# SYNTHESIS AND CHARACTERIZATION OF METAL MATRIX COMPOSITES

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***Abstract—****The aluminum matrix composite (AMCs) is considered to be a most suitable material for low and high temperature applications. Particles reinforced AMCs materials have high specific strength and modulus of elasticity due to the reinforcement present in the matrix. In order to get the desired property alumina and chromium oxide are added as reinforcement with aluminium base metal. Stir-casting route was selected to synthesize the composites as it is considered as the most effective tool in metal matrix preparation .The key mechanical properties such as hardness and wear resistance of the composite was evaluated .Under stir-casting, the alumina and CrO3 were found to be uniformly distributed in the aluminum alloy and bonding between alumina and chromium oxide reinforcement with the aluminum base was effective. The hardness and wear resistance property of the metal matrix composite were compared with Aluminum 6061.*

***Keywords— Stir casting; Aluminum Matrix Composite; Reinforcement; Alumina; Chromium oxide***

## 1. INTRODUCTION

The metal matrix composite commonly referred as MMC is a combination of two or more different kinds of metal. There are three types of metal matrix composite, they are Dispersion-strengthened, Particle-reinforced and Fiber-reinforced metal matrix composite. In dispersion strengthened MMC matrix contains a uniform dispersion of very fine particles with diameters in range 10-100 nm, In Particle-reinforced in which particle of sizes greater than 1µm are present, Fiber-reinforced, where the fibers may be continuous throughout the length of the component, or less than a micrometer in length, and present at almost any volume fraction,from,say,5-75% [1].Material demands in the advanced industries such as automobile ,aerospace , defense ,underwater application etc.. cannot be fulfilled by monolithic materials .Therefore, composite materials have been developed with the aim of meeting the special requirement. The combination of desired properties of metals (ductility and toughness) and ceramics (high strength and high modulus) is the aim main of composites production .Composite materials, especially metal matrix composites (MMCs), have found various applications in the new industries [2] Aluminum and its alloys are attractive for many application in chemical, automobile and aerospace industries than other metal matrix composite because of their excellent properties such as high strength-to-weight ratio, high electrical and thermal conductivities and good formability. However their hardness, wear resistance and mechanical properties are poor in comparison to steel [3] .There are various method by which the metal matrix composite can be obtained. In order to get uniform mixing of reinforcement material in the matrix phase and for mass production stir casting method is found to be most suitable[4,5]. A stir casting setup consisted of a resistance muffle furnace and a stirrer assembly Aluminum 6061 is used as the matrix phase and alumina and chromium oxide is used as the reinforcement . Alumina is the most cost effective and widely used material In the family of engineering ceramics. the raw material from which this high performance technical grade ceramic is made is readily available and reasonable priced. Alumina is used as reinforcement because dispersion of $Al_2O_3$ particles in aluminum matrix improves the Wear resistance of the matrix material [6-9] and increase the density of the metal matrix composite [10,11]. The addition of chromium as reinforcement to the aluminum matrix improves the ductility of the composite [12]. The hardness of resultant composite produced is greater than hardness of both matrix phase and reinforcement phase [13]. The aluminum metal matrix composite is produced by varying the amount of the reinforcement added to the composite. The hardness and wear resistance behavior of the test specimen are evaluated.

## 2. EXPERIMENTAL METHODOLOGY

### *2.1 Matrix Phase*

Aluminum alloy 6061 was used as the matrix phase. Aluminum alloy was taken in the form of hexagonal rods and cut into smaller pieces. Composition of the matrix alloy was analyzed and the chemical composition of the matrix alloy is given in Table 1

TABLE:1 CHEMICAL COMPOSITION OF AL6061 ALLOY

| Element | Mg | Si | Cu | Mn | Fe | Ti | Zn | Cr | Al |
|---|---|---|---|---|---|---|---|---|---|
| Wt (%) | 0.84 | 0.76 | 0.33 | 0.29 | 0.14 | 0.02 | 0.004 | 0.006 | 97.61 |

The international alloy designation system is the most widely accepted naming scheme for wrought alloy. Each alloy is given a four-digit number where first digit indicates the major alloying elements.6000 series is mainly alloyed with magnesium and silicon ,and can be easily machine, and can be precipitation hardened . The mechanical property of Al6061 is given in Table 2.

