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Tribiological Properties of Alluminium 2024 Alloy and Beryl Particulate MMC

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Abstract **In present study, Al2024-Beryl synthesized by using a stir casting technique. The different weight percentage of Beryl incorporated are 2Wt.% to 8 Wt.% in steps of 2 Wt.%. The effect of Beryl particles integration on hardness and tensile strength response on Al2024 were investigated. It is demonstrated that Beryl particles distributed homogeneously in the Al2024 matrix acts as effective reinforcement to enhance the mechanical properties. Compared to base Al2024 matrix, Al2024- 6 wt.% Beryl composites exhibited higher yield strength of 47.42%, ultimate tensile strength of 44.08% and Al2024-8Wt.% enhancement in hardness of 27.71% when compared to Al2024.**

Keywords---Tensile Strength, Demonstrated, Homogeneously, Reinforcement, Higher Yield Strength, Ultimate Tensile Strength,

I. ALLUMINIUM ALLOYS

Selecting the right alloy for a given application entails considerations of its tensile strength, density, ductility, formability, workability, weld ability, and corrosion resistance. Aluminium alloys are alloys in which aluminium (Al) is the predominant metal. The typical alloying elements are copper, magnesium, manganese, silicon, and zinc. There are two principal classifications, namely casting alloys and wrought alloys, both of which are further subdivided into the categories heat-treatable and non-heat-treatable. About 85% of aluminium is used for wrought products, for example rolled plate, foils and extrusions. Cast aluminium alloys yield cost effective products due to its low melting point, although they generally have lower tensile strengths than wrought alloys. The most important cast aluminium alloy system is Al-Si, where the high levels of silicon (4.0% to 13%) contribute to give good casting characteristics.

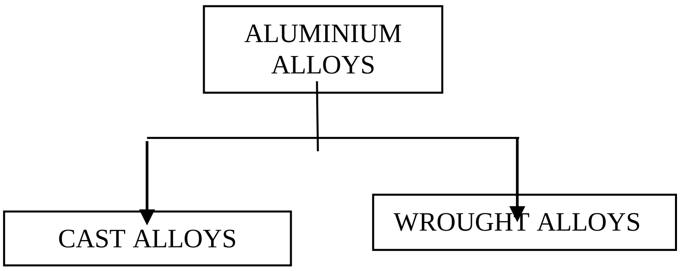

Figure.1.1 Classification of Aluminium alloy

1.1.1 CAST ALLUMINIUM ALLOYS:

in Aluminium and its alloys are used in a variety of cast and wrought form and conditions of heat treatment. Forgings, sections, extrusions, sheets, plate, strip, foils and wire are some of the examples of wrought form while castings are available as sand, pressure and gravity die-castings e.g. Al-Si and Al-Mg alloys. The designation of Cast Aluminium alloy is shown

Alloy designation	Details
1XXX	99% pure Aluminium
2XXX	Cu containing alloy
3XXX	Si, Cu/Mg containing alloy
4XXX	Si containing alloy
5XXX	Mg containing alloy
6XXX	Zn containing alloy

Table 1.2 Designation of Cast Aluminium alloys

1.1.2WROUGHT ALUMINIUM ALLOYS:

Alloy designation	Details
1XXX	99% pure Aluminium
2XXX	Cu containing alloy
3XXX	Mn containing alloy
4XXX	Si containing alloy
5XXX	Mg containing alloy
6XXX	Mg and Si containing alloy
7XXX	Zn containing alloy
8XXX	Other alloys

Table 1.3 Designation of Wrought Aluminium alloys

To meet various requirements, aluminium is alloyed with copper, manganese, magnesium, zinc and silicon as major alloying elements. The designation of wrought aluminium alloys

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1.1.3 DESIGNATION OF ALUMINIUM ALLOYS:

The Aluminium Association of America has classified the wrought aluminium alloys according to a four-digit system. The classification is adopted by the International Alloy Development System (IADS).The first digit identifies the alloy type the second digit shows the specific alloy modification. The last two digits indicate the specific aluminium. Aluminium Alloy in present

Letter	Condition of alloy
F	F As-fabricated
O	O Annealed
T4	T4 Solution treated
T6	T6 Solution treated and aged

Table 1.4 Temper Designation System

1.1.4APPLICATION OF ALUMINUM ALLOY:

Aluminium Alloy	Alloy Characteristics	Common Use
1050/1200	Non heat-treatable. Good formability, weldability and corrosion resistance	Food and Chemical Industry
2014	Heat-treatable. High strength. Non wieldable. Poor corrosion resistance	Airframes
5251/5052	Non-heat-treatable. Medium strength work hardening alloy. Good weld ability, formability and corrosion resistance.	Vehicle paneling, structures exposed to marine atmospheres, mine cages.
6063	Heat-treatable. Medium strength alloy. Good weld ability and corrosion resistance. Used for intricate profiles.	Architectural extrusions (internal and external) window frames, irrigation pipes.
6061/6082	Heat-treatable. Properties very similar to 6082. Preferable as air quenchable, therefore has less distortion problems. Not notch sensitive.	Stressed structural members, bridges, cranes, roof trusses, beer barrels
7075	Heat-treatable. Age hardens naturally, therefore will recover properties in heat-affected zone after welding.	Armored vehicles, military bridges, motor cycle and bicycle frames

Table 1.5 Application of Aluminium Alloy program.

1.2 COMPOSITES

1.2.1 INTRODUCTION TO COMPOSITE:

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 of common materials (metals, alloys, doped ceramics and polymers mixed with additives) also have a small amount of dispersed phases in their structures, however they are not considered as composite materials since their properties are similar to those of their base constituents (physical property of steel are similar to those of pure iron) . Favorable properties of composites materials are high stiffness and high strength, low density, high temperature stability, high electrical and thermal

1.2.2 MATRIX PHASE:

1. The primary phase, having a continuous character,
2. Usually more ductile and less hard phase,
3. Holds the reinforcing phase and shares a load with it.

