International Journal of Scientific Research in Science and Technology
Print ISSN: 2395-6011 | Online ISSN: 2395-602X (www.ijsrst.com)
doi : https://doi.org/10.32628/IJSRST523103145

Investigation of Mechanical Characterization on Al-7075 Reinforced with Silicon Carbide and Graphite

Madanapu Ashok*[1], Dr. V. Nagaprasad Naidu[2]

*[1]Research scholar, Department of Mechanical Engineering, JNTUA, Anantapur, Andhra Pradesh, India

[2] Supervisor, Professor & HOD, Department of Mechanical Engineering, JNTUA College of Engineering, Kalikiri, Andhra Pradesh, India

ARTICLEINFO

Article History:

Accepted: 01 June 2023

Published: 12 June 2023

Publication Issue

Volume 10, Issue 3

May-June-2023

Page Number

829-836

ABSTRACT

Composite materials defined as two or more chemically different constituents that are combined microscopically to yield a useful material. The properties of new material are significantly different than that of constituents. This can be classified into three different types, which are metal matrix composite, polymer matrix composite, ceramic matrix composite. In this journal we work is on metal matrix composite. Aluminium Metal Matrix Composites (AMMC) have good mechanical properties which has various applications like automobile, military industries, aerospace and others due to light weight, thermal properties, stiffness, high mechanical strength corrosion resistance. The present work deals with the preparation and mechanical characterization of Aluminium 7075 metal matrix reinforced with silicon carbide and graphite. Composition can be made 3% graphite and silicon carbide variations like 2%, 4%, and 6% with Aluminium.

To prepare this material and test mechanical characterization like tensile strength, compressive strength and hardness

Keywords: AMMC's, Stir casting- silicon carbide and graphite, Mechanical properties

I. INTRODUCTION

A composite material (also called a composition material or shortened to composite,) is a material which is produced from two or more constituent materials. These constituent materials have notably dissimilar chemical or physical properties and are merged to create a material with properties unlike the individual elements. Within the finished structure, the individual elements remain separate and distinct, distinguishing composites from mixtures and solid solutions[1]

1.1 Typical engineered composite materials include:

- Reinforced concrete and masonry
- Composite wood such as plywood
- Reinforced plastics, such as fibre-reinforced polymer or fiberglass
- Ceramic matrix composites (composite ceramic and metal matrices)
- Metal matrix composites
- and other advanced composite materials

There are various reasons where new material can be favoured. Typical examples include materials which are less expensive, lighter, stronger or more durable when compared with common materials, as well as composite materials inspired from animals and natural sources.

Composites were developed because no single, homogeneous structural material could be found that had all of the desired characteristics for a given application. Fiber-reinforced composites were first developed to replace Aluminium alloys, which provide high strength and fairly high stiffness at low weight but are subject to corrosion and fatigue. An example of a composite material is a glass-reinforced plastic fishing rod in which glass fibers are placed in an epoxy matrix. Fine individual glass fibers are characterized by their high tensile stiffnesses and very high tensile strengths, but because of theirsmall diameters, have very small bending stiffnesses. If the rod were made only of epoxy plastic, it would have good bending stiffness, but poor tensile properties. When the fibers are placed in the epoxy plastic, however, the resultant structure has high tensile stiffness, high tensile strength, and high bending stiffness.

1.2 Types of composites

Composite materials are mainly divided into three types. They are

1. Polymer matrix composites (PMCs),
2. Metal matrix composites (MMCs),
3. Ceramic matrix composites (CMCs)

1. Manufacturing and forming methods

MMC manufacturing can be broken into three types—solid, liquid, and vapor.

2.1 Solid state methods

Powder blending and consolidation (powder metallurgy): Powdered metal and discontinuous reinforcement are mixed and then bonded through a process of compaction, degassing, and thermo-mechanical treatment (possibly via hot isostatic pressing (HIP) or extrusion)

Foil diffusion bonding: Layers of metal foil are sandwiched with long fibers, and then pressed through to form a matrix[2][3].

