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Fabrication And Mechanical Property Investigation Of AL-7075 Reinforced With SIC And Graphite

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ABSTRACT

Composite material is defined as combination of two or more materials and to prepare and measure the characteristics of in detail about material. It can be classified into three types one is metal matrix composite, polymer matrix composite, ceramic matrix composite. The present work is on metal matrix composite "The present work deals with the preparation and mechanical characterization of Aluminium 7075 metal matrix reinforced with silicon carbide and graphite. Silicon carbide and graphite can be considered in different percentages like (2+3), (4+3) and (6+3). By using these materials to prepare and investigate the Mechanical characteristics like Ultimate tensile strength, Breaking strength, Rockwell hardness, Brinell hardness, Compression strength and toughness." Aluminium Metal Matrix Composites (AMMC) have various properties which makes it to be applicable into various places like automobile, military industries, aerospace, building constructions andothers due to light weight, thermal properties, stiffness, high mechanical strength corrosion resistance. During the analysis of the composite matrix of Aluminium, the properties / characteristic was investigated.

Key words: AMMC's, Stir casting, Mechanical properties of Aluminium 7075.

INTRODUCTION

Composite materials

A composite material is a material that consists of one or more discontinuous components (particles/fibers/reinforcement) that are placed in a continuous medium (matrix). In a fiber composite the matrix binds together the fibers, transfers loads between the fibers and protects them from the environment and external damage. Composite materials, or shortened to composites, are microscopic or macroscopic combinations of two or more distinct engineered materials (those with different physical and/or chemical properties) with a recognizable interface between them in the finished product. For structural applications, the definition can be restricted to include those materials that consist of a reinforcing phase such as fibers or particles supported by a binder or matrix phase. Wood composites are commonly seen examples of composite materials. Other features of composites include the following:

(1) The distribution of materials in the composite is controlled by mechanical means.

(2) The term composite is usually reserved for materials in which distinct phases are separated on a scale larger than atomic, and in which the composite's mechanical properties are significantly altered from those of the constituent components.

(3) The composite can be regarded as a combination of two or more materials that are used in combination to rectify a weakness in one material by a strength in another.

(4) A recently developed concept of composites is that the composite should not only be a combination of two materials, but the combination should have its own distinctive properties. In terms of strength, heat resistance, or some other desired characteristic, the composite must be better than either component alone.

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 their small 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.

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)

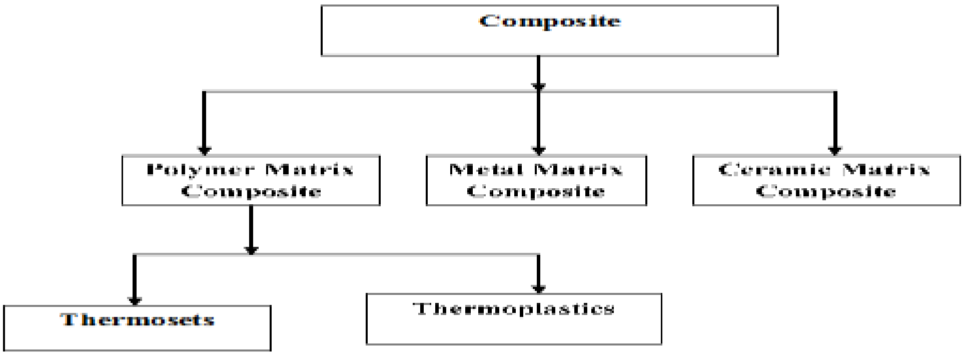

Fig 1. Types of composites

Polymer Matrix Composites (PMC)

Polymer matrix is the major component of the transdermal patch fabricated with multiple layers of polymer in which a reservoir is sandwiched between two polymeric layers. Polymer is composed of an outer impregnable layer preventing the loss of active substances and an inner polymeric layer functioning as a controlling membrane. The polymer matrix is designed based on the active substance used for the patch formulation, adhesion-cohesion balance, compatibility, and stability with other components of the patch. The requirements of a good matrix material are that it can infiltrate between the fibers and form a strong interfacial bond. It is also essential that there is no chance of chemical reaction between the matrix material and fibers and that the matrix material does not cause damage to the fibers. It have properties like low specific weight, high material stability against corrosion, good electrical and thermal insulation, ease of shaping and economic mass production and attractive optical properties

Metal matrix composites (MMC)