1.2.3 REINFORCING PHASE:

1. Second phase (or phases) is imbedded in the matrix in a discontinuous form,

2. Usually stronger than the matrix, therefore it is sometimes called reinforcing phase.

1.2.4 Composites as engineering materials normally refer to the material with the following characteristics:

1. These are artificially made (thus, excluding natural material such as wood).
2. These consist of at least two different species with a well defined interface.
3. Their properties are influenced by the volume percentage of ingredien

1.2.5 Performance of Composite depends on:

1. Properties of matrix and reinforcement,
2. Size and distribution of constituents,
3. Shape of constituents,
4. Nature of interface between constituents.

1.2.6 CLASSIFICATION OF COMPOSITES:

Composite materials are classified

I. On the basis of matrix material,

II. On the basis of filler material.

I. **On the basis of Matrix:**

(a) Metal Matrix Composites (MMC)

Metal Matrix Composites are composed of a metallic matrix (aluminium, magnesium, iron, cobalt, copper) and a dispersed ceramic (oxides, carbides) or metallic (lead, tungsten, molybdenum) phase.

(b) Ceramic Matrix Composites (CMC)

Ceramic Matrix Composites are composed of a ceramic matrix and imbedded fibers of other ceramic material (dispersed phase).

(c) Polymer Matrix Composites (PMC)

Polymer Matrix Composites are composed of a matrix from thermoset (Unsaturated polyester (UP), Epoxy) or thermoplastic (PVC, Nylon, Polysterene) and embedded glass, carbon, steel or Kevlar fibers (dispersed phase).

II. **On the basis of Material Structure:**

Particulate Composites

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Particulate Composites consist of a matrix reinforced by a dispersed phase in form of particles.

1. Composites with random orientation of particles.
2. Composites with preferred orientation of particles.

III. **Fibrous Composites**

(a) Short-fiber reinforced composites:

Short-fiber reinforced composites consist of a matrix reinforced by a dispersed phase in form of discontinuous fibers (length < 100*diameter).

1. Composites with random orientation of fibers.
2. Composites with preferred orientation of fibers.

(b) Long-fiber reinforced composites:

Long-fiber reinforced composites consist of a matrix reinforced by a dispersed phase in form of continuous fibers.

1. Unidirectional orientation of fibers.
2. Bidirectional orientation of fibers (woven).
3. Laminate Composites

When a fiber reinforced composite consists of several layers with different fiber orientations, it is called multilayer (angle-ply) composite.

1.3 METAL MATRIX COMPOSITES (MMCS):

Metal Matrix Composites are composed of a metallic matrix (Al, Mg, Fe, Cu, etc.) and a dispersed ceramic (oxide, carbides) or metallic phase (Pb, Mo, W, etc.). Ceramic reinforcement may be silicon carbide, boron, alumina, silicon nitride, boron carbide, boron nitride etc. Whereas Metallic Reinforcement may be tungsten, beryllium etc. MMCs are used for Space Shuttle, commercial airliners, electronic substrates, bicycles, automobiles, golf clubs and a variety of other applications.

Compared to monolithic metals, MMCs have:

- Higher strength-to-density ratios
- Higher stiffness-to-density ratios
- Better fatigue resistance
- Better elevated temperature properties
  - ➢ Higher strength
  - ➢ Lower creep rate
- Lower coefficients of thermal expansion
- Better wear resistance

The advantages of MMCs over polymer matrix composites are:

- Higher temperature capability
- Fire resistance
- Higher transverse stiffness and strength
- No moisture absorption
- Higher electrical and thermal conductivities
- Better radiation resistance
- No out gassing
- Fabric ability of whisker and particulate-reinforced MMCs with conventional metalworking equipment.

Some of the disadvantages of MMCs compared to monolithic metals and polymer matrix composites are:

- Higher cost of some material systems
- Relatively immature technology
- Complex fabrication methods for fiber-reinforced systems (except for casting)
- Limited service experience
- Numerous combinations of matrices and reinforcements have been tried since work on MMC began in the late 1950s. However, MMC technology is still in the early stages of development and other important systems undoubtedly will emerge. Numerous metals have been used as matrices. The most important have been aluminium, titanium, magnesium, and copper alloys and super alloys.
- The most important MMC systems are:
- Aluminium matrix
  - ➢ Continuous fibers: boron, silicon carbide, alumina, graphite
  - ➢ Discontinuous fibers: alumina, alumina-silica
  - ➢ Whiskers: silicon carbide
  - ➢ Particulates: silicon carbide, boron carbide
- Magnesium matrix
  - ➢ Continuous fibers: graphite, alumina
  - ➢ Whiskers: silicon carbide
  - ➢ Particulates: silicon carbide, boron carbide
- Titanium matrix
  - ➢ Continuous fibers: silicon carbide, coated boron
  - ➢ Particulates: titanium carbide
- Copper matrix
  - ➢ Continuous fibers: graphite, silicon carbide
  - ➢ Wires: niobium-titanium, niobium-tin
  - ➢ Particulates: silicon carbide, boron carbide, titanium carbide.

