Fabrication, Synthesis and Characterization of Particle Reinforced Aluminium Matrix Composite

A
Thesis Report

Submitted in partial fulfillment of the requirement for the award of degree

MASTER OF ENGINEERING
IN
DESIGN

Under Guidance of :	**Submitted By :**
Mr. Puneet Sharma (Asst. Professor)	**Shivek Saini**
Deptt. of Mechanical Engineering	**Reg.d No. 11011890**

DEPARTMENT OF MECHANICAL ENGINEERING

LOVELY PROFESSIONAL UNIVERSITY

PHAGWARA, PUNJAB (INDIA) -144402

ABSTRACT

The present work is focused on the production of Al–10%B_4C, Al–15%B_4C, Al–20%B_4C, Al–25%B_4C (weight fraction) composites by stir casting techniques. On the other hand, casting methods undergoes reduced amalgamation and distribution of the reinforcement particles in the alloy matrix. Such tribulations become particularly considerable as the size of reinforcement shrinks because of greater agglomeration trend and reduced wettability of the particles with the melt. Scanning electron microscopy (SEM) was used to evaluate the micro-structural properties of the composite samples. The investigation revealed that heat treatment of B4C particles and addition of k_2TiF_6 flux enhanced the wettability and dispersion of reinforcement particles into melt. However, high fractions of reinforcement addition had ultimately lead to agglomerations at some locations. Mechanical properties of composite samples were also investigated. Tensile strength, Impact and Hardness have been improved w.r.t to the base alloy. Further, wear characteristics of composites showed the superior behavior for Al–B_4C composite than the base alloy.

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SHIVEK SAINI

Reg.d No:-11011890

Lovely Professional University Jalandhar, Punjab

CERTIFICATE

I hereby certify that the work which is being presented in the Dissertation-I entitled **"Fabrication, Synthesis And Characterization Of Particle Reinforced Aluminium Matrix Composite"** in partial fulfillment of the requirement for the award of degree **Master of Technology** and submitted in Department of Mechanical Engineering, Lovely Professional University, Punjabis an authentic record of my own work carried out during period of Dissertation under the supervision of Mr. **PUNEET SHARMA**, **Assistant Professor**, Department of Mechanical Engineering, Lovely Professional University, Punjab .

The matter presented in this dissertation has not been submitted by me any where for the award of any other degree or to any other institute.

Date: 29/06/2015 **(SHIVEK SAINI)**

This is to certify that the above statement made by the candidate is correct to best of my knowledge.

Date:29/06/2015 **(Mr. PUNEET SHARMA)**

Supervisor

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CHAPTER 1

INTRODUCTION

1.1 Composite materials

The prime engineering tool to be accepted and considered as most advanced are Composites. These beneficial and demanding tools have been originated by the growth in technology and materials. By mixing two or components with a suited matrix and a reinforcing material composites are made which are heterogeneous in nature. The origin of matrix may be metallic, ceramic or polymeric. The shape, surface appearance, environmental tolerance and overall durability of composites are given by matrix and outer forces are tolerated by reinforcement resulting in stiffness and strength of material. A composite material is a combination of its most required properties of its constituents and lacks the less required features and can give superior and different mechanical and physical properties. Now a days composites represents extremely well strength to weight and modulus to weight parameters and are referred to as lead material in automobile area, aerospace industries and many other applications. In aerospace and space vehicle industry high staging rigid composites are in demand which are made from glass, graphite, kevlar, boron or SiC fibers in polymeric matrices.

1.2 Classification of Composite materials

Two or more different phases (matrix phase and disseminate phase) are included in a composite material and they possess bulk character mainly apart from those of any of the elements.

- **Matrix phase:** The prime phase, depict same character, is called matrix. Matrix is mainly more ductile and less hard phase. It converges the disseminated phase and shares a load with it.

- **Dispersed (reinforcing) phase:** The subordinate phase (or phases) which is not regular is set within the matrix. This is called dispersed phase. Dispersed phase is usually stronger than the matrix, so considered as reinforcing phase.

Certain materials (doped ceramics, polymers metal alloys) which are not purely composites still their features resembles to their basic qualities (physical properties of steel and iron are same) also have little amount of dispersed phases.

Composite materials are divided into two categories. First is based on the matrix material (metal, ceramic, polymer) and the second is related to material structure:

- **Based on matrix material:**
  - **Metal Matrix Composites (MMC)**
    Metal Matrix Composites made up of a dispersed ceramic (oxides, carbides) or metallic (Pb, W, Mo) phase and a metallic matrix (Al, Mg, Fe, Co, Cu).
  - **Ceramic Matrix Composites (CMC)**
    Ceramic Matrix Composites are made up of a ceramic matrix and implanted fibers of other ceramic material (disseminated phase).
  - **Polymer Matrix Composites (PMC)**
    Polymer Matrix Composites are made up of a matrix from thermoset (Unsaturated Polyester(UP)), Epoxy (EP)or thermoplastic, Polycarbonate(PC), Polyvinylchloride (PVC), Nylon, Polystyrene and implanted glass, carbon, steel or Kevlar fibers (dispersed phase).

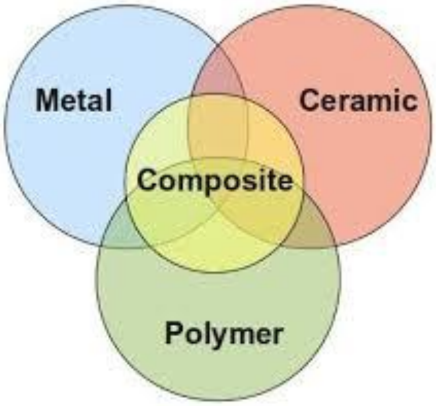


Fig. 1.1 categorization of composites

- **Based on reinforcing material structure:**

  - **Particulate Composites**

    Particulate Composites consist of a matrix enhanced by a dispersed phase; Disseminated phase of corresponding materials consists of 2-D flat platelets projected parallel to each other.

    - **Composites with arbitrary particle arrangement.**
    - **Composites with desired particle arrangement.**

  - **Fibrous Composites**

    1. **Short fiber strengthened composites:**

       Short-fiber strengthened composites comprise of a matrix strengthened by a disseminated phase in form of irregular fibers.

       - **Composites with arbitrary fibers arrangement.**
       - **Composites with desired fibers arrangement.**

    2. **Long fiber strengthened composites:**

       Long fiber strengthened composites be made up of of a matrix strengthened by a disseminated phase in form of continuous fibers.

       - **Unidirectional fibers arrangement.**
       - **Bidirectional fibers arrangement (woven).**

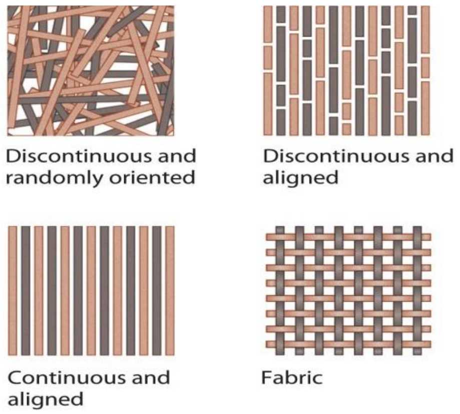


Fig. 1.2 Fiber Reinforced Composites

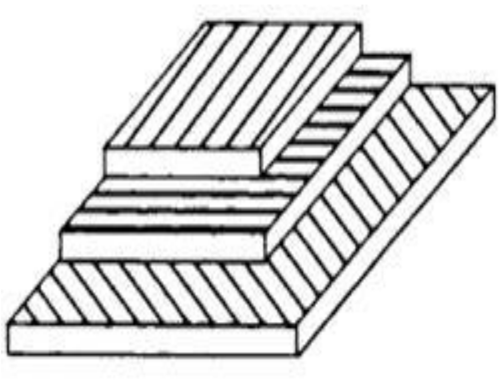


Fig. 1.3 Laminated Composite

- **Laminate Composites**

  When a fiber strengthened composite involves numerous coatings of dissimilar fiber alignments, it is called Laminate **(angle-ply)** composite[w2].