2.2 Liquid state methods

Electroplating and electroforming: A solution containing metal ions loaded with reinforcing particles is co-deposited forming a composite material

Stir casting: Discontinuous reinforcement is stirred into molten metal, which is allowed to solidify

Pressure infiltration: Molten metal is infiltrated into the reinforcement through use a kind of pressure such as gas pressure

Squeeze casting: Molten metal is injected into a form with fibers pre-placed inside it

Spray deposition: Molten metal is sprayed onto a continuous fiber substrate

Reactive processing: A chemical reaction occurs, with one of the reactants forming the matrix and the other the reinforcement

2.3 Semi-solid state methods

Semi-solid powder processing: Powder mixture is heated up to semi-solid state and pressure is applied to form the composites.

II. Applications

- Aerospace
- Automotive/Transportation/Farm/Construction
- Civil Infrastructure
- Construction
- Corrosive Environments
- Electrical
- Marine.

III.A review of the literature

Zhao et al.[4] investigated the microstructures and mechanical properties of ECAP-processed and naturally aged ultrafine grained (UFG) and coarse grained (CG) Al7075 alloys, as well as their evolution complying with heat treatment. Their research found that resulting from the testing, natural ageing, tensile yield strength, ultimate strength, & micro hardness of UFG materials were 103%, 35%, and 48% greater than that of CG samples, respectively. According to their findings, severe plastic deformation has the potential to improve the mechanical characteristics of age-hardening Al alloys.

The preparation and mechanical characterisation of silicon carbide and graphite-reinforced aluminium 6063 metal matrix are the focus of **Mr. S. Chandrasekhar's[5] work**. Different percentages of silicon carbide and graphite, such as (1+2), (3+2), and (5+2), can be taken into consideration. By preparing and analysing these materials, it is possible to learn more about the mechanical properties such as ultimate tensile strength, breaking strength, Brinell hardness, Brinell hardness, compression strength, and toughness. Due to their light weight, thermal characteristics, stiffness, high mechanical strength, and corrosion resistance, aluminium metal composites are useful in a variety of industries, including the automotive, aerospace, and defence sectors, as well as the building and construction industries. The qualities and characteristics of the composite aluminium matrix were investigated.

Karthikeyan et al. [6] use the stir casting process to create Al7075 alloy composites with varying volume fractions of short basalt fibre. In this work, the experimental strength values of the composites are compared to the theoretical values. Because of the random distribution of basalt fibres in the Al7075 matrix, the results revealed that the experimental values best matched the theoretical values.

Pradeep R et.al[7] noticed the study of mechanical properties of Al- Red Mud and Silicon Carbide Metal Matrix Composite (MMC) of Aluminium aluminium alloy of grade 7075 in addition of varying percentages of weight composition such as SiC8%+Al7075, SiC6%+Red mud2%+ Al7075, SiC4%+Red mud 4%+Al7075, SiC2%+Red mud 6%+Al7075, Red mud 8%+Al7075ed mud and Silicon Carbide elements by stir casting process. Results of the study show that the combination of Reinforced matrix material, such as Sic and Red mud particles, enhances mechanical qualities.

Keshava Murthy R et al. investigated Al7075-TiB2 in-situ composites produced by stir casting with commercially available Al-10%Ti and Al-3%Br master alloys. Microstructure analysis, micro hardness testing, grain size research, and tensile testing were performed on both the matrix alloy and the composite. The microstructure of the matrix alloy exhibits a very homogeneous dispersion of TiB2 particles. The composite's average grain size was less than that of the unreinforced alloy. When compared to unreinforced alloy, the micro hardness, yield strength, and ultimate tensile strength of Al7075-TiB2 composite were much greater.

IV. METHODOLOGY& MATERIALS USED IN EXPERIMENT

5.1 Aluminium 7075

7075 aluminium alloy (AA7075) is an aluminium alloy with zinc as the primary alloying element. It has excellent mechanical properties and exhibits good ductility, high strength, toughness, and good resistance to fatigue. It is more susceptible to embrittlement than many other aluminium alloys because of micro segregation, but has significantly better corrosion resistance than the alloys from the 2000 series. It is one of the most commonly used aluminium alloys for highly stressed structural applications and has been extensively used in aircraft structural parts.7075 aluminium alloy's composition roughly includes 5.6–6.1% zinc, 2.1–2.5% magnesium, 1.2–1.6% copper, and less than a half percent of silicon, iron, manganese, titanium, chromium, and other metals. It is produced in many tempers, some of which are 7075-0, 7075-T6, 7075-T651.

