefficient, thermal conductivity and others, reinforcement is used. As from recent studies, MMCs have found a lot of application in automobile industry for the production of brakes and parts of engines and in aerospace industry for the production of structural components, as well as in electrical and electronic industry and in many other applications. Composite materials which main constituent part is a metal are called Metal Matrix Composites (MMCs). The other compounds may be metals too, ceramics or even organics. They are well known for their excellent thermophysical and mechanical properties.

II. EXPERIMENTAL SET UP

Work Material

In this study the AL LM-25 is used as a matrix material and SiC as a reinforcement material. The Al LM-25 + volume percentage of SiC MMC is fabricated by using a stir casting method. Chemical composition of Al LM-25 is as shown in table 1.

| Element | Cu | Mg | Si | Fe | Mn | Ni | Zn | Pb | Sn | Ti | Al |
|---------|----|----|----|----|----|----|----|----|----|----|----|
| Wt. %   | 0.1 max | 0.2 – 0.6 | 6.5 – 7.5 | 0.5 max | 0.3 max | 0.1 max | 0.1 max | 0.1 max | 0.05 max | 0.2 max | Remainder |

Table 1 Chemical composition of AL LM-25
Fabrication of Al MMC (AL LM-25 + Vol. % of SiC) by Stir Casting

In this study the matrix material used is Al LM-25 and SiC is used as reinforcement material. The liquid metallurgy technique i.e. Stir Casting is used to prepare composite specimens, because it is most economical to fabricate composites. In this process, matrix alloy was firstly super heated over its melting temperature (800°C) and then temperature was lowered gradually below the liquidus temperature to keep the matrix alloy in the semi-solid state at this temperature, the preheated SiC particles were introduced into the slurry and mixed. The temperature of the composite slurry was increased to fully liquid state and automatic stirring was continued for 12 min at an average stirring speed of 400 rpm. Alloys were melted in an electrical furnace and poured at a temperature of 750°C in to a steel mould at room temperature and finally poured into the cast iron permanent mould of 18 mm in diameter and 200 mm in height.

Wear Testing (PIN-on-Disc Wear Testing TR-20 Standard)

A single pin type pin-on-disc apparatus was used to carry out dry sliding wear characteristics of the composite material as per ASTM G99-95 standards. The tests were carried out at the room temperature under dry operating conditions. Wear specimen (pin) of size 12 mm diameter and 25 mm length was cut from as cast samples machined and then polished metallographically. A single pan electronic weighing machine with least count of 0.0001 g was used to measure the initial weight of the specimen. The cylindrical pin flat ended specimens of size 12 mm diameter and 25 mm length were tested against EN31 steel disc by applying the load. After running through a fixed sliding distance, the specimens were removed, cleaned with acetone, dried and weighed to determine the weight loss due to wear.

![Fig.1: Pin On Disc Apparatus](image)

The difference in the weight of the material measured before and after test gave the sliding wear of the composite specimen and then the weight loss was calculated. The sliding wear of the composite was studied as a function of the weight percentage of the SiC composite, Sliding distance, applied load and rpm.

Plan of Experiments using Orthogonal Array

Tribological behaviors of the samples were studied by conducting the dry sliding wear test as per the standard orthogonal array. The wear parameters chosen for the experiment were: Sliding Velocity (m/sec), Pressure (mpa) and time (Min). The non-linear behavior of the process parameters if exists can only be revealed if more than two levels of the parameters are investigated. Therefore, each parameter was analyzed at three levels. The process parameters along with their values at three levels are given in Table 2.

| Level | Low | Medium | High |
|-------|-----|--------|------|
| Pressure (mpa) | 0.3747 | 0.7494 | 1.1242 |
| Time (Sec) | 30 | 60 | 90 |
| Sliding Velocity (m/s) | 1.0472 | 2.0944 | 3.1416 |

III. RESULTS ANALYSIS AND DISCUSSION

The tests were conducted with the aim of relating the influence of Time, Pressure, Sliding Velocity and percentage of SiC with dry sliding wear of the composite material. On conducting the experiments as per orthogonal array the following results were obtained for the wear of various combinations of parameters.