1.3 Metal matrix composites

In the present work, our study focuses on the metal matrix composites. MMC's materials have established implementation in most of the fields of routine life. The term light metal matrix composites (MMCs) is frequently considered to be same as metal matrix composite for scholars because of their enhanced mechanical properties. Considerable advancement in the growth of these light MMC's has been attained in the last 10 years so as the use of these light MMC's could be inaugurated in the significant applications. Metal matrix composites are being merchandized in fiber strengthened pistons and aluminum crank cases with nourished cylinder surfaces as well as particle-strengthened brake disks in automotive industries[w3].

A metal matrix composite (MMC) involves the mixing of two discrete phases, one of which is a metal. The secondary material can be some metal or different matter, may be an organic or ceramic compound[w4].

1.3.1 Composition

MMCs are prepared by diffusing a strengthening material into a metallic base. To avoid the chemical reaction between the base and reinforcing material, surface coating of latter part is necessary. Taking an e.g. To produce composites having higher strength and low density, carbon fibers are used with aluminium base matrix. But carbon show reaction with Al which in turns creates a hard and water soluble compound Al_4C_3 on the surface of the fiber. To avoid this reaction, the carbon fibers are glazed with nickel or titanium boride[w4].

1.3.2 Matrix Phase

The matrix is the monolithic material in which the reinforcement is rooted, and it is completely uniform which means that there is a way through the matrix to any point in the material, dissimilar to the two materials jammed together. In various structural applications, the matrix is mostly a lighter metal such as aluminum, magnesium, or titanium, and gives an amenable support for the reinforcement. In high-temperature applications, Co and Co–Ni alloy matrices are common[w4].

1.3.3 Reinforcement Phase

The reinforcement material is implanted into a matrix. The reinforcement does not continually aid a purely structural assignment (reinforcing the compound), but is also used to alter physical character such as wear resistance, friction coefficient, or thermal conductivity. The reinforcement can be either continuous, or discontinuous. Discontinuous MMCs can be isotropic, and can be functioned with ordinary metalworking methods, such as extrusion, forging, or rolling. Furthermore, they can be machined using conservative techniques, but generally would need the use of polycrystalline diamond tooling (PCD).

Continuous reinforcement uses monofilament wires or fibers such as carbon fiber or SiC. Because the fibers are implanted into the matrix in a definite direction, the consequence is an anisotropic structure in which the alignment of the material affects its strength. The first MMCs used boron filament as reinforcement. Discontinuous reinforcement uses "whiskers", short fibers, or particles. The utmost corporate reinforcing materials in this category are Al2O3 and SiC[w4].

1.4 Processing of MMC'S

Discontinuous Reinforced Metal Matrix Composites (DMMC) have achieved a dominant position in the metal matrix composite field because of low production cost as compared to continuously reinforced materials In an effort to optimize the structure and properties of particle reinforced metal matrix composite, various processing techniques have been evolved over the last twenty years Processing of DMMC materials generally involves at least two operations - production of the composites materials itself, and fabrication of this composite into useful product forms Both operations can affect the properties and interfacial characteristics of the final product The methods, which are commonly employed to manufacture DMMC, can be grouped depending on the temperature of the metallic matrix during processing

- Liquid phase processes, and
- Solid state processes[1].

1.4.1 Liquid Phase Fabrication Methods

Generally there are three liquid phase fabrication methods or casting routes, which are presently in rehearsal are stir casting, liquid metal infiltration and squeeze casting. The application of this high temperature processing technique is limited by poor wettability and a high inclination for chemical reaction of the reinforcement with liquid metal. However, there are a number of techniques used to control this phenomenon. Normally this type of fabrication method is carried out under vacuum or using an inert gas atmosphere to minimize the oxidation of the liquid metal[1].

The methods of liquid phase processing of MMC 's are:

- Liquid Metallurgy(Stir Casting)
- Infiltration
- Gas Pressure casting
- Squeeze Casting
- Pressure Die casting

1.4.1.1 Liquid Metallurgy(Stir Casting)

Liquid Metallurgy technique is a liquid phase technique used to fabricate composite materials, which involves mixing of a disseminated phase (short fibers, ceramic particles) with a molten melt of a metallic element or alloy. It requires mechanical stirring for mixing of two discrete materials [fig.4]. The prepared molten melt is then cast by ordinary casting procedures and can also be synthesized by conservative Metal-forming processes. In this process particles are mostly forms clusters, which must be liquefied by forceful stirring [2]. Porosities and reactions in the melt can be evident due to gas entrapment on extreme stirring which must be avoided. A deep focus should be on the orientation for the reinforcements, because of this the reactivity of the material can be synchronized with respect to the temperature of the melt and the duration of stirring, and reaction from the liquid phase can result to the dissolution of the reinforcement. Reactivity is less critical to stirred particle than the fiber because of the lower surface with respect to volume ratio of spherical particles.

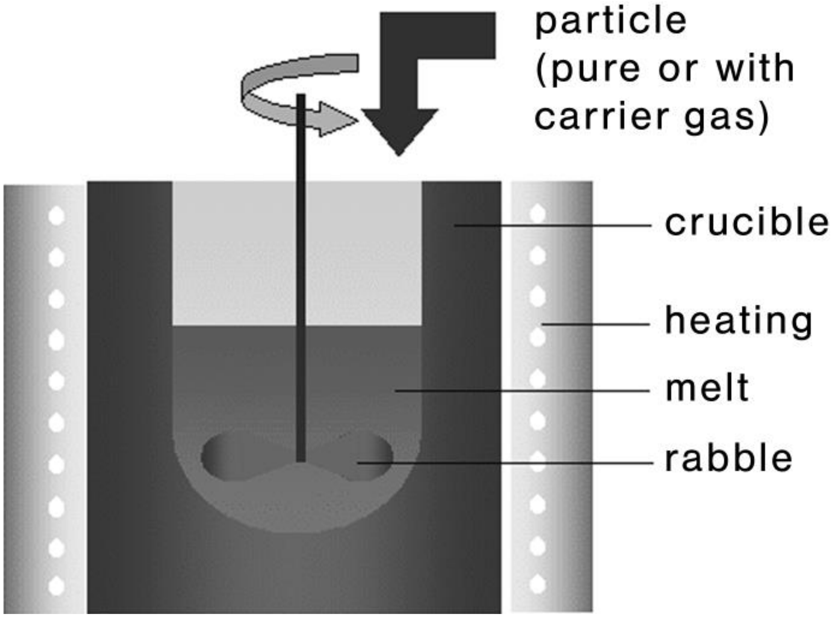


Fig. 1.4 Schematic Operational Sequence during Melt Stirring [2]

1.4.1.2 Infiltration

This is a technique of liquid phase for manufacturing of composite material, which includes soaking of dispersed phase (ceramic particles, fibers, woven) within a molten matrix metal, which complete the space in the dispersed phase. The force required for this method can either be capillary force of the dispersed phase (spontaneous infiltration) or an external pressure (gaseous, mechanical, electromagnetic, centrifugal or ultrasonic).

1.4.1.3 Gas Pressure Casting

This is forced casting method for synthesizing the liquid phase of Metal Matrix Composites. A pressurized gas is used for pressure over the molten metal and forcing it to pass to a preformed dispersed phase [fig.5]. In this method of casting the melted material penetrates the preform with a gas applied from the outside [2]. The melting of matrix and the casting occurs at a certain pressure vessel.

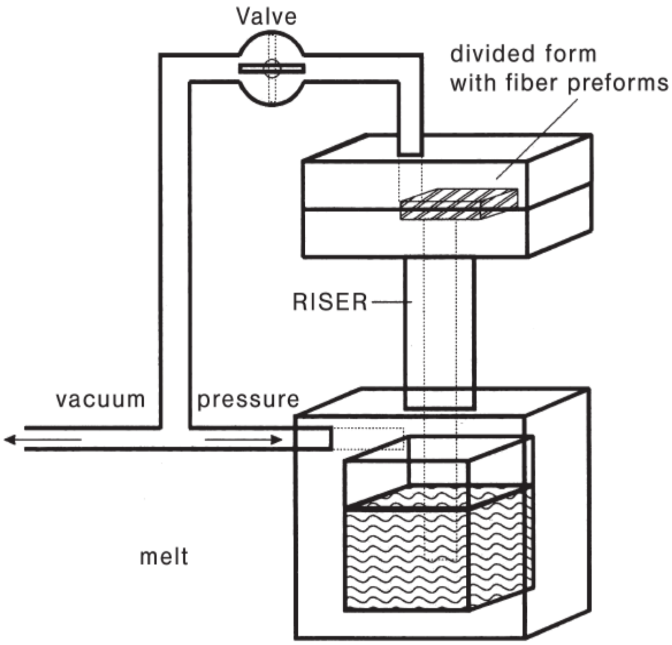


Fig. 1.5 Gas Pressure Casting Technique [2]

Gas Pressure Infiltration method is used in the production of big composite material. This technique permits the use non-coated fibers because of less contact time between the fibers with the hot metal. In variance for the methods which use mechanical force.

