THE MECHANICAL CHARCTERIZATION OF FLY ASH AND TiB_2 REINFORCED ALUMINIUM HYBRID METAL MATRIX COMPOSITE

A project report submitted in partial fulfilment of the requirement for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

MECHANICAL ENGINEERING

Submitted by

318126520206 Y. RAJENDRA

319126520L29 B. CHAKRADHAR

319126520L33 K.K SAI JAYANTH

319126520L45 I.T.S KRISHNA CHOWDARY

319126520L53 P. KARTHIK

Under the guidance of

Mr. A.P.S.V.R. SUBRAHMANYAM

Assistant Professor

Dept. of Mechanical Engineering

ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY & SCIENCES (A)

(Permanently affiliated to Andhra University, Approved by AICTE, Accredited by NBA & NAAC) Sangivalasa – 531162, Bheemunipatnam (Mandal), Visakhapatnam (District), Andhra Pradesh, India.

2018-2022

ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY AND SCIENCES

Autonomous status accorded by UGC and Andhra University (Approved by AICTE, Permanently Affiliated to Andhra University, Accredited and reaccredited by NBA, accredited by NAAC - 'A' Grade) Sangivalasa, Bheemunipatnam Mandal Visakhapatnam (District) - 531162

PRAGNANAM BRAHMA
ANITS

CERTIFICATE

This is to certify that the Project Report entitled **"THE MECHANICAL CHARCTERIZATION OF FLYASH AND TiB2 REINFORCED ALUMINIUM HYBRID METAL MATRIX COMPOSITE"** being submitted by **(318126520206) Y. RAJENDRA, (319126520L29) B. CHAKRADHAR, (319126520L33) K.K SAI JAYANTH, (319126520L45) I.T.S KRISHNA CHOWDARY, (319126520L53) P. KARTHIK.** In partially fulfilment for the award of Degree of Bachelor of Technology in Mechanical Engineering. It is the work of bonafide, carried out under the guidance and supervision of **MR.A.P.S.V.R. SUBRAHMANYAM** Assistant Professor Department of Mechanical Engineering during the academic year 2018 to 2022

26/5/22

PROJECT GUIDE
(Mr. A.P.S.V.R. SUBRAHMANYAM)
Assistant Professor
Mechanical Department
ANITS, Visakhapatnam

HEAD OF THE DEPARTMENT
(Dr. B. NAGA RAJU)
Head of the Department
Mechanical Department
ANITS, Visakhapatnam

PROFESSOR & HEAD
Department of Mechanical Engineering
ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY & SCIENCES
Sangivalasa 531 162 VISAKHAPATNAM Dist A P

THIS PROJECT IS APPROVED BY THE FOLLOWING BOARD OF EXAMINERS

INTERNAL EXAMINER:

PROFESSOR & HEAD
Department of Mechanical Engineering

EXTERNAL EXAMINER:

ACKNOWLEDGEMENTS

We are extremely fortunate to work under the guidance of **Mr. A P S V R SUBRAHMANYAM**, associate professor of department of mechanical engineering, Anil Neerukonda Institute of Technology and Science. he provides extraordinary guidance and support. his suggestions in the experimental stage, interpretation of results and these writings have been really great help.

We were very thankful to **PROF. T.V. HANUMANTHA RAO,** principal and **Dr. B. NAGARAJU,** head of the department, mechanical engineering department, Anil Neerukonda Institute of Technology & sciences for their valuable suggestions.

We express our sincere thanks to the members of non-teaching staff of mechanical engineering for their kind cooperation and support to carry on work.

Last but not the least, we like to convey our thanks to all who have contributed either directly or indirectly for the completion of our work.

318126520206 Y. RAJENDRA

319126520L29 B. CHAKRADHAR

319126520L33 K.K SAI JAYANTH

319126520L45 I.T.S KRISHNA CHOWDARY

319126520L53 P. KARTHIK

ABSTRACT

The need of today's industry is to have light weight, high strength materials with desired functionality. The Al 7075 known for its application in aerospace and aviation sector due to its light weight, high strength, good thermal and mechanical properties. Fly ash is a heterogeneous by-product material produced in the combustion process of coal used in power stations. It is a fine grey coloured powder having spherical glassy particles that rise with the flue gases. Titanium diboride (TiB_2) is an extremely hard ceramic which has excellent heat conductivity, oxidation stability and wear resistance.

In our present study, an attempt has been made to combine the Fly ash and TiB_2 in 4:4 and 3:5 respective proportions to Al matrix. Fly ash particles are added to develop metal matrix composites using liquid metal processing route. The results considered by the experimental studies regarding mechanical properties indicated that increasing the mass percentage of TiB_2 and Fly ash in the composition of 4:4 mass ratio improves the mechanical characteristics such as hardness, impact strength and tensile strength of material.

Keywords: Al7075, TiB_2 and Fly ash, AHMMCs, Mechanical properties.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION TO COMPOSITES

A composite material is a combination of two materials with different physical and chemical properties. When they are combined they create a material which is specialised to do a certain job, for instance to become stronger, lighter or resistant to electricity. They can also improve strength and stiffness. The reason for their use over traditional materials is because they improve the properties of their base materials and are applicable in many situations. Weight saving is one of the main reasons for using composite materials rather than conventional materials for components. While composites are lighter they can also be stronger than other materials. Another advantage of using a composite over a conventional type of material is the thermal and chemical resistance as well as the electrical insulation properties. Unlike conventional materials, composites can have multiple properties not often found in a single material. Fibre reinforced composites, such as fibre reinforced plastic (FRP composites), are finding increasing use in the design and manufacture of final products for commercialisation.

1.2 ADVANTAGES

- Low costs compared to metals
- Design flexibility
- Resistance to a wide range of chemical agents
- Low weight
- Durability
- Electric insulation
- High Impact strength

1.3 DISADVANTAGES

• The resin used in composite material weakens at temperatures as low as 150 degrees, making it essential for these aircraft to avoid fires.

• Fires involved with composite materials can release toxic fumes and micro particles into the air. Temperatures above 300 degrees can cause structural failure.

• Finally, composite materials can be expensive, but long-term cost savings typically offset the high initial costs

• Composite materials don't break easily, but that makes it hard to tell if the interior structure has been damaged at all. In contrast, aluminium bends and dents quickly, making it easy to detect structural damage; the same damage is harder to detect with composite structures. Repairs can also be more difficult when a composite surface is damaged.

1.4 PROPERTIES OF COMPOSITE MATERIALS

- High Strength to Weight Ratio: Fibre composites are extremely strong for their weight. By refining the laminate many characteristics can be enhanced.
- Lightweight: A standard Fibreglass laminate has a specific gravity in the region of 1.5, compared to Alloy of 2.7 or steel of 7.8. When you then start looking at Carbon laminates, strengths can be many times that of steel, but only a fraction of the weight.
- Fire Resistance: The ability for composites to withstand fire has been steadily improving over the years. There is two types of systems to be considered:
- Fire Retardant: Are self-extinguishing laminates,
- Fire Resistant: More difficult and made with the likes of Phenolic Resins.
- Electrical Properties: Fibreglass Developments Ltd produced the Insulator Support straps for the Trans Rail main trunk electrification. The straps, although only 4mm thick, meet the required loads of 22 kN, as well as easily meeting insulation requirements.

1.5 USES

Another advantage of using a composite over a conventional type of material is the thermal and chemical resistance as well as the electrical insulation properties. Unlike conventional materials, composites can have multiple properties not often found in a single material.

Fibre reinforced composites, such as fibre reinforced plastic (FRP composites), are finding increasing use in the design and manufacture of final products for commercialisation.