A metal matrix composite (MMC) is a composite material with at least two parts; one typically being some desired metal, and another being a reinforcing material (typically another metal or some organic compound). When at least three materials are present, it is called a hybrid composite. MMCs are made by dispersing a reinforcing material into a metal matrix. The reinforcement surface can be coated to prevent a chemical reaction with the matrix. For example, carbon fibers are commonly used in Aluminium matrix to synthesize composites showing low density and high strength. However, carbon reacts with aluminium to generate a brittle and water-soluble compound on the surface of the fiber. To prevent this reaction, the carbon fibers are typically coated with nickel, titanium boride, or some other element or compound. The reinforcement material is embedded into a matrix. The reinforcement does not always serve a purely structural task (reinforcing the compound). It can also be used to change physical properties (such as wear resistance, friction coefficient, or thermal conductivity). And the reinforcing material can be continuous or discontinuous. Discontinuous MMCs can be isotropic and be worked with standard metalworking techniques (extrusion, forging, rolling, etc). They can also be machined using conventional techniques, but commonly need the use of polycrystalline diamond tooling (PCD).

Ceramic matrix composites (CMC)

Composite materials are materials in which a homogenous matrix is reinforced by a stronger and stiffer constituent that is usually fibrous but may have a particulate or other shape (web.mit.edu). They are produced when two or more materials or phases are used together to give a combination of properties that cannot be attained otherwise. For example, steel reinforced concrete, plywood and fiber glass. Ceramic matrix composites are a type of composite with ceramics as both the reinforcement and the matrix material. The reinforcement provides its special properties while the matrix material holds everything together. These composites were developed for applications with demanding thermal and mechanical requirements, such as in aerospace vehicles, nuclear industries, ground transportation, space structures and chemical industries.

Applications of composite materials

Aerospace: Price used not to be a real deal in the Aerospace. It's not true anymore. The rise of new rivals and the amount of part to be produced imposed new manufacturing techniques and better production yields. New challenges come with new solutions.

Automotive & Road Transportation: Composites will play a very important role very soon in the Automotive & Road Transportation sector due to CO2 emission regulations on a global scale. One of the easiest way of reducing a car emission is by enlightening it. Composites are obviously materials of choice for such task.

Building & Civil Engineering: "Built to last" is one of the motto used in the Building & Civil Engineering sector. Composites fulfil it and help older structures to keep their integrity over time. More and more engineers from this sector leave concrete and steel for smarter solutions.

Defence, security & Ballistics: Personal, vehicle and equipment protections take full benefits of composites which absorb of dissipate energy thanks to their intrinsic nature. Moreover, composites allow to downsize of the weight penalty of any protection.

Design, Furniture & Home: Every other composite end-use area is of interest for any research and development related to a composite material.

Railway Vehicles & Infrastructure: User safety is the number one rule in the railway sector. Its standards are really stringent but at the same time, this sector is seeking for lighter and more practical solutions. Composites still can win new market share in this rather conservative environment.

Sports, Leisure & Recreator: The place to try new materials in a very severe environment in terms of loads or shocks, Sports & Leisure sectors see a continuous development of new materials, applications or processes.

LITERATURE SURVEY

Zhao et.al. studied the microstructures and mechanical properties of equal-channel angular pressing (ECAP) processed and naturally aged ultrafine grained (UFG) and coarse grained (CG) Al7075 alloys and their evolutions during heat treatment. Their studies established that after the tests, natural aging, tensile yield strength, ultimate strength and micro hardness of UFG samples were higher by 103%, 35% and 48% respectively than those of the CG samples. Their studies show that severe plastic deformation has the potential to significantly improve the mechanical properties of age-hardening Al alloys.

Mr. S. Chandrasekhar deals with the preparation and mechanical characterization of aluminium 6063metal matrix reinforced with silicon carbide and graphite. Silicon carbide and graphite can be considered in different percentages like (1+2), (3+2), (5+2). By using these materials to prepare and investigate the mechanical characteristics like ultimate tensile strength, breaking strength, Rockwell hardness, Brinell hardness, compression strength and toughness. Aluminium metal composites have various properties which makes it to be applicable into various places like automobile, military industries, aerospace, building constructions and others due to light weight, thermal properties, stiffness, high mechanical strength, corrosion resistance. During the analysis of the composite matrix of aluminium the properties / characteristic were investigated

Karthikeyan et.al. Al7075 alloy composites containing different volume fraction of short basalt fiber are developed using the stir casting process. The experimental strength values of the composites are compared with the theoretical values in this paper. The results suggested that the experimental values best suited the theoretical values owing to the random distribution of basalt fibers in the Al7075 matrix.

