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# PRODUCTION & CHARACTERIZATION OF AS CAST AND HEAT TREATED AL2024/SIC/GR HYBRID METAL MATRIX COMPOSITES

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## ABSTRACT

Aluminium alloys are widely used in automobile industries and aerospace applications due to their good mechanical properties as compared with conventional metals and alloys. The low production price and better mechanical properties of the composites make them very useful for various applications in many fields. The present investigation has been focused on the development of hybrid composite involving Aluminum metal matrix reinforced with particulates of silicon carbide and graphite. The composites are fabricated using liquid metallurgy routing. The Al 2024 Hybrid composites were cast by stir casting liquid metallurgy route with a percentage of Silicon Carbide varying from 0%,5%, 10% and 15% weight whereas the percentage of Graphite is kept constant at 2.5%wt. The cast composites were tested for hardness, wear, tensile characteristics with and without heat treatment (T6). The result indicates that there is a nominal improvement in the hardness values, wear and Tensile properties of both with and without Heat treated specimens.

**Keywords:** Abrasion, hardness number, Hybrid metal matrix composite, Pin on disk apparatus, quenching, Stir casting, tribology, wettability, tensile strength.

## INTRODUCTION

With the increasing demand for high performance materials with versatile properties new composite materials are being formulated and tested to satisfy the product needs. Composites are a mixture of materials consisting of a matrix with micron-level and Sub-micron level dispersion of similar kinds of materials. Usually the reinforcing component (primary material) is distributed in the continuous or matrix component (Secondary material). In hybrid materials the constituents combine at molecular level, therefore there is a situation of orbital interaction which creates new properties by new electron orbits formed between each material, this leads to new material that can exhibit new properties not necessarily found in the individual components. In this paper the wear, hardness and tensile properties of the composites are investigated. Aluminium 2024 is a ductile and corrosion resistant to atmospheric conditions. Silicon carbide is added to the formulation to investigate the hardness properties and graphite to investigate the tribological properties.

## LITERATURE REVIEW

S.O.Adeosun et al[1]. Aluminum hybrid reinforcement technology is a response to the dynamic ever increasing service requirements of such industries as transportation, aerospace, automobile, marine, etc. It is unique in that it offers a platform of almost unending combinations of materials to produce various hybrid composites. This article reviews the studies carried out on various combinations of aluminum hybrid composite and the effects on mechanical, physical and chemical properties. It is observed that the extent of enhancement of these properties of hybrid composites is strongly dependent on the nature of the reinforcement, its hardness, particle size and volume fraction, uniformity of dispersion within the matrix and the method of hybrid production.

Mahammed Naveed et al[2]. Newer techniques of improving the hardness and wear resistance of Al6061 by dispersing an appropriate mixture of hard ceramic powder and whiskers in the aluminium alloy are gaining popularity The conventional aluminium based composites possess only one type of reinforcements. Addition of hard reinforcements such as silicon carbide, alumina, titanium carbide, improves hardness, strength and wear resistance of the composites. heat treatment has a profound influence on mechanical properties of heat treatable

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aluminium alloys and its composites. For a solutionising temperature of 530C solutionising duration of 1hr, ageing temperature of 175C,quenching media and ageing duration significantly alters mechanical properties of both aluminium alloy and its composites. Results indicate that increase of graphite content decreases ultimate tensile strength of hybrid composites reinforced with constant SiC reinforcement.

Valmir martins monteiro et al [3]. This work studies the microstructural characteristics and mechanical properties for different aluminium alloys (1100, 3104 and 8011) hot rolled sheets that were subjected to a solution heat treatment with distinct soaking times, in order to promote microstructural and mechanical changes on these alloys with solute fractions slightly above the maximum solubility limit. Scanning Electronic Microscopy (SEM) / Energy Dispersive Spectroscopy X-Ray (EDS), X-Ray Diffraction (XRD) and Hardness Tests were employed to observe the microstructural / compositional and mechanical evaluation. For the 1100 and 8011 alloys the more suitable soaking time occur between 1 and 2 hours, and for the 3104 alloy occurs between.

Karunamoorthy et al [4]. Analysed that A 2D microstructure-based FEA models were developed to study the mechanical behaviour of MMC. The model has taken into account the randomness and clustering effects. The particle clustering effects on stress-strain response and the failure behavior were studied from the model. The optimization of properties was carried out from analysis of microstructure of MMC since the properties depend on particles arrangement in microstructure. In order to model the microstructure for finite element analysis (FEA), the micro-structures image converted into vector form from the raster than it conversion push to IGES step and mesh in FEA model in ANSYS 7. The failure, such as particle interface decohesion and fracture the predicted for particle clustered and non-clustered micro structures. They analyzed that failure mechanisms and effects of particle arrangement.