1.6 APPLICATIONS

- **Aerospace:** Major OEMs such as Airbus and Boeing have shown the potential for large-scale composite applications in aviation, and NASA is continually looking to composites manufacturers for innovative space solutions for rockets and other spacecraft.
- **Architecture**: The architecture community is experiencing substantial growth in the understanding and use of composites. Composites offer architects and designer performance and value in large-scale projects and their use is increasing in commercial and residential buildings.
- **Energy:** New advancements in composites, particularly those from the U.S. Department of Energy, are redefining the energy industry. Composites help enable the use of wind and solar power and improve the efficiency of traditional energy suppliers.
- **Automotive**: As the largest composites market, the automotive industry is no stranger to composites. Composites help make vehicles lighter and more fuel efficient.
- **Infrastructure:** Composites are used all over the world to help construct and repair a wide variety of infrastructure applications, from buildings and bridges to roads and railways.
- **Marine:** The marine industry uses composites to help make hulls lighter and more damage resistant. Composites can be found in many more areas of a maritime vessel, including interior mouldings and furniture on super yachts.
- **Pipe & Tank:** Fibre-reinforced polymer composite pipes are used for everything from sewer upgrades and wastewater projects to desalination, oil and gas applications. When corrosion becomes a problem with pipes made with traditional materials, FRP is a solution.
- **Sports & Recreation:** From football helmets and hockey sticks to kayaks and bobsleds, carbon fibre and fibreglass composite materials help athletes reach their highest performance capabilities and provide durable, lightweight equipment.
- **Transportation:** While FRP in cars gets most of the attention, composites can also play a big role in increasing fuel efficiency in trucks. A number of U.S. state Departments of Transportation are also using composite to reinforce the bridges those trucks travel on.

1.7 MATRIX

Composites usually comprising one continuous phase known as a matrix together with one or more discontinuous phase are called reinforcements. Composite materials have two phases, the reinforcing and matrix, for the matrix phase, ceramic's metals or polymers utilized, and for reinforcing phase Fibers, Particles utilized. The matrix binds the fibre reinforcement, transfers loads between fibers, gives the composite component its net shape and determines its surface quality. A composite matrix may be a polymer, ceramic, metal or carbon. Polymer matrices are the most widely used for composites in commercial and high-performance aerospace applications. Ceramic and metal matrices are typically used in very high-temperature environments, such as engines. Carbon as a matrix is used in extreme high-temperature applications, such as carbon/carbon brakes and rocket nozzles.

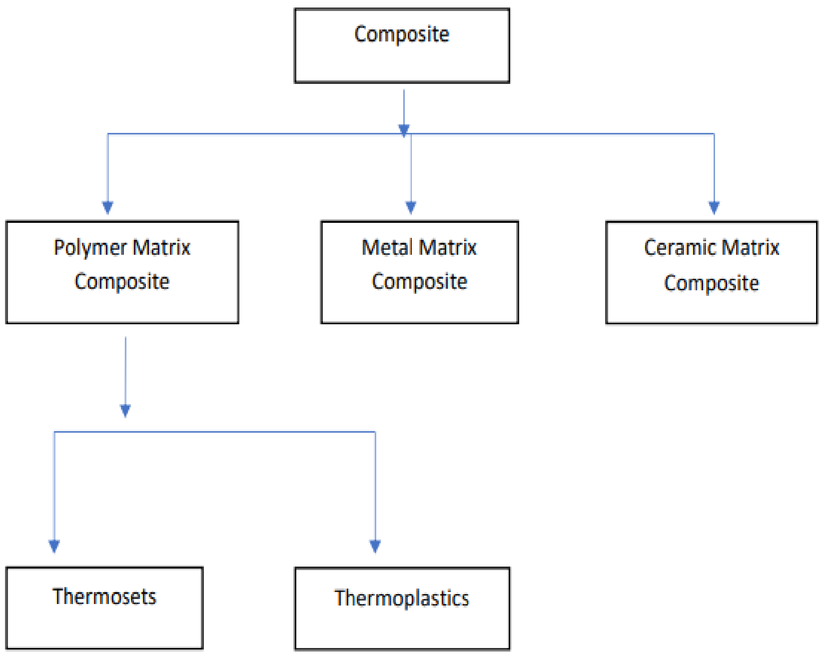


Figure 1.1 classification of composites

1.8 TYPES OF MATRIX

1) Ceramic matrix composition

Composite material comprised into two parts one is matrix and another one is reinforcement. Matrix provides strength and stiffness. Ceramic matrix composition are subgroup of composite material.

The ceramic matrix consists of ceramic fibre reinforced (CFRc)

CMC Reinforcing Materials

Typical reinforcing fiber materials include the following:

- Carbon, C
- Silicon Carbide, SiC
- Alumina, Al_2O_3
- Mullite or Alumina Silica, Al_2O_3-SiO_2

2) Metal matrix composition

Metal matrix composites (MMCs) are composite materials that contain at least two constituent parts – a metal and another material or a different metal. The metal matrix is reinforced with the other material to improve strength and wear. Where three or more constituent parts are present, it is called a hybrid composite. In structural applications, the matrix is usually composed of a lighter metal such as magnesium, titanium, or aluminium. In high temperature applications, cobalt and cobalt-nickel alloy matrices are common. Typical MMC's manufacturing is basically divided into three types: solid, liquid, and vapor. Continuous carbon, silicon carbide, or ceramic fibers are some of the materials that can be embedded in a metallic matrix material. MMCs are fire resistant, operate in a wide range of temperatures, do not absorb moisture, and possess better electrical and thermal conductivity. They have also found applications to be resistant to radiation damage, and to not suffer from outgassing. Most metals and alloys make good matrices for composite applications.

3) Polymer matrix composition

Polymer matrix composites (PMCs) can be divided into three sub-types, namely, thermoset, thermoplastic, and rubber. Polymer is a large molecule composed of repeating structural units connected by covalent chemical bonds. PMC's consist of a polymer matrix combined with a fibrous reinforcing dispersed phase. They are cheaper with easier fabrication methods. PMC's are less dense than metals or ceramics, can resist atmospheric and other forms of corrosion, and exhibit superior resistance to the conduction of electrical current.

i. Thermosets: Thermosets have qualities such as well-bounded three-dimensional moleculer structure after curing. They decompose instead of hardening.
ii. Thermoplastics: Thermoplastics have one or two dimensional moleculer structure they tend to at an elevated temperatures and show exaggregated melting point another advantage is that the process of softening at elevated temperatures can reversed to regain its properties during cooling.

1.9 METAL MATRIX COMPOSITION(MMC):

A.H. M.M.C.s are metallic alloys reinforced with mostly ceramic materials. The common metallic alloys utilized are alloys of light metals (Titanium, Magnesium and Aluminium) however; other metallic alloys like zinc (Zn), copper (Cu) and stainless steel have been used and Aluminium remains the most utilized metallic alloy as matrix material in the development of A.M.M.C.s. A.M.M.C.s, like all composites, consist of at least two chemically and physically distinct phases, suitably distributed to provide properties not obtainable with either of the individual phases alone. Typically, a MMC has two phases, e.g., a fibrous or particulate phase distributed in a metallic matrix.
With respect to metals, Aluminium hybrid M.M.C.s provide the following advantages:

- Higher strength to weight ratio.
- Higher elevated temperature stability, i.e., Creep resistance.
- Significantly improved cyclic fatigue characteristics.

1.10 FUNCTIONS OF MATRIX

- Holds the fibres together
- Protects the fibre from environment
- Distributes the loads evenly between fibres so that all fibres are subjected to the same amount of strain
- Enhances transverse properties of a laminate
- Improves impact and fracture resistance of a component
- Carry inner laminar shear

1.11 REINFORCEMENT

Reinforcement is defined as the action or process of strengthening the composite material. Reinforcement material was added to the matrix material for physical properties of the final composite material. There are Two kind of reinforcement material was used mostly one is synthetic fibre and another one is natural fibre. Secondary reinforcement was added to the composite material to further enhance the properties of the composite. When two or more reinforcement material were added to the matrix material, then composite was called as hybrid composite. Reinforcement increases the mechanical properties and it provides strength and stiffness to the composite. The reinforcement changes the material properties like wear resistance, thermal conductivity.

1.11.1 FIBRE REINFORCEMENT COMPOSITES (FRC)

Fibres are the most important class of reinforcement as they satisfy the desired conditions and transfer strength to the matrix constituent influencing and enhancing their properties as desired. Fibres fall sort of ideal performance due to several factors. The performance of the fibre judged by its length, shape, orientation and composition of the fibres and the mechanical properties of the matrix. The orientation of the fibre in matrix is an indication of strength.