ADVANTAGES	DISADVANTAGES
Compared to Un- Reinforced Aluminium Alloys	
➢ Higher Specific Strength ➢ Higher Specific Stiffness ➢ Improved High Temperature Creep ➢ Resistance ➢ Improved Wear Resistance	➢ Lower toughness and ductility ➢ More Expensive and complicated ➢ Production Method
Compared To Polymer Matrix Composites	
➢ Higher Transverse	➢ Less developed

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Strength Higher Toughness ➢ Higher Damage Tolerance Improved Environmental Resistance ➢ Higher Electrical and Thermal Conductivity.	Technology ➢ Smaller Database Technology ➢ Higher Cost
Compared Ceramic Matrix Composites	
➢ Higher Toughness and Ductility ➢ Ease of Fabrication ➢ Lower Cost	➢ Inferior High Temperature Capability

Table 1.6 Comparison between Reinforced & Un-Reinforced Al alloy

1.4 PROCESSING OF MMCS:

Accordingly to the temperature of the metallic matrix during processing the fabrication of MMCs can be classified into three categories:

(a) Liquid phase processes,

(b) Solid state processes, and

(c) Two phase (solid-liquid) processes

1.4.1 Liquid Metal Techniques:

Liquid state fabrication of Metal Matrix Composites involves incorporation of dispersed phase into a molten matrix metal, followed by its Solidification. In order to provide high level of mechanical properties of the composite, good interfacial bonding (wetting) between the dispersed phase and the liquid matrix should be obtained. Wetting improvement may be achieved by coating the dispersed phase p articles (fibers). Proper coating not only reduces interfacial energy, but also prevents chemical interaction between the dispersed phase and the matrix. The simplest and the most cost effective method of liquid state fabrication is Stir Casting.

The methods of liquid state fabrication of Metal Matrix Composites are:

- Stir casting
- Infiltration
- Gas Pressure Infiltration
- Squeeze Casting Infiltration
- Pressure Die Infiltration
- Deposition Processes

1.4.2 Stir Casting Process:

Stir Casting is a liquid state method of composite materials fabrication, in which a dispersed phase (ceramic particles, short fibers) is mixed with a molten matrix metal by means of mechanical stirring. The liquid composite material is then cast by conventional casting methods and may also be processed by conventional Metal forming technologies.

Figure 1.1 Stir Casting Process

1.5. PROCESS PARAMETER:

For manufacturing of composite material by stir casting knowledge of its operating parameter are very essential. As there is various process parameters if they properly controlled can lead to the improved characteristic in composite material.

1.5.1. Stirring speed:-

Stirring speed is the important process parameter as stirring is necessary to help in promoting wetability i.e. bonding between matrix & reinforcement. Stirring speed will directly control the flow pattern of the molten metal. Parallel flow will not promote good reinforcement mixing with the matrix. Hence flow pattern should be controlled turbulence flow. Pattern of flow from inward to outward direction is best. In our project we kept speed from 300-600 rpm. As solidifying rate is faster it will increase the percentage of wetability.

1.5.2. Stirring temperature:-

It is an important process parameter. It is related to the melting temperature of matrix i.e. aluminium. Aluminium generally melts at 650◦C. The processing temperature is mainly influence the viscosity of Al matrix. The change of viscosity influences the particle distribution in the matrix. In our project in order to promote good wetability we had kept operating temperature at 630°C which keeps Al (6061) in semisolid state.

1.5.3. Reinforcement preheat temperature :-

Reinforcement was preheated at a specified 500◦C temperature 30 min in order to remove moisture or any other gases present within reinforcement. The preheating of also promotes the wetability of reinforcement with matrix.

1.5.4. Addition of magnesium:

addition of Magnesium enhances the wetability. However increase the content above 1wt. % increases viscosity of slurry and hence uniform particle distribution will be difficult.

1.5.5. Stirring time :-

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Stirring promotes uniform distribution of the particles in the liquid and to create perfect interface bond b/w reinforcement and matrix. The stirring time b/w matrix and reinforcement is considered as important factor in the processing of composite. For uniform distribution of reinforcement in matrix in metal flow pattern should from outward to inward.

1.5.6. Blade Angle :-

The blade angle and number of blades are prominent factor which decides the flow pattern of the liquid metal at the time of stirring. The blade with angle 45° & 60° will give the uniform distribution. The number of blade should be 4. Blade should be 20mm above the bottom of the crucible. Blade pattern drastically affect the flow pattern

1.5.7. Inert Gas :-

As aluminium melt it start reacting with environment oxygen and will produce an oxide layer at the top. This oxide layer will avoid further oxidation but along that it will difficult to brake. So such layer will be big trouble for reinforcement mixture with metal. So in order to avoid this we had used inert gas like nitrogen.

1.5.8. Preheated Temperature of Mould :-

In casting porosity is the prime defect. In order to avoid these preheating the permanent mould is good solution. It will help in removing the entrapped gases from the slurry in mould It will also enhance the mechanical properties of the cast AMC. While pouring molten metal keep the pouring rate constant to avoid bubble formation.

1.5.9. Powder Feed Rate :-

To have a good quality of casting the feed rate of powder particles must be uniform. If it is non-uniform it promotes clustering of particles at some places which in turn enhances the porosity defect and inclusion defect, so the feed rate of particles must be uniform.