T.S.A.Suryakumari et al [5]. The present study involves the development of Aluminium metal matrix composite reinforced with particulate Sic and Al2O3 by stir casting method. Weight fraction of 7.5% of Sic, 7.5% of Al2O3 is reinforced with base Aluminium Alloy matrix. The fabricated aluminium alloy was solution treated and then precipitation treated for T-6 condition. Casted composite and heat treated composite machined carefully to prepare specimens for micro hardness, tensile strength and micro structure as per the ASTM standards. Mechanical properties include micro hardness; microstructure and tensile properties were evaluated for the composite before and after heat treatment. Micro hardness and tensile strength was improved by 34% and 7% by heat treatment.

L.H.Manjunatha et al [6]. In the present investigation, an Al6061 alloy was used as the matrix and MWCNT as the reinforcing material. The composite was produced using stir casting technique. The MWCNT was added by 0.5 wt.%, 1 wt.%, 2 wt.% and 3 wt.% to the molten metal. The Ascast Al6061-metal matrix alloy and its composites have been subjected to solutionizing treatment at a temperature of 555°C for 8 h followed by quenching in boiled water. The quenched samples are then subjected to both natural and artificial ageing. Under heat treated conditions adopted Al6061-MWCNT composites exhibited better hardness and reduced wear loss when compared with Al 6061 alloy.

## MATERIAL PROPERTIES

**Aluminium 2024**

Aluminum alloy 2024 is an aluminum alloy, with copper as the primary alloying element. It is used in applications requiring high strength to weight ratio, as well as good fatigue resistance. It is weld able only through friction welding, and has average machinability. Due to poor corrosion resistance, it is often clad with aluminum or Al-1Zn for protection, although this may reduce the fatigue strength. 2024 is widely used in aircraft structures.

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*Table 1: Composition of composite*

| Materials | Weight % |
|---|---|
| Aluminium (Al) | 93.3% |
| Copper (Cu) | 4.3% |
| Manganese (Mn) | 0.4% |
| Magnesium (Mg) | 1.3% |
| Iron (Fe) | 0.4% |
| Silicon (Si) | 0.3% |

**Silicon Carbide**

Silicon carbide is composed of tetrahedral carbon and silicon atoms with strong bonds in the crystal lattice. This produces a very hard and strong material. Silicon carbide is not assailed by any acids or alkalis or molten salts up to 800°C. In air, SiC forms a protective silicon oxide coating at 1200°C and is able to be used up to 1600°C. Silicon Carbide is one of the highly hard material it has the hardness of 2800 Kg/mm$^2$.

**Graphite**

Graphite is one of two naturally occurring crystalline forms of the sixth element, carbon, the other being diamond. It is a soft greyish black mineral with a metallic lustre. A graphite crystal is made up of loosely stacked one atom thick grapheme layers much like a deck of cards. These layers can slide around giving graphite its lubricity. Graphite is an excellent conductor of heat and electricity and is relatively inert being unaffected by most chemicals. It maintains its properties even at extreme temperatures in excess of 3500°C, which makes it invaluable to the industry. It is a good dry lubricant and hence reduces wear and abrasion.

## EXPERIMENTAL PROCEDURE

The details of the experiments carried out on Al 2024 alloy subjected to refinement and with heat treatment has been highlighted under the following headings.

- Preparation of reinforcement
- Melting and Stir casting
- Heat Treatment Process

Silicon carbide and graphite are sieved to a fine grain size of maximum 37µm. Al 2024 bars were machined according to the size of the crucible without adding any coolant.

*Table 2: Composition of composite*

| Sl No | Al 2024 % By Grams | SiC % by grams | Gr % by grams |
|---|---|---|---|
| 1 | 100 | 0 | 0 |
| 2 | 92.5 | 5 | 2.5 |
| 3 | 87.5 | 10 | 2.5 |
| 4 | 82.5 | 15 | 2.5 |

The Al 2024 alloy melts at a temperature of 710 ± 20 °C in a graphite crucible in a high temperature furnace. The stirring device was a graphite pole, which was equipped with 2 stirring blades, each 3 mm thick. The blades were mounted radially on a rotating rod. Preheated Silicon carbide and Graphite particles was added into the vortex slowly and steadily while continuing stirring to ensure the complete dispersion of reinforced particles it also promotes wettability. The addition of Silicon carbide and Graphite will be added on the %wt of the Aluminium alloy 2024.The molten alloy was stirred at 200 rpm for up to 3 minutes. Die is preheated to avoid porosity and scale formation on the samples due to sudden cooling. The molten metal was poured into the preheated die after the removal of slag. Addition of Magnesium enhances the wetability. However increase the content above 1wt. % increases viscosity of slurry and hence uniform particle distribution will be difficult. 22mm dia and 300mm length were prepared. The same compositions were heat treated and tested.