1.11.2 TYPES OF REINFORCEMENT

1) Whisker's reinforcement composites: In whiskers reinforcement composites has single crystals grown with nearly zero defects are termed as whiskers. They are usually discontinuous and short fibres of different cross sections made from several

materials like graphite, silicon carbide, copper etc. typically they are in 3 to 5mm range.

2) Flake reinforcement composites: In flake reinforcement composites has single flakes are often used in place of fibres as can be densely packed. Metal flakes that are in close contact with each other in polymer matrices can conduct electricity or heat, while mica flakes and glass can resist both

3) Particulate reinforced composites: In particulate reinforced composites the microstructures of metal and ceramics composites, which show particles of one phase strewn in the other. square, triangular and round shapes of reinforcement are known but the dimensions of all their sides are observed to be more are less equal.

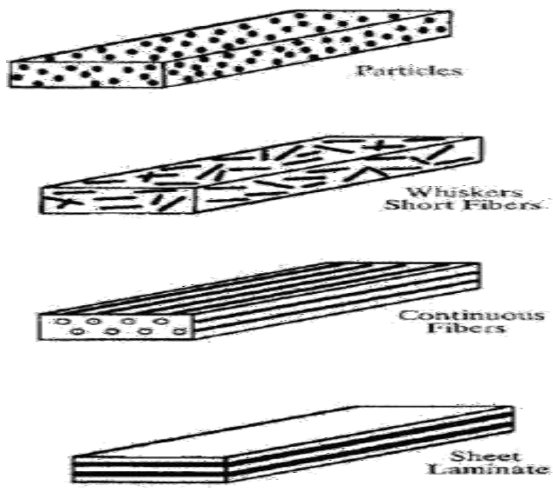


Figure 1.2 Types of reinforcements

1.12 FUNCTIONS OF REINFORCEMENT

- It provides strength and stiffness
- Provides heat resistance
- Provides corrosion resistance
- Properties of composite are controlled by properties of fillers.

1.13 FABRICATION METHORD OF MMC

- stir casting specimens exhibited high hardness compared to powder metallurgy specimens. Stir casting specimens are finer grains in the microstructure than the powder metallurgy specimen. After extrusion, both the extruded specimen exhibited reduced porosity, more uniform particle distribution, elimination of clusters and improved ductility and also both the specimens experienced grain refinement and increased strength. The load required for extrusion was less for the powder metallurgy process than for the stir casting process. The above results concluded that stir casting specimens have higher strength than powder metallurgy specimens.

- Liquid state fabrication of MMC involves incorporating dispersed phase into a molten metal matrix, followed by its solidification. Good mechanical properties uniformly throughout the composite should be obtained to provide good mechanical properties uniformly throughout the composite, good interfacial bonding (wetting) between the dispersed phase and liquid metal matrix. One way to improve wetting is by coating the dispersed phase. The proper coating reduces the interfacial energy and prevents chemical interaction between the dispersed phase and matrix. The simplest and most effective method for liquid state casting is stir casting.

1.14 MECHINICAL PROPERTIES

The attractive physical and mechanical properties obtained with metal matrix composites, such as high specific modulus, strength and thermal stability, have been documented extensively. Several investigators have also reviewed the various factors controlling the properties of particulate A.H.M.M.C.s and the influence of the manufacturing route on the MMC properties. Improvement in modulus, strength, fatigue, creep and wear resistance has already been demonstrated for various reinforcements. The tensile strength is the most convenient and widely quoted measurement of these properties and is of central importance in many applications.

It is apparent from the literature that parameters controlling the mechanical properties of particulate reinforced composites are still not understood in any detail. However, some of the essential factors are becoming apparent.

- The strength of composites is observed to be most strongly dependent on the volume and particle size of the reinforcement.
- Due to the increased dislocation density, dislocation strengthening will play a more significant role in the MMC than in the unreinforced alloy.

- Of most significant concern appears to be the introduction of defects and homogeneities in the various processing stages, which has resulted in considerable scatter in the mechanical properties.

1.15 DISCUSSIONS

A detailed study was undertaken to pool up the existing literature on Aluminium-based M.M.C.s, and efforts were put into understanding the basic needs of the growing Composite industry. This includes various aspects such as Characterization, fabrication, testing, analysis and correlation between microstructure and the properties obtained.

Specific conclusions were drawn

- Pure aluminium matrix is preferred to various alloy matrices due to the high-temperature stability of the Aluminium as compared with aluminium alloys. Lower working temperatures in the case of alloy matrices are attributed to the lower strength of the alloy matrix and coarsening of the grains. In addition, the load transfer in the case of a pure aluminium matrix is more effective due to the clean interface.
- There is a wide range of databases in the literature for different reinforcements in Aluminium Metal Matrix Composites.
- In particle reinforced composites, the fracture mode was observed to depend on reinforcement purity, reinforcement particle size, nature of the interface, the volume fraction of reinforcement, fabrication route adopted, the extent of hot working, presence of any intermetallic precipitates and extent of coherency of the second phase with the matrix.
- Thus the priority of this work will be to prepare aluminium hybrid MMCs using titanium diboride (TiB_2) and fly ash as reinforcement and to study its mechanical properties.

CHAPTER 2

2.1 LITERATURE REVIEW

We have searched with the term Aluminium Hybrid composites in google scholar with time period between 2010-2021. We have nearly 150 research articles and 20 review articles. Some of the articles are closely related to our proposed work. So, we summarized these works as follow.

Various weight percentage of titanium diboride reinforced aluminium matrix composites were successfully fabricated by stir casting fabrication technique. X-Ray Diffraction analysis reveals the existence of TiB2 particles throughout the aluminium matrix. Wear rate enhances and coefficient of friction reduces with the increase in load due to high friction generation in between specimen pin of composite material rubbing against counter plate surface **[1].**

Yield tensile performance of the metal matrix composites increased the strength of the regular aluminium alloy and maximum yield tensile stress is achieved. From the tensile test, it could be said that both the ultimate tensile strength and the yield tensile strength have been increased by increasing the SiC weight percent from 0 to 10. Especially in comparison to SiC, the impact of ultimate tensile stress and yield strength on the percentage weight of fly ash is slightly lower. Brinell hardness numbers for composite materials have also improved relative to Al7075 alloy without the strengthening of silicon carbide and fly ash **[2].**

Hardness of MMC increased with the addition of SiC weight fraction and Al2O3 weight fraction. Addition of reinforcements should be considered in proper proportions in order to gain optimum hardness. Better results were obtained on tensile strength by using different reinforcement particles such as graphite, fly ash. To increase the compressive strength, fly ash particles are the most preferred ones as it hardens the base alloy. Uniform particle distribution seen in the micro graphs of various composites reinforced with carbide ceramics. Optimization and modelling techniques gives an idea of optimal combination of parameters considered for the fabrication process as well as reinforcements **[3].**

Al7075-Gr-TiB2 hybrid composites have been fabricated productively by stir-casting technique utilizing a combination of ex-situ and in-situ methods. Dispersion of reinforcement’s graphite and TiB2 in Al7075 composites were found to be uniform with minimal clustering. Hardness was found to increase with the increase in reinforcement content. The increase in hardness depends mainly on the scattering of reinforcements in the matrix and their strengthening ability. Ultimate tensile strength rises with the rise in reinforcement content. with the inclusion of 8 wt%graphite and 5 wt%Titanium di Boride ultimate tensile strength increased by 68.85% The ductility of hybrid composite is reduced by 4.8% with the inclusion of 8 wt%graphite and 5 wt%Titanium di Boride **[4].**

The mechanical properties like Tensile strength and Hardness increases with increase in %wt addition of Al_2O_3.While at the other end ductility and impact strength will gets reduced. The poor wettability of the phases in the matrix is the major problem at higher weight fraction of reinforcement, due to this problem the strength decreases after certain limit **[5].**

The tensile strength and hardness of AHMMCs increases with the increase of hybrid reinforced particles content. Whereas the tensile strength of alumina along with fly ash reinforced composite is lower than silicon carbide along with fly ash reinforced composites, due to the presence of cenosphere fly ash along with alumina. SEM results revealed the very near uniform distribution of hybrid reinforced particles in the centre portion of the casting with slight clustering and agglomeration of hybrid reinforced particles. The microstructural analyzes also revealed the good interfacial bond between the hybrid reinforcements and matrix alloy **[6].**