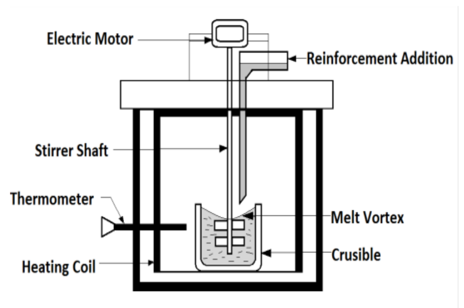


Figure1.2 Stir Casting Setup

Method	Range of shape & Size	Metal Yield	Range of volume fraction	Damage to Reinforcement	Cost
Stir Casting	Not limited by size	Medium	0.4 to 0.7	Little damage	Least Expensive
Squeeze casting	Limited by perform shape Up to 2cm height	Low	Up to 0.45	Severe damage	Moderately Expensive
Powder metallurgy	Widerange, restricted size	High	-	Reinforcement Fracture	Expensive
Spray casting	Limited shape, large size	Medium	0.3 to 0.7	-	Expensive

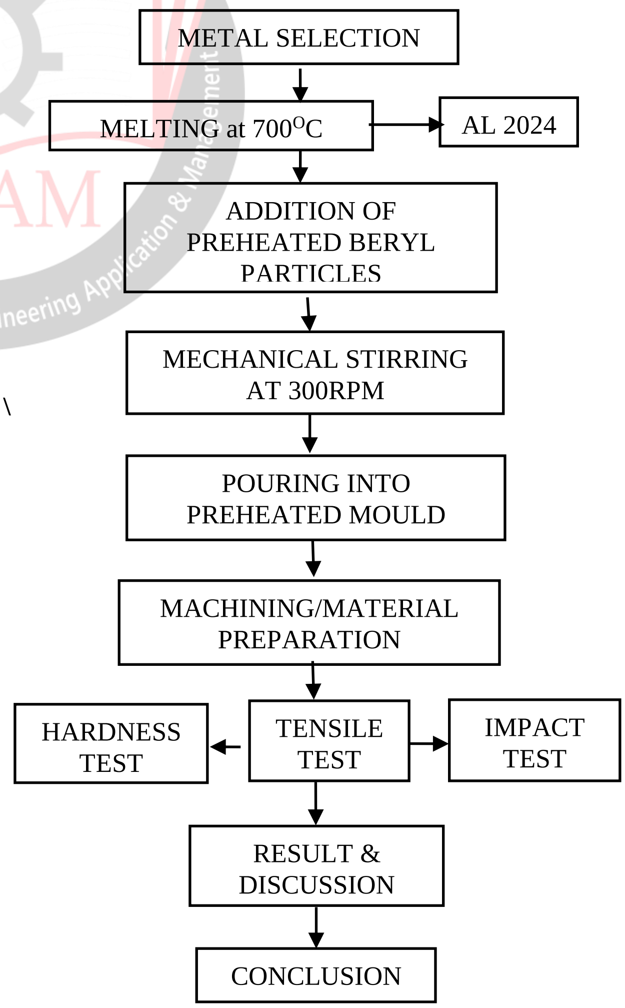
Table 1.6 Comparative analysis of different techniques of fabrication.

II. OBEJECTIVES

2.1 MAIN OBJECTIVES OF THE PROJECT

- To understand the mechanical behavior of the developed composites
- To analyze the hardness of the composite
- To study the tensile fracture analysis of the composites
- To evaluate the composite materials as well as the base matrix Alloy Al 2024 to determine the tensile strength behavior studies on different composition.

III. METHODOLOGY



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IV. MATERIALS AND FABRICATION

4.1. MATERIAL USED

4.1.1. ALUMINIUM ALLOY AL 2024 – BERYL

Aluminium alloy AL2024 –BERYL is one of the most extensively used of the 6000 series aluminium alloys. It is a versatile heat treatable extruded alloy with medium to high strength capabilities. AL2024 –BERYL is a precipitated hardened Aluminium alloy containing magnesium and silicon as its major alloying elements.

Composition of aluminium alloy AL2024 –BERYL

Components	**Amount wt.%**
Aluminium	Balance
Magnesium	0.9-1.25
Silicon	0.45 – 0.8
Iron	Max. 0.5
Zinc	Max. 0.25
Titanium	Max. 0.15
Copper	0.15-0.40
Manganese	Max.0.15
Chromium	0.04-0.35
Others	0.05

Table 4.1 Typical composition of aluminium alloy AL2024 –BERYL

4.1.2 Typical properties of aluminium alloy AL2024 –BERYL include:

- Medium to high strength
- Good toughness
- Good surface finish
- Excellent corrosion resistance to atmospheric conditions
- Good corrosion resistance to sea water
- Can be anodized
- Good weld ability and bras ability
- Good workability
- Widely available

4.1.3 Physical Properties of AL2024 –BERYL:

- Density: 2.4 g/cm3
- Melting Point: Approx. 550°C
- Modulus of Elasticity: 60-70 GPa
- Poisson Ratio: 0.33

4.1.4 Applications of AL2024 –BERYL:

Typical applications for aluminium alloy AL 2024 –BERYL include:

- Aircraft and aerospace components
- Marine fittings
- Transport
- Bicycle frames
- Camera lenses
- Drive shafts
- Electrical fittings and connectors
- Brake components
- Valves

4.2. REINFORCING MATERIALS:

Beryl (Be) is also acknowledged as Beryllium Aluminum Cyclosilicate. Its chemical formula is (Be3Al2 (SiO3)6). The major elements Beryl contains are Silicon oxide (Wt.% 62.12), Aluminum oxide (Wt.% 18.05), Beryllium oxide (Wt.% 8.24), Ferric Oxide (Fe2O3) and Calcium oxide (Wt.% 1.34). Beryl is a mineral, naturally occurs and very hard reinforcements. Beryl density is almost the same as aluminum of about 2600 to 2800 kg/m3. The particle size of the Beryl used in the present study ranges between 30 to 50 microns.

Figure 4.1. Beryl powder

4.3 EXPERIMENTAL SET UP USED IN STIR CASTING OPERATION

Equipment used to perform the Stir Casting operation and testing of composites.

