

## **Studies on The Effects of Titanium Carbide and Graphite Reinforcement On Aluminium Alloy Using Powder Metallurgy**

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### **Abstract**

In this paper, we discuss how duralumin is reinforced to form a metal matrix composite which shows an enhanced strength, thermal conductivity, ductility and other mechanical characteristics. Duralumin is a light weight and robust material, thus widely used in automotive parts production, aerospace and aviation industries. Duralumin is produced from recycled aluminium wheels and copper wires. Titanium carbide and graphite nanopowders are used as reinforcement to improve the mechanical properties of duralumin. These powders are blended using an overhead mechanical stirrer and then filled and compressed into the drilled holes of duralumin surface, followed by heating it in a muffled furnace. Various mechanical tests such as micro hardness test, tensile strength test, electrical and thermal conductivity tests are performed to evaluate the enhancement in mechanical properties. The tests are focused on the enhancement in hardness of the material and wear resistance. An eco-friendly method is adopted to prepare an advanced metal matrix with enhanced mechanical properties.

**Keywords :** Duralumin, Titanium Carbide, Graphite, Reinforcement Particles.

### **Introduction**

Hybrid metal matrix composites are made by adding two or more ceramic materials into the metal matrix. Industrial waste materials like graphite, fly ash, red mud, etc. are added and have obtained good outcomes [1-6]. Metal matrix composites mainly comprise of a metal structure which is reinforced with a ceramic or organic material. In today's advancing era MMCs are preferred due to their enhanced mechanical and thermal properties. MMCs are mainly used in the battery plates, aerospace, automotive engine blocks and aviation. Metal matrix composites are made for the sole purpose of distributing the load equally to the composite material and reinforcing

material [7-8]. The current research is mainly focused over to altering the phase of the constituents or filler materials in the MMCs to modify the mechanical properties, physical properties and tribological properties [9].

Aluminium is a light weight material and offer high resistance to corrosion. Aluminium alloys are widely used in the production of metal matrix composites as they have good wear response, fatigue resistance, relatively low cost of production and can be easily shaped [10-12]. It shows characteristics that is well suited to form a metal matrix composite. Ceramic particles such as boron carbide, titanium carbide, silicon carbide, aluminium oxide, etc. Are used to form AMCs. It is also reinforced with carbon based materials like carbon nanotubes and graphite [13-18]. The aim is to enhance the mechanical characteristics of duralumin by reinforcement of such particles. They usually improve the hardness, tensile strength, porosity and thermal stability. Graphite nanopowders when used for reinforcement acts as an excellent self-lubricating material. Hence they are used in the production of automotive parts.

Duralumin is a aluminium alloy which is widely recognized for its high strength, lightweight and low density. Duralumin is composed of about 90-95% aluminium and 4-5% copper, along with little amount of manganese, magnesium, silicon, iron, zinc, etc. According to the requirement of the mechanical properties in duralumin, these metals like iron, silicon and zinc can act as impurities. If iron is present in excess it can reduce the strength of duralumin but, on the other hand zinc can improve strength and aid in corrosion resistance. Duralumin shows a high strength-to-weight ratio which helps in applications where performance and efficiency are influenced by weight. Automobile industry has shown various applications as they are used in the chassis structures, engine components, etc. where strength and wear resistance is required alongside weight reduction.

Titanium carbide nanoparticles has numerous advanced applications due to their distinctive characteristics and enhanced performance. It has found its place in the field of material science, where the TiC nanoparticles has transfigured the development of advanced materials. TiC nanoparticles show high strength, hardness and wear resistance, which makes it ideal for reinforcing composites, coating and structural material in sectors stretching from automotive to aerospace [19-21]. Titanium carbide based alloys offer superior hardness, wear resistance, heat resistance and fracture toughness. They are often known for their excellent thermal shock resistance and minimum adhesive interaction with the processed material which helps with a finer finished surface. By increasing the material strength and thermal conductivity we could improve the thermal shock resistance. To enhance it further we can reduce the thermal expansion coefficient and internal stress levels.

TiC reinforced aluminium-based composites has proved its application in various industries, due to its distinctive features imparted by the incorporation of TiC nanoparticles. In the automotive sector TiC reinforced aluminum composites have contributed to the evolution of lightweight vehicles with higher fuel efficiency. Similarly in the field of aerospace these composites have shown its value in manufacturing lightweight and high-strength components for aeroplane, which has raised the fuel efficiency and overall performance. TiC aluminium composites have high thermal conductivity which is perfect material for production of heat sinks and

electronic casing [22]. TiC has a density of about 4.94 gm/cc and that of graphite is 2.33 gm/cc. Graphite is an excellent self-lubricating material along with other valuable properties like high heat conductivity, higher tensile strength, lower density, friction and wear resistance [29]. Although it offers lubrication benefits, but increased weight percentage of graphite nanoparticles into the composite can decrease the mechanical properties and electrical conductivity [23-24]. In materials engineering, addition of graphite nanopowders to a metal matrix composite can improve its internal structure by making it more fine and even. This benefits the composite by protecting it from corrosion and makes the material strong and tough.

### **Methodology**

The base material that is required to start with is Duralumin which is prepared by using recycled aluminium and copper. Aluminium is collected from the scrap automobile wheels and copper is obtained from coils and waste wires. Firstly these materials are cleaned to remove contaminants and they are analyzed to determine their chemical composition. Now the aluminium is melted in the furnace at a temperature close to 700°C and copper is heated in a separate furnace to the same temperature. Both the molten metals are combined under the same temperature to ensure effective mixing. The mixture is poured into the rectangular molds and is left to cool down. This way we obtained the solidified aluminium alloy which has high strength and is lightweight. An environmentally sustainable method is used to produce duralumin as we rely on recycled materials.