The Al7075-TiB2composite was fabricated successfully using Al–Ti and Al-Br master alloys by stir casting technique. Optical micrograph shows reasonably uniform distribution of TiB2 and AlTi3 particles. A considerable improvement in the hardness of the composite is observed when compared with the unreinforced alloy. Al7075-TiB2 composite exhibited higher tensile strength, yield strength and lower ductility when compared with unreinforced alloy **[7].**

The review of investigations on the various aspects of HAMCs provides several conclusions regarding the influence of various parameters on the performance of the composites. Firstly, the microstructures of the HAMCs fabricated by stir casting route have been found to be stable with uniformed distribution of reinforcing particles. Consequently, the HAMCs can be fabricated with different combinations of reinforcements to achieve desirable mechanical properties not available in ceramic reinforced composites. The density of HAMCs increases with increasing contents of ceramic reinforcements, while incorporation of partial reinforcements like fly ash, rice husk ash, mica, etc. reduces the density of composites. **[8].**

The result of this project is the optimized process parameters of the aluminium casting process which results in minimum defects. The optimum process parameters levels are pouring temperature is 690 Celsius, pouring rate is 1.2 s and the solidification time is 8.1 s. Also, the experiments give a comprehensible picture of contribution of all factors taken to the variation in amount of shrinkage present in the casting, thus the quality can be improved without further investment **[9].**

AA7075/TiB2 AMCs with 6 wt%, 9 wt% and 12 wt% of reinforcement were successfully synthesized by stir casting method using in situ reaction of KBF4 and K2TiF6 salts. The reinforcement particles are almost homogeneously distributed in the aluminium matrix and the grain size decrease with increase in wt.% of the reinforcement. Ultimate tensile strength (UTS) and hardness of AA7075/TiB2 AMCs increase with increase in wt.% of TiB2 reinforcement **[10].**

The mechanical characteristics of stir cast Al6061–TiB2 matrix composite reveals that there is an increase in the hardness with the addition of reinforcement of TiB2 with Al6061 matrix. This is mainly due to the hard nature of the reinforcement of TiB2. Increase in the amount of TiB2 increases the tensile strength, ultimate tensile strength and modulus of the Al6061 **[11].**

From their work, Al5083-graphene-fly ash composites, increased hardness was noticed for the composite due to the grain refinement and reinforced graphene and fly ash. Higher variations in the cutting forces were also noticed in the composite which is due to the added graphene and fly ash. The results suggest that by incorporating graphene and fly ash into Al5083, structures with higher hardness and improved machinability ca be produced **[12].**

From above literature reviews we studied that the mechanical characteristics of different types of AHMMC and reinforcement have been studied and investigated by various reserchers. The Al7075 with TiB_2 and fly ash are reinforcement have not been studied by others.

CHAPTER 3

3. MATERIALS

3.1 ALUMINIUM 7075

Aluminum is a very common metal that has many useful alloys; so many in fact that the Aluminum Association has defined classes of these alloys using a numbered-naming scheme based on alloying elements. The topic of this article is from the 7xxx series, or alloys which use zinc as their main alloying element, and its name is type 7075 aluminum alloy. Properties of aluminum are the mechanical properties evaluation reveals an improvement in hardness and the strength values with the amount of fiber addition. From the experimental studies, the optimum volume fraction of short basalt fibre in Al 7075 alloy on the basis of microstructure and mechanical properties is found to be 6 vol%

Due to its high strength, low density, thermal properties, and its ability to be highly polished, 7075 is widely used in mold tool manufacturing. This alloy has been further refined into other 7000 series alloys for this application, namely 7050 and 7020.

Table 3.1 The mechanical properties of Aluminium 7075

S.no	properties	values
1	Density	2.81 g/cc
2	Hardness	175 HV
3	Ultimate tensile strength	572 MPa
4	Tensile yield strength	503 MPa
5	Modulus of Elasticity	71.7 GPa
6	Thermal conductivity	130 W/m-K
7	Melting Point	477-635 C

3.1.1 THE APPLICATIONS OF ALUMINIUM 7075

1. Aircraft fittings
2. Gears and shafts
3. Missile parts
4. Regulating valve parts
5. Worm gears
6. Aerospace/defence applications

3.2 TITANIUM DIBORIDE (TIB_2):

Titanium diboride (TiB_2) is an extremely hard ceramic which has excellent heat conductivity, oxidation stability and wear resistance. TiB_2 is also a reasonable electrical conductor, so it can be used as a cathode material in aluminium smelting and can be shaped by electrical discharge machining.

TiB_2 is resistant to oxidation in air at temperatures up to 1100 °C, and to hydrochloric and hydrofluoric acids, but reacts with alkalis, nitric acid and sulfuric acid.

TiB_2 is the most stable of several titanium-boron compounds. The material does not occur in nature but may be synthesised by carbothermal reduction of TiO_2 and B_2O_3.

Table 3.2 mechanical properties of titanium diboride

Property	**value**
Density (g.cm^3)	4.52
Melting Point (°C)	2970
Modulus of Rupture (MPa)	410-448
Hardness (Knoop)	1800
Elastic modulus (GPa)	510-575
Poisson's Ratio	0.1-0.15
Thermal conductivity (W/m. K)	25

3.2.1 THE APPLICATIONS OF (TIB_2):

The chemical inertness and good electrical conductivity of TiB_2 have led to its use as cathodes in Hall-Heroult cells for primary aluminium smelting. It also finds use as crucibles for handling molten metals and as metal evaporation boats.

3.3 FLY ASH:

Fly ash is a heterogeneous by-product material produced in the combustion process of coal used in power stations. Fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys of coal-fired power plants, and together with bottom ash removed from the bottom of the boiler is known as coal ash. It is a fine grey coloured powder having spherical glassy particles that rise with the flue gases. As fly ash contains pozzolanic materials components which reach with lime to form cementitious materials. Thus, Fly ash is used in concrete, mines, landfills and dams.

Fly ash is used as the secondary reinforcement material in the present investigation it is a coal combustion product composed of particulates (fine particles of burned fuel) driven out of coal-fired boilers and the flue gases. Ash that falls to the bottom of the boiler is called bottom ash. In modern coal-fired power plants, fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys. Together with bottom ash removed from the bottom of the boiler, it is known as coal ash. Depending upon the source and composition of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide (SiO_2) (both amorphous and crystalline), aluminium oxide (Al2O3) and calcium oxide (CaO), the main mineral compounds in coal-bearing rock strata.

The minor constituents of fly ash depend upon the specific coal bed composition. Still, they may include one or more of the following elements or compounds found in trace concentrations (up to hundreds of ppm): arsenic, beryllium, Boron, cadmium, chromium, hexavalent chromium, cobalt, lead, manganese, mercury, molybdenum, selenium, strontium, thallium, and vanadium, along with minimal concentrations of dioxins and PAH compounds. It also has unburnt carbon.

A) MANUFACTURING OF FLY ASH:

Fly ash is produced by coal-fired electric and steam generating plants. Typically, coal is pulverized and blown with air into the boiler's combustion chamber, where it immediately ignites, developing heat and producing a molten mineral residue. Boiler tubes extract heat from the boiler, cooling the flue gas and causing the molten mineral residue to harden and form ash. Coarse ash particles, referred to as bottom ash or slag, fall to the bottom of the combustion chamber, while the lighter fine ash particles, termed fly ash, remain suspended in the flue gas. Before exhausting the flue gas, fly ash is removed by particulate emission control devices, such as electrostatic precipitators or filter fabric baghouses.

Figure 3.1FLY ASH

3.3.1 PROPERTIES OF FLY ASH

Their properties, such as high compressive strength, light weight, low water absorption, chemical inertness, and good thermal resistance, make them suitable to a wide range of applications

3.3.2 APPLICATIONS OF FLY ASH

Construction material: Fly ash can be used as prime material in many cement-based products, such as concrete block, poured concrete, and brick. One of the most common uses of fly ash is in Portland cement concrete pavement or P.C.C. pavement. Road construction projects using P.C.C. can use a great deal of concrete, and substituting fly ash provides significant economic benefits. Fly ash has also been used as mine fill and embankment, and it has increasingly gained acceptance by the Federal Highway Administration.