4.3.1 MUFFLE FURNACE

Muffle Furnace was used to heat the material to desired temperatures by conduction, convection, or blackbody radiation from electrical resistance heating elements. A muffle furnace (sometimes, retort furnace) in historical usage is a furnace in which the subject material is isolated from the fuel and all of the products of combustion including gases and reinforcement particles. The maximum temperature of muffle furnace is 1100°C.

Figure 4.2 Muffle furnace

4.3.2 STIRRER:

The function of a stirrer was to agitate liquids for speeding up reactions. Stirrer was designed to homogenous mixing of liquid, viscous material and solid liquid.

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Figure 4.3 Stirrer

4.3.3 GRAPHITE CRUCIBLE

A crucible is a refractory container used for metal, glass, and pigment production as well as a number of modern laboratory processes, which can withstand temperatures high enough to melt or otherwise alter its contents. Historically, they have usually been made of clay, but they can be made of any material with a higher temperature resistance than the substances they are designed to hold. Graphite crucible is used.

4.3.4 STIR CASTING SETUP: For manufacturing of composite material by stir casting knowledge of its operating parameter are very essential. The important process parameters are

- Stirring speed
- Stirring temperature
- Reinforcement preheat temperature
- Stirring time (Holding time)
- Preheated Temperature of Mould
- Powder Feed Rate
- Addition of Mg

Stirring speed is the important process parameter as stirring is necessary to help in promoting wettability bonding between matrix & reinforcement.

Figure 4.4 Stir Casting setup

4.4 PROCEDURE FOLLOWED:

Aluminium Alloy was melted in a crucible by heating it in a muffle furnace at 800°C for three to four hours.

The beryllium was preheated at 1000°C and respectively for one to three hours to make their surfaces oxidized. The furnace temperature was first raised above the liquidus temperature of Aluminium near about 750°C to melt the Al alloy completely and was then cooled down just below the liquidus to keep the slurry in Semi solid state. A stirring was carried out with the help of radial drilling machine for about 10 minutes at stirring rate of 290 RPM.

Specimen No.	Component	%Composition
1	AL 2024	98
	BERYL	2
	AL2024+BERYL	100
2	AL 2024	96
	BERYL	4
	AL2024+BERYL	100
3	AL 2024	94
	BERYL	6
	AL2024+BERYL	100
4	AL 2024	92
	BERYL	8
	AL2024+BERYL	100

Table 4.1 Al-BERYL percentage

V. MECHANICAL TESTING

5.1 INTROODUCTION

Mechanical testing reveals the elastic and inelastic behavior of a material when force is applied. A mechanical test shows whether a material or part is suitable for its intended mechanical applications by measuring elasticity, tensile strength, elongation, hardness, fracture toughness, impact resistance, stress rupture and fatigue limit. The mechanical testing for composites includes tensile test, hardness test and impact test.

5.2 TENSILE TEST

Tensile testing, also known as tension testing, is a fundamental materials science test in which a sample is subjected to a controlled tension until failure. The results from the test are commonly used to select a material for an application, for quality control, and to predict how a material will react under other types of forces. Properties that are directly measured via a tensile test are ultimate tensile strength, maximum elongation and reduction in area. From these measurements the following properties can also be determined Young's modulus, Poisson's ratio, Yield strength and strain hardening characteristics. Uniaxial tensile testing is the most commonly used for obtaining the mechanical characteristics of isotropic material, for anisotropic materials, such as composite materials and

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textiles, biaxial tensile testing is required.

The test process involves placing the test specimen in the testing machine and applying tension to it until it fractures. During the application of tension, the elongation of the gauge section is recorded against the applied force.

$$\varepsilon = \frac{\Delta L}{L_0} = \frac{L - L_0}{L_0}$$

The elongation measurement is used to calculate the engineering strain, ε, using the following equation:

Where ΔL is the change in gauge length, L_0 is the initial gauge length, and L is the final length.

Figure 5.1 Universal testing machine

The force measurement is used to calculate the engineering stress, σ, using the following equation:

Where, F is the force and A is the cross-section of the gauge section.

$$\sigma = \frac{F_n}{A}$$

The machine does these calculations as the force increases, so that the data points can be graphed into a stress-strain curve.

5.2.1 TESTING MACHINE

A universal testing machine (UTM), also known as a universal tester, materials testing machine or materials test frame, is used to test the tensile stress and compressive strength of materials. It is named after the fact that it can perform many standard tensile and compression tests on materials, components, and structures. Tensile test is clamping a single piece of anything on each of its ends and pull it apart until it breaks. This measures how strong it is (tensile strength) how stretchy it is (elongation), and how stiff it is (tensile modulus). Compression test is the exact opposite of a tensile test. This is where you compress an object between two level plates until a certain load or distance has been reached or the product breaks. The typical measurements are the maximum force sustained before breakage (compressive force), or load at displacement (i.e.55 pounds at 1” compression) or displacement at load (i.e.0.28” of compression at 20 pounds of force).

Figure 5.2 Universal testing machine

Machine specification

Machine Name : Tensile testing machine

Testing load range : Max 5 ton

Gear rotation speed

(for gradual loading) : 1.25 1.5 & 2.5 mm/min

Software details : FIE make India

5.2.2 SAMPLE PREPARATION

A tensile specimen is a standardized sample cross-section. It has two shoulders and a gauge (section) in between. The shoulders are large so they can be readily gripped, whereas the gauge section has a smaller cross-section so that the deformation and failure can occur in this area. The shoulders of the test specimen can be manufactured in various ways to mate to various grips in the testing machine (see the image below). Each system has advantages and disadvantages

for example, shoulders designed for serrated grips are easy and cheap to manufacture, but the alignment of the specimen is dependent on the skill of the technician. On the other hand, a pinned grip assures good alignment. Threaded shoulders and grips also assure good alignment, but the technician must know to thread each shoulder into the grip at least one diameter's length, otherwise the threads can strip before the specimen fractures.