1.4.1.4 Squeeze Casting

This is forced penetrating method for liquid phase manufacturing Composites of Metal Matrix, which involves movable ram for applying the pressure on the molten metal and is applied to infiltrate performed dispersed phase, placed in the lower fixed mold part [fig. 6]. This is same as the technique used for metal alloys casting which is Squeeze casting. They are the most common manufacturing variants for metal matrix composite[2]. The melt becomes solid when high pressure after a slow mold filling, which results to a fine-grained structure. In comparison with die-casted parts the squeeze-casted parts do not contain gas inclusions, which allows thermal treatment of the produced parts[3].

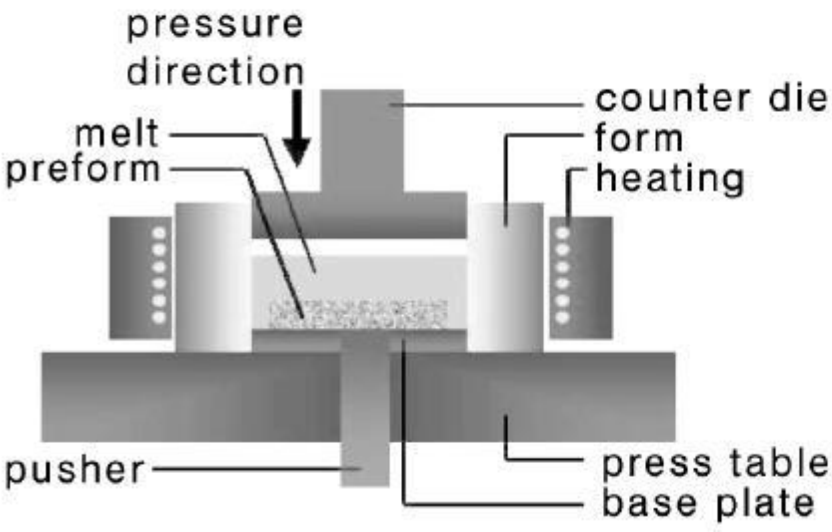


Fig. 1.6 Squeeze Casting [2]

1.4.1.5 Pressure Die Casting

This is a forced intrusion process of liquid stage manufacturing of MMC, which also uses a die casting process, when a preformed dispersed phase is placed in a die and filled with a molten metal entering the die through a sprue and preform under the pressure of a movable piston (plunger) [fig. 7][3].

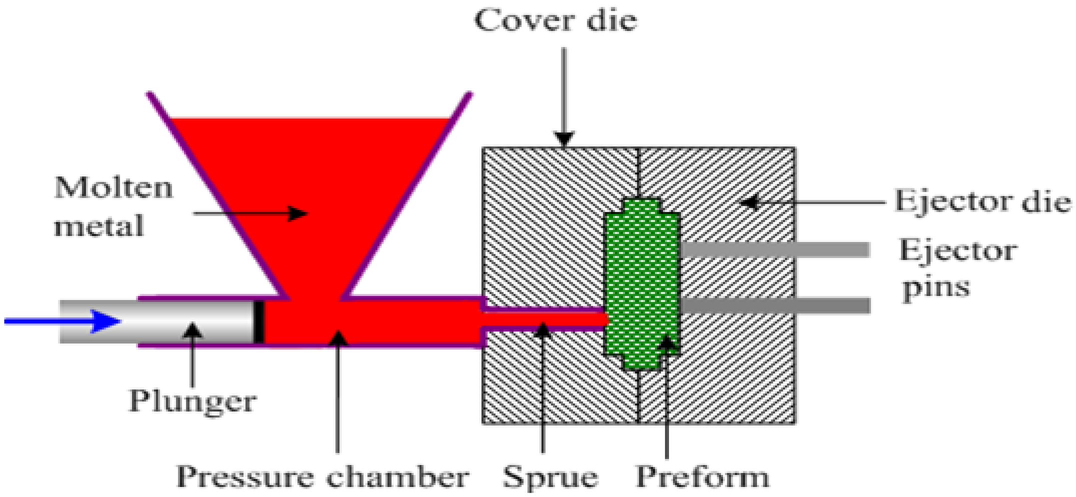


Fig. 1.7 Pressure Die Casting[3].

1.4.2 Solid State Fabrication Methods

This method consist of various steps for finishing amalgamation. These require the fabrication of particles strengthened metal matrix composites from mixed elemental powders. The two process in this methods are:

- Powder metallurgy
- High energy rate processing
- Diffusion Bonding[4].

1.4.2.1 Powder Metallurgy

Solid state process consist blending of quickly solidified powders with particulates, platelets with multiple steps. They are sieving of the quickly solidified powders, blending with the reinforcement phase, increasing up to 75% of density, final manufacturing by forging, extrusion, rolling or other hot-working process. This method yields parts which are better in microstructure need of the parts manufactured by conservative liquid state techniques. It is because of rapid solidification of powders that results in the improvement of matrix materials that have compositional bounds which unable to influenced by the thermodynamics of conservative coagulating procedures.

Additional merits of the this technique to the conservative casting and liquid metallurgical methods is such that, particles are more distributed in this method[4].

The restrictions of powder metallurgy process are:

- Fewer obtainability of metallic powders
- Higher cost of metallic powders
- Higher cost of hot pressing

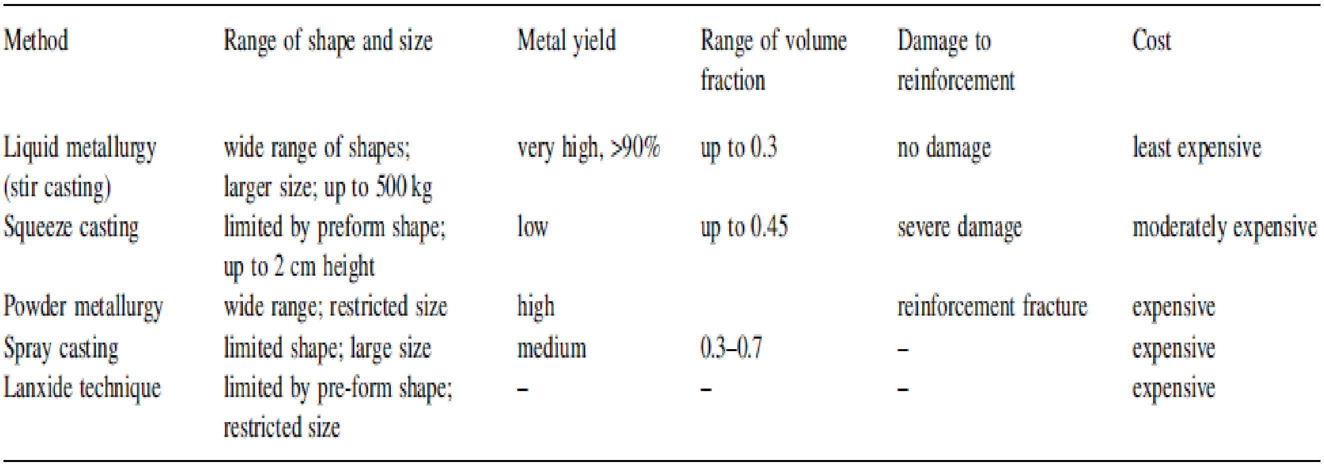
1.4.2.2 High Energy Rate Processing

This is a technique that can be done to consolidate metal powders having a fine distribution of ceramic particles. In this technique, the consolidation of powder mixture is done by giving more energy, either mechanical or electrical, over a less amount of time. In the case of electrical energy, the high energy high rate pulse heats the conducting powder rapidly in a die along with cold walls. The less time enables the producer to control phase transformations [4].

1.4.2.3 Diffusion Bonding

It is a common solid state welding method. The merit of this technique are the capability of using a wide variety of matrix materials, control of fiber orientation and the volume fraction of the fiber. The demerits are processing times of several hours and high cost of processing temperatures and pressures. Metal alloys are in the form of sheet and reinforcement material is in the form of fibers and these are placed in arrays in a particular order. Bonding occurs by press forming directly. After bonding, as a secondary process machining is done[4].