TABLE 2 PROPERTIES OF AL 6061

| | |
|---|---|
| Modulus of Elasticity | 68.9 GPa |
| Notched Tensile Strength | 324 Mpa |
| Ultimate Bearing Strength | 607 Mpa |
| Bearing Yield Strength | 386 Mpa |
| Poisson's Ratio | 0.33 |
| Fatigue Strength | 96.5 Mpa |
| Fracture Toughness | 29 MPa – $m^{1/2}$ |
| Machinability | 50% |
| Shear modulus | 26 Mpa |
| Shear Strength | 207 MPa |

*2.2 Reinforcement phase*

Alumina which is one of the major reinforcement element has the chemical formula Al2O3.It is commonly referred to as alumina, or corundum Alumina is the most cost effective and widely used material in the family of engineering ceramics . The property of Alumina is given in Table 3.Chromium oxide which is one of the two reinforcing element used is a inorganic compound with the formula CrO3 . It is the acidic unhydride of chromium acid This component is the dark –red/orange brown solid,which dissolves in water concomitant .

TABLE 3 PROPERTY OF ALUMINA

| PROPERTIES | ALUMINIUM OXIDE |
|---|---|
| Melting point | $2072^0$c |
| Hardness(Kg/mm2) | 1175 |
| Density(g/cm2) | 3.69 |
| Coefficient of thermal expansion(µm/$m^0$c) | 8.1 |
| Fracture toughness(Mpa) | 3.5 |
| Poisson's ratio | 0.21 |
| Colour | White |

*2.3 Stir Casting Setup*

A stir casting setup used consists of a resistance muffle furnace and a stirrer assembly, was used to synthesize the composite. The schematic diagram of the stir casting furnace used is shown in Fig 1-3.

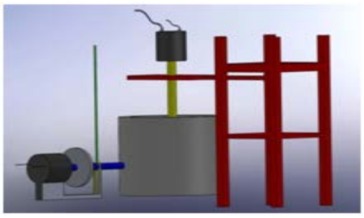

Fig.1 Model of Stir casting equipment used

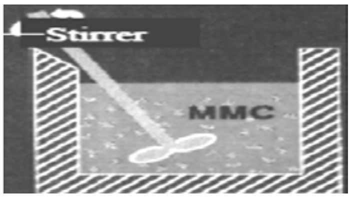


Fig.2 Working of Stir Casting Equipment used

Fig. 3 Actual Stir Casting Setup

Aluninium 6061 alloy whuch was cut into small pieces was taken in the crucible and kept in the furnace. 0.2 kg of Al alloy in solid form was melted 8200C in the resistance furnace and converted into liquid phase. The reinforcement alumina and chromiuoxide was Preheated for about an hour to remove moisture and gases from the surface of the particulate. The strirrer was switched on and the speed was gradually raised to 800 rpm and the preheated reinforced particles were added with a spoon at the rate of composition into the melt.The speed controller controlled the speed of the stirrer, as the stirrer speed got reduced to50-60 rpm due to increase in viscosity of the melt when particulate were added into the melt . After addition of reinforcement stirring was continued for 8 to 12 minutes for proper mixing of prepared particles in the matrix. The melt was kept in the crucible for approximate of half minute in the static condition and then it was poured into the mould .various composition of the sample prepared are mentioned in the Table 4.The cast samples were machined to prepare standard samples. 10 standard samples were prepared using lathe machine for each composition and hardness and wear test were conducted. The detail of the test conducted are mentioned below.