Experimental Results and Analysis by Taguchi Method for AL LM-25 & 0% SiC Composite Analysis of Variance

This analysis was carried out for a level of significance of 5%, i.e. the level of confidence 95%. Table 4 shows the result of ANOVA analysis. One can observe from the ANOVA analysis that the value of P is less than 0.05 in all three parametric sources. Therefore it is clear that sliding distance is most influential followed by sliding speed and load.

| Sr. No. | Sliding Velocity (m/s) | Pressure (Mpa) | Time (min) | Actual Value | Design Expert Predicted Value |
|---------|------------------------|----------------|------------|--------------|-----------------------------|
| 1       | 1.0472                 | 0.3747         | 30         | 22           | 22.317                      |
| 2       | 1.0472                 | 0.7494         | 60         | 52           | 50.222                      |
| 3       | 1.0472                 | 1.1242         | 90         | 96           | 96.126                      |
| 4       | 2.0944                 | 0.3747         | 60         | 42           | 42.507                      |
| 5       | 2.0944                 | 0.7494         | 90         | 84           | 85.269                      |
| 6       | 2.0944                 | 1.01242        | 30         | 30           | 30.888                      |
| 7       | 3.1416                 | 0.3774         | 90         | 72           | 71.555                      |
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**Table 4: Analysis of variance table using quadratic approach**

| Sr. No. | Mean | Std. Dev. | R-Squared | Adj R-Squared | P-Value |
|---------|------|-----------|-----------|---------------|---------|
| 1       | 55.89| 2.47      | 0.9990    | 0.9917        |         |

**Experimental Results and Analysis by Taguchi Method for AL LM-25 & 4% SiC Composite**

**Table 5: Wear for AL LM-25 - 4% SiC Composite**

| Sr. No. | Sliding Velocity (m/s) | Pressure (Mpa) | Time (min) | Actual Value | Design Expert Predicted Value |
|---------|------------------------|----------------|------------|--------------|-------------------------------|
| 1       | 1.0472                 | 0.3747         | 30         | 18           | 18.063                        |
| 2       | 1.0472                 | 0.7494         | 60         | 50           | 51.015                        |
| 3       | 1.0472                 | 1.1242         | 90         | 94           | 93.682                        |
| 4       | 2.0944                 | 0.3747         | 60         | 38           | 36.730                        |

**Table 6: Analysis of variance table using quadratic approach**

| Std. Dev. | Mean | R-Squared | Adj R-Squared | P-Value |
|-----------|------|-----------|---------------|---------|
| 0.62      | 51.56| 0.9990    | 0.9995        |         |

**Experimental Results and Analysis by Taguchi Method for AL LM-25 & 8% SiC Composite**

**Table 7: Wear for AL LM-25 & 8% SiC Composite**

| Sr. No. | Sliding Velocity (m/s) | Pressure (Mpa) | Time (min) | Actual Value | Design Expert Predicted Value |
|---------|------------------------|----------------|------------|--------------|-------------------------------|
| 1       | 1.0472                 | 0.3747         | 30         | 11           | 10.111                        |
| 2       | 1.0472                 | 0.7494         | 60         | 58           | 58.634                        |
| 3       | 1.0472                 | 1.1242         | 90         | 97           | 97.730                        |

**Table 8: Analysis of variance table using quadratic approach**

| Std. Dev. | Mean | R-Squared | Adj R-Squared | P-Value |
|-----------|------|-----------|---------------|---------|
| 3.39      | 57.78| 0.9985    | 0.9883        |         |

**Table 9: Hardness of the Samples**

| Sr. No. | Sample | Wt. % | Hardness (BHN) |
|---------|--------|-------|----------------|
| 1       | A      | 4     | 112            |
| 2       | B      | 8     | 115            |
| 3       | C      | 12    | 116            |

**Table 10: Tensile strengths**

| Sr. No. | wt. % | Tensile strength (N/mm²) |
|---------|-------|--------------------------|
| 1       | 4     | 160.33                   |
| 2       | 8     | 161.73                   |
| 3       | 12    | 180.43                   |

### IV. CONCLUSIONS AND EFFECTS OF WT. % OF SiC ON ALLM-25

It was found that Pressure, sliding Velocity, time are most influencing parameters on wear. The highest wear resistance can be found out with the Al/ SiC alloy composite. From wear test, it is observed that the sliding velocity is the wear factor that has the highest physical properties as well as statistical influence on the dry sliding wear of the composites. For dry sliding wear of Al SiC alloy metal matrix composites, the time has moderate influence on the wear. The pressure has least influence on dry sliding wear of the composites. It is observed that the uniform distribution of SiC in all samples is not possible by Stir Casting technique, so that some of the properties and results are almost same. Wear resistance of tested alloy increased with increasing SiC weight percentage. Hardness of alloy decreased with SiC content. Tensile strength increases with increase in weight percentage of SiC same for 117ehav strength and percentage elongation.
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