Table 1.1: Comparsion Among Techniques Used In Fabrication[12]



Method	Range of shape and size	Metal yield	Range of volume fraction	Damage to reinforcement	Cost
Liquid metallurgy (stir casting)	wide range of shapes; larger size; up to 500 kg	very high, >90%	up to 0.3	no damage	least expensive
Squeeze casting	limited by preform shape; up to 2 cm height	low	up to 0.45	severe damage	moderately expensive
Powder metallurgy	wide range; restricted size	high		reinforcement fracture	expensive
Spray casting	limited shape; large size	medium	0.3–0.7	–	expensive
Lanxide technique	limited by pre-form shape; restricted size	–	–	–	expensive

1.5 Advantages & disadvantages of MMC's

1.5.1 Advantages of MMC's

Compared to monolithic metals, MMCs have:

- ✓ High strength-to-density ratios
- ✓ High stiffness-to-density ratios
- ✓ Enhanced fatigue resistance
- ✓ Better elevated temperature properties
  - High strength
  - Low creep rate
  - Low coefficients of thermal expansion
  - Improved wear resistance

The advantages of MMCs over polymer matrix composites are:

- ✓ High temperature capability
- ✓ Fire resistance
- ✓ High 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.

1.5.2 Disadvantages of MMC's

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.

1.6 Aluminium and its alloys

1.6.1 Introduction to Aluminium

Aluminium is the paramount metal present plentiful in the world and also the third most familiar constituent, consists of 8% of the earth's crust. It has adaptability in it that makes it the most extensively used metal followed to steel. Aluminium was first metal manufactured about 170 years ago, although aluminium compounds had been in usage for hundreds of decades.

Softness, ductility, corrosion resistance and high electrical conductivity are some most common and amazing properties of pure aluminium. It is extensively used in production of conductor cables and foil, but after mixing with some other components because to provide higher strengths desirable for additional applications. It is one of the lightest industrial components, that is having a strength to weight ratio higher to steel. By employing widespread combinations of its superior properties such as recyclability, strength, formability, lightness and corrosion resistance, aluminium is being utilized in an ever-increasing number of supplications[w5].

1.6.2 Properties

The major advantages of using aluminium are due to its' remarkable properties. Some of these properties are discussed as follows[w5]:

- **Strength to Weight Ratio**

  The density of Aluminium is almost one third of steel due to which it is used dmoinantly in applications where extraordinary strength and low weight are is the hour. This includes vehicles where less mass results in higher load capacity and which also reduced fuel consumption.

- **Corrosion Resistance**

  The outer surface of aluminium metal is exposed to air at that time, oxidation occurs as a result a shielding layer of oxide film is formed on its surface. This oxide film prevents corrosion and can be again improved by the surface treatments (anodizing).

- **Electrical and Thermal Conductivity**

  Aluminium is a finest conductor when talk about electricity and heat. The main advantage of aluminium is its weight and the conductivity of aluminium is almost double than copper which means that aluminium is the most familiar metal for application of huge power transmission applications.

- **Light and Heat Reflectivity**

  Aluminium has a decent reflective character(properties) of visible light and heat which makes it a good substance for architectural insulation, light fittings and thermal rescue blankets.

- **Toxicity**

  Aluminium is a non toxic substance and creates no odours or blemish yields when comes to any contact with other materials which makes aluminium appropriate for application like packaging of delicate products such as food or pharmaceuticals in which aluminium foil is mainly used.

- **Recycling**

  The aluminium recyclability is exceptional. There is no change in properties when recycled aluminium is matched to original aluminium. Moreover, recycling of aluminium needs a maximum of 5% of the power only which is essential to produce original aluminium metal[w5].

1.6.3 Aluminium Alloys

Aluminium alloys are alloys in which aluminium is predominant metal. Selecting the right alloy for a given application require considerations of its properties like strength ,ductility , workability , formability , weldability and density etc.

Copper , magnesium , manganese , silicon ,and zinc are the naturally alloying elements. The two major groups of aluminium alloys are wrought alloys and cast alloys and those are again categorized into heat-mendable and non-heat-mendable. Aluminium which is used in application for wrought products e.g. rolled plates, foils and extrusions is about 85%. Casting of aluminium alloys demonstrates budget products because of its less melting point, also they normally have low tensile strengths in comparison wrought aluminium alloys. The absolute principal casted aluminium alloy arrangement is Aluminium-Silicon, in which the high levels of Si (4% to 12%) that donates to enhance casting features.

Shaping processes like extrusion, forgings, rolling, pressing and stamping use Wrought aluminium alloys. Cast aluminium alloys arises after permanent mould casting,sand casting, die casting etc. Aluminium alloys are classified as follows:

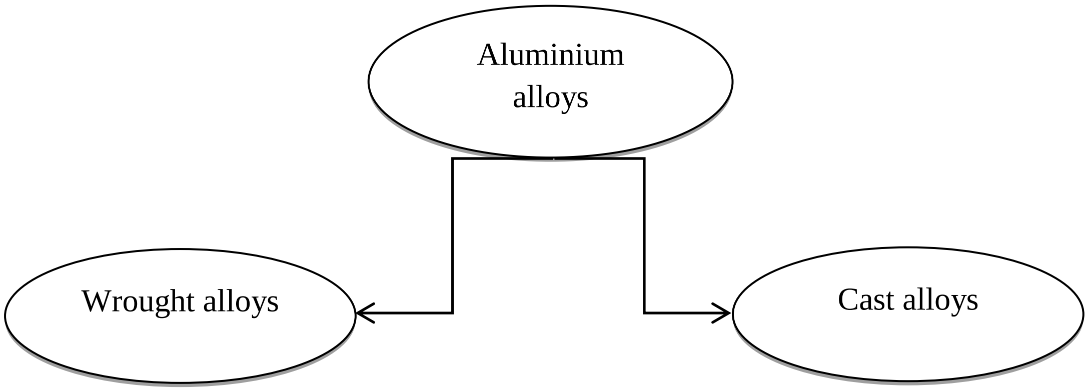


Fig. 1.8 Classification of Al Alloys.

1.6.3.1 Wrought & Cast Aluminium Alloys

To meet the necessary requirements in the process of modernization, aluminium is alloyed with copper , manganese , magnesium , zinc and silicon as major alloying elements. The designation of wrought and Cast aluminium alloy is shown in table 1.2 and 1.3 respectively.

Table 1.2: Designation of Wrought Al Alloys[5]

Alloy designation	**Details**
1XXX	99% Pure Al
2XXX	Cu content
3XXX	Mn content
4XXX	Si content
5XXX	Mg content
6XXX	Mg & Si content
7XXX	Zn content
8XXX	Other elements

Table 1.3: Designation of Cast Al Alloys[5]

Alloy designation	Details
1XXX	99% Pure Al
2XXX	Cu content
3XXX	Si, Cu/Mg content
4XXX	Si content
5XXX	Mg content
6XXX	Zn content

1.6.3.2 Chemical Composition of AA5083 Al Alloy

The chemical composition of AA5083 in shown as below in Table 1.4.

Table 1.4: Chemical Composition Of AA5083[w6]

Elements	% content
Silicon(Si)	0.4
Iron(Fe)	0.4
Copper(Cu)	0.1
Mangenese(Mn)	0.4-1.0max
Magnesium(Mg)	4.0-4.9max
Zinc(Zn)	0.25
Titanium(Ti)	0.15
Chromium(Cr)	0.05-0.25max
Aluminium(Al)	Remainder

1.6.3.3 Application of Aluminium alloy

The application of aluminium alloy is shown in Table 1.5.

Table 1.5: Application of Aluminium alloys[5]

Aluminium Alloy	**Alloy Characteristics**	**Common Use**
1050/1200	Non heat-treatable. Good formability, weld ability, resistance to corrosion	Food and chemical Industry
2014	Non heat-treatable, High strength, Non weldable, poor resistance to corrosion	airframes
5251/5052	Heat-treatable. Good weld ability, formability, Medium strength work hardening alloy and resistance to corrosion	Vehicles paneling, structures open to naval atmospheres, mine cages.
6063	Heat-treatable. Good weld ability and resistance to corrosion, Medium strength alloy. used for intricate profiles.	Architectural extrusion (internal and external) window frames, irrigation pipes.
6061/6082	Heat-treatable. Similar properties to AA6082, Desirable to air quenching, thus, having fewer distortion complications, unsensitive to notch.	roof trusses ,Stressed structural members, beer , cranes, bridges , barrels.
7075	Heat-treatable. natural Age hardening , thus recuperate properties in heat-affected region after welding, suspectable to stress corrosion.	motor cycles ,armored automobiles, military channels , cycle frames.