Soil Stabilization: Soil stabilization is soil's permanent physical and chemical alteration to enhance its physical properties. Stabilization can increase the shear strength of a soil and/or control the shrink-swell properties of a soil, thus improving the load-bearing capacity of a sub-grade to support pavements and foundations. Stabilization can be used to treat a wide range of sub-grade materials, from expansive clays to granular materials. Stabilization can be achieved with various chemical additives, including lime, fly ash, Portland cement, and by-products such as lime-kiln dust (L.K.D.) and cement-kiln dust (CKD). Proper design and testing is an essential components of any stabilization project.

3.3.3 THE ADVANTAGES OF FLY ASH

- Increases ultimate strength
- Reduces permeability
- Improves ductility

3.4 INTRODUCTION OF ALUMINIUM HYBAID MMCs

The aluminium metal composite materials combine two or more constituents in a matrix, and the other is filler materials (reinforcements). The aluminium metal matrix may be laminated, fibres or particulates composites. These materials are usually processed through powder metallurgy, liquid cast metal technology, or a unique manufacturing process. The processing of discontinuous particulate metal matrix material involves two significant processes powder metallurgy route and liquid cast metal technology. The powder metallurgy process has its own limitation, such as processing cost and size of the components. Therefore, only the casting method is considered the most optimum and economical route for processing aluminium composite materials. Ceramic particulate reinforced Al-alloy composites led to a new generation of tailorable engineering materials with improved specific properties.

The structure and properties of these composites are controlled by the type and size of the reinforcement and the nature of bonding. From the contributions of several researchers, some of the techniques for the development of these composites are stir casting powder metallurgy, spray atomization and co- deposition, plasma spraying and squeeze-casting.

Manufacturing aluminium alloy-based casting composite materials via stir casting is a significant and economical route for developing and processing metal matrix composites materials. Properties of these materials depend upon many processing parameters and the selection of matrix and reinforcements. The above processes are the most important of which, liquid metallurgy technique has been explored much these days. Vital applications in the engineering field require alloys & materials with a broad range of properties like high stiffness, weight ratio, and high impact strength which is rarely possible in monolithic material systems. Hence, we adapt for newer MMC (metal matrix composite) in engineering applications.

MMC is now being used in aerospace and automobile industries, owing to their improved properties such as elastic modulus, hardness, and tensile strength at even very intense temperatures. Most commonly used metallic matrices include A.L., M.G., T.I., CU, and alloys. Aluminium is considered one of the most predominant matrix materials considering its combined properties of ductility and toughness of the soft matrix material and strength, hardness and modulus of hard reinforcement material. For A.H.M.M.C.s, titanium diboride and fly ash are the most common preferred particulate reinforcements. Abrasion resistance is greatly improved due to ceramic particulate reinforced composite.

Casting Processes for Aluminium Hybrid M.M.C.s:

- Compo-Casting
- Squeeze casting
- Centrifugal casting
- Stir casting
- Powder metallurgy

A) COMPO CASTING:

Recent development in the stir casting process is a double stir casting or two- step mixing process. In this process, the matrix material is first heated to above its liquidus temperature. The melt is then cooled down to a temperature between the liquidus and solidus points to a semi-solid state. At this point, the preheated reinforcement particles are added and mixed. again the slurry is heated to a fully liquid form and mixed thoroughly. The resulting microstructure has been more uniform in double stir casting than in conventional stirring. The potency of this two-step mixing method is mainly due to its ability to break the gas layer around the particle surface, which otherwise impedes wetting between the particles and molten metal. Thus, mixing the particles in the semi-solid state helps break the gas layer because of the abrasive action due to the high melt viscosity.

B) SQUEEZE CASTING:

Squeeze casting, also known as liquid-metal forging, is a casting and forging process. The molten metal is poured into the bottom half of the preheated die. As the metal starts solidifying, the upper half closes the die and applies pressure during the solidification process. The amount of pressure thus applied is significantly less than used in forging, and part of the grade detail can be produced. Coring can be used with this process to form holes and recesses. The porosity is low and mechanical properties are improved. Both ferrous and non- ferrous materials can be produced using this method.

C) CENTRIFUGAL CASTING:

Centrifugal casting or roto-casting is a casting technique that is typically used to cast thin-walled cylinders. It is used to cast such materials as metal, glass, and concrete. It is noted for the high quality of the results attainable, particularly for precise control of their metallurgy and crystal structure. Unlike most other casting techniques, centrifugal casting is chiefly used to manufacture stock materials in standard sizes for further machining, rather than shaped parts tailored to a particular end-use. In centrifugal casting, a permanent moulis rotated continuously about its axis at high speeds (300 to 3000 rpm) as the molten metal is poured. The molten metal is centrifugally thrown towards the inside mould wall, where it solidifies after cooling. The casting is usually fine-grained with a fine outer diameter, owing to chilling against the mould surface. Impurities and inclusions are thrown to the surface of the inside diameter, which can be machined away. Casting machines may be the either horizontal or vertical axis. Horizontal axis machines are preferred for long, thin cylinders, vertical machines for rings.

Most castings are solidified from the outside first. This may encourage directional solidification of the casting and thus beneficial metallurgical properties to it. The inner and outer layers are often discarded, and only the intermediary columnar zone is used.

D) POWDER METALLURGY:

Powder metallurgy is a term covering a wide range of ways in which the materials are components are made from metal powders. The powder metallurgy process can significantly reduce the need to use metal removal processes, thereby drastically reducing yield losses in manufacturing and often resulting in lower costs. Powder metallurgy is also used to make unique materials impossible to melt or form in other ways.

E) STIR CASTING:

Among the various manufacturing processes available for discontinuous metal matrix composites, stir casting is generally accepted as a particularly promising route, currently practised commercially. Its advantages lie in its simplicity, flexibility and applicability to large quantity production with a cost advantage. In the Stir casting route method of composite materials fabrication, a dispersed phase (ceramic particles, short fibers) is mixed with a molten matrix metal through mechanical stirring. The liquid composite material is then cast by conventional casting methods and may also be processed by traditional metal forming technologies. The stir casting methodology is relatively simple and low cost. This can usually be prepared by fairly conventional processing equipment and can be carried out continuously and semi-continuously by using a stirring mechanism. Stir casting is more economical and is more feasible; hence stir casting method is used in this experimentation, and a detailed description is given in the latter part of the report.

3.5 THE METAL MATRIX COMPOSITION OF TITANIUM DIBORIDE, FLY ASH & ALUMINIUM 7075

The methodology we use in this project is stir casting, with three different materials like titanium diboride, fly ash with hybrid aluminium 7075. So here we are taking three metal matrix composition with different ratios and percentages of metals.

Now we are taking fixed aluminium 7075 as fixed composition of 95% and taking the Tib2 and fly ash in three ratios 5:3, 4:4,3:5 as respectively

The density of ALUMINIUM 7075 = 2.81 g/cm^3

The density of TiB_2 = 4.52 g/cm^3

The density of Fly Ash = 1.7 g/cm^3

Table 3.3Composition of TiB2 and fly ash in 4:4 mass ratio

METALS	PERCENTAGE %	VOLUME (cm^3)	MASS (g)
Aluminium 7075	92	69	193.89
TiB_2	4	3	13.56
Fly Ash	4	3	5.1

Table 3.4Composition of TiB2 and fly ash in 3:5 mass ratio

METALS	PERCENTAGE %	VOLUME (cm^3)	MASS (g)
Aluminium 7075	92	69	193.89
TiB_2	3	2.25	10.17
Fly Ash	5	3.75	6.37

Total material mass used for this project (Matrix and reinforcement)

The total Al7075 composition was 387.78 grams

The total TiB2 composition was 23.73 grams

The total fly ash composition was 11.47 grams

CHAPTER 4

4.1 MANUFACTURING AND TEST METHODOLOGY

4.1.1 CASTING

Casting is a manufacturing process in which a liquid material is usually poured into a mold that contains a cavity of the desired shape and then allowed to solidify. The solidified part is also known as the casting, which is ejected or broken from the mold to complete the process.

