FABRICATION OF ALUMINIUM POLYMER COMPOSITE

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ABSTRACT

In the present day, Aluminium polymer composites are widely used in the field of engineering applications, especially in automobile, aerospace, marine, and processing industries, because of their improved higher specific strength, wear resistance, low density, high strength, and good structural rigidity. Presently hybrid composites play a vital role in engineering applications. In this present work, Aluminium alloy 6063 has been used as the matrix and recycled polymer as the reinforcement. The Aluminium composite is produced by liquid metallurgical route (stir casting). This method is less expensive and very effective. The objective of this work is to predict the tensile strength, compression, impact, and Corrosion behaviour of the Composites.

Keywords: *Aluminium Polymer Composite, Fabrication, Metal Matrix Composites, Reinforcement*

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1. Introduction

The engineering fraternity has always been on the lookout for wonders materials that would fit the bills for all types of service conditions. It stems from the need to make progressive discoveries made by scientists, affordable. This affordability quotient has persuaded many researchers to develop such materials which would satisfy various unexplored conditions. In today's world, all generic materials have been tried for various uses and their limitations have been met. But the never-ending quest of civilization requires that materials qualify for harsher environments.

This unavoidable situation demands that new materials be created from various combinations of other compatible materials. It is to be noted here that this method is not new; it has been with mankind for ages. In every part of the world, various materials have been combined to achieve some intended properties, albeit each case differs from the others, i.e., one can create new materials with unique properties, which can be tailor-made and are different from their base ingredients. This concept holds true for a genre of materials called composite materials in which the various types of materials are combined with the reinforcements, which contribute to the enhancement of the properties. Neither the matrices nor the reinforcements taken alone can stand up to the requirement, but the composite may be able to do so. This alteration in properties can be controlled in many ways, viz. controlling the matrix reinforcement quality, their proportion, or the fabrication route. This flexibility in manufacturing allows one to develop composites with varying properties in a precisely controlled fashion.

Composite material is a material composed of two or more distinct phases (matrix phase and reinforcing phase) and having bulk properties significantly different from those of any of the constituents. Many common materials (metals, alloys, doped ceramics, and polymers mixed with additives) also have a small number of dispersed phases in their structures; however, they are not considered composite materials since their properties are similar to those of their base constituents (the physical property of steel are similar to those of pure iron). Favourable properties of composite materials are high stiffness and high strength, low density, high-temperature stability, high electrical and thermal conductivity, adjustable coefficient of thermal expansion, corrosion resistance, improved wear resistance, etc.

2. Literature Review

The research on aluminium metal matrix composites with particle reinforcement is summarised in this paper. The current work analyses the issues raised and conclusions reached by many writers who have made contributions in the field of stir-cast aluminium metal matrix composites with particulate reinforcement (Jawalkar, C. S., et.al 2017). In order to achieve a high strength-to-weight ratio, recent work on reinforcing E-glass into aluminium foil is presented in this study. In addition to being resistant to corrosion, lightweight, and ductile, aluminium also exhibits increased strengths that are desirable for high-tech applications when alloyed with other metals. In the current effort, a laminate is created by combining aluminium, e-glass, and epoxy (Kumar, G. V., Pramod, R.,2017). Numerous organic materials serve as great design models for the creation of lightweight composite materials with high damage tolerance. The layered structure of the nacre, which has a degree of toughness greater than the sum of its parts, is one notable example. Although replacing the polymer phase with metal could increase damage tolerance, the molten metal's surface tension makes it challenging to incorporate metal into intricate ceramic scaffolds. In order to solve this problem, pressure less and squeeze casting infiltration techniques were used to infiltrate aluminium alloy 5083 into bioinspired micro-layered (L) alumina scaffolds with varying ceramic fractions ranging from 18 to 85% (Wan, H., et. al 2022). The current paper examines a thorough overview of the approaches used by various researchers to synthesize reinforced aluminium-based materials, including solid, semi-solid, liquid, and vapor routes. Recent considerations of the impact of reinforcing natural resources and industrial waste are briefly reviewed. Based on a survey of the literature, research has also concentrated on examining the most affordable and popular synthesis techniques for the creation of aluminum matrix composites (Singh, H et. al 2021). A composite, in general, is a monolithic material created by mixing many incompatible constituent metals to produce an upgraded superior material with distinct properties. Most often, the properties and characteristics of such MMCs materials may be influenced by a number of the stir-casting process parameters, including the correct choice of base matrix, the weight percentage of reinforcements, and the grain size of reinforcement particles (Ramamoorthi, R., et.al 2021). Due to their high strength, high modulus, and low density, carbon fiber-reinforced polymer composites are high-performance materials that are now the most widely utilized advanced composite materials in the automotive, sporting goods, and aerospace industries. In this study, a novel method for fabricating aluminum foam was adopted, in which molten aluminum was filled with argon gas while NaCl served as a gap filler. The examination of stress-strain curves provided compressive attributes such as compressive strength, elastic modulus, and failure strain (Hashim, U. R, 2014). For all Post curing temperatures, the mechanical characteristics of nanocomposite with 0.1 wt% nanoparticle content were at their peak. It was noted that nanocomposite materials in the form of rods displayed strong mechanical qualities (Prasad, B., & Singh, M.,2017). This study looked at how an aluminum composite behaved under compression. The findings demonstrated that the quasi-static stress-strain (-) curves of the aluminum composite matched those of the aluminum foams. The ideal energy absorption efficiency (I) of the composites was higher than that of Al foams in the two strain ranges of 0.03 and > 0.2. The composite had a lower I value than Al foams when was between 0.03 and 0.2 (Li, Y. G., et.al 2015). This study looked into how aluminum powder surface modification affected the tensile, fracture, and tribological behaviours of composites made of aluminum and epoxy. An analysis using a scanning electron microscope (SEM) revealed that the salinization of aluminium powders increased the bonding and dispersion of aluminium particles in the epoxy, which in turn improved the tensile and fracture parameters of silane-treated aluminium/epoxy composites (Kim, H. J., et.al 2012). The current study focuses on creating hybrid nanocomposites of aluminium (Al), carbon nanotubes (CNTs), and silicon carbide particles (SiCP) by elementally alloying the powder particles of Al, CNTs, and SiCP into a homogeneous powder mixture and sintering the powder mixture using spark plasma sintering (SPS). As a result, the micro-hardness of the hybrid composite (Al-5%CNTs-10%SiC) is two times more than that of pure Al (Prakash, C., et.al 2020).

In this work, the performance of continuous carbon, Kevlar, and glass fibre-reinforced composites created with the help of additive manufacturing's fused deposition modelling (FDM) technology is assessed. A Mark forged Mark One 3D printer was used to create the fiber-reinforced nylon composites. The results were contrasted with known values for material property values from published literature as well as control specimens made of non-reinforced nylon. Glass specimens showed a maximum efficiency in tensile strength as the fiber content neared 22.5%, with greater fiber percentages (up to 33%) only producing marginal gains in strength (Dickson, A. N., et. al 2017). Research in the fields of material science, medical implants, and new product development is increasingly using fused deposition modelling (FDM). The study shows that the infill density and number of stacked layers of metal spray have a substantial impact on the tensile properties; peak strength is directly proportional to infill density while the number of layers is inversely proportional (Vardhan, H., et.al 2020).