Pradeep R et.al observed the study of mechanical properties of Al- Red Mud and Silicon Carbide Metal Matrix Composite (MMC) of Aluminum alloy of grade 7075 with addition of varying weight percentage 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 particles by stir casting technique. The experimental result reveals that the combination of a matrix material with reinforcement such as Sic and Red mud particles, improves mechanical properties.

Keshava Murthy R et.al studied about Al7075-TiB2 in-situ composite, processed by stir casting technique using commercially available Al-10%Ti and Al- 3%Br master alloys. Both matrix alloy and composite were subjected to microstructure analysis, micro hardness test, grain size studies and tensile test. Microstructure shows fairly uniform distribution of TiB2 particles in matrix alloy. Average grain size of the composite was lower than unreinforced alloy. Micro hardness, yield strength and ultimate tensile strength of Al7075-TiB2 composite, were considerably higher when compared with unreinforced alloy.

METHODOLOGY & MATERIALS USED IN EXPERIMENT

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.

Table 1. Compositions of Aluminium 7075

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

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.

Properties of Silicon Carbide:

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Silicon Carbide (SiC) is highly worn resistant and also has good mechanical properties, including high temperature strength and thermal shock resistance. Silicon Carbide (SiC), as a technical ceramic, is produced in two main ways. Reaction bonded SiC is made by infiltrating compacts made of mixtures of Silicon Carbide (SiC) and Carbon with liquid Silicon. The Silicon reacts with the Carbon forming Silicon Carbide (SiC). The reaction product bonds the SiC particles. Sintered SiC is produced from pure SiC powder with non-oxide sintering aids. Conventional ceramic forming processes are used and the material is sintered in an inert atmosphere at temperatures up to 2000°C or higher.

Fig 2. Silicon Carbide as reinforcement

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.

Fig 3. Graphite as reinforcement

Properties of Graphite:

Graphite is a good conductor of electricity due to its free delocalized electron which is free to move throughout the sheets. Graphite is insoluble in organic solvents and water, this is because the attraction between solvent molecules and carbon atoms is not strong enough to overcome the

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covalent bonds between the carbon atoms in the graphite. Graphite has a high melting point of 36500C near the melting point of Diamond. Due to its layer-like structure, it is soft and slippery in nature. Graphite has the ability to absorb high-speed neutrons**.**

MATERIAL COMPOSITION

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

Table 2. Material compositions

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 the addition 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.

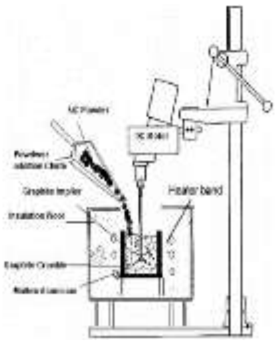

Fig 4. Stir Casting process

Turning operation

Turning is a machining process performed on a machine in which the cutting tool (non-rotary tool bit) follows a helix tool path by moving linearly along the workpiece. Turning traditionally refers to the action of cutting external surfaces, whereas “boring” refers to the action of cutting internal surfaces (holes). Thus, the phrase “turning and boring” classifies several processes known as lathing. Turning can be done manually, as in the traditional form of the lathe, which often requires constant supervision by the operator. An automated lathe that doesn’t require operator input and is most commonly referred to as a computer numerical control, or CNC. An object that undergoes turning operations is called a “turn part” or a “machined object.” It is possible to process most cylindrical, conical, end faces, grooves, and thread surfaces that have rotary surfaces with turning operations. Let’s understand the process of turning.

Turning Process

In the turning process, the tool normally moves with the main axis (z) while the workpiece rotates. When configured with a diameter less than the actual diameter of the workpiece, it cuts off the workpiece’s “surface” and reduces its diameter. It can also run perpendicular to the central axis. This operation is typically used to remove material only from the flat face (facing operation) or to remove a specific portion from the total length (cut-off).

The figure above illustrates the standard turning process forces, which can also be seen given the parallel direction of the cutting tool and the spindle’s velocity.

Fig 5. Turning process

There are a few things to consider when a good accuracy and surface finish are required. Good operating quality, clamping stability, and correct centre height is three of these important factors. It is assumed that the chip generated during turning slides on the tool’s rake face. As positive rake angles produce higher shear angles, cutting forces are reduced, and chips flow more easily, resulting in a better surface finish.

RESULT AND DISCUSSION

Tensile Test

The tensile test procedure involves attaching the sample to the testing machine and applying force until the material fractures. The results are typically recorded in a stress-strain diagram. The most important parameters measured in the test are the ultimate tensile strength, yield strength, and elongation at break. A

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tensile test is used to determine the yield point or yield strength, tensile strength or ultimate tensile stress, and percentage elongation of a metal. The tensile Testing method measures the force required to break a metallic, composite, or plastic specimen and the extent to which the specimen stretches or elongates to that breaking point.