The duralumin which is cast has a rough surface, so we have to grind the surface and shape it to the required dimensions. This is followed by drilling 3 holes into the top surface with a 15mm diameter and depth in accordance with alignment and uniformity. The surface modifications are done to achieve geometric characteristics which are necessary for further processing and tests. Titanium Carbide and Graphite nanopowders are used to reinforce the duralumin. Both the powders have to be blended in ratios of 60:40 and 80:20 using ethanol as a blender. An overhead mechanical stirrer is used for this purpose. The ethanol is added to a beaker along with the graphite and stirred for about 30 minutes. Later the titanium carbide powder is added to the beaker and stirred for another 45 minutes. Ethanol is filtered out using a filter paper into a conical flask and a funnel. Now the wet mixture is dried out in direct sunlight to remove the remaining moisture content. This dried powder is filled into the drilled holes of the duralumin and compressed into the holes using external pressure. The duralumin is now heated to a temperature of 500°C for half an hour in the muffle furnace. Again we heat it to a temperature of 600°C for the same amount of time. Above 600°C the duralumin starts to melt and lose its geometric shape so we stop heating at 600°C. The powder has solidified resulting in better mechanical performance of the composite.

## Results and Discussions

### Mechanical properties of the composites

Mechanical properties mainly represents the data that we collected from the three samples of duralumin. The key parameters that are measured include porosity, density, hardness, compressive strength, electrical and thermal conductivity. The pure duralumin and two composite variants reinforced with TiC and Gr in the ratios of 60:40 and 80:20 are the three samples which are evaluated. Porosity is basically the measure of how much void space is present in the material. The pure duralumin shows the lowest porosity of 1.1%, duralumin reinforced with 60:40 has 1.65% which shows a slight increase in porosity and the 80:40 ratio sample has 1.68% porosity. The trend indicates that the porosity increases with the increase in the TiC reinforcement.

**Table : 1**

Tests	Sample 1	Sample 2	Sample 3
	Duralumin	Duralumin + 60%TiC + 40 % Gr	Duralumin + 80% TiC + 20% Gr
Density (g/cm <sup>3</sup> )	2.67	2.87	2.93
Porosity (%)	1.1	1.65	1.68
Electrical conductivity (MS/m)	27.25	43.80	39.15
Thermal conductivity (W/(m°C))	140	116	124
Hardness (HRB)	77	78	87
Compressive strength (MPa)	450	500	600

Density is the amount of mass present in a material per unit volume and as the porosity increases the density decreases due to the increase in the empty space. Thus density and porosity are co-related but distinct properties of a material. Duralumin has the highest density and as the duralumin is reinforced with high amount of TiC the density decreases. Graphite is a good electric conductor, thus we can see that in sample 2 with a higher ratio of graphite has a electrical conductivity of 43.80 MS/m and that of sample 3 has decreased to 39.15 MS/m due to decrease in graphite content. Now as we compare this values to the duralumin sample it has quite a low value of electrical conductivity, which shows that the graphite rich reinforcement is useful for applications need high electrical conductivity. We can see a reverse trend in the thermal conductivity readings of the sample. The sample 1 of pure duralumin has the

highest thermal conductivity, while the sample 3 of 80% TiC composite has a value of 124 W/(m°C) and sample 2 of 60% TiC composite shows a reduction to 116 W/(m°C). This clearly states that the ceramic TiC particles have a comparatively better thermal properties than the graphite particles. The hardness of the pure duralumin and sample 2 reinforced in the 60:40 ratio exhibit nearly similar results. But 80:20 ratio reinforcement shows significant increase in hardness due to the more amount of ceramic particles used in the reinforcement. The compressive strength of the samples also follow a similar trend. The pure duralumin has a compressive strength of 450 MPa, while the sample 2 has a slight increase to 500 MPa and sample 3 shows a double amount of strength increase of that of sample 2. Sample 2 has a increase of 50 MPa and sample 3 shows increase of 150 MPa from the pure duralumin sample. The results states that TiC has a high load-bearing capacity due to its resistance to deformation and rigidity.

### **Conclusion**

This study based on the effects of reinforcement of titanium carbide and graphite to duralumin has shown a significant enhancement in the overall performance and mechanical characteristics of duralumin. We have taken 3 samples for analysis - pure duralumin, 60 TiC : 40 Gr % reinforced duralumin and finally 80 TiC : 20 Gr % reinforced duralumin . Pure duralumin is analyzed for comparatively studying the properties of reinforced composites. The results demonstrates how different ratios of the reinforcements enhance the specific characteristics of the specimen. The 60 TiC : 40 Gr % reinforcement offers better electrical conductivity along with a moderate level of load resistance and also shows self-lubricating property due to the presence of high levels of graphite particles. While sample 3 with 80 TiC : 20 Gr % reinforcement shows superior mechanical characteristics as it offers high hardness and compressive strength along with moderate thermal and electrical conductivity. Sample 3 also has a low density making it ideal for a lightweight composite with applications which require durability and high wear resistance.

The mechanical properties of the reinforced duralumin are investigated and have shown sufficient improvement. The wear resistance of the material is enhanced by the reinforcement process. The duralumin is produced from the recycled raw materials thus making it a economic advantage to the process. If we consider this method for large-scale production it supports environmental sustainability by reducing automobile scraps and electrical wastes to some extent and provide advanced hybrid metal matrix composites at low cost. By altering the composition ratios of the reinforcement can help to enhance the specific mechanical characteristics to the requirement in an eco-friendly way.

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