CHAPTER 2

LITERATURE REVIEW

This chapter presents a review of the literature data available on the effect of various reinforcement types, their size and volume fraction, ageing behavior with Al based MMCs. Selection of matrix phase can be done from various aluminium alloys and number of reinforcement may be SiC, B_4C, Al_2O_3 etc. which can be offered in different masses, morphologies and volume fractions. Combination of these various matrices with different reinforcements results in fabrication of huge composite classifications. Additionally, there are numerous manufacturing methods are available i.e. powder metallurgy, squeeze casting, stir casting and hot extrusion etc. Composite structures have shown universally a savings of at least 20% over metal counterparts and a lower operational and maintenance cost.

J. Hashim *et al.* [1999][6] studied a conventional and cost effective technique i.e. stir casting which is examined for usage in the fabrication of SiC/Al metal matrix composites. The mechanical difficulties allied with gaining a dispersal of reinforcement to be uniform, better wettability among matrix and reinforcement, and material with minimum level of porosity are conferred and examined.

A.R. Kennedy *et al.* [2001][7] aimed for fabrication of Al-B4C composites by accumulation of B4C particulates along with a reactive flux on the surface of liquefied Aluminium. B4C and Al were merged to produce metal matrix composite by solid state technique. However, B4C has low wettability below 1100°C which means that difficulty arise in producing Al-B4C composites by diffusing the particulates into the liquid phase. In order to improve the wettability of B4C particles and enhance its incorporation into Al melt, an exclusive K2TiF6 flux was co-added with B4C powder to the surface of molten commercial pure Al. The microstructural characterization revealed that B4C particles can be led into smelted Aluminium if Ti containing flux is used.

K.M. Shorowordi *et al.* [2003][8] fabricated three different aluminium MMC’s consisting of reinforced particles i.e. Al2O3, SiC and B4C of different volume fractions by the stir casting technique trailed by hot extrusion. Product or layer formed by interfacial reaction was evident on Aluminium–Silicon interface for composites constrained for a comparatively extended fabricated time (more than 30 minutes). When studied using Scanning Electron Microscopy, reaction product were negligible at Al–B4C and Al–Al2O3 boundaries. While, two subordinate phases (Al2O3 and a different phase comprising Al, B and C) were figured in the matrix (AMC) left from the boundary in Al–B4C composites. Fracture analysis on surface showed that B4C strengthened Aluminium composite seems to reveal a good interfacial bond in contrast to other composites.

Feng Tang *et al.* [2007][9] Pin-on-disk dry sliding wear tests at sliding speeds ranging from 0.6 to 1.25 m/s and under loads ranging from 3.98 to 6.37MPa (50–80 N) were conducted for pin specimens of composites with Al-5083 matrices reinforced with 5 and 10 wt.% B4C particles. The wear rate of the composite with 10 wt.% B4C was approximately 40% lower than that of the composite with 5 wt.% B4C under the same test condition. Two stages were observed in the reduction of pin length/sliding distance curves in several specimens, with the length reduction rate in the first stage being one to two orders of magnitude lower than that in the second stage. The low length reduction rate in the first stage corresponded with a flat stage with a low coefficient of friction (COF) in the COF/sliding distance curve.

A. Sakthivel *et al.* [2008][10] focused on preparation of AA2618 metal matrix composites (MMCs) which is strengthened by two particulate sizes and 10% mass proportions of SiC particulates by stir casting technique followed by forging. The density measurement reveals that the samples of prepared composites had low level of porosity with increasing volume fractions. Microstructural studies showed constant dispersal of particles. Also agglomeration of particulates and porosity level increased at some locations. Reducing particle size and increment in weight percentage of the particles enhanced the hardness and tensile strength of the prepared specimen. The tensile strength and hardness of the forged composites were greater as compared to cast specimens.

S. AMIRKHANLOU *et al.* [2010][11] In his work, produced aluminium matrix composites using A356 with 5% volume fraction of silicon carbide particulates, with typical particle sizes of 8 and 3 microns, through injecting reinforced particles in different manners into liquid phase (Stir casting) and semisolid phase (compocasting). The SEM results showed that incorporation of Silicon

Carbide particulates in the form of Al-SiCp composite in the powdered from and via compocasting method led to reduction in the SiC particulate size and improves the wettability between the melt and the reinforcements. Furthermore, it also improved the dispersal of the reinforcement particulates in the coagulated matrix. Further, it enhanced the hardness and the toughness of the cast product and reductions in porosity content.

F. Toptan *et al*. [2010][12] In the present work, Al-B4C composites were produced by casting route at 850°C and titanium-containing flux was used to overcome the wetting problem between B4C and liquid aluminium metal. The microstructure of matrix/reinforcement interface was investigated using SEM studies with or without Ti added composites. The reaction layer was also characterized with EDS analysis and X-ray mapping. It was found from the microstructural observations by high resolution field emission gun SEM (FEG-SEM) that the wetting issue was effectively solved by the formation of very thin (80-180 nm in thickness) Ti-C and Ti-B reaction layers.

S.A. Sajjadi *et al.* [2011][13] used compo casting technique to produce aluminium matrix composite strengthened by micro and nano Al2O3 particulates. Various mass proportions of micro and nano Al2O3 particles were introduced into the semisolid melt of A356 aluminum alloy with help of injection with inert gas and mechanical stirring was done at various speeds of 200, 300 and 450 rpm. The microstructure study revealed above process led to an alteration of a dendrites region to a non-dendritic structure in the base alloy. Nano Al2O3 particulates were encircled by Si-eutectic evaluated by SEM graphs and disposed to accelerate in the direction of inter dendritic territory and in addition of 1, 2 and 3 wt.% nano alumina or 3 and 5 wt.% micro alumina, no agglomeration was found. However, additional rise in alumina (4 wt.% nano and 7.5 wt.% micro alumina) directed to accumulation. The porosity content in the composites increased with increment in weight percentages and speed of stirring and decreasing particle size. Moreover, the hardness of the composites increased with reducing size and increasing weight percentages of particles.

K. Kalaiselvan *et al*. [2011][14] focused on the processing of AA6061 Heat treated (T6 Heat treatment) aluminum matrix composites which is strengthened with different mass fraction of B4C particles via improved stir casting method. Improvement was gained in wettability of B4C particles through addition of K2TiF6 halide salt in the melt. The microstructural and mechanical characterization of the processed composites are evaluated. It is seen that B4C particles in the matrix was dispersed uniformly as founded by means of Scanning Electron Microscopy (SEM) and X-ray diffraction (XRD). Furthermore, Enhancement in hardness and tensile strength have been noted with the increment in weight proportion of B4C particles in the base alloy.

Y. Mazaheri *et al.* [2013][15] in his present work produced three different aluminium matrix composites with 10%wt. titanium carbide(TiC), 10%wt. boron carbide(B4C) and 10%wt. titanium carbide and boron carbide hybrid by stir casting method. Microstructural study of the composites were observed via scanning electron microscopy (SEM) supplied with energy dispersive spectroscopy (EDS) and X-ray diffraction (XRD) and outcomes of which revealed that wettability is enhanced with addition of heat treated of B4C particles and also TiC particles with the flux and reduced agglomeration of reinforcement particles into the molten matrix. Mechanical studies of models indicated that hybrid composite had extreme hardness among three. Aluminium/boron carbide composite had Maximum yield and tensile strength whereas aluminium/titanium carbide composite had maximum elongation. Further, wear character of composites showed the improved performance for aluminium/boron carbide composite.

A. Baradeswaran et *al.* [2013][16] investigated the effect of B4C particles on the mechanical and Tribological behavior of AA7075 Aluminium composites. AA7075 Aluminium particle reinforced composites were produced through stir casting technique followed T6 heat treatment, in addition K2TiF6 added as the flux with the particles to improve the wettability between B4C and the melt. The study of the mechanical properties of the specimens revealed that hardness has increased as compared to the base alloy which was due to the existence of the improved reinforced phase. The wear properties of the composites enhanced with growing level of B4C particulates due to which wear rate was significantly reduced for the composites related to the base alloy. A mechanically diffused layer comprising iron and oxygen was evident at the surface of the samples which acted as an active protection thus avoiding metal to metal contact. The coefficient of friction reduced with increased boron carbide particles and reached the minimum value at 10 vol% boron carbide.