4.1.2 STIR CASTING PROCESS

Stir casting is a liquid state method of fabrication in which the particulate reinforcement is distributed into the metal melt by mechanical stirring (Mechanical stirring is key to this process). Composites with up to 30% volume fractions can be suitable for manufactured with this process. A problem associated with this process is the segregation of reinforcement particles due to particle settling during solidification. The distribution of particles in the final solid depends on the strength of mixing, wetting condition, solidification rate, and relative density. The liquid composite material is cast by conventional casting methods and may also be processed by traditional metal forming techniques. There has been an increasing interest in composites containing low density and low-cost reinforcements.

Conventional monolithic materials have limitations in achieving good strength, stiffness, toughness and density. Green hybrid M.M.C.s possess significantly improved properties, including high specific strength; specific modulus; damping capacity and good wear resistance compared to unreinforced alloys and monolithic materials; thus invoking recent interest in manufacturing Green M.M.C.s. Composites with SiC as reinforcement will likely overcome the cost barrier for widespread automotive and small engine applications. Therefore, it is expected that the incorporation of silicon particles in Aluminium has the potential for conserving energy-intensive Aluminium and, thereby, reducing the cost of aluminium products.

Stir casting is generally accepted as a particularly promising route, currently practised commercially. The main advantages of stir casting are its simplicity, flexibility and applicability to large quantity production. It is also attractive because it allows for conventional metal processing of the product and hence minimizes the final cost of the final product. The cost of preparing composites by the stir casting method is about one-third of that of competitive strategies, and for high volume production, the price will fall to about one-tenth.

Stir casting of MMC involves producing a melt of selected metal matrix material followed by introducing reinforcement material into the melt and dispersion of the reinforcing material through stirring. Stirring is carried out vigorously to form a vortex where the reinforcement material is presented from the side of this vortex. This vortex drags reinforcement material into the melt and any impurities on the surface of the melt are dragged into it. The vortex also entraps air into the melt, which is very difficult to remove as the metal solidifies and the viscosity of the slurry increases. z

Figure 4.1 stir casting

We performed the stir casting at Raghu engineering college, Visakhapatnam.

MACHINING

For performing the various characterization techniques, the casted specimens should be machined on respective machines to obtain the desired specimens with standard dimensions. A CNC Lathe machine and a shaper machines and certain hand operations have been done on the casted specimens.

4.1.3 CNC LATHE

For performing the various characterization techniques the casted specimens should be machined on respective machines to obtain the desired specimens with standard dimensions. A CNC Lathe machine and a shaper machines and certain hand operations have been done on the casted specimens.

Computer numerical control (C.N.C.) has been incorporated into a variety of new technologies and machinery. One such machine of this sort that is used for a wide array of production processes is known as a C.N.C. lathe.

Due to technological advancements, C.N.C. lathes quickly replace some of the older and more traditionally used production lathes, such as the multispindle. C.N.C. lathes come with several benefits. They can be easily set up and operated. They offer outstanding repeatability, along with top-notch accuracy in production.

A CNC lathe is typically designed to utilize modern versions of carbide tooling and processes. A part can be designed for customization, and the machine's tool paths are often programmed using the CAD or C.A.M. processes. However, a programmer can also manually design a part or tool path. The resulting coded computer file is then uploaded to the C.N.C. machine, and the machine will then automatically produce the desired parts for which it was programmed to design.

A CNC lathe is controlled by a menu-type interface on a computer. The operator who manages the process can actually see a visual simulation of how the machine will function during the production phase. Thanks to this technology, the machine operator generally does not need to know as much about the specifics of the machine they oversee compared to what machine operators must know about more traditional lathes that require some manual labour.

C.N.C. lathes are designed in a variety of ways, based on the manufacturer producing the machine. However, most have some significant similarities in their composition. A turret is a part of the machine that holds the tool holders and indexes them accordingly. The spindle is designed to hold the workpiece. In addition, some slides allow the turret to move in multiple axes simultaneously. C.N.C. machines are typically completely enclosed for health and safety reasons of any operators present.

There has been considerable growth in the C.N.C. machining industry, particularly regarding the design and use of C.N.C. lathes. Different lathe manufacturers utilize variety of user interfaces, which can be a challenge to the operators. But these systems are mostly based on the same principles across the board since a C.N.C. lathe is programmed to perform similar functions in terms of what it is intended to manufacture.

Figure 4.2 CNC LATHE MACHINE

Figure 4.3 indicates that material cutting after casting process

4.1.4 BRINELL HARDNESS TEST

The Brinell Hardness Test method is the most commonly used hardness measurement technique in the industry. In the Brinell Hardness Testing, the hardness of a metal is determined by measuring the permanent indentation size produced by an indenter. Harder materials will generate shallow indentations while the softer materials will produce deeper indentations. This test method was first proposed by Swedish engineer Johan August Brinell in 1900 and according to his name, the test is popular as Brinell Hardness Test.

The Brinell Hardness test is performed in a Brinell hardness test unit. In this test method, a predetermined force (F) is applied to a tungsten carbide ball of fixed diameter (D) and held for a predetermined time period, and then removed. The spherical indenter creates an impression (permanent deformation) on the test metal piece. This indentation is measured across two or more diameters and then averaged to get the indentation diameter (d). Using this indentation size (d) Brinell Hardness Number (BHN) is found using a chart or calculated using the Brinell hardness test formula.

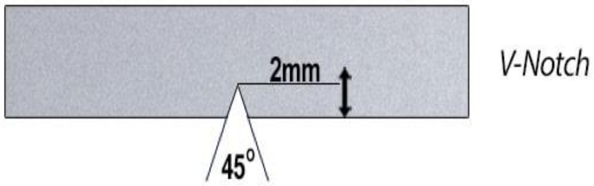
The surface of specimen of which hardness is to be measured should be reasonably smooth and free from surface defects, oils etc. a sastisfactory surface can be obtained by grinding or filing with a fine file. The surface on which the impression is to be taken should be Parallell to the bottom surface so as to obtain circular impressions if this not perfectly so the impressions are elliptical.

Figure 4.4 Brinell hardness test

4.1.5 IMPACT TEST (CHARPY)

Impact tests are used in studying the toughness of material. A material's toughness is a factor of its ability to absorb energy during plastic deformation. Brittle materials have low toughness as a result of the small amount of plastic deformation that they can endure. The impact value of a material can also changes with temperature. Generally, at lower temperatures, the impact energy of a material is decreased. The size of the specimen may also affect the value of the Izod impact test because it may allow a different number of imperfections in the material, which can act as stress risers and lower the impact energy.

Impact testing most commonly consists of charpy and izod Specimen configurations. The charpy are conducted on instrumented machines capable of measuring less than 1 foot-pound to 300 foot-pounds at temperatures ranging from -320°F to over 2000°F. Impact test specimen types include notch configurations such as V-Notch, U-Notch, Key-Hole Notch, as well as Un-notched and ISO (DIN) V-Notch, with capabilities of impact testing sub size specimens down to ¼ size. IZOD Impact Testing can be done up to 240 foot-pounds on standard single notch and type-X3 specimens.



Also known as the Charpy V-notch test, is a standardized high strain-rate test which determines the amount of energy absorbed by a material during fracture. This absorbed energy is a measure of a given material's notch toughness and acts as a tool to study temperature-dependent ductile-brittle transition.