In this study, a polyurethane superhydrophobic coating with embedded SiO2 nanoparticles was created on an aluminium substrate using the spin coating approach. Super hydrophobicity with a water static contact angle of 156 3° and tilt angle of 6 1° is successfully accomplished by inserting SiO2 nanoparticles into the polyurethane matrix. (Ramamoorthi, R., et. al 2021). Due to improved mass transfer for substrate molecules to and from the enzyme reactive sites, the nanofibers also demonstrated a significant improvement in the enzyme activity above bulk films. These robust, stable, and catalytically active nanofiber-based mats were the perfect choice for large-scale applications since they could be readily retrieved from solution (Herricks, T. E., et. al 2005). This article makes an effort to analyse numerous carbon nanomaterials reinforced by aluminium or its alloy matrix-based nano-composite materials, as well as their production, characteristics, and potential uses in a variety of industries. The problems of the carbon nanomaterials reinforced aluminium matrix nanocomposites have been noted in this article and can be addressed by researchers in the future (Mondal, S., et. al 2022). The display and discussion of an automated production line. Similar to other closed-cell aluminium foams, APM aluminium foam-polymer hybrids have mechanical qualities. The qualities of typically closed-cell aluminium foam fillings were greatly improved when APM foams were incorporated into profiles. APM composite foams are a desirable alternative because of their special qualities that make them a practical and affordable building material with specific applications like the reinforcing of composite buildings to absorb energy (Stöbener, K., & Rausch, G.,2009). Aluminium matrix composites (AMCs) are a type of lightweight, high-performance material systems that are aluminium-centric. Intriguingly, research on particle-reinforced cast AMCs began in India in the 1970s, reached industrial maturity in the industrialized world, and is today on the verge of becoming a mainstream material. This study provides a summary of the processing, microstructure, characteristics, and application features of AMC material systems (Surappa, M. K.,2003). Controlling the thermal emissivity's from metal/polymer composites made using the solution approach is the topic of this paper. The interfacial polarisation is assumed to be the cause of the discrepancies in dielectric constant values between experimentally measured values and theoretically predicted values (Babrekar, H. A., et. al 2010).nIn terms of available techniques, bonding procedures, mechanisms, and characteristics, the joining of CFRP and aluminium alloys in the literature are thoroughly examined in this research. When adhesives are used in conjunction with bolts, rivets, or clinch, hybrid joints operate better (Kumar, G. V., & Pramod, R., 2017).

The current study sought to determine how varied stacking patterns and heat cycling affected the flexural characteristics of fiber metal laminates (FMLs). Aluminium has been surface-modified using the electrochemical anodizing process, and its surfaces have been studied using scanning electron microscopy (SEM) (Azghan, M. A., & Eslami-Farsani, R.,2018).

3. Objectives

- To develop the new aluminium alloy composite.
- To use stircasting setup facilities to fabricate aluminium 6063 reinforced with PET (Polyethylene Terephthalate).
- To use CNC wire EDM machine to cut the casting material into no. of pieces with desired cutting standard.
- To study the tensile, impact, compression and corrosion properties of the developed composite before and after heat treatment.

4. Materials for Composite

4.1 ALUMINIUM ALLOYS:

Aluminium alloys are alloys in which Al is the predominant metal. The typical alloying elements are copper, magnesium, manganese, silicon, and zinc. There are 2 principal classifications, namely cast alloys and wrought alloys

4.2 TYPES OF ALUMINIUM ALLOYS:

AEROSPACE ALUMINIUM ALLOYS:

- 7068 aluminium
- 7075 aluminium
- 6061 aluminium
- 6063 aluminium
- 2024 aluminium
- 5052 aluminium
- 7050 aluminium

MARINE ALLOYS:

- 5052 aluminium
- 5059 aluminium
- 5083 aluminium
- 5086 aluminium
- 6061 aluminium
- 6063 aluminium

AUTOMOTIVE ALLOYS:

- 6111 aluminium
- 2008 aluminium
- 5083 aluminium
- 5754 aluminium
- 2036 aluminium
- 6016 aluminium
- 5456 aluminium

4.3 WROUGHT ALLOYS:

The International Alloy Designation System is the most widely accepted naming scheme for wrought alloys. Each alloy is given a four-digit number, where the first digit indicates the major alloying elements.

- 1000 series is essentially pure aluminium with a minimum 99% aluminium content by weight and can be work hardened.2000 series are alloyed with copper and can be precipitation hardened to strengths comparable to steel. Formerly referred to as duralumin, they were once the most common aerospace alloys but were susceptible to stress corrosion cracking and are increasingly replaced by 7000 series in new designs.
- 3000 series are alloyed with manganese and can be work hardened.
- 4000 series are alloyed with silicon. They are also known as Silumin.
- 5000 series are alloyed with magnesium.
- 6000 series are alloyed with magnesium and silicon easy to machine and can be precipitation hardened, but not to the high strengths that 2000 and 7000 can reach.
- 7000 series are alloyed with the zine and can be precipitation hardened to the highest strengths of any aluminium alloy.

4.4 ALUMINIUM ALLOY 6063 SERIES:

AA 6063 is aluminium, with magnesium and silicon as the alloying elements. The standard controlling its composition is maintained by The Aluminium Association. It has generally good mechanical properties and is heat treatable and weldable. It is similar to the British aluminium alloy HE9.6063 is the most common alloy used for aluminium extrusion. It allows complex shapes to be formed with very smooth surfaces fit for anodizing and so is popular for visible architectural applications such as window frames, door frames, roofs, and sign frames. Aluminium alloy 6063 is a medium-strength alloy commonly referred to as an architectural alloy. It is normally used in intricate extrusions. It has a good surface finish, high corrosion resistance is readily suited to welding, and can be easily anodized.

4.5 MECHANICAL PROPERTIES:

The mechanical properties of 6063 depend greatly on the temper, or heat treatment, of the material.

6063:

Un-heat-treated 6063 has a maximum tensile strength of no more than 130 MPa (19,000 psi), and no specified maximum yield strength. The material has an elongation (stretch before ultimate failure) of 18%.

6063-T1:

T1 temper 6063 has an ultimate tensile strength of at least 120 MPa (17,000 psi) in thicknesses up to 12.7 mm (0.5 in), and 110 MPa (16,000 psi) from 13 to 25 mm (0.5 to 1 in) thick, and yield strength of at least 62 MPa (9,000 psi) in thickness up to 13 millimetres (0.5 in) and 55 MPa (8,000 psi) from 13 mm (0.5 in) thick. It has an elongation of 12%.

6063-T4:

T4 temper 6063 has an ultimate tensile strength of at least 140 MPa (20,000 psi) in thicknesses up to 13 millimetres (0.5 in), and 130 MPa (19,000 psi) from 13 mm (0.5 in) thick, and yield strength of at least 97 MPa (14,000 psi) up to 13 millimetres (0.5 in) and 90 MPa (13,000 psi) from13 to 25 mm (0.5 to 1 in). It has an elongation of 5%.

6063-T5:

T5 temper 6063 has an ultimate tensile strength of at least 140 MPa (20,000 psi) in thicknesses up to 13 millimetres (0.5 in), and 130 MPa (19,000 psi) from 13 mm (0.5 in) thick, and yield strength of at least 97 MPa (14,000 psi) up to 13 millimetres (0.5 in) and 90 MPa (13,000 psi) from13 to 25 mm (0.5 to 1 in). It has an elongation of 8%.

6063-T6:

T6 temper 6063 has an ultimate tensile strength of at least 190 MPa (28,000 psi) and a yield strength of at least 160 MPa (23,000 psi). In thicknesses of 3.15 millimetres (0.124 in) or less, it has an elongation of 8% or more; in thicker sections, it has an elongation of 10%.