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The Aluminium composites were heat treated and tempered to T-6 condition, i.e. the samples were heated at 530 °C for 3 hours and then immediately quenched in water at room temperature and finally were artificially aged in furnace at 100 °C for 6 hours and then air cooled at room temperature.

*Figure 1: Stir casting apparatus & Composite material*

*Figure 2: Muffle furnace & Hot air oven*

## TESTING PROCEDURES

**Wear Test**

A pin-on-disc test apparatus is used to investigate the dry sliding wear characteristics of the Aluminium alloy and its composites as per ASTM G99 standards. As per ASTM standards, specimens were machined to 8mm diameter and 30mm height. The initial weight of the specimen was measured with an electronic weighing machine with at least count of 0.001 g. During the test machined samples were placed perpendicular to the steel disc. The parameters were set accordingly and pin was made to slide against the disc. The frictional traction experienced by the pin during sliding is measured continuously by PC-based data-logging system for post testing analysis. The test was carried out on a pin on disc apparatus at ambient.

*Figure 3: Pin-on-disc apparatus*

**Hardness Test**

Hardness is the property of a material that enables it to resist plastic deformation, usually by penetration. However, the term hardness may also refer to resistance to bending, scratching, abrasion or cutting. The specimen or the area or location must be selected and polished so as to give a reliable indication of the

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properties of the material. The specimen was placed on the anvil so that the surface is normal to the direction of applied load. Load (100 kgf) with a 1/6 inch diameter steel ball indenter and wait for 30 seconds duration, to ensure the complete acting of the load on the specimen by the indenter. Remove the load after 30 seconds, measure the indentation by using a travelling microscope and find out the RHN using formula.

***Figure 4: Rockwell hardness tester***

**Tensile Test**

Test specimens were prepared according to ASTM standards, specimen diameter of 10 mm and 60 mm gauge length was used. The specimen was loaded in computerized universal testing machine. Tests were conducted on composites of different combinations of reinforcing materials and ultimate tensile strength was measured. Simultaneous readings of load and elongation were taken at uniform intervals of load.

***Figure 5: UTM Machine***

## RESULTS & DISCUSSION

The Comparison was carried out on before heat treated and after heat treated specimens with respect to As cast and varying percentage of silicon carbide from 5 to 15% and with graphite 2.5% constant.

**Hardness**

Hardness property is influenced by silicon carbide (SiC) and its percentage is kept increasing, so the hardness vary drastically. The negligible variation in the hardness is due to the kept constant graphite percentage. Compared to without heat treatment, T6 heat treated specimen exhibits better hardness and the maximum hardness of 75RHN in A20241+10%SiC+2.5%Gr. It's an increase hardness compared to As cast Al2024.

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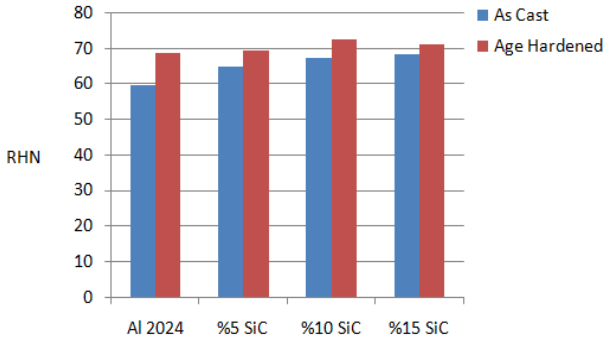


*Figure 6: Composition v/s RHN value*

**Dry Sliding Wear Test**

The trial was carried out on a pin on disk apparatus at ambient. For the following parameters the wear properties were examined.

Velocity of the disc = 400rpm
Track diameter of the disc = 80mm
Load in Kg= 1kg
Running time of the disc = 15min.

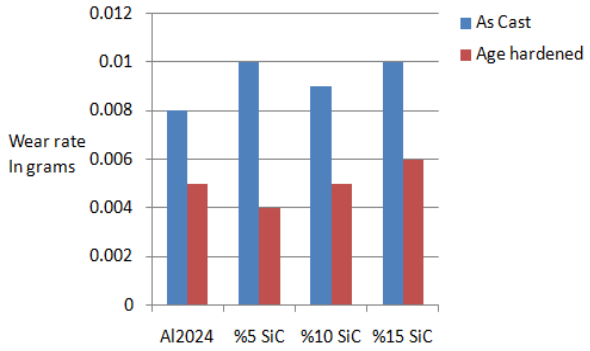


*Figure 7: Composition v/s Wear rate*

Wear rate is very high in aluminium 2024 and it was reduced to 60% by T-6 heat treated Wear rate decreases with graphite reinforcement. The rate of decrease in wear depends on the reduction in graphite percentage. A good improvement in the wear properties was achieved when heat treated (T-6). Investigation shows wear rate decreases with graphite reinforcement.

