

# Experimental Investigation on Mechanical and Microstructural Properties of Al2024-WC-Gr Hybrid Composites

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**ABSTRACT:** Hybrid composite materials are also called as an advance composite material. In which combination of two or more second phase materials either in the form of particulate or fibers is reinforced in base matrix. In this present aimed study deals with the preparation of Al2024 based hybrid composite by liquid metallurgy i.e., stir casting techniques the simplest and most commercial method of production of MMC's. With the extent incorporation of graphite and tungsten carbide which is limited to 5% by weight, In which graphite kept constant i.e., 1w%, where as Tungsten carbide 1-5% of particulate were dispersed in base matrix in step of 1. The increased percentage of reinforcement contributes in increase hardness of the hybrid composites. Also the strength of the hybrid composite increases with increasing in reinforcement material is noticed and specimen of each composition examined under optical microscope.

**KEYWORDS:** Hybrid Composites, Microstructure, Mechanical properties, stir casting, tungsten carbide.

## I. INTRODUCTION

In a composite material matrix material is one, which is of continuous phase and discrete constituent called as a reinforced material. Hybrid or hybridization is nothing but usage of more than two reinforcements in a matrix material.

Most of the researcher showing much interest in hybrid composites because of its better yielding towards stiffness, strength, strength to weight ratio and other mechanical as well as tribological behaviour. Presently aluminium metal matrix hybrid composites playing major role because of its low density good electrical and thermal conductivity and good corrosion resistance and its wide application like structural as well as functional.

## II. MATERIALS

### Aluminum 2024

Aluminium alloy 2024 is an aluminium 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 not weldable, and has average machinability. Due to poor corrosion resistance, it is often clad with aluminium or Al-1Zn for protection, although this may reduce the fatigue strength [1].

### Composition[1]

Al 2024 composition roughly includes

Copper	4.3-4.5%
Magnesium	1.3-1.5%
Manganese	0.5-0.6%
Zinc, Nickel, Chromium, Lead, Bismuth	<0.5%

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## Tungsten carbide:

Since the late 1800's when a French chemist, Henri Moissan, first synthesized it, tungsten carbide has been known as one of the hardest substances in existence, approaching diamond in this respect. In fact, he was seeking to produce man-made diamonds, but WC was the result.

Tungsten carbide compositions range from two to three times as rigid as steel and four to six times as rigid as cast iron and brass. Compressive strength is higher than virtually all melted and cast or forged metals and alloys. High resistance to deformation and deflection is very valuable in those many applications where a combination of minimum deflection and good ultimate strength merits first consideration. These include spindles for precision grinding and rolls for strip or sheet metal. For such a hard material with very high rigidity, the impact resistance is high. It is in the range of hardened tool steels of lower hardness and compressive strength. Specific grades are available with corrosion resistance approaching that of noble metals. Conventional grades have sufficient resistance to corrosion-wear conditions for many applications. Tungsten carbide wears up to 100 times longer than steel in conditions including abrasion, erosion and galling. Wear resistance of tungsten carbide is better than that of wear-resistance tool steels [2].

## Graphite.

In recent years, considerable work has been done on graphite reinforced metal matrix composites which exhibit low friction, low wear rate and excellent anti seizing properties. The graphite in these composites presumably imparts improved tribological properties to the composites through the formation of a graphite-rich film on the tribo-surface which provides solid lubrication. Journal bearings made of graphite particle dispersed composites perform much better than conventional bearing alloys [3].

### III. FABRICATION OF HYBRID COMPOSITES USING STIR CASTING TECHNIQUE

Stir casting technique has been widely adopted for the fabrication of MMCs because of its simplicity, flexibility and applicability of the technique to large scale production of commercial components [4]. Composites fabricated by this technique involve melting of the matrix material using electric resistance furnace and followed by the addition of reinforcement to the melt with simultaneous stirring, followed by casting in a mould. The schematic diagram of stir casting process is shown in [fig.1](#).