Sourabh Gargatte *et al.* [2013][17] reports the dry sliding wear behavior & Brinell hardness test of AA 5083 aluminium reinforced with SiC particles fabricated by stir casting technique. Different volume fraction of SiC particles (3, 5 and 7 wt%) were used for synthesis. The wear test has been conducted on pin-on-disc testing machine to examine the wear behaviour of the aluminium alloy and its composites. An attempt has been made to study the influence of wear parameters like applied load, sliding speed, sliding distance and percentage of reinforcement on the dry sliding wear of metal matrix composites (MMCs).

Bharath V *et al.* [2014][18] attempted to process MMC using 6061Al as matrix reinforced with Al2O3 particles using stir casting technique. Different weight percentages of reinforcement is added from 6 - 12wt% in steps of 3wt%. Reinforcement particles were preheated at a temperature of 200°C and then distributed in three step addition into the vortex of molten alloy to improve wettability and distribution. Mechanical characterization of the prepared composite were determined before and after addition of Al2O3 particulates to note the range of enhancement. Microstructural study of the composites has identified a good uniform distribution and some extent to grain filtration in the specimens. Furthermore, the hardness and tensile properties are enhanced for composites when compared to unreinforced alumimium matrix. Also increasing reinforcement content has resulted in increase in both hardness and tensile strength.

G.L Rajesh *et al.* [2014][19] The paper reports a study on wear properties of boron carbide reinforced Al metal matrix composite processed via stir casting route at lower temperature of 775^{o}C using halide salt K_2TiF_6 with ratio 0.05Ti/B_4C_p to enhance better wettability. Fairly uniform distribution of B_4C_p in the matrix with no segregation is seen and revealed from SEM microphotographs. Micro hardness of the alloy and the composite was determined using Vickers micro hardness tester and found to increase with increase in volume fraction of B_4C_p addition to as cast 6061Al alloy. Pin-On-Disc tribometer was used to analyze wear behaviour of prepared composite and the alloy by applying normal load of 49.05m/s for a sliding velocity ranging from 3.34m/s - 10m/s up to a sliding distance of 565.4m at room temperature. Minimum wear rate was observed for 6061Al+ 6% B_4C_p at sliding velocity of 6.67m/s, normal load of 49.05N with sliding distance of 565.4N compared to 6061Al+ 4% B_4C_p composite and as cast 6061Al alloy. Worn surface were studied using optical microscopy to understand the wear mechanism exhibited by composites prepared.

T.Hariprasad *et al.* [2014][20] Present work deals with the investigation of the wear behavior of Al 5083 composites synthesized by stir casting technique reinforced with constant weight percentage (5%) of Al2O3 and four different weight percentages of B4C (0%, 3%, 5%, and 7%)were taken for investigation. Evaluation of wear properties with the different reinforcement has been obtained. Wear test carried out by the pin-on-disc method under dry conditions with the different load 10, 20N. The worn surface was investigated by the Scanning Electron Microscope (SEM). The investigation reveals that the wear resistance has been improved by increasing weight percentage of B4C and Al2O3, the worn samples show a light adhesive wear traces at the same condition.

V. Auradi *et al.* [2014][21] produced 11wt% B4C particle reinforced Al matrix composites (AA6061) by ordinary melt stirring method. Processing was carried out at a temperature of 750°C involving two step additions. B4C particulates along with K2TiF6 halide flux was firstly preheated and then initiated in two step addition rather than adding all at once. SEM/EDX and X-RD studies were applied for Characterization of fabricated composites. Good uniform distribution of B4C particulates was noted without much clustering in 6061Al matrix from SEM studies. XRD studies confirmed that composites consists of B4C and small phases like Al3Ti, AlB2 and Al3BC. The addition of B4C particles in 6061Al matrix had resulted enhancements in mechanical properties of the base matrix.

2.2 Gaps Found In the Literature

A lot of work has been done in aluminium matrix composite at different types of reinforcements, different sizes and manufactured by stir casting technique to enhance the mechanical properties of aluminium matrix composites. The work carried out by different researchers can be broadly categorized into broad classes as:

- Very limited amount of work has been reported on AA5083 aluminium matrix composite especially by stir casting technique.
- Compared to the reinforcements like (SiC, Al2O3) which are most commonly used research on B4C as reinforcement is very less.
- Moreover, very limited studies have been reported on B4C reinforced with AA5083 aluminium matrix composites.

CHAPTER 3

PROBLEM FORMULATION

3.1 Scope of the Study

- To reduce the agglomeration of reinforcement particles by modifying the stir casting technique with two step addition method i.e. preheating of ceramic particles before mixing into melt.
- To improve the wettability of boron carbide particles below 1000°C by using halide flux (**K-Al-Ti-F)** which enhances the metallic character of reinforcement particles with the melt.

3.2 Objective of the study

The main objective of the present research is to study the mechanical behavior of Al-B4C metal matrix composite (MMC) of aluminium alloy of 5XXX series i.e. AA5083 with addition of varying percentage composition of B4C particles fabricated by stir casting technique with Two step addition method. The tensile strength, toughness and Hardness like mechanical properties will also be taken into consideration. For the achievement of the above study, an experimental setup will be used where all the necessary inputs will be made. The aim of the experiment is to study the effect of variation of the percentage composition to predict the mechanical properties of the metal matrix composite (MMC). The experiment will be carried out by preparing the sample of different percentage composition by stir casting technique. The present work emphasizes the literature review of Aluminium alloys and its composites. There are many manufacturing processes to form composites commercially. But those methods are expensive and are mostly limited to low production fabrication. The technique adopted here is rapid solidification process. The stir forming is still under progress for its commercialization in developing countries like India.

The objectives of present proposal are as follows:

- To prepare the cost-effective MMC material by taking AA5083 Aluminium alloy with ceramic particulate like boron carbide as reinforced phase using stir technique.
- To analyse the micro structural characteristics of the as cast material.
- Tensile strength, Impact strength & Hardness like property measurements of the as prepared MMC.

CHAPTER 4

EXPERIMENTAL SETUP

4.1 Material to be used in fabrication

- Aluminium alloy AA5083 as matrix and magnesium as degassing agent.
- Boron carbide (B4C) as reinforcement.
- K2TiF6 halide salt to be added along with the reinforcement.

4.2 Equipments to be used in the stir casting

Table 4.1: Equipments To Be Used In The Process

S.NO	EQUIPMENTS TO BE USED		
1.	Muffle furnace	**5.**	Universal testing machine
2.	Graphite stirrer	**6.**	Impact testing machine
3.	Electric motor	**7.**	Hardness testing machine
4.	Graphite crucible/mold	**8.**	Wear testing machine & SEM

- **Muffle furnace**

  Muffle furnace will be used to heat the material to desired temperatures by conduction, convection, or blackbody radiation from electrical resistance heating elements.
- **Graphite stirrer**

  The function of a stirrer is to agitate liquids for speeding up reactions. Stirrer was designed to homogeneous mixing of liquid, oilment, solution, viscous material and solid-liquid.
- **Electric motor**

  Electric motor will be used to rotate the stirrer in the melt .It can be operated at different speeds.

- ✓ **Graphite crucible**

  A crucible is 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 designed to hold.

- ✓ **Universal testing machine**

  UTS will be used to measure the tensile strength of as prepared specimens.

- ✓ **Hardness testing machine**

  Brinell hardness test will be applied to test the hardness of the specimens.

- ✓ **Wear Testing Machine**

  A tribometer is a device that processes tribological magnitudes, such as coefficient of friction, friction force, and wear volume, between two surfaces in contact.

- ✓ **Scanning electron microscope (SEM)**

  It is a microscope that uses electrons instead of light to form an image. SEM has a large depth of field, which allows more of specimen to be in focus at one time. It will be used to study the microstructure of the specimens made.