In large castings and forgings, it is common to add extra material, which is designed to be removed from the casting so that test specimens can be made from it. These specimens may not be exact representation of the whole work piece because the grain structure may be different throughout. In smaller work pieces or when critical parts of the casting must be tested, a work piece may be sacrificed to make the test specimens. For work pieces that are machined from bar stock, the test specimen can be made from the same piece as the bar stock.

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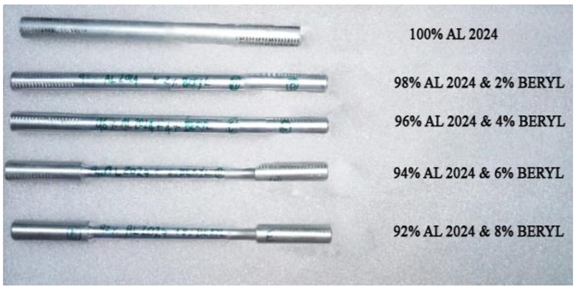

Figure 5.3 Tensile test specimen

5.2.3 TESTING PROCEDURE

The following steps to be followed while testing

- Two specimens which are cut to the standards are checked for its dimension and entered in the system.
- Then these specimens are mounted in the Universal Testing Machine and check for its tightness.
- When it is mounted properly, the loading starts and the tensile strength are measured in the system.
- Finally cracked specimen is removed from the machine.
- Again the same process is carried out for other specimen and result graphs are documented
- The control system has three major parts: the system software running on a personal computer, the digital controller, and a remote station control panel.

5.3 HARDNESS TEST

Hardness is a measure of how resistant solid matter is to various kinds of permanent shape change when am force is applied. Macroscopic hardness is generally characterized by strong intermolecular, but the behavior of solid materials under force is complex; therefore, there are different measurements of hardness: scratch hardness, indentation hardness, and rebound hardness. Hardness is dependent on ductility, elastic stiffness, plasticity, strain, strength, toughness, viscoelasticity, and viscosity.

5.3.1 TESTING MACHINE

The Rockwell scale is a hardness scale based on indentation hardness of a material. The Rockwell test determines the hardness by measuring the depth of penetration of an indenter under a large load compared to the penetration made by a preload. There are different scales, denoted by a single letter, that use different loads or indenters. The result is a dimensionless number noted as HRA, where A is the scale letter. When testing metals, indentation hardness correlates linearly with tensile strength.


Figure 5.4 Rockwell hardness test machine

5.3.2 SAMPLE PREPARATION

The specimen for this test is just a rectangular plate whose length is greater than its width. The test specimen dimension for this test is taken as shown in the figure below. The two specimens are cut in the same dimension.

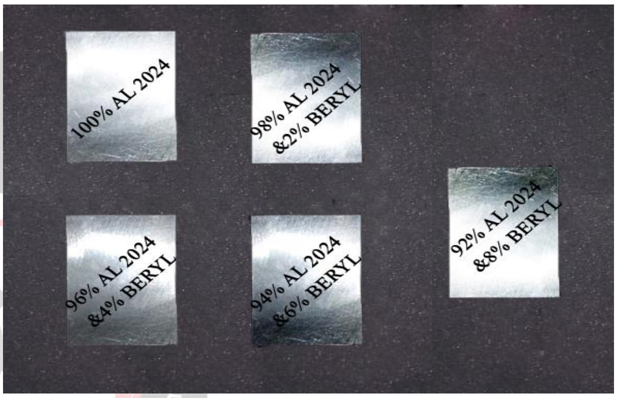

Figure 5.4 Hardness test specimen

According to ASTM A370, the standard specimen size for CHARPY impact

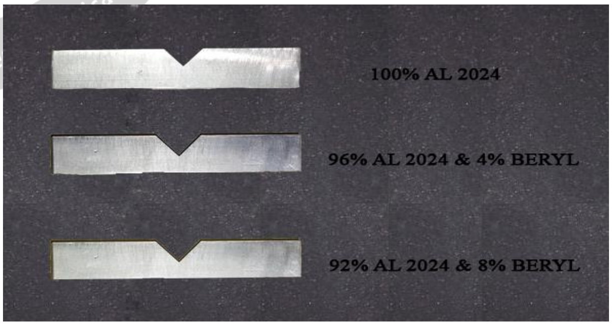

Figure 5.6 Impact test specimen

VI. RESULTS AND ANALYSIS

6.1 HARDNESS TEST

The results for the hardness test and indented pieces were shown below.

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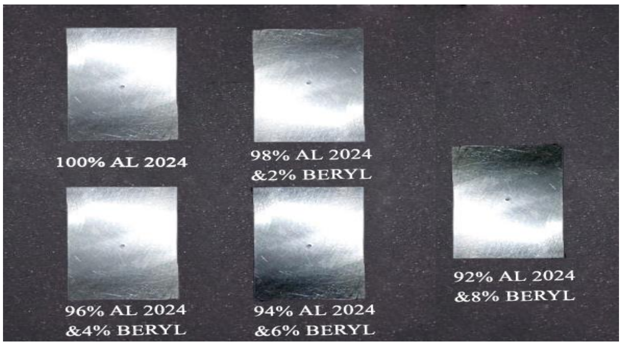


Figure 6.1 Specimen after hardness testing

SAMPLE	SAMPLE DESIGNATION	BHN
A	Al2024	84.8
B	Al2024 + 2wt.% Beryl	91.2
C	Al2024 + 4wt.% Beryl	96.1
D	Al2024 + 6wt.% Beryl	105.8
E	Al2024 + 8wt.% Beryl	108.3

Table 6.1 contains results of hardness test.