4.6 REINFORCEMENT PARTICLE:

Reinforcement is a constituent of composite4material which increases the composite's stiffness and tensile strength. Here we used the PET (Polyethylene Terephthalate) bottle as reinforcement. It is the most common thermoplastic polymer resin of the polyester family and is used in fibres for clothing, containers for liquids and foods, thermoforming for manufacturing, and in combination with glass fibre for engineering resins.

Fig. 1 PET bottle pieces

The figure shows the no. of PET bottle pieces which are taken from the scrap Plastic bottles made from PET are widely used for soft drinks and packaged drinking water.

4.7 PET (Polyethylene Terephthalate):

It is the most common thermoplastic polymer resin of the polyester family and is used in clothing, containers for liquids and foods, thermoforming for manufacturing, and in combination with glass fiber for engineering resins. Plastic bottles made from PET are widely used for soft drinks, both still and sparkling. For beverages that are degraded by oxygen, such as beer, a multilayer structure is used. PET sandwiches an additional polyvinyl alcohol (PVOH) or polyamide (PA) layer to further reduce its oxygen permeability. PET can be compounded with glass fibre and crystallization accelerators, to make thermoplastic resins. These can be injection moulded into parts such as housings, covers, electrical appliance components and elements of the ignition system.

5. Experimental Procedure

5.1 Stir Casting

Metal Matrix Composites (MIMCs) are generally produced either by Liquid Metallurgy Route (LMIR) or Powder Metallurgy Technique (PMT). In LMR the particulate phases are mechanically dispersed in the liquid phase before solidification of the melt. Stir casting technique is one of popular LMR method and also known as a very promising route for manufacturing near net shape hybrid metal matrix composite components at a normal cost. The execution of stir casting technique yields relatively homogenous and fine microstructure which improves the addition of reinforcement material in the molten metal. In addition, the porosity level of the composite should be minimized and the chemical reaction between reinforcement and matrix should be avoided. The proper selection of process parameters such as pouring temperature, stirring speed, and pre-heat temperature of reinforcement can produce good quality composites. In this present work, the stir casting technique was used to fabricate 6063 aluminium alloy with Recycled polymer as reinforcement. The stir casting furnace is mounted on the floor and the temperature of the furnace is precisely measured and controlled in order to achieve sound quality composite. Two thermocouples and one PID controlled were used for this purpose. Because mild steel materials have high-temperature stability, it is selected as stirrer rod and impeller. This stirrer was connected to a 1 HP DC motor through the flexible link and was used to stir the molten metal in the semi-solid state. The screw operator lift is used to bring the stirrer in contact with the composite material. The metal was maintained at a temperature between 800 to 850 °C for one hour. The vortex was created by using a mechanical stirrer.

Fig.2 Furnace Temperature Controller

The Fig.2 shows the temperature of the stir casting furnace. The metal was maintained at a temperature between 800 to 850 °C. Furnaces allow heat to be generated and kept within a certain range in order to melt the metal.

Fig.3 Stir Casting Furnace

The Fig.3 shows the stir casting furnace. Stir casting offers better matrix particle bonding due to stirring action of particles into the melts. The recent research studies reported that the homogeneous mixing and good wetting can be obtained by selecting appropriate processing parameters liking stirring speed, time and temperature of molten metal, preheating temperature of mould and uniform feed rate of particles. The reinforcement was added at a constant feed rate into the molten aluminium. The proper selection of process parameter such as pouring temperature, stirring speed, pre-heat temperature of reinforcement can produce good quality composites. The above process is the most important of which liquid metallurgy technique has been explored much these days. This involves the incorporation of ceramic particulate into liquid aluminium melt and allowing the mixture to solidify. Stir casting is a type of casting process in which a mechanical stirrer is introduced to form vortex to mix reinforcement in the matrix material. It is a suitable process for production of metal matrix composites due to its cost effectiveness, applicability to mass production, simplicity, almost net shaping and easier control of composite structure. Stir casting setup as shown in Fig.1, consist of a furnace, reinforcement feeder and mechanical stirrer. The furnace is used to heating and melting of the materials. The bottom poring furnace is more suitable for the stir casting as after stirring of the mixed slurry instant poring is required to avoid the settling of the solid particles in the bottom the crucible. The mechanical stirrer is used to form the vortex which leads the mixing of the reinforcement material which are introduced in the melt. Stirrer consist of the stirring rod and the impeller blade. The impeller blade may be of, various geometry and various number of blades. Flat blade with three number is the preferred as it leads to axial flow pattern in the crucible with less power consumption. This stirrer is connected to the variable speed motors, the rotation speed of the stirrer is controlled by the regulator attached with the motor. Further, the feeder is attached with the furnace and used to feed the reinforcement powder in the melt. A permanent mold, sand mold or a lost-wax mold can be used for pouring the mixed slurry.

Fig.4 Heating of Al6063

The Fig.4 shows the Aluminium metal is placed in the crucible cup and then it is placed inside furnace. The metal was maintained at a temperature between 800 to 850 °C. Furnaces allow heat to be generated and kept within a certain range in order to melt the metal. Out of various furnaces, bottom pouring furnace is suitable for fabrication of metal matrix composites in stir casting route, this type of furnace consists of automatic bottom pouring technique which provides instant pouring of the melt mix (matrix and reinforcement). Automatic bottom pouring is mainly used in investment casting industry. In this technique, a hole is created in the base of melting crucible to provide bottom pouring and was shielded by a cylinder-shaped shell of metals [15]. In stir casting process, the matrix material is melted and maintained a certain temperature for 2–3 h in this furnace. Simultaneously, reinforcements are preheated in a different furnace. After melting of the matrix material, the stirring process has been started to form the vortex. The stir casting furnace is mounted on the floor and the temperature of the furnace is precisely measured and controlled in order to achieve sound quality composite. Two thermocouples and one PID controlled were used for this purpose. Because mild steel materials have high-temperature stability, it is selected as stirrer rod and impeller.

Fig.5 Die (mold)

The Fig.5 shows the die cleaning process with the help of the emery sheet before pouring the molten metal. Both the sides of the die were cleaned using the emery sheet. The scales, dust and rust were removed in this die cleaning process.

Fig.6 Graphite Crucible Cup

The above Fig.6 shows the Graphite Crucible Cup. A graphite crucible is a container used for melting and casting non-ferrous, non-iron metals such as gold, silver, aluminium, and brass. Their thermal conductivity, high temperature resistance, small thermal expansion coefficient for high temperature applications, and anti-strain properties to rapid heating and cooling make graphite crucibles an ideal metal casting tool. They are resistant to the effects of acids and alkaline solutions and have excellent chemical stability. Graphite crucibles have slowly developed into an essential part of metal forming. They can be as small as teacups or large enough to hold several tons of molten metal and be permanent parts of furnaces. Graphite crucibles are used in fuel fired, electric, and induction furnaces or as a method for transferring and moving molten metals. They have to be designed to fit the temperature, chemical, and physical requirements of the specific operation. Graphite crucibles for electric resistance furnaces must be specially designed since electric furnaces heat up much slower than fuel-fired furnaces. Crucibles have to have a high graphite content in the carbon binder for energy savings and high thermal conductivity. They are basin-shaped and are placed at an equal distance from the heating elements. The Aluminium was placed inside the Graphite crucibles and it is placed inside the electric furnace. Crucibles for the processing of aluminium and aluminium alloys are carbon or ceramic-bonded clay graphite and silicon carbide since these metals melt at 400°C or 750°F to 1600°C or 2912°F. The non-reactive nature of graphite crucibles makes them ideal for use in the casting process. Their excellent heat performance helps in melting metals quickly for faster production cycles. Since graphite crucibles are resistant to chemicals and corrosion, they are not affected by workshop conditions, characteristics that make them durable and long-lasting. During casting, temperatures are increased to decrease the tensile and yield strength of the metals alloys being cast. The temperature at which metals melt varies depending on the type of metal. Factors that influence casting are the temperature of the alloy being cast and the temperature of the crucible. Graphite crucibles are exceptionally capable of providing the proper vessel for casting due to their high resistance to the effects of increases in temperature, regardless of the type of metal alloy. The many hundreds of shapes of graphite crucibles are categorized by letters, which begin with A. Each form is divided into subcategories that are determined by the crucibles inside diameter (d or ID), outer diameter (D or OD), and height (H) and its shape. The crucible pictured below is cylindrical with a flat bottom and no spout or lid.