Materials	Percentage of composition
Zinc	6.10 %
Magnesium	2.65 %
Copper	1.55 %
Chromium	0.0028 %
Silicon	0.01 %
Manganese	0.001 %

Table 1. Composition of aluminium 7075

5.2 Silicon Carbide as reinforcement:

Silicon Carbide is the only chemical compound of carbon and silicon. It was originally produced by a high temperature electro-chemical reaction of sand and carbon. Silicon carbide is an excellent abrasive and has been produced and made into grinding wheels and other abrasive products for over one hundred years. Today the material has been developed into a high-quality technical grade ceramic with very good mechanical properties. It is used in abrasives, refractories, ceramics, and numerous high-performance applications. The material can also be made an electrical conductor and has applications in resistance heating, flame igniters and electronic components. Structural and wear applications are constantly developing.

5.3 Graphite:

Graphite is a mineral composed of stacked sheets of carbon atoms with a hexagonal crystal structure. It is the most stable form of pure carbon under standard conditions. Graphite is very soft, has a low specific gravity, is relatively non-reactive, and has high electrical and thermal conductivity. Graphite occurs naturally in igneous and metamorphic rocks, where high temperatures and pressures compress carbon into graphite. Graphite can also be created synthetically by heating materials with high carbon content. The carbon-rich material is heated to 2500 to 3000 degrees Celsius, which is hot enough to "purify" the material of contaminants, allowing the carbon to form its hexagonal sheets. Graphite is extremely soft and breaks into thin flexible flakes that easily slide over one another, resulting in a greasy feel. Due to this, graphite is a good "dry" lubricant and can be used in applications where wet lubricants (like lubricating oil) cannot.

V. MATERIAL COMPOSITION

MATERIAL	AL 7075(%)	SIC(%)	GRAPHITE(%)
A2	95	2	3
A4	93	4	3
A6	91	6	3

Table : Material compositions

VI. STIR CASTING AND MACHINING

Stir casting is currently the most popular commercial method of producing aluminium-based composites Stir casting of MMCs was initiated in 1968, when S. Ray introduced alumina particles into aluminium melt by stirring molten aluminium alloys containing the ceramic powders; allows for the use of conventional metal processing methods with theaddition of an appropriate stirring system such as mechanical stirring; ultrasonic or electromagnetic stirring; or centrifugal force stirring. to achieve proper mixing of reinforcement into melt which depends on material properties and process parameters such as the wetting condition of the particles with the melt, strength of mixing, relative density, and rate of solidification. The distribution of the particles in the molten matrix depends on the geometry of the mechanical stirrer, stirring parameters, placement of the mechanical stirrer in the melt, melting temperature, and the characteristics of the particles added and finally the liquid composite material is then cast by conventional casting methods and may also be processed by conventional Metal forming technologies.

VII. Characterization test

8.1 Tensile Test

A tensile specimen of standard dimensions machined from the metal is inserted in a tensile testing machine. The machine consists essentially of two parts: the straining or pulling device and an arrangement to measure and register the load on a dial. A gradually increasing tensile load is applied to the specimen and the resultant extension (or strain) of the specimen is observed.

Formula used:

$$\sigma_{ut} = \frac{\text{ultimate load}}{\text{Cross sectional area}}$$

Cross sectional area of the specimen is

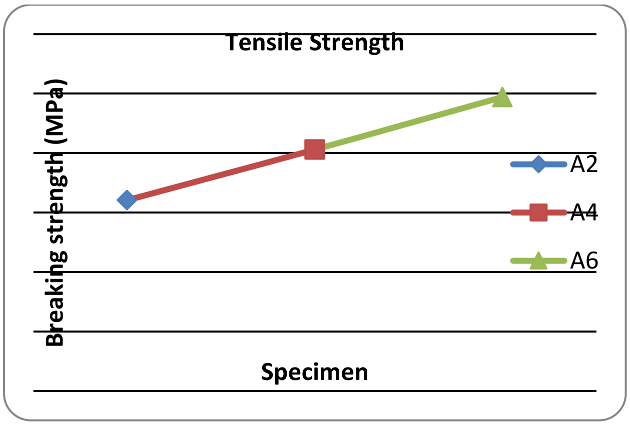
$A = \pi r^2 = \pi * 6^2 = 113.04\ mm^2$