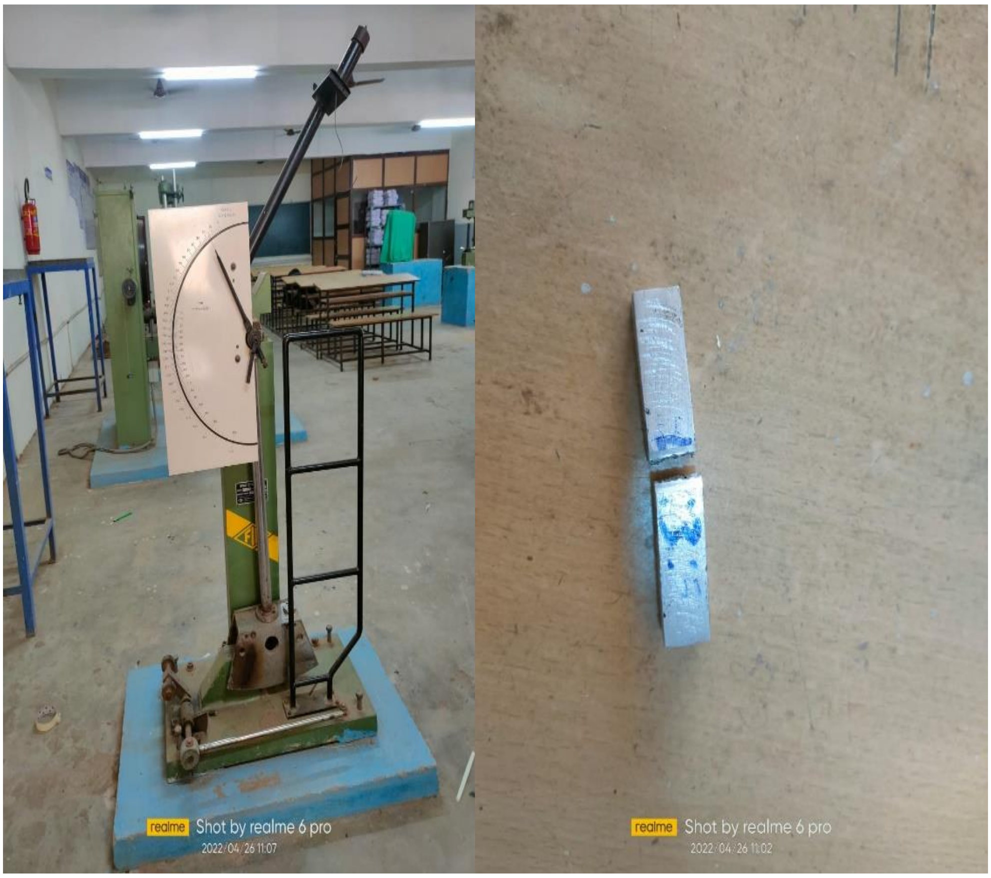


Figure 4.5 impact testing machine

4.1.6 TENSILE TEST

Tensile testing machine performs the most fundamental mechanical testing. A tensile test applies tensile pulling force to a material and measures the specimen's response to the stress. By doing this, tensile tests determine how strong a material is and how much it can elongate. Tensile tests are typically conducted on electromechanical or universal testing machines, are simple to perform, and are fully standardized. A tensile testing machine consists of a test frame that is equipped with a load cell, testing software, and application-specific grips and accessories, such as extensometers. The type of material being tested will determine the type of accessories needed, and a single machine can be adapted to test any material within its force range simply by changing the fixturing. A tensile test is performed by loading the material to a positive force and then reducing the load to zero and repeating this process until the sample fails with the number of cycles till failure as the desired value to be measured. Tensile creep is similar to this except that the load is not altered but rather steadily applied until the sample fails.

Generally tensile test is to be run until the specimen fails or breaks under the load. The values that may be measured from this type of test can range from but are not limited to tensile strength, ultimate strength, elongation, modulus of elasticity, yield strength, Poisson's ratio, and strain hardening. The measurements taken during the test reveals the characteristics of a material while it is under a tensile load.

Figure 4.6 universal testing machine

Figure 4.7 specimen of tensile test before and after

The Al7075, TiB_2 and fly ash has fabricated successfully by stir casting process. The results of Brinell hardness test, izod test and hardness test was tabulated below. From the results we concluded that various characteristics of the new composite under the various tests as follows.

CHAPTER 5

5.1 RESULTS AND DISSCUSSION

5.1.1 BRINELL HARDNESS TEST RESULTS

Table 5.1 Brinell hardness test performed on reinforcement of TiB2 and fly ash in 4: 4 mass ratio

S.no	Load N	Diameter of indentor (D)mm	Diameter of indentation (d)mm	Surface area mm	BHN
1	250	5	1.8	2.54	94.95
2	250	5	1.7	2.26	106.86
3	250	5	1.8	2.54	94.95
4	250	5	1.8	2.54	94.95

The average Brinell hardness number is: **97.92**

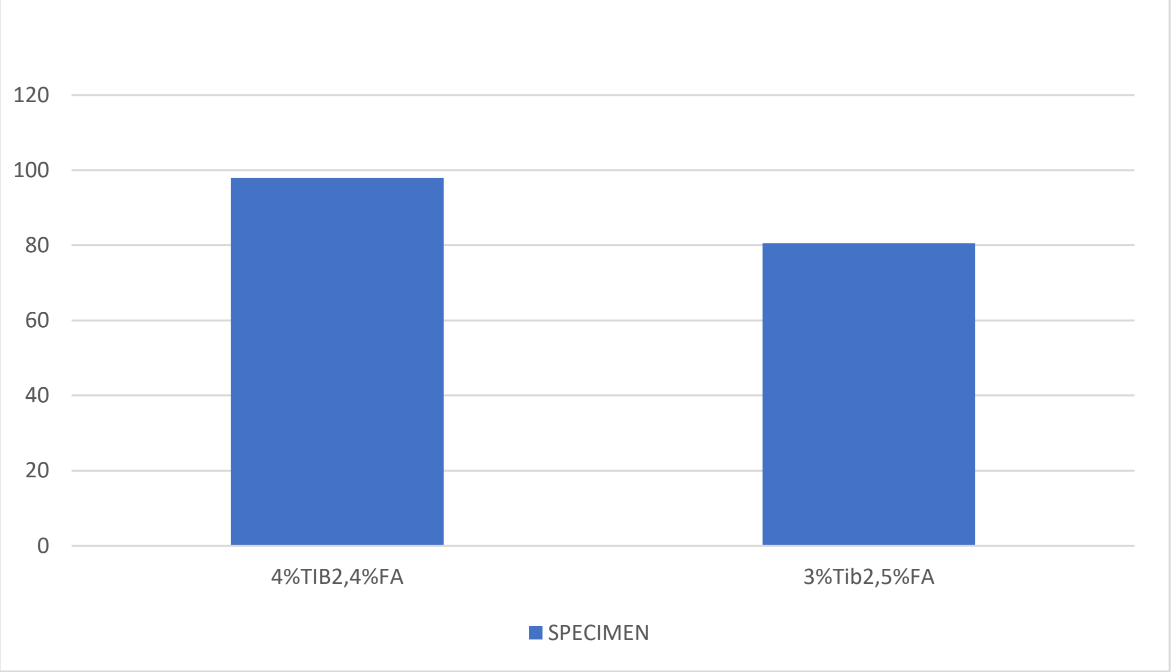
Table 5.2 Brinell hardness test performed on reinforcement of TiB2 and fly ash in 3:5 mass ratio

S.no	Load N	Diameter of indentor (D)mm	Diameter of indentation (d)mm	Surface area mm	BHN
1	250	5	2	3.14	76.25
2	250	5	1.9	2.83	84.86
3	250	5	2	3.14	76.25
4	250	5	1.9	2.83	84.86

The average Brinell hardness number is :**80.55**

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

From the above formula the Brinell hardness number was calculated



Graph 5.1 comparision of brinell hardness test

By Brinell hardness test we can Observed that reinforcement of TiB2 and FA of 4:4 mass ratio has greater hardness number as compared to 3:5. So here 4:4 composition material performs hardness test well as compared with 3:5 composition material.