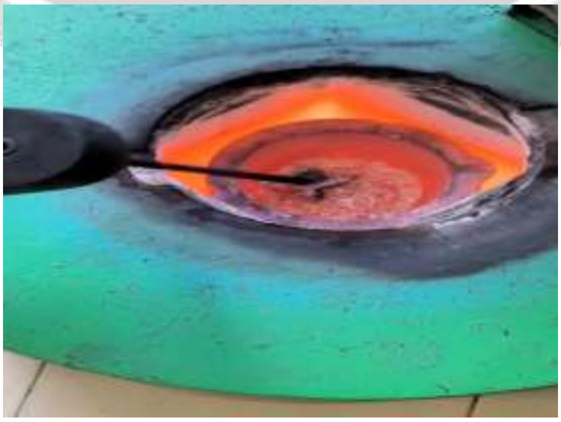


Fig.7 Stirrer

The Fig.7 shows the stirrer. The stirrer was preheated before immersing into the melt, and is located approximately to a depth of 2/3 height of the molten metal from the bottom and runs at a speed of 1000 rpm. The composite mixture was poured into permanent cast iron molds having a length of 200mm and a diameter of

20mm at a pouring temperature of 7500°C. The mechanical stirrer is used to form the vortex which leads the mixing of the reinforcement material which are introduced in the melt. Stirrer consist of the stirring rod and the impeller blade. The impeller blade may be of, various geometry and various number of blades. Flat blade with three number is the preferred as it leads to axial flow pattern in the crucible with less power consumption. This stirrer is connected to the variable speed motors, the rotation speed of the stirrer is controlled by the regulator attached with the motor. Further, the feeder is attached with the furnace and used to feed the reinforcement powder in the melt. A permanent mold, sand mold or a lost-wax mold can be used for pouring the mixed slurry.

Fig.8 Melting of reinforcement

The Fig. 8 shows the melting of reinforcement. The reinforcement is placed in the Metal plate and burned and it's melted with the help of the Butane gas torch. And then the reinforcement is added to the molten metal. Reinforcement is a constituent of composite material which increases the composite's stiffness and tensile strength. Here we used the PET (Polyethylene Terephthalate) bottle as reinforcement. It is the most common thermoplastic polymer resin of the polyester family and is used in fibers for clothing, containers for liquids and foods, thermoforming for manufacturing, and in combination with glass fiber for engineering resins.

Fig.9 Stir Casting Setup

The Fig. 9 shows the stir casting setup. Stir casting offers better matrix particle bonding due to the stirring action of particles into the melts. Reinforcement is a constituent of composite material which increases the composite's stiffness and tensile strength. Here we used the PET (Polyethylene Terephthalate) bottle as reinforcement. It is most common thermoplastic polymer resin of the polyester family and is used in fibers for clothing, containers for liquids foods, thermoforming for manufacturing, and in combination with glass fiber for engineering resins. Recent research studies reported that homogeneous mixing and good wetting can be obtained by selecting appropriate processing parameters like stirring speed, time and temperature of molten metal, preheating temperature of mold, and uniform feed rate of particles. Disadvantages that may occur if the process parameters are not adequately controlled include the fact that non-homogeneous particle distribution results in sedimentation and segregation. The above process is the most important of which liquid metallurgy technique has been explored much these days. This involves the incorporation of ceramic particulate into liquid aluminium melt and allowing the mixture to solidify. Al6063 and recycled polymers are mixed and melted. The melt is stirred slightly above the liquid us temperature (800-850 °c).

Fig.10 Pouring of mixture in the mold

The molten mixture is then poured in preheated mold and kept for natural cooling and solidification. After the solidification the surface cleaning and finishing is done.

Fig.11 Casting material

Finally, the casting material, the Aluminium polymer composite material is obtained after the solidification process. The net weight and the total density of the material is identified.

Fig.12 Material cutting process

All the three casting materials were cut into pieces for testing process and the materials were cut according to the desired cutting standards. The testing material were cut into no. of pieces with help of the wire EDM machine method.

Fig.13 CNC wire EDM machine

The testing material were cut into no. of pieces with help of the wire EDM machine method. Any conductive material such as steel, titanium, aluminium, brass, alloys and superalloys can be cut using the EDM wire method. With its accuracy, the EDM wire cut technique has become a convention cutting method in all industries.

Fig.14 Tensile testing machine

Tensile tests were performed on round specimens having 15mm gauge diameter and 30mm gauge length. An average of three observations has been considered in this study. The equipment used for carrying out the tensile was universal testing machine. Tensile test was carried out at room temperature. The Fig 14 shows the tensile testing machine. The test set up requires that equipment be properly matched to the test at hand. There are three requirements of the testing machine force capacity sufficient to break the specimens to be tested; control of test speed (strain rate or load rate, as required by the test specification; and precision and accuracy sufficient to obtain and record properly the load and extension information generated by the test. The grips must properly fit the specimens and they must have sufficient force capacity so that they are not slipped during testing. A tensile involves mounting the specimen in a machine and subjecting it to tension. The grips must properly fit the specimens and they must have sufficient force capacity so that they are not slipped during testing. A tensile involves mounting the specimen in a machine and subjecting it to tension. The tensile force is recorded as a function of the increase in gauge length. As a result we get a stress-strain curve. ASTM B557M is a standard test method for tension testing of metallic materials. In general, the particle reinforced Al-MMCs are found to have higher elastic modulus, tensile and fatigue strength over monolithic alloys. Increases in elastic modulus and strength of the composites are reasoned to the strong interface that transfers and distributes the load from the matrix to the reinforcement.

Fig.15 Compression testing machine

A Compression test uses compression testing machines to determine material behaviour under constantly increasing compressive loading. Compression tests examine the safety, durability, and integrity of materials and components. Typical applications include compression tests on plastic tubes and plastic pipes, compression test on flexible cellular foam material, compression/crush tests on paper and cardboard, compression spring testing in the metals industry, compression tests in the medical/pharmaceutical field including compression testing of medical implants, stents, syringes or medical packaging, compression and notched compression tests on composites. A compression testing machine is a universal testing machine (UTM) equipped with application-specific compression test tools or compression platens. The tools are selected and installed in the machine based on criteria such as test type, specimen material and dimensions, test temperature and maximum force values expected. A Compression Testing Machine or Compression Tester is a machine or equipment used to test the quality of the material by checking the compression resistance of that material. This can also be defined as a machine that is used to test the compressive strength of any material using a standard static force and a standard displacement rate. Because of the variety of uses, there are several different types of compression testing machines available. The type of CTM machine used depends on the material being tested and the type of information needed from the result. For example, some types are used for gas cylinders (compression only), oil barrels, and for cylinder blocks. Others measure tensile forces, but not torsional forces. Some are used for non-destructive evaluation (NDT) for inspection and acceptance testing of pressure vessels and piping, welded joints, and castings. Some machines can measure more than one feature at a time, such as different combinations of force, pressure, and time; time-temperature curves; strain; torque; compression, or tension. The type chosen should be based on what is most relevant to the users' needs.