4.3 Experimental Procedure of Work

The experimental procedure of research work is shown below in fig. 4.1

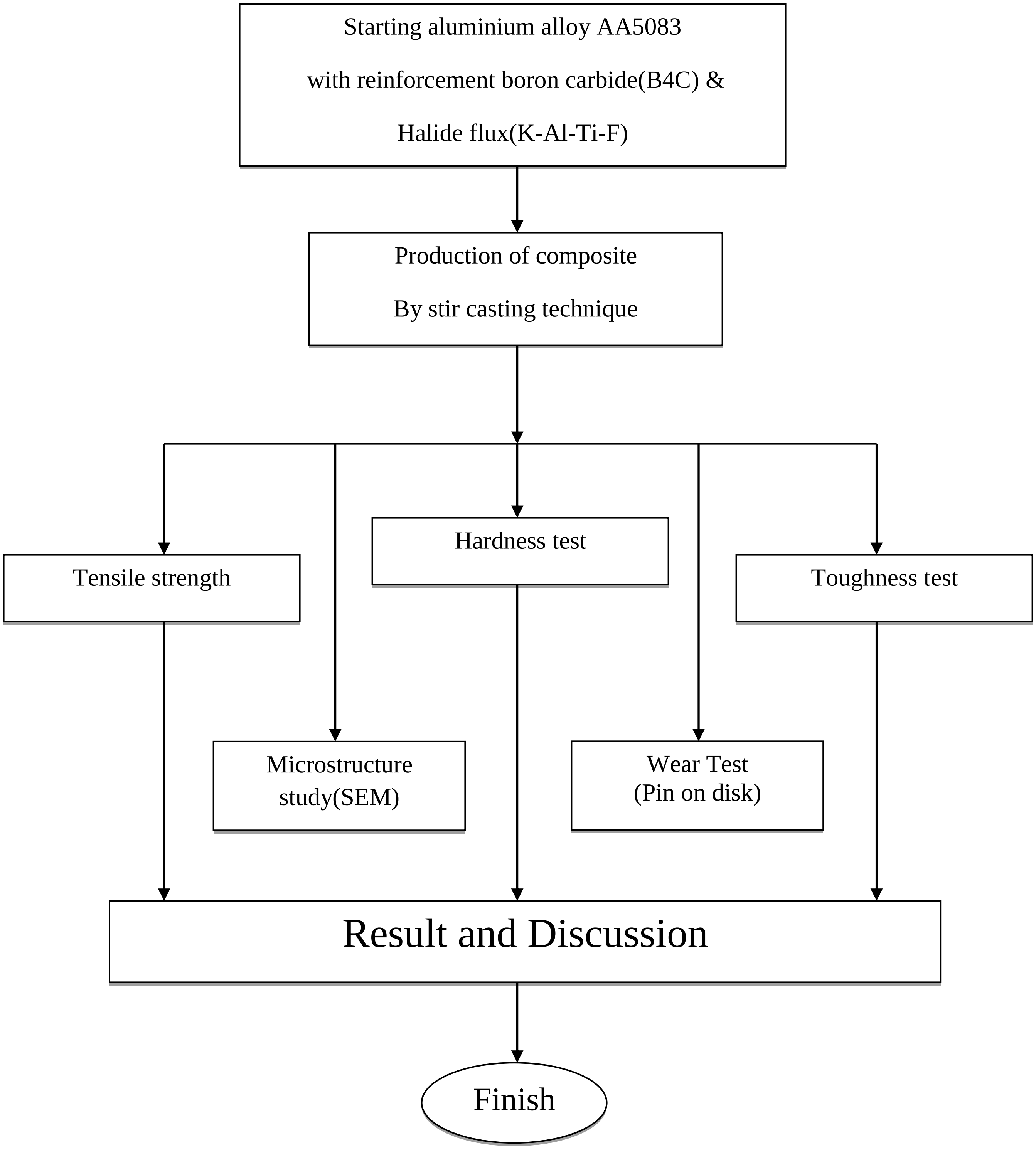


Fig. 4.1 Flow chart of experimental techniques followed.

4.4 Preparation of samples

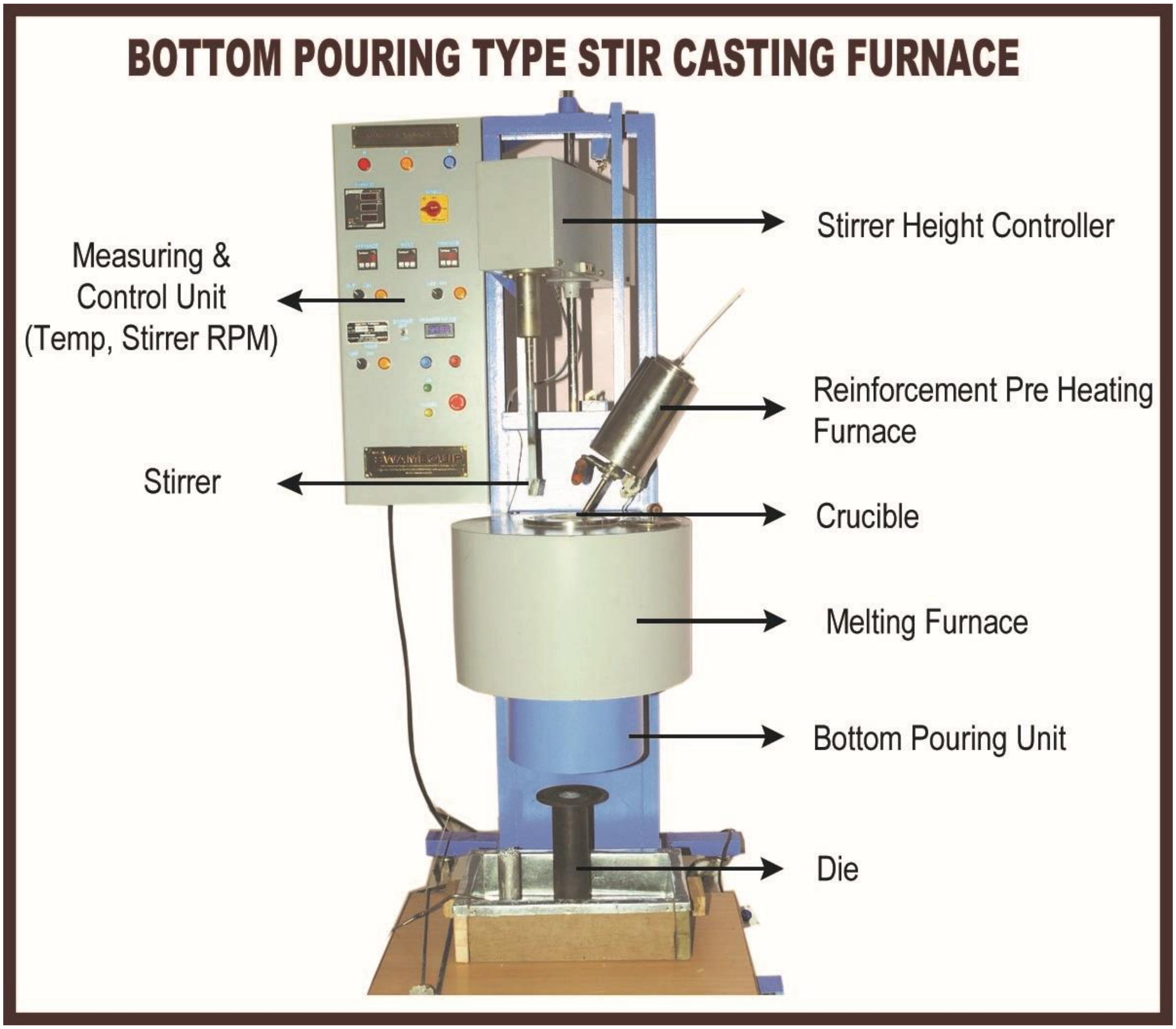


Fig. 4.2 Stir Casting Furnace

Muffle furnace was first heated at 850°C for about three hours till it attained the set temperature. Afterwards, aluminium alloy i.e. AA5083 was melted in the crucible above its liquidus temperature of 740°C. The boron carbide powder with particle size of 68µm and potassium titanium fluoride salt (K2TiF6) were first mixed in the ratio of 0.2 (Ti/B4C) and then preheated at 250°C for half an hour to increase the wettability of boron carbide particles with aluminium alloy. Once the alloy is completely melted, degassing was done using magnesium to remove the absorbed gases in the melt. The stirring of melt was started at the rate of 300 RPM for 5 mins and then preheated mixture of B4C particles and K2TiF6 salt was introduced to the vortex manually. After the addition of the mixture, the stirring was done at the rate of 500 RPM for 5-7 mins and pouring was carried out at pouring temperature of 710°C ± 10°C and stirring speed of 700 RPM in a preheated cylinderical mould of dimensions 300mm x 50mm. The reinforcement distribution in the casted specimens was analysed by cutting the cast from different locations and evaluated under microscopic testing. Compositions for preparing the samples used shown in Table 4.2.