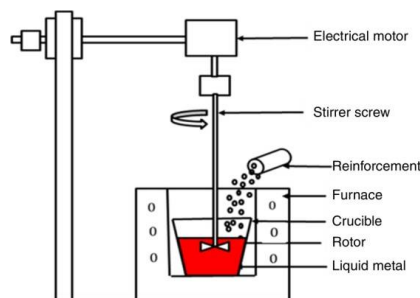


Fig. 1 stir casting technique

## Melting of Al2024 matrix material:

Ingots of Al2024 alloys are loaded in to crucible of electric resistance furnace and allowed it to attain a temperature of 800<sup>0</sup>. After reaching 800-850<sup>0</sup> the metal inside the crucible melts and reaches molten state. By adding tablet of hexachloroethane (C<sub>2</sub>Cl<sub>2</sub>) called degasser, the melt was degassed.

## International Journal of Innovative Research in Science, Engineering and Technology

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Fig. 2: Melting of Al2024 matrix material

### Mixing of Reinforcement and stirring of composites:

Before adding reinforcement material into molten Al2024 alloy, it is necessary to preheat it, in order to increase wettability and to reduce temperature gradient between matrix alloy and reinforcement particulate.



Fig. 3: Mixing and stirring of reinforcement material

The stirring set up is brought near to the furnace. Balasivanada [5] investigated stirring speed and stirring time on distribution of ceramic particle in cast metal matrix. And he has recommended that 600rpm of stirring speed and 10 minutes of stirring time, which gives best results on properties of cast aluminium. Based up on these available resources stirrer is dipped into molten Al2024 alloy approximately one third of the height of molten metal and stirred at 600rpm. Preheated tungsten carbide and graphite reinforcement particles as per calculated amount slowly added in to melt during stirring, it is shown in fig. 3 and stirring time maintained for minimum of 10 min. Then reinforcement particle drowned into the melt from the surface because of vortex produced by rotating impeller of stirrer.

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(An ISO 3297: 2007 Certified Organization)

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## Pouring of prepared hybrid composite matrix:



Fig. 4: Pouring of molten hybrid composites.

Before pouring molten hybrid composite in to die, it is necessary to preheat and should coat with additives for ease removal of casting. And also dies are coated with sodium silicate and china clay to prevent surface contamination. Then after completion of stirring time, molten hybrid composite mixture poured into prepared die it is shown in fig. 4.



Fig.5: obtained hybrid metal matrix composites.

After pouring hybrid molten metal composites, it starts to solidify. Once after solidification the obtained hybrid metal matrix composites shown in fig. 5.

## IV. PREPARATION OF TEST SPECIMEN

The entire test carried out in accordance with ASTM standards.

Tensile tests were conducted in accordance with ASTM standard E8M-15a. The gauge length of specimen is 45mm and diameter is 9mm were machined from the cast hybrid composites.

The micro hardness test were conducted in accordance with ASTM standard E384 using a Vickers hardness tester with pyramid diamond indenter of  $136^\circ$  angle and with the range 5 to 2,000g of load.

As per ASTM standards E9 compression test specimen with medium dimension of 13mm diameter and 38mm length were prepared. And in UTM by increasing loads gradually until the specimen failed correspondingly compression strength were measured.

By polishing and etching the surfaces of metallographic specimen were prepared, and it was analysed by using optical microscope.