Fig.16 Impact testing machine

The Charpy impact test, also known as the Charpy V-notch test, is a high strain-rate test that involves striking a standard notched specimen with a controlled weight pendulum swung from a set height. The impact test helps measure the amount of energy absorbed by the specimen during fracture. The Charpy impact test, 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. Absorbed energy is a measure of the material's notch toughness. It is widely used in industry, since it is easy to prepare and conduct and results can be obtained quickly and cheaply. A disadvantage is that some results are only comparative. The apparatus consists of a pendulum of known mass and length that is dropped from a known height to impact a notched specimen of material. The energy transferred to the material can be inferred by comparing the difference in the height of the hammer before and after the fracture (energy absorbed by the fracture event). The notch in the sample affects the results of the impact test thus it is necessary for the notch to be of regular dimensions and geometry. The size of the sample can also affect results, since the dimensions determine whether or not the material is in plane strain. This difference can greatly affect the conclusions made.

Fig.17 Salt spray test chamber

The salt spray test (or salt fog test) is a standardized and popular corrosion test method, used to check corrosion resistance of materials and surface coatings. Usually, the materials to be tested are metallic (although stone, ceramics, and polymers may also be tested) and finished with a surface coating which is intended to provide a degree of corrosion protection to the underlying metal.

Salt spray testing is an accelerated corrosion test that produces a corrosive attack to coated samples in order to evaluate (mostly comparatively) the suitability of the coating for use as a protective finish. The appearance of corrosion products (rust or other oxides) is evaluated after a pre-determined period of time.

Test duration depends on the corrosion resistance of the coating; generally, the more corrosion resistant the coating is, the longer the period of testing before the appearance of corrosion or rust. The salt spray test is one of the most widespread and long-established corrosion tests.

Salt spray testing is popular because it is relatively inexpensive, quick, well standardized, and reasonably repeatable. Although there may be a weak correlation between the duration in salt spray test and the expected life of a coating in certain coatings such as hot-dip galvanized steel, this test has gained worldwide popularity due to low cost and quick results.

Most Salt Spray Chambers today are being used NOT to predict the corrosion resistance of a coating, but to maintain coating processes such as pre-treatment and painting, electroplating, galvanizing, and the like, on a comparative basis. For example, pre-treated + painted components must pass 96 hours Neutral Salt Spray, to be accepted for production.

Failure to meet this requirement implies instability in the chemical process of the pre-treatment, or the paint quality, which must be addressed immediately so that the upcoming batches are of the desired quality. The longer the accelerated corrosion test, the longer the process remains out of control, and larger is the loss in the form of non-conforming batches. The principal application of the salt spray test is, therefore, enabling quick comparisons to be made between actual and expected corrosion resistance. Most commonly, the time taken for oxides to appear on the samples under test is compared to expectations, to determine whether the test is passed or failed. For this reason, the salt spray test is most often deployed in a quality audit role, where, for example, it can be used to check the effectiveness of a production process, such as the surface coating of a metallic part. The salt spray test has little application in predicting how materials or surface coatings will resist corrosion in the real world, because it does not create, replicate or accelerate real-world corrosive conditions. Cyclic corrosion testing is better suited to this.

6. Results and Discussion

6.1TENSILE TEST:

The tensile tests were carried out using computerized universal testing machine as per ASTM standards. But we can find the Tensile strength by conversion of Rockwell hardness to tensile strength. The approximate tensile strength is taken according to hardness value of aluminium composite. Tensile test is a fundamental material science test in which a sample is subjected control tension until failure. Properties that are directly measured via tensile test are ultimate tensile strength.

SPECIMEN	LOAD Fmax (KN)	TENSILE STRENGTH (Mpa)
T1	7.08	163
T2	4.72	194
T3	5.92	141
T4	3.86	158
T5	6.15	140
T6	3.64	148

Table 6.1 Tensile test

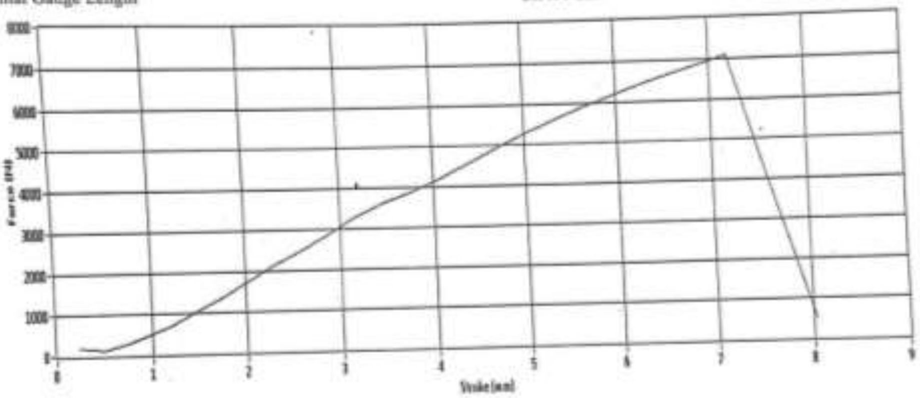
Test Report

Test Details

Machine ID:	ROOM TEMP:26°C	Date:	10-03-2023
Material Name:	ALU & POLY TEST SAMPLE	TOCR NO:	22-0859
Serial No:	T1	Test Method:	ASTM E8/E8M-21
Batch No:	6		

Input Data

Mode of Test	Tension
Sample Type	Flat
Thickness	7.35 mm
Width	5.92 mm
Area	43.51 mm²
Gauge Length	25.00 mm
Final Gauge Length	26.490 mm
Final Gauge Length	26.490 mm



Results

Fmax	7.08 KN
UTS	162.75 MPa
% EL	5.96 %
Yield Stress(Ys)	105.46 MPa

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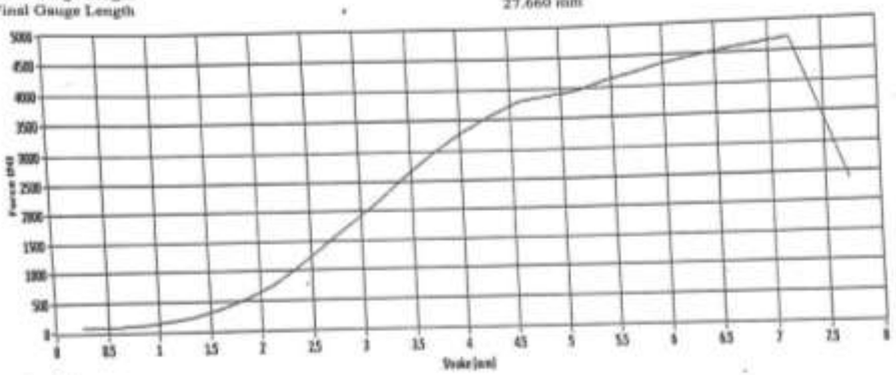
Test Report

Test Details

Machine ID:	ROOM TEMP:26°C	Date:	10-03-2023
Material Name:	ALU & POLY TEST SAMPLE	TOCR NO:	22-0859
Serial No:	T2	Test Method:	ASTM E8/E8M-21
Batch No:	6		

Input Data

Mode of Test	Tension
Sample Type	Flat
Thickness	4.12 mm
Width	5.89 mm
Area	24.27 mm²
Gauge Length	25.00 mm
Final Gauge Length	27.660 mm
Final Gauge Length	27.660 mm



Results

Fmax	4.72 KN
UTS	194.48 MPa
% EL	10.64 %
Yield Stress(Ys)	121.62 MPa

T-Rex Analytical Lab.