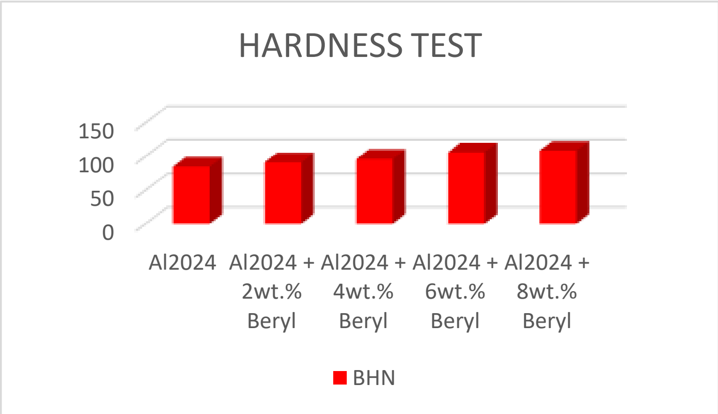


Table 6.2 Hardness test comparison

6.2 TENSILE TEST

The result for the tensile test and fractured pieces were shown below.

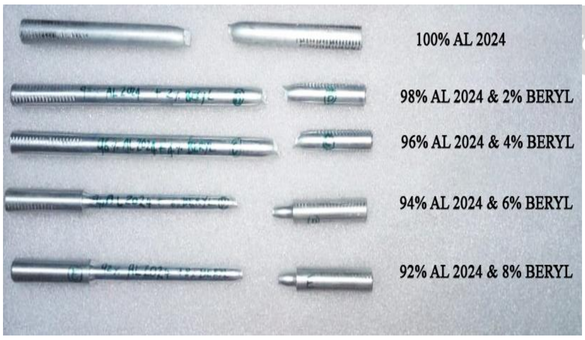
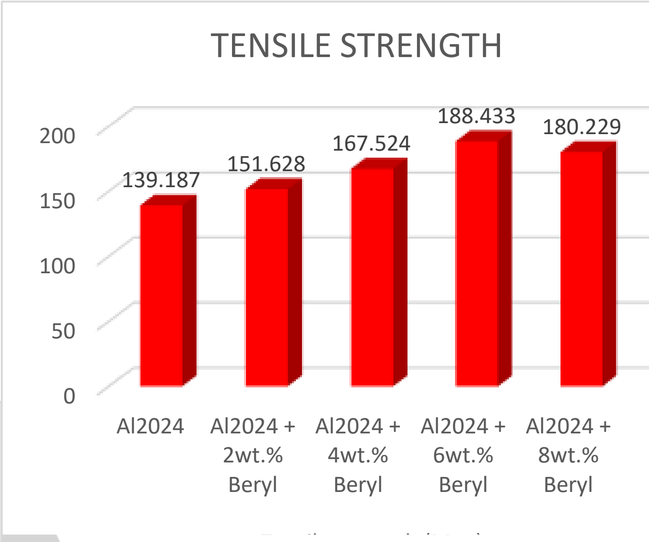


Figure 6.3 Tensile specimen after testing

The below table 6.3 contains results of Tensile test

Sample	Sample Description	Ultimate Tensile Strength (Mpa)	Yield Strength (Mpa)
A	Al2024	139.187	113.773
B	Al2024 + 2wt.% Beryl	151.628	129.485
C	Al2024 + 4wt.% Beryl	167.524	144.068
D	Al2024 + 6wt.% Beryl	188.433	165.705
E	Al2024 + 8wt.% Beryl	180.229	158.601

Table 6.2 Tensile test Tabulation



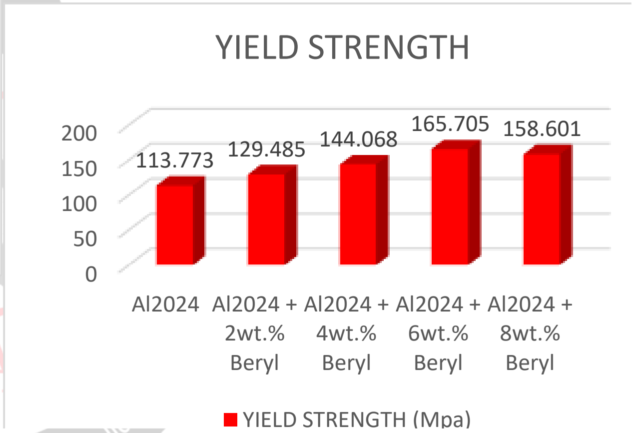


Fig 6.4 tensile & yield test comparison

6.3. IMPACT TEST

The below table 6.2 contains results of Impact strength.

SAMPLE	SAMPLE DESIGNATION	OBSERVED VALUES (JOULES)
A	Al2024	2.1
B	Al2024 + 2wt.% Beryl	2.1
C	Al2024 + 4wt.% Beryl	2.16
D	Al2024 + 6wt.% Beryl	2.25
E	Al2024 + 8wt.% Beryl	2.1