Fig .4. pouring molten metal

TABLE 4.SAMPLE COMPOSITION

| Composition | Alumina in % | Chromium trioxide in % | Aluminium Alloy in % |
|---|---|---|---|
| Pure Al Alloy | - | - | 100 |
| 1st | 2 | 8 | 90 |
| 2nd | 4 | 6 | 90 |
| 3rd | 6 | 4 | 90 |
| 4th | 8 | 2 | 90 |

## 3. RESULT AND DISCUSSION

*3.1 Hardness Testing*

Hardness testing is the method for measuring the hardness of the material microscopically. A precision diamond indenter is impressed into the material at load. from a few gram to 1 kilogram .A hardness number is then calculated using the test load, the impression length and shape factor for the indenter type used for the test . The various value obtained as the result of hardness testing are mentioned in the Table 5

TABLE 5 HARDNESS MEASUREMENT VALUE

| SPECIMEN | COMPOSITION | LOAD (Kg) | HARDNESS (RHN) |
|---|---|---|---|
| **Pure Metal** | Pure Aluminum Alloy | 100 | 84.25 |
| **1st** | Al+2%$Al_2O_3$+8%CrO3 | 100 | 44.25 |
| **2nd** | Al+4%$Al_2O_3$+6%CrO3 | 100 | 79.25 |
| **3rd** | Al+6%$Al_2O_3$+4%CrO3 | 100 | 86 |
| **4th** | Al+8%$Al_2O_3$+2%CrO3 | 100 | 87.75 |

TABLE 6 WEAR TEST SPECIFICATIONS.

| | |
|---|---|
| Abrading distance | 3000m |
| Track diameter | 120mm |
| Time obtained | 14min |
| Velocity | 3.5m/s |
| Rotation | 560rpm |
| Applied Load | 10N |

TABLE 7 WEAR TEST RESULTS.

| Time (min) / Wear (µm) | 1.4 | 2.8 | 4.2 | 5.6 | 7.0 | 8.4 | 9.8 | 11.2 | 12.6 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|
| Pure Aluminium | 29 | 46 | 61 | 86 | 98 | 115 | 127 | 142 | 162 | 168 |
| Al+2% $Al_2O_3$+8%CrO3 | 78 | 78 | 77 | 76 | 75 | 74 | 72 | 69 | 65 | 64 |
| Al+4% $Al_2O_3$+6%CrO3 | 73 | 75 | 72 | 73 | 72 | 72 | 61 | 67 | 75 | 73 |
| Al+6% $Al_2O_3$+4%CrO3 | 65 | 68 | 68 | 62 | 63 | 61 | 59 | 66 | 58 | 56 |
| Al+8% $Al_2O_3$+2%CrO3 | 66 | 63 | 62 | 62 | 64 | 59 | 61 | 65 | 81 | 85 |

The above table shows that incorporation of (Al+8%Al2O3+2%CrO3) a mixture composite particle in aluminium matrix causes reasonable increase in hardness as well as reasonable in density. The strengthening of the composite can be due to dispersion strengthening as well as due to particle reinforcement

*3.2 WEAR BEHAVIOR TEST*

Wear occurs as a natural consequence when two surfaces with a relative motion interact with each other . Wear may be defined as the progressive loss of materials from contacting surfaces in relative motion. Pin-on-Disc method was used for tribological characterization of composites . The value of wear obtained in the experiment are given in the Table 7.

Coefficient of Friction (COF) = Frictional Force (FF) / Applied Load (L)