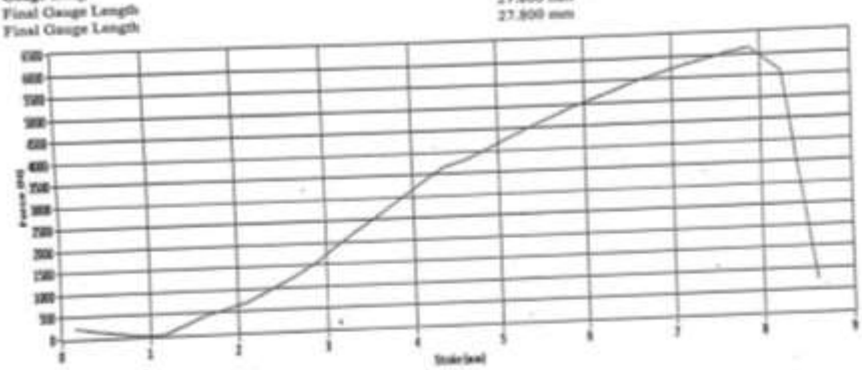
Test Report

Test Details

Machine ID:	ROOM TEMP:26°C	Date:	10-03-2023
Material Name:	ALU & POLY TEST SAMPLE	TOCR NO:	22-0859
		Test Method:	ASTM E8/E8M-21
Serial No:	T5		
Batch No:	15		

Input Data

Mode of Test	Tension
Sample Type	Flat
Thickness	7.44 mm
Width	5.91 mm
Area	43.97 mm²
Gauge Length	25.00 mm
Final Gauge Length	27.800 mm
Final Gauge Length	27.800 mm



Results

Fmax	6.15 KN
UTS	139.84 MPa
% EL	11.20 %
Yield Stress(Ys)	107.87 MPa

T-Rex Analytical Lab.

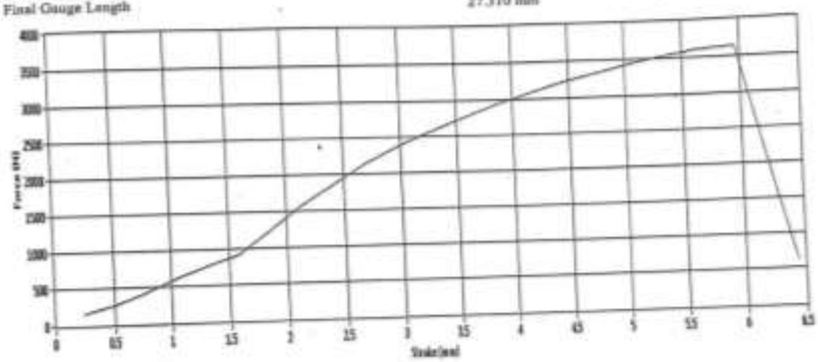
Test Report

Test Details

Machine ID:	ROOM TEMP:26°C	Date:	10-03-2023
Material Name:	ALU & POLY TEST SAMPLE	TOCR NO:	22-0859
		Test Method:	ASTM E8/E8M-21
Serial No:	T6		
Batch No:	15		

Input Data

Mode of Test	Tension
Sample Type	Flat
Thickness	4.13 mm
Width	5.94 mm
Area	24.53 mm²
Gauge Length	25.00 mm
Final Gauge Length	27.310 mm
Final Gauge Length	27.310 mm



Results

Fmax	3.64 KN
UTS	148.22 MPa
% EL	9.24 %
Yield Stress(Ys)	89.72 MPa

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6.2 Tensile test conclusion

SPECIMEN	TENSILE STRENGTH (Mpa)	CONCLUSION
T2	194	HIGH STRENGTH
T5	140	LOW STRENGTH

Table 6.2 Tensile test conclusion

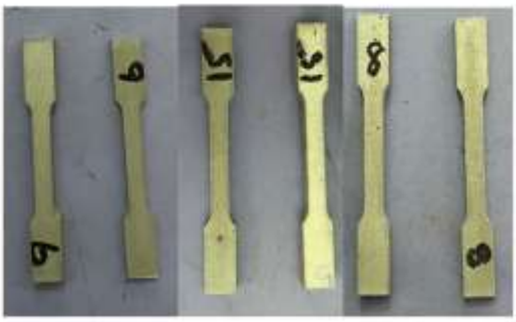


Fig.18 Tensile specimen before test

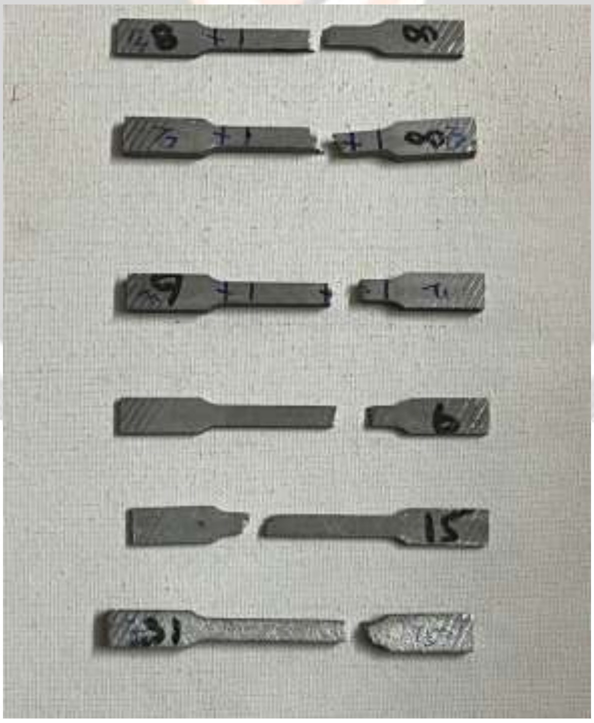


Fig.19 Tensile specimen after test

6.3 IMPACT TEST

The Charpy impact test, also known as the Charpy V-notch test, is a high strain-rate test that involves striking a standard notched specimen with a controlled weight pendulum swung from a set height. The impact test helps measure the amount of energy absorbed by the specimen during fracture. It is a standardized high strain rate test which determines the amount of energy absorbed by a material during fracture. Absorbed energy is a measure of the material's notch toughness. It is widely used in industry, since it is easy to prepare and conduct and results can be obtained quickly and cheaply. A disadvantage is that some results are only comparative. The below result shows the impact test result of aluminium polymer composite which was carried out in impact test machine. When compared to specimen 1(Al6063-94%, PET-6%) and specimen 2(Al6063-92%, PET-8%) and specimen 3(Al6063-85%, PET-15%).