r = radius of the circular cross section

= 6 mm

Specimen	Diameter d (mm)	Areaof the cross section (mm^2)	Breaking load(N)	Breaking strength (N/ mm^2)
A2	12	113.04	1813	16.04
A4	12	113.04	2294	20.3
A6	12	113.04	2793	24.71

Table 3.Tensile Strength



Graph 1. Specimen vs Tensile strength

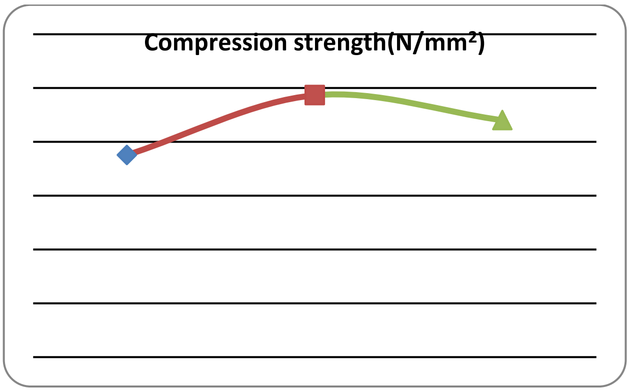
8.2 Compression Test

In compression testing, the sample or the component is compressed between two moving platens. A load cell and an extensometer or strain gauge are used to measure load and displacement. Compression tests are useful for testing material or component load-bearing capabilities under compressive loads. Compression pressure, for example, is taken into account in the design of tower structures, columns, bridge structures, and other load-bearing structures. The test is quite simple to conduct as well as the preparation of samples for testing.

Diameter of specimen is 20mm

Specimen	Area A(mm^2)	Load(P) KN	Compression strength(N/mm^2)
A2	314.15	118	375.61
A4	314.15	145	486.52
A6	314.15	132	440.19

Table 4.Compression Strength



Graph 2. Specimen vs Compression strength

8.3 IMPACT TEST

Toughness is, broadly, a measure of the amount of energy required to cause an item a test piece or a bridge or a pressure vessel to fracture and fail. The more energy that is required then the tougher the material. From this work the science of fracture toughness developed and gave rise to a range of tests used to characterize 'notch toughness' of which the Charpy-V test described in this article is one. There are two main forms of impact test, the Izod and the Charpy test.

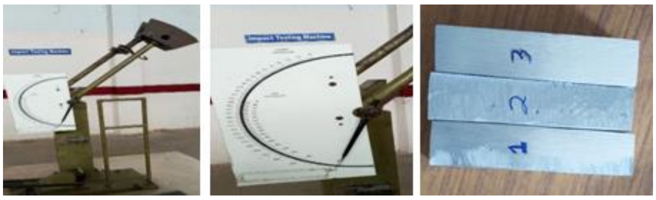


Fig 9. Impact Testing machine and its specimens

Observations of impact testing machine;