**Weight Reduction**

The reduction in weight of the samples gives the wear behavior of the samples. The samples were weighed before and after wear test. The weight difference gives the wear of the samples. Wear is influenced by graphite percentage because of its lubrication property. The graphite percentage inversely proportional to weight reduction, which means wear is reduced. As compared to un-heat treated specimen, T6 heat treated specimen has better wear resistance.

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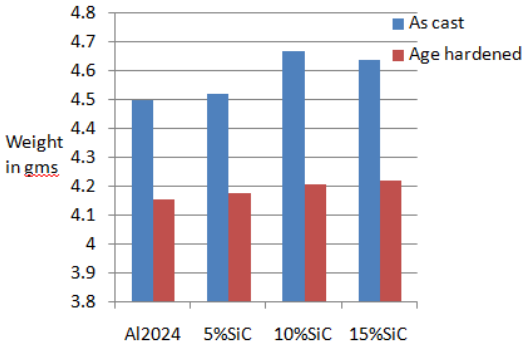


***Figure 8: Composition v/s Weight reduction***

**Friction Co-Efficient**

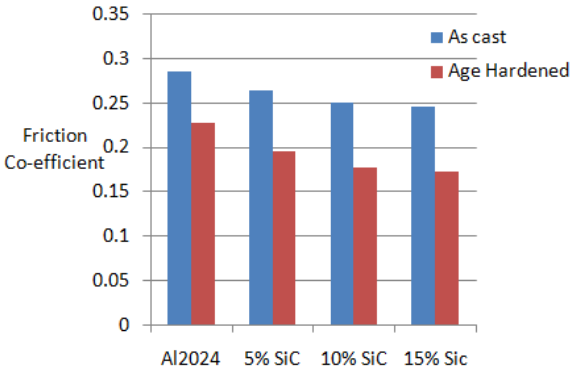


***Figure 9: Composition v/s Friction co-efficient***

As graphite percentage increase the friction coefficient decreases. Minimum friction is obtained at Al 6061+10%SiC+6%Gr which is 20% lesser than As cast Al6061.

**Tensile Strength**

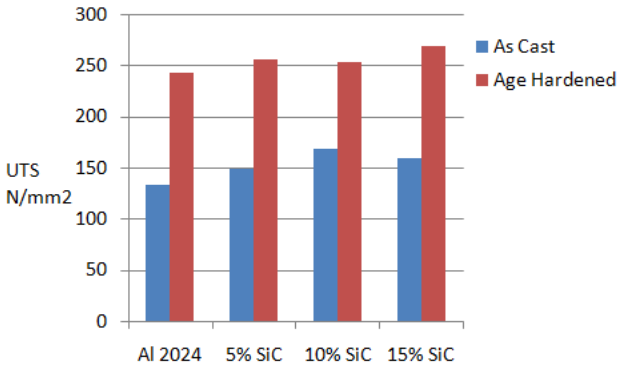


***Figure 10: composition v/s Ultimate tensile strength***

Tensile test has been conducted on the specimens that are showing best wear characteristics. A tensometer is a device used to evaluate Young's modulus (how much it stretches under strain) of a material. The tensometer is usually loaded with a sample between two grips that are adjusted manually to apply force to the specimen.

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From the graph it is observed that 10% SiC As cast has better tensile strength, 10% SiC age hardened has better tensile strength

## CONCLUSION

The aim of the study is to characterize the properties of heat treated and un-heat treated hybrid metal matrix composites The above study on various heat treated and un-heat treated hybrid matrix composites of aluminium 2024 alloy and its reinforcements of silicon carbide and graphite powder reveal a good improvement in properties of wear, hardness and tensile strength.

1) The die is preheated to avoid the scale formation and reduce the porosity of the samples.
2) Wear loss of composites decreases with the increase in the content of graphite and silicon carbide reinforcement. Heat treatment has a profound effect on wear behaviour of matrix alloy and its composites.
3) Rockwell hardness number (RHN) does not vary drastically because of the constant Silicon carbide reinforcement. Heat treatment has a significant effect on Rockwell hardness of Al2024 matrix alloy and its composites.
4) Ultimate tensile strength (UTS) varies drastically because of the Silicon carbide reinforcement. Age hardened has a significant effect on tensile test of Al2024 matrix alloy and its composites.

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