Tensile Test Procedure

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.

Fig 6. Tensile Testing machine

The relation between applied stress (i.e., load divided by cross-section) and extension or elongation is indicated by a stress-strain curve such as the one shown in the below figure, which is typical of ductile carbon steel. Up to point P on the curve, the stress is proportional to the strain as indicated by a straight line. It is termed the limit of proportionality. Beyond P, the curve deviates from the straight line. Point E on the curve is the elastic limit. This means that up to this point the specimen returns to its original dimensions when the load is removed and thus exhibits elasticity. As the load is increased beyond the elastic limit, there comes a point at which there is a sudden extension, indicated by the drop of the beam and continued extension with a lower load. If the load is removed, the specimen does not recover its original dimensions and it is said to have undergone plastic deformation or plastic flow.

Tensile Test Specimens Dimensions

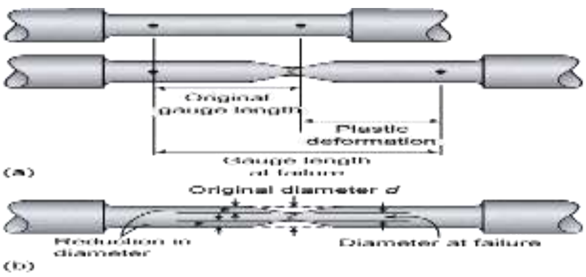

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Fig 7. Tensile Test Specimens

In the tensile specimen, gauge length and parallel length are standard dimensions. These are shown in the Figure below. Gauge length which is usually 50 mm is marked by two points on the specimen before testing, and the final gauge length after fracture is measured.

Formula used:

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

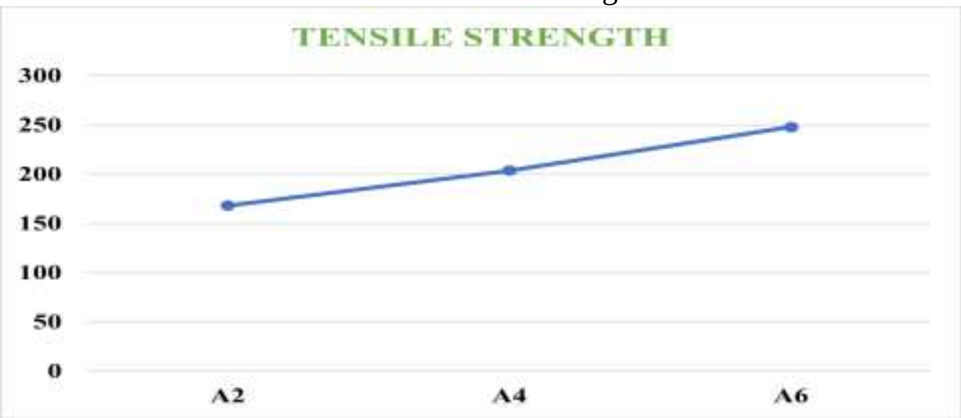
Cross sectional area of the specimen is $A = \pi r^2$ = 3.14*6*6 = 113.04 mm^2

r = radius of the circular cross section = 6 mm

Tensile strength

S. No	Material	Gauge length(mm)	Diameter 2r(mm)	Area of the cross section	Breaking load (Kgf)	Breaking strength (KPa)
1	A2	100	12	113.04	190	168
2	A4	99	12	113.04	230	203.46
3	A6	98	12	113.04	280	247.69

Table 3. Tensile Strength



Graph 1. Specimen vs Tensile strength

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.

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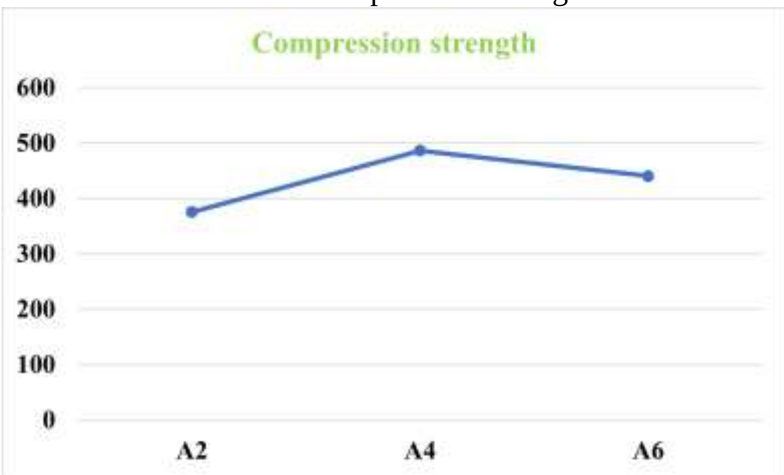
Fig 8. Compression testing machine and Test specimens

S.No	Diameter	Length	Area A(mm^2)	Load(P) KN	Compression strength(N/mm^2)
A2	20	40	314.15	118	375.61
A4	19.48	39.5	298.03	145	486.52
A6	19.54	39	299.87	132	440.19

Table 4. Compression Strength



Graph 2. Specimen vs Compression strength

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.