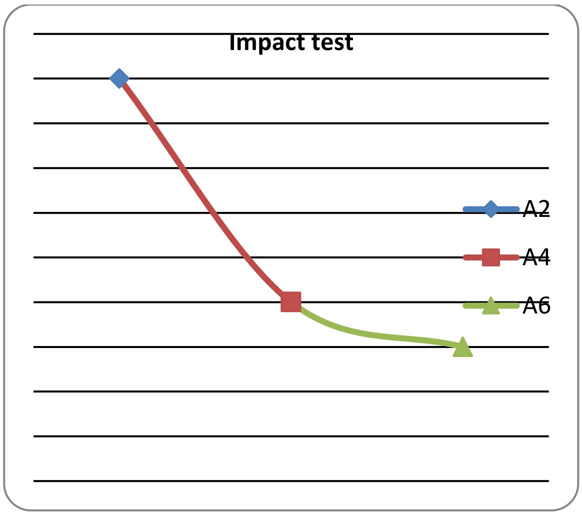
One division on scale = 2 joules

Charpy scale range = 0 –300 joules

Angle drop of pendulum =120^0

S.No	Material	Energy(j)
1	A2	60
2	A4	55
3	A6	54

Table5. Impact Test



Graph 3. Specimen vs Energy

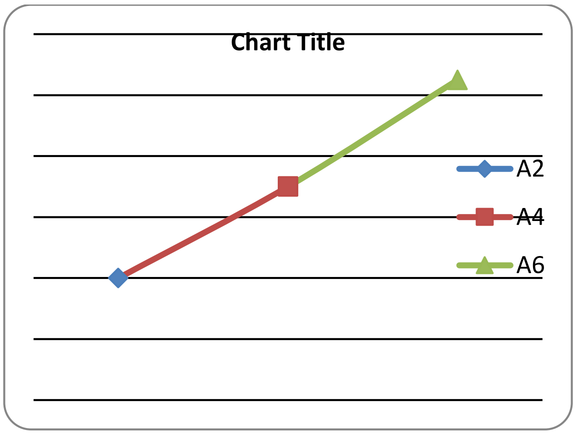
8.4 Hardness Test

Heat treating has evolved into a highly complex, precise process that improves characteristics of metal parts. A critical component of quality heat treating is employing the correct hardness testing method to show manufacturers their parts achieve design requirements.Hardness testing methods vary based on the material and heat treatment chosen. It's important that engineers specify hardness testing methods correctly to ensure timely heat treatment and avoid costly delays. Common hardness testing methods are introduced below.

Rockwell Hardness Test

Material	Load applied (100 kgf)	Reading on the indicator scale			Average RHN
		Trail 1	Trail 2	Trail 3	
A2	100	53	52	55	65
A4	100	58	55	53	66.5
A6	100	54	58	61	68.25

Table 6. Rockwell Hardness



Graph 4. Specimen vs RHN

Brinell's hardness Test

Module	Indent diameter Trail 1	Indent diameter Trail 2	Indent diameter Trail 3	Average
A2	5.16	5.18	5.23	5.19

A4	5.28	5.3	5.38	5.32
A6	5.66	5.69	5.78	5.71

Table 7. Brinell's Hardness

Where P is the applied load in kgf = 500 kgf

D = Diameter of the indenter = 10 mm

$$HB = \frac{2P}{\pi D\left(D - \sqrt{D^2 - d^2}\right)}$$

Where HB = Brinell's Hardness Number

VIII. Conclusion

Fabricated Hybrid metal matrix composites reinforced with silicon carbide and graphite by stir casting.

As per the results,

- In the tensile test, we noticed that raising the SiC % gradually enhances the tensile strength. Our research A6 sample had its highest strength, 24.71 N/mm2.
- In the compression test, we found that as the SiC % increases, the compression strength rises first and then turns down. Our investigation's A4 specimen has the maximum strength, 486.52 N/mm2.
- In the impact test, we discovered that when the SiC % increases, the energy reduces progressively. In our analysis, the A2 specimen has the maximum energy, 60 J.
- In the Rockwell hardness test, we discovered that raising the SiC % steadily raises the hardness value. Our research A6 specimen had the maximum hardness value of 68.25.
- We discovered in the Brinell hardness test that The hardness value rises as the SiC % rises. The A6 specimen has the greatest hardness value of 5.71.

IX. CONCLUSION

In this monitoring and management for green environment.

Cite this article as :

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Cite this article as :

Madanapu Ashok, Dr. V. Nagaprasad Naidu, "Investigation of Mechanical Characterization on Al-7075 Reinforced with Silicon Carbide and Graphite", International Journal of Scientific Research in Science and Technology (IJSRST), Online ISSN : 2395-602X, Print ISSN : 2395-6011, Volume 10 Issue 3, pp. 829-836, May-June 2023. Available at doi :
https://doi.org/10.32628/IJSRST523103145
Journal URL : https://ijsrst.com/IJSRST523103145