Specification of wear Tester

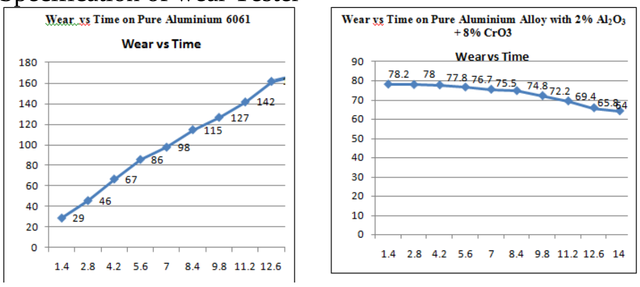


Fig 5. a, b

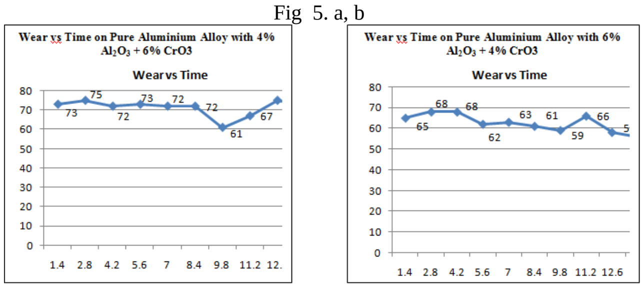


Fig 5 c,d

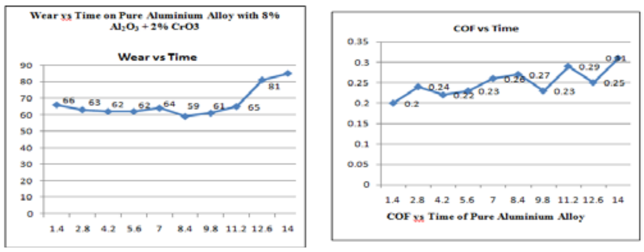


Fig 5 e,f

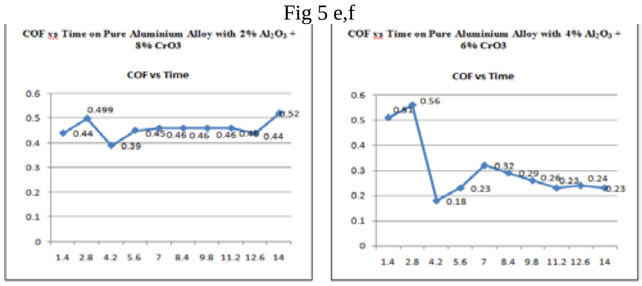


Fig 5 g,h

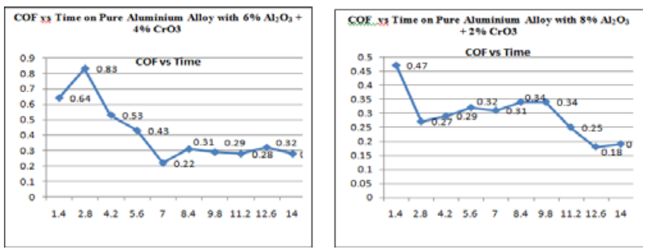


Fig 5 i,j.

The Figures 5 a-j representing the wear results of time versus co efficient of friction. Typical friction coefficients of as cast Al and (Al+8%Al2O3 +2%CrO3) composite. The (Al+8%Al2O3 +2%CrO3) composite represents a lower friction coefficient than that of as cast Al. Thus friction coefficient decreases significantly with the incorporation of Alumina in Aluminum melt.

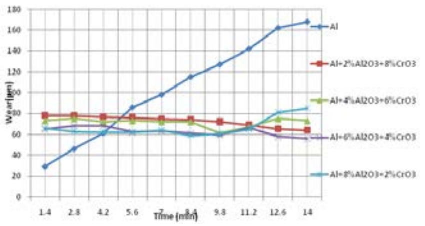


Fig 6 wear loss graph.

## 4. CONCLUSION

Aluminium based metal matrix composites have been successfully fabricated by stir casting technique with fairly uniform distribution of Chromium Tri-oxide and Aluminium oxide particulates. The results confirmed that stir formed Al alloy 6061 with Chromium Tri-oxide and Al2O3 reinforced composites is clearly superior to base Al alloy 6061 in the comparison of Hardness i.e. the Hardness increases after addition of Al2O3 and Chromium Tri-oxide particles in the matrix . It is found that wear rate tends to decrease with increasing particles wt. percentage (2.5-10%), which confirms that Chromium Tri-oxide and alumina addition is beneficial for reducing the wear rate of MMCs. The Optical micrography and SEM images revealed that CrO3 and Alumina particulates are fairly distributed in Aluminium alloy Matrix. It also revealed from SEM images that at some places voids has been occurred before wearing. From the optical micrography grooves, ridges and some cracks have been appeared after wearing. The grooves and ridges running parallel to the sliding direction but cracks are propagated in arbitrary directions.

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