**V. RESULT AND DISCUSSION**

**Microstructure:**

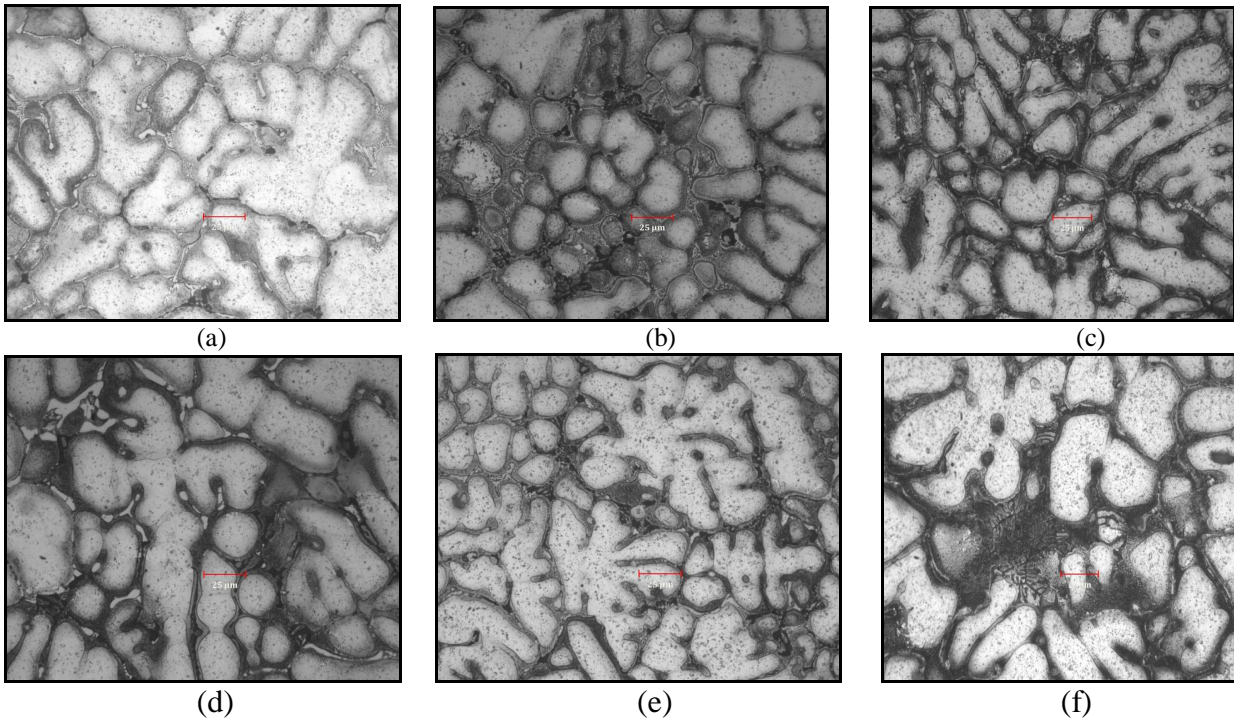


Fig. 6: Microphotographs (a) Al2024 as cast, (b) Al2024+1% WC+1%Gr, (c) Al2024+2% WC+1%Gr, (d) Al2024+3% WC+1%Gr, (e) Al2024+4% WC+1%Gr, (f) Al2024+5% WC+1%Gr

Figure 6 (a), (b), (c), (d), (e), (f) shows the optical micrographs of AL2024-WC-Gr hybrid composites. With the evidence of microphotographs, it's clear indication that in hybrid composite material the reinforcement material distributed homogeneously. And also it has been observed that there is a minimal porosity both in case of base alloy and hybrid composites materials.

**Hardness:**

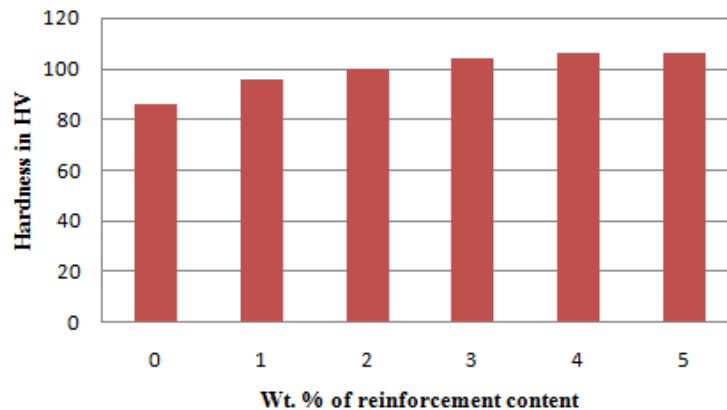


Fig.7: variation in hardness with increased content of reinforcement in the hybrid composites

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Materials resistant to surface indentation itself considered as measure of hardness. Fig. 7 shows the variation in hardness with respect to increase in reinforcement content. And also it has been noticed that increased content of reinforcement material in matrix alloy results in increased hardness of hybrid composite. Compare to as cast, developed hybrid composite material hardness is gradually increased. This may be attributed because tungsten carbide is a harder material; in general harder reinforcement in soft and ductile matrix alloy will always enhances the hardness. And it may also because of lesser extent of porosity in developed hybrid composite.