5.1.2 IMPACT TEST(CHARPY) RESULT

$$\text{Impact strength} = \frac{\text{Energy absorbed}}{\text{Area of specimen}}$$

Area of specimen=55*10=550mm^2

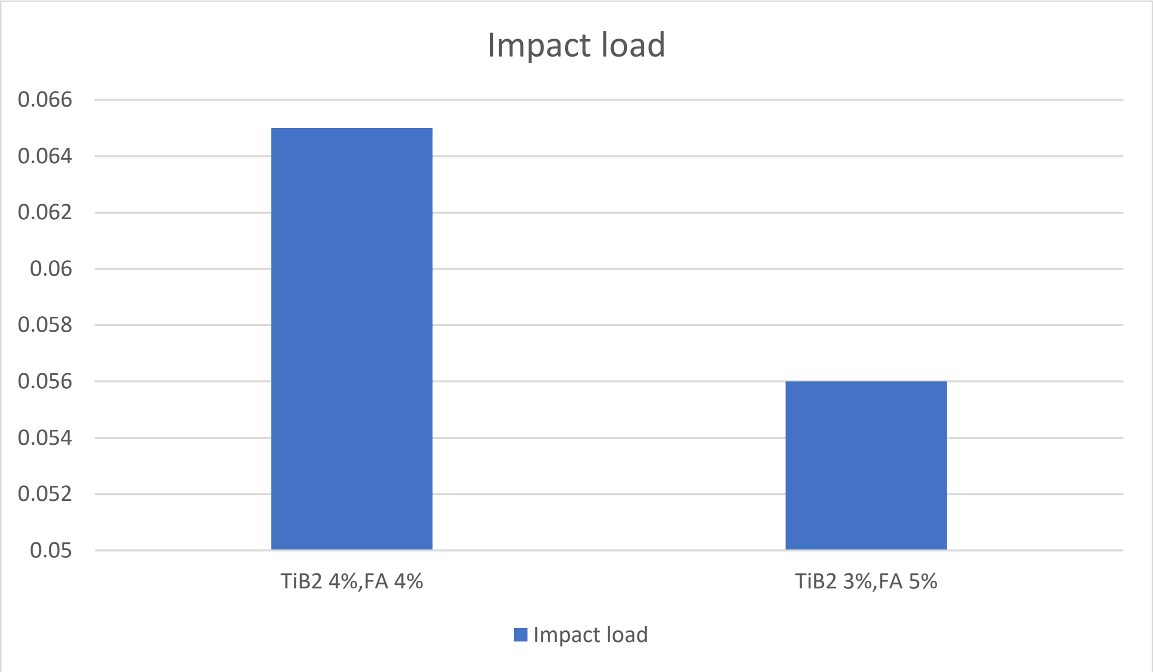
For reinforcement of TiB_2 and fly ash in 3:5 ratio the impact strength is

31/550=0.056J

For reinforcement of TiB_2 and fly ash in 4:4 ratio the impact strength is

36/550=0.065J

From impact strength the ratio 4:4 has high impact strength as compared to 3:5



Graph 5.2 comparison of impact test

5.1.3 TENSILE TEST RESULT

We performed tensile test on GITAM University, Visakhapatnam.

Organization	GITAM (Deemed to be University)
Laboratory	Fatigue Testing Laboratory
Requester Details	Mr.P.Karthik
Requestor Organisation	Mech, ANITS,vizag
Type of Test	Tensile test
Material Grade	al7075 alloy
Rate 1	3.00000 mm/min

Table 5.3 Tensile test table for reinforcement of TiB2 and fly ash in 4:4 mass ratio

	Specimen label	Maximum load (N)	Ultimate tensile strength
1	11354.23	11339.46702	225.89

	Tensile stress at tensile strength (MPa)	Tensile stress at break (standard) (MPa)	Tensile strain at maximum load	Tensile strain at tensile strength
1	225.88525	225.59154	0.02310	0.02310

	Data point at break (standard)	Tensile strain at break (strain)	Energy at maximum load (J)	Modulus (Automatic) (MPa)
1	5969	0.02333	4.37194	21110.95111

From the above table the maximum load occurs at 11354.23 N. the load at breaking was 11339.46702 N and remaining tensile values as seen in table.

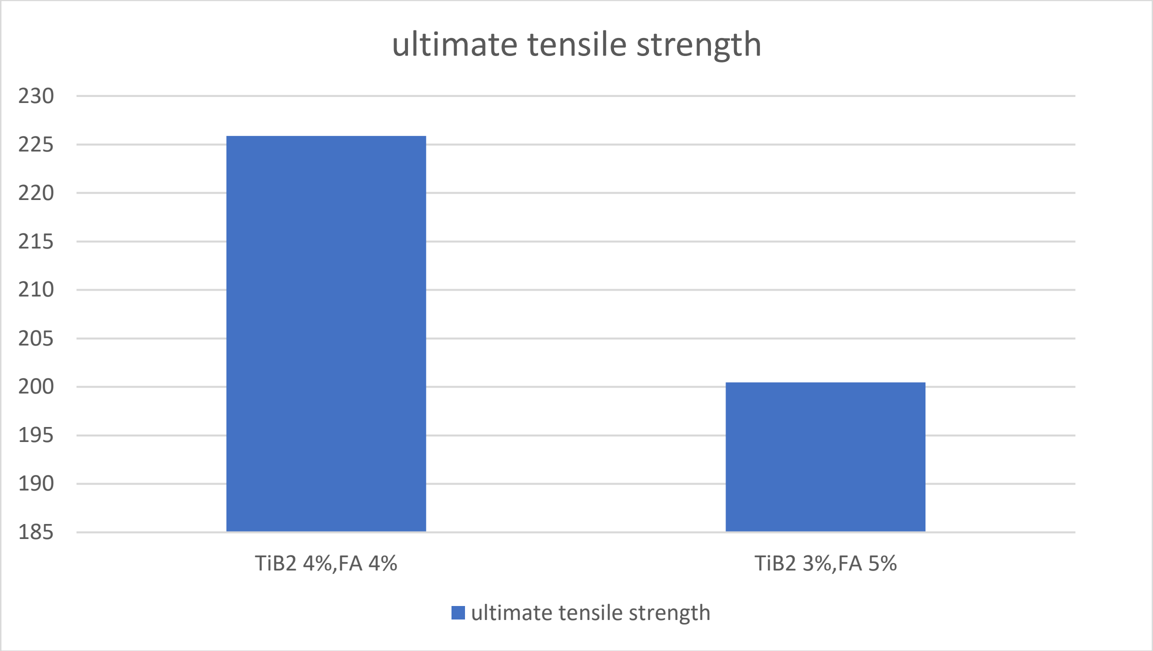
Table 5.4 Tensile test table for reinforcement of TiB2 and fly ash in 3:5 mass ratio

	Specimen label	Maximum load (N)	Load at break (Standard) (N)	Ultimate tensile strength (UTS) (MPa)
1	2	94467.55	9435.22540	200.45

	Tensile stress at tensile strength (MPa)	Tensile stress at break (standard) (MPa)	Tensile strain at maximum load	Tensile strain at tensile strength
1	190.77245	190.45265	0.01926	0.1923

	Data point at break (standard)	Tensile strain at break (strain)	Energy at maximum load (J)	Modulus (Automatic) (MPa)
1	4525	0.01944	3.5421	20451.2544

From the above table the maximum load occurs at 94467.55 N. the load at breaking was 9435.22540 N and remaining tensile values as seen in table.



Graph 5.3 comparison of tensile test

The tensile test was performed for metal matrix reinforcement of TiB_2 and fly ash of 4:4 and 3:5 mass ratio. hence the strength and hardness values are increased by the combination of TiB_2 and fly ash in reinforced aluminium hybrid metal matrix composition. From the tensile test, we can conclude that both the ultimate tensile strength and the yield tensile strength have been increased by increasing the reinforcement.

CHAPTER 6

6.1 CONCLUSION

Composite materials are effectively manufactured utilizing the stirring process. Based on the results the conclusions can be drawn

- Fly ash as well as TiB_2 particles have been combined with various mass ratios and evenly distributed throughout the aluminium 7075 alloy.
- The hardness of Al7075/TiB_2/FA composites increases with increase in fly Ash content.
- The property of elongation increases with addition of Fly Ash.
- From Brinell hardness test the hardness of the specimen was increased by reinforcement of TiB_2 and fly ash in proportion of 4:4 ratio as compared to TiB_2 and fly ash of 3:5 ratio.
- The impact strength of the specimen was more in the 4:4 ratio of TiB_2 and fly while compare to 3:5 ratio of TiB_2 and fly ash.
- From the tensile test result we can conclude that the ultimate tensile strength and yield tensile strength of 4:4 ratio of TiB_2 and fly Ash has more while compare to 3:5 ratio of TiB_2 and fly ash.
- The poor wettability of the phases in the matrix is the major problem at higher weight fraction of reinforcement, due to this problem the strength decreases after certain limit. From this problem we can overcome by adding small amount of Magnesium and by pre heating the composites and the die.
- All the hybrid cases were having better mechanical properties than pure alloy.

CHAPTER 7

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