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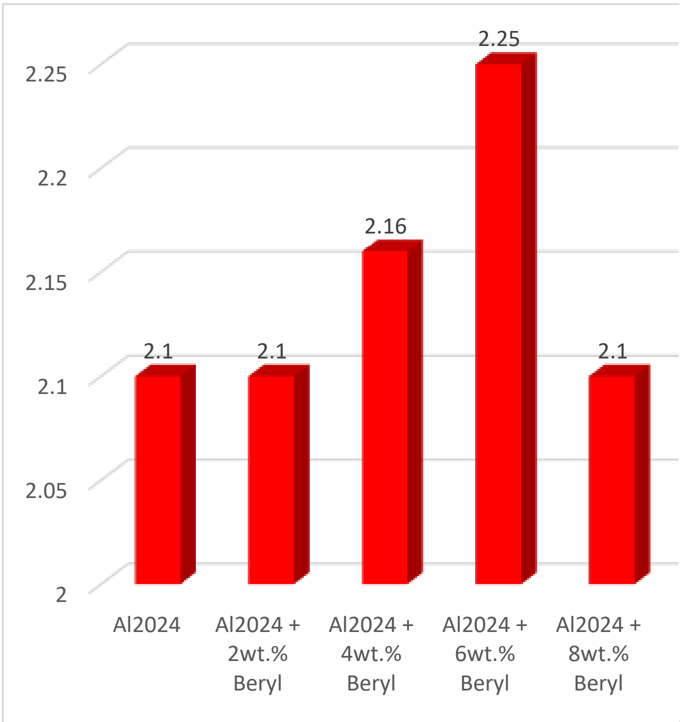

Table 6.1 impact test comparison

VII. CONCLUSION

a. Stir casting techniques was successfully adopted to synthesis the Al2024 and Al2024-Beryl composites.
b. The mechanical (Tensile strength test and hardness) properties have been investigated for both the Al2024 and Al2024-Beryl MMC.
c. The ultimate tensile strength of Al2024-Beryl composites shows a peak strength of **188.433 MPa** at 6 wt.% of particulate showing enhancement of **35.38%** when compared to Al2024 matrix
d. The hardness of Al2024-Beryl composites demonstrations an extreme hardness of **108.3 BHN** at 8 wt.% of Be particulate showing enhancement of **27.71%** when compared to Al2024 alloy.
e. The impact test of Al2024-Beryl composites shows a peak strength of **2.25** at 6 wt.% of particulate showing compared to Al2024 matrix.

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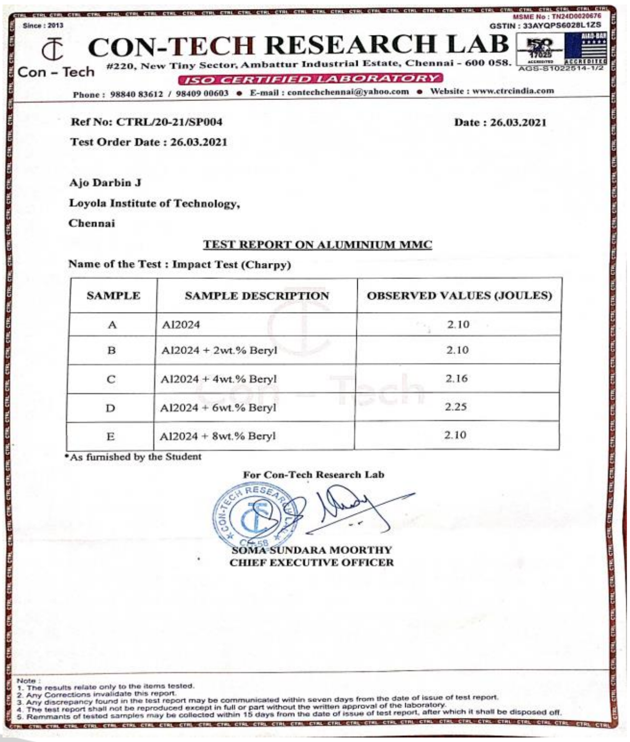

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Test Order Date : 26.03.2021

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TEST REPORT ON ALUMINIUM MMC

Name of the Test : Impact Test (Charpy)

SAMPLE	SAMPLE DESCRIPTION	OBSERVED VALUES (JOULES)
A	Al2024	2.10
B	Al2024 + 2wt.% Beryl	2.10
C	Al2024 + 4wt.% Beryl	2.16
D	Al2024 + 6wt.% Beryl	2.25
E	Al2024 + 8wt.% Beryl	2.10

*As furnished by the Student

For Con-Tech Research Lab

SOMA SUNDARA MOORTHY
CHIEF EXECUTIVE OFFICER

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2. Any Corrections invalidate this report.
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5. Remmants of tested samples may be collected within 15 days from the date of issue of test report, after which it shall be disposed off.

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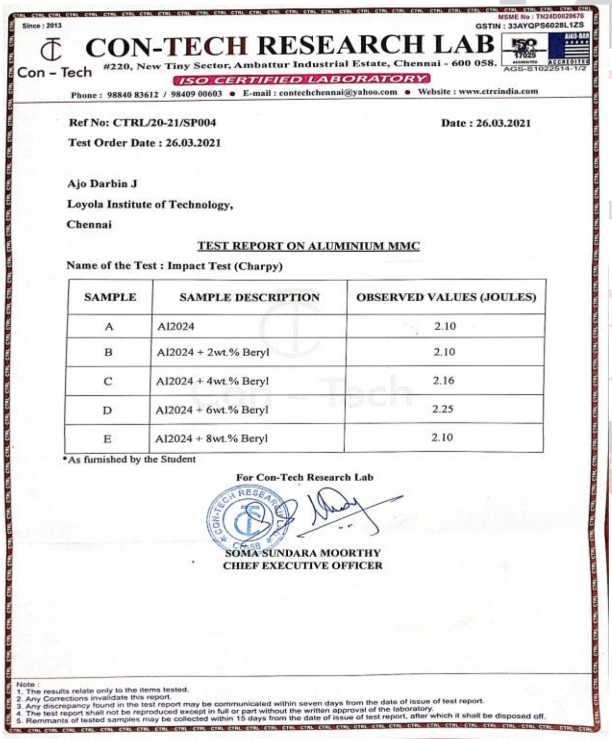

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