### Compression:



Fig. 8: variation of compression strength with increased content of Reinforcement in hybrid composites

By increasing Tungsten carbide reinforcement material in matrix alloy compressive strength increased gradually up to 3%, then after at 4% and 5% strength has been decreased. So optimum results obtained is at 3% this may be because of decrease in reinforcement inter particular spacing.

### Tensile strength:

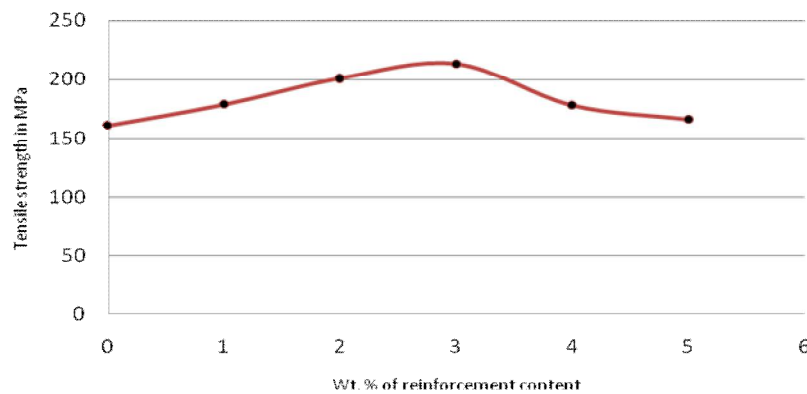


Fig.9: U T S V/s % of comosition

From fig.9 it is noticed that with increase in the percentage of reinforcement materials, tensile strength has been increased, only up to 3%. Then after by increasing further reinforcement content, the strength has been decreased. This may be because of scattered distribution of WC reinforcement particle which leads restriction in plastic flow.

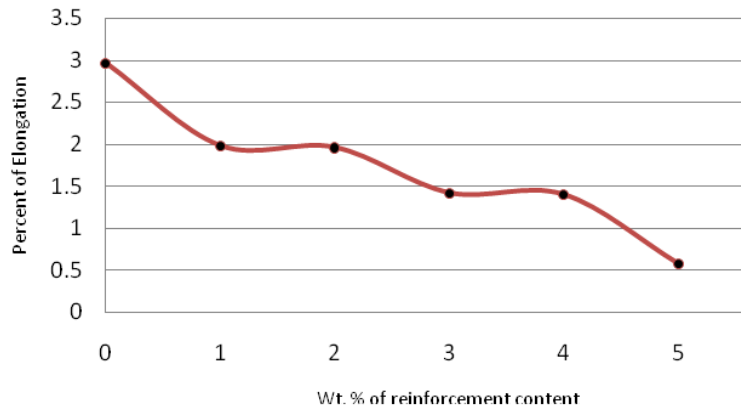


Fig. 10: Percent of elongation V/s % of composition

Ductility of developed material has dropped 100% by increasing 0-5% of tungsten carbide content. And it is clear that any material exhibits higher brittleness with the harder filler contents. So it has been concluded that increased content of tungsten carbide in Al2024 matrix lead to increase in brittleness and decrease in ductility. This is because harder ceramic phase that is prone to localized crack initiation and increase embrittle effect due to local stress concentration site at the reinforcement matrix interface [6].

## VI. CONCLUSION

Metal matrix hybrid composites of Al2024-WC-Gr were prepared successfully by liquid metallurgical route method for different percentages of WC. And microstructural photograph revealed that WC and graphite distributed uniformly and thereby existing good bonding between aluminium and reinforcement material. Increase in the percentage of Tungsten carbide leading to increase in hardness, tensile strength, and compressive strength of developed hybrid composite.

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