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Fig 9. Impact Testing machine and its specimens

Observations of impact testing machine;

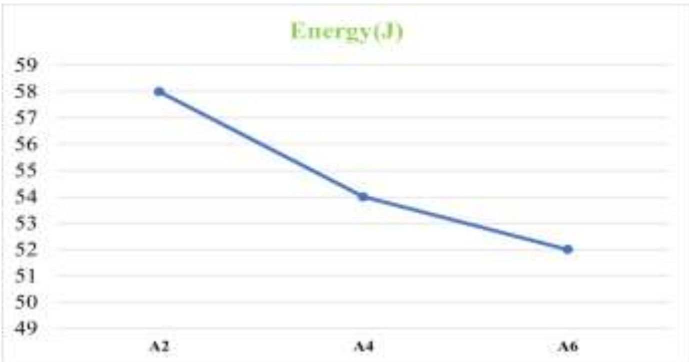
One division on scale = 2 joules

Charpy scale range = 0 – 300 joules

Angle drop of pendulum = 120^0

S. No	Material	Energy(j)
1	A2	58
2	A4	54
3	A6	52

Table 5. Impact Test



Graph 3. Specimen vs Energy

Hardness Test

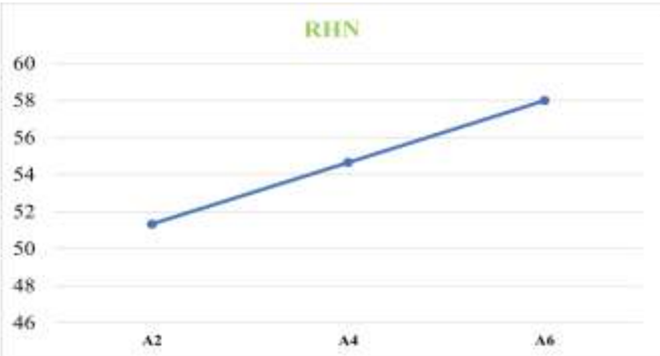
Heat treating has evolved into a highly complex, precise process that improves characteristics of metal parts. A critical component of quality heat treating is employing the correct hardness testing method to show manufacturers their parts achieve design requirements. Hardness testing methods vary based 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.

Fig 10. Hardness Testing machine

Rockwell Hardness Test

Material	Load applied (100 kgf)	Reading on the indicator scale			Average RHN
		Trail 1	Trail 2	Trail 3	
A2	100	51	53	50	51.33
A4	100	56	55	53	54.66
A6	100	55	58	61	58

Table 6. Rockwell Hardness



Graph 4. Specimen vs RHN

Brinell's hardness Test

Modules S. No	Indent diameter Trail 1	Indent diameter Trail 2	Indent diameter Trail 3	Average
A2	5.12	5.15	5.18	5.15
A4	5.24	5.29	5.36	5.3
A6	5.55	5.61	5.68	5.61

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

Conclusion

The fabrication of hybrid metal matrix composites reinforced with silicon carbide and graphite by stir casting method was completed successfully. According to the results,

- In Tensile test, we observed that as increasing the SiC percentage, the tensile strength increases gradually. We observe the highest strength in our investigation A6 specimen i.e. 247.69 KPa.
- In Compression test, we observed that as increasing the SiC percentage, the compression strength increases first and decreases gradually. We observe the highest strength in our investigation A4 specimen i.e. 486.52 N/mm^2.
- In Impact test, we observed that as increasing the SiC percentage, the energy decreases gradually. We observe the highest energy in our investigation A2 specimen i.e. 58 J.
- In Rockwell hardness test, we observed that as increasing the SiC percentage, the hardness value increases gradually. We observe the highest hardness value in our investigation A6 specimen i.e. 58.
- In Brinell hardness test, we observed that as increasing the SiC percentage, the hardness value increases gradually. We observe the highest hardness value in our investigation A6 specimen i.e. 5.61.

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