RESULT:

SPECIMEN NO.	IMPACT(JOULES)
1	12
2	8
3	8

Table6.3 Impact test

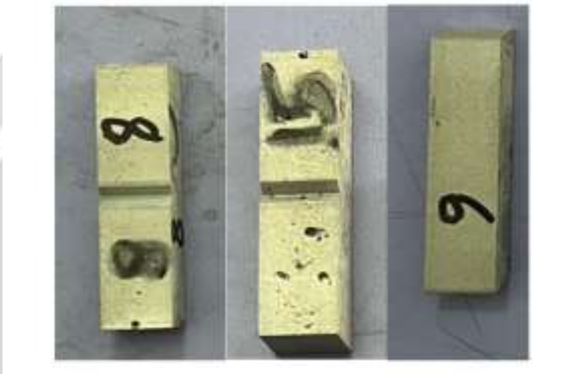


Fig.20 Impact specimen before test

Fig.21 Impact specimen after test

Table 6.3 Impact test result

SPECIMEN	IMPACT (J)	CONCLUSION
1	12	HIGH IMPACT
2&3	8	LOW IMPACT

6.4 COMPRESSION TEST:

A Compression test uses compression testing machines to determine material behaviour under constantly increasing compressive loading. Compression tests examine the safety, durability, and integrity of materials and components. Typical applications include compression tests on plastic tubes and plastic pipes, compression test on flexible cellular foam material, compression/crush tests on paper and cardboard, compression spring testing in the metals industry, compression tests in the medical/pharmaceutical field including compression testing of medical implants, stents, syringes or medical packaging, compression and notched compression tests on composites. The below result shows the compression test result of aluminium polymer composite which was carried out in impact test machine. When compared to specimen 1(Al6063-94%, PET-6%) and specimen 2(Al6063-92%, PET-8%) and specimen 3(Al6063-85%, PET-15%).

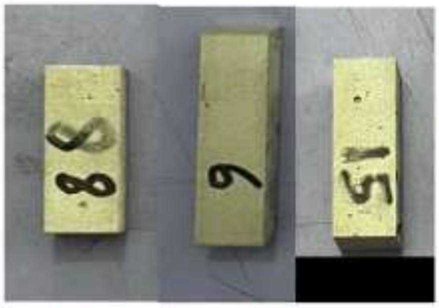


Fig.22 Compression specimen before test

Fig.23 Compression specimen after test

SPECIMEN	LOAD (KN)	COMPRESSIVE STRENGTH (Mpa)
C1	26.41	210
C2	49.58	398
C3	18.92	152

Table 6.4 Compression test

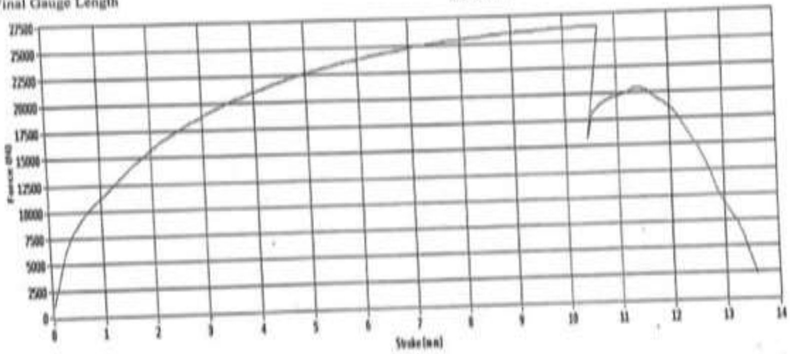
Test Report

Test Details

Machine ID:	ROOM TEMP:26°C	Date:	10-03-2023
Material Name:	ALU & POLY TEST SAMPLE	TOCR NO:	22-0859
Serial No:	C1	Test Method:	ASTM E9
Batch No:	6		

Input Data

Mode of Test	Compression
Sample Type	Flat
Thickness	9.91 mm
Width	12.71 mm
Area	125.96 mm²
Gauge Length	1.00 mm
Final Gauge Length	0.000 mm
Final Gauge Length	0.000 mm



Results

Fmax	26.41 KN
UTS	209.70 MPa

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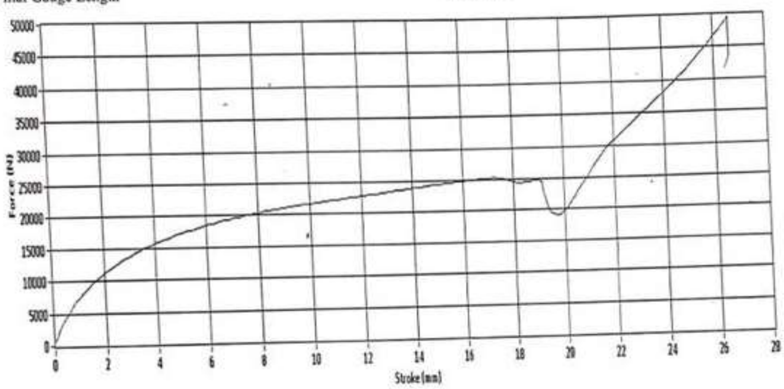
Test Report

Test Details

Machine ID:	ROOM TEMP:26°C	Date:	10-03-2023
Material Name:	ALU & POLY TEST SAMPLE	TOCR NO:	22-0859
Serial No:	C2	Test Method:	ASTM E9
Batch No:	8		

Input Data

Mode of Test	Compression
Sample Type	Flat
Thickness	9.92 mm
Width	12.56 mm
Area	124.60 mm²
Gauge Length	1.00 mm
Final Gauge Length	0.000 mm
Final Gauge Length	0.000 mm



Results

Fmax	49.58 KN
UTS	397.90 MPa

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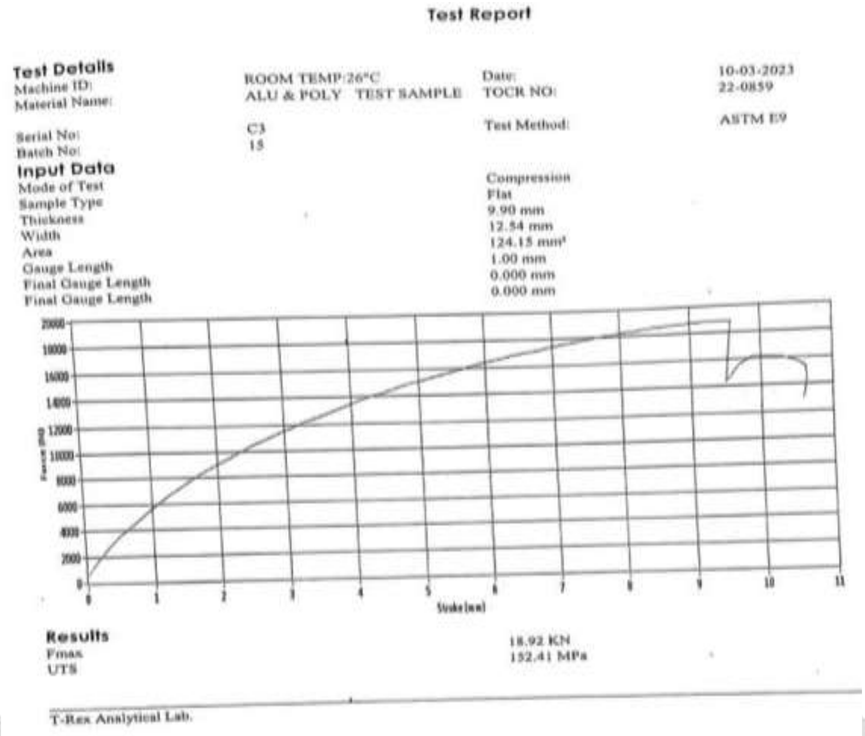
Test Report

Test Details
Machine ID: ROOM TEMP:26°C
Material Name: ALU & POLY TEST SAMPLE
Date: 10-03-2023
TOCR NO: 22-0859
Serial No: C3
Batch No: 15
Test Method: ASTM E9

Input Data
Mode of Test: Compression
Sample Type: Flat
Thickness: 9.90 mm
Width: 12.54 mm
Area: 124.15 mm²
Gauge Length: 1.00 mm
Final Gauge Length: 0.000 mm
Final Gauge Length: 0.000 mm

Results
Fmax: 18.92 KN
UTS: 152.41 MPa

T-Rex Analytical Lab.

6.5 SALT SPRAY TEST:

The salt spray test (or salt fog test) is a standardized and popular corrosion test method, used to check corrosion resistance of materials and surface coatings. Usually, the materials to be tested are metallic (although stone, ceramics, and polymers may also be tested) and finished with a surface coating which is intended to provide a degree of corrosion protection to the underlying metal. Salt spray testing is an accelerated corrosion test that produces a corrosive attack to coated samples in order to evaluate (mostly comparatively) the suitability of the coating for use as a protective finish. The appearance of corrosion products (rust or other oxides) is evaluated after a pre-determined period of time. Test duration depends on the corrosion resistance of the coating; generally, the more corrosion resistant the coating is, the longer the period of testing before the appearance of corrosion or rust. The salt spray test is one of the most widespread and long-established corrosion tests.

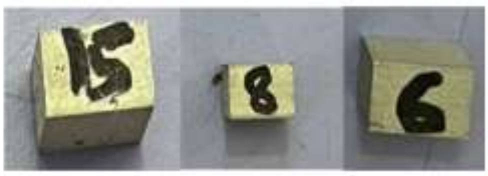

Fig.24 Salt spray sample before test

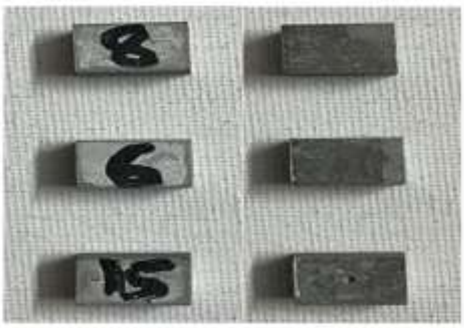

Fig.25 Salt spray sample after test

Test duration depends on the corrosion resistance of the coating; generally, the more corrosion resistant the coating is, the longer the period of testing before the appearance of corrosion or rust. The salt spray test is one of the most widespread and long-established corrosion tests. Salt spray testing is popular because it is relatively inexpensive, quick, well standardized, and reasonably repeatable. Although there may be a weak correlation between the duration in salt spray test and the expected life of a coating in certain coatings such as hot-dip galvanized steel, this test has gained worldwide popularity due to low cost and quick results. Most Salt Spray Chambers today are being used NOT to predict the corrosion resistance of a coating, but to maintain coating processes such as pre-treatment and painting, electroplating, galvanizing, and the like, on a comparative basis.

Nature of Test : Salt spray test

Test References : ASTM B117-19

Sample Details :

Aluminium 6063 {94% (734g)} + PET (Polyethylene terephthalate) {6% (6g)}, Qty.: 1 No.

Test Results

PROJECT BY: DAKSHNA.S.

OBSERVATION: Chemical /Corrosion test

SALT SPRAY TEST AS PER ASTM B117-19			
Sl.No.	**TEST CONDITION**	**REQUIREMENTS**	**ACTUAL**
1.	Chamber Temperature	35 ± 2°C	33.9 - 34.8°C
2.	pH of solution	6.5 to 7.2	6.8
3.	Air Pressure	12 to 18 psi	15 psi
4.	Concentration of sodium chloride	5 ± 1%	4.8 - 5.0%
5.	Collection of solution per hour	1 to 2ml	1.3 ml
6.	Test hours	48 hrs	48 hrs

Note: White rust observed at the end of **48 hrs** of testing.

The photograph taken is exhibited as below:

Before Test	**After Test**
	

Nature of Test : Salt spray test

Test References : ASTM B117-19

Sample Details :

Aluminium 6063 {92% (732g)} + PET (Polyethylene terephthalate) {8% (8g)}, Qty.: 1 No.

Test Results

PROJECT BY: DAKSHNA.S.

OBSERVATION: Chemical /Corrosion test

SALT SPRAY TEST AS PER ASTM B117-19			
Sl.No.	**TEST CONDITION**	**REQUIREMENTS**	**ACTUAL**
1.	Chamber Temperature	35 ± 2°C	33.9 - 34.8°C
2.	pH of solution	6.5 to 7.2	6.8
3.	Air Pressure	12 to 18 psi	15 psi
4.	Concentration of sodium chloride	5 ± 1%	4.8 - 5.0%
5.	Collection of solution per hour	1 to 2ml	1.3 ml
6.	Test hours	48 hrs	48 hrs

Note: White rust observed at the end of **48 hrs** of testing.

The photograph taken is exhibited as below:

Before Test	**After Test**
	

Nature of Test : Salt spray test
Test References : ASTM B117-19

Sample Details :
Aluminium 6063{85% (725g)} + PET (Polyethylene terephthalate) {15% (15g)}, Qty.: 1 No.

Test Results

PROJECT BY: DAKSHNA.S.
OBSERVATION: Chemical /Corrosion test

SALT SPRAY TEST AS PER ASTM B117-19			
Sl.No.	**TEST CONDITION**	**REQUIREMENTS**	**ACTUAL**
1.	Chamber Temperature	35 ± 2°C	33.9 - 34.8°C
2.	pH of solution	6.5 to 7.2	6.8
3.	Air Pressure	12 to 18 psi	15 psi
4.	Concentration of sodium chloride	5 ± 1%	4.8 - 5.0%
5.	Collection of solution per hour	1 to 2ml	1.3 ml
6.	Test hours	48 hrs	48 hrs

Note: White rust observed at the end of **48 hrs** of testing.

The photograph taken is exhibited as below:

Before Test **After Test**

7. Scope

- ❖ Identifying new materials
- ❖ Replacement of current materials in automobile, aerospace, military and sports components.
  - i. Break calliper
  - ii. Vehicle Exhaust manifold casing
  - iii. Upper and lower receiver of M16 Rifle parts
  - iv. Net of Lacrosse sticks
  - v. Camping gadgets

8. Conclusion

The conclusions based on the present work on Al6063 – PET (Polyethylene Terephthalate) metal matrix composites are as follows,

- ❖ The Selection of matrix base material.
- ❖ Mould making as per specimen.
- ❖ Composite preparation with Al6063 and PET (Polyethylene Terephthalate)
- ❖ Casting of metal matrix composites by stir casting process by using Al6063 / PET (Polyethylene Terephthalate) as reinforcements.
- ❖ Surface cleaning and finishing.
- ❖ Pouring and solidification.
- ❖ The casting material is obtained and weight percentage of the composite materials is calculated.
- ❖ We have undergone Mechanical testing like Tensile, Impact, and Compression.
- ❖ In tensile testing there are totally six specimens (T1,T2,T3,T4,T5,T6) out of the six T2 was found to high strength and T5 was found to be low strength.
- ❖ In Impact testing there are totally three specimens in which the specimen no.1 was found to be stronger than other two.
- ❖ Also in Compression test there are 3 specimens (C1,C2,C3) out of the three specimens the C2 is found to be stronger.
- ❖ In Corrosion test the salt spray test was conducted for 48hrs after the test the corrosion was found to be minimal in sample no.1 out of the three samples.

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