Table 4.2: Composition for sample preparations

composition				
Sample no.	Aluminium alloy(gm)	B4C (gm)	K2TiF6 (gm)	Remarks
1.	1200	0	0	Pure alloy
2.	1300	130	130	10% B4C
3.	1200	180	180	15% B4C
4.	1100	220	220	20% B4C
5.	1000	250	250	25% B4C

Fig. 4.3 Cast Product after Casting

CHAPTER 5

RESULTS AND DISCUSSION

5.1 Impact test Results

The Charpy test is the test to focus the resistance of a material against stuns. The test temperature is vital in light of the fact that the resistance does diminish with falling temperature.

Fig. 5.1 Impact Testing Machine

The test comprises of breaking by one blow from a swinging pendulum, under conditions characterized by models, a test piece indented in the center and upheld at every end. The energy assimilated is evaluated in joules. This retained energy is a gauge of the effect quality of a material. The test specimens were prepared as per ASTM 370 standard with dimensions as follows:

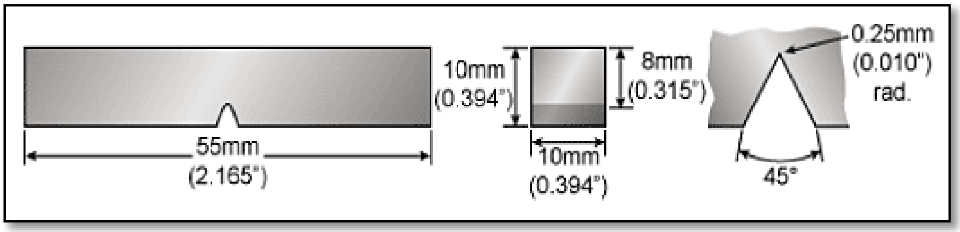


Fig. 5.2 Dimension of Charpy Test Specimen

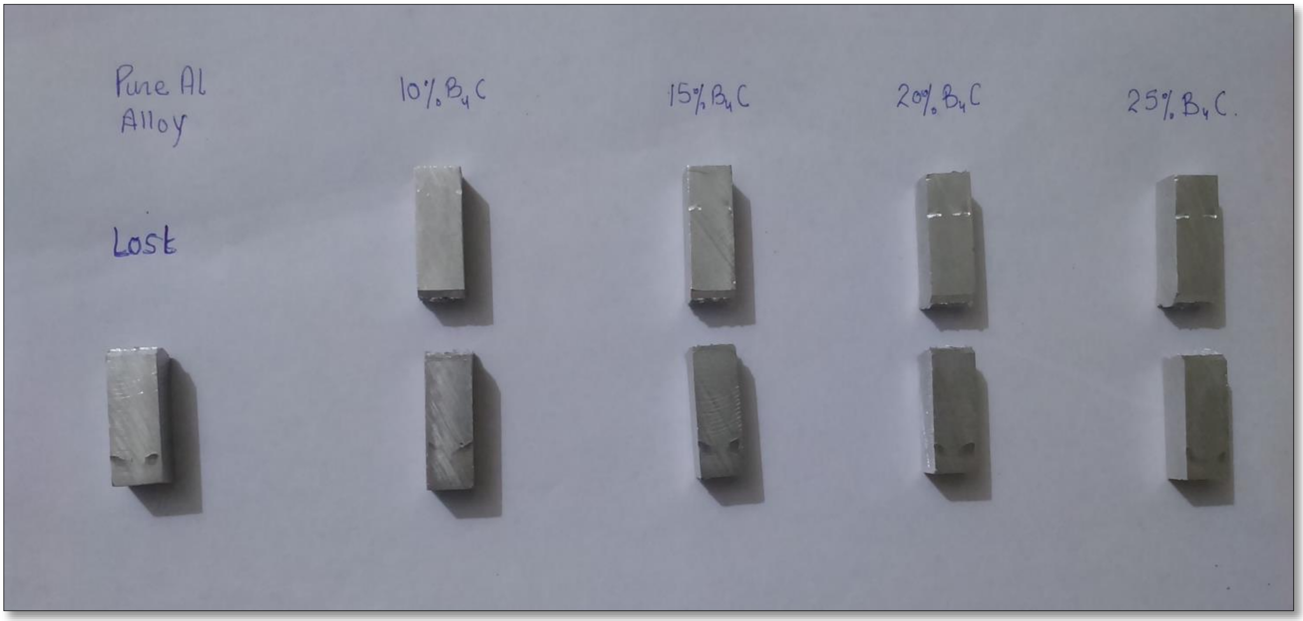


Fig. 5.3 Impact Test Specimen after Testing

The Results of Impact Tests using trail method are shown below:

Table 5.1: Results of Impact Tests

S. NO	Composites	Trails				Average Force Nm
		1	2	3	Total Force Nm	
1	Pure Al-5083	8	7.3	8.2	23.5	7.83
2	10% B4C-Al	11.4	12	12.2	35.6	11.87
3	15% B4C-Al	16.1	16	16.4	48.5	16.16
4	20% B4C-Al	18	16.9	17	51.9	17.30
5	25% B4C-Al	18.5	19	18.9	56.4	18.80

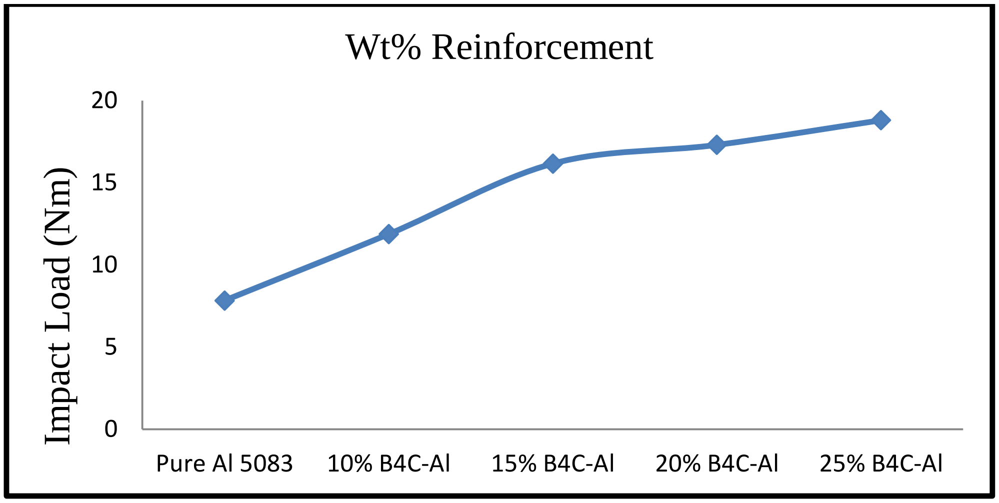


Fig. 5.4 Effect of %age Variation on the Impact Strength of Casted AMC's.

Figure 5.4 shows that with the increase in B4C particles impact strength has improved gradually upto 15% B4C-Al composite and then slope of the curve has reduced to some extent. The improvement can be due to the uniform distribution of B4C particles in the base alloy and also due to strong interfacial bonding between the reinforcement and the matrix interfaces i.e. B4C and Al 5083.

5.2 Hardness Test Results

The Microhardness test procedure based on BIS IS 1501:2002 works on a range of light loads using diamond indenter to make an indentation which is measured and converted to a hardness value. A square base pyramid shaped indentor is used in vicker's scale.

Fig. 5.5 Micro Vicker Hardness Tester

To conduct the test, surfaces of all samples generally needs a metallographic finish which was done with the help of 150, 320, 400, 600, and 1000 grit size emery paper. Load applied on the Micro-Vicker Hardness Tester was 10 N for each sample on three trials. Tests results for the hardness are shown in table 9.

Fig. 5.6 Micro-Hardness Test Specimen

Table 5.2: Results of Micro-Hardness Tests

Test Method:-	IS 1501:2002	Instrument Used:-	Vicker Hardness Tester Make: FIE
Temperature:-	25±3°C	Rel. Humidity:-	40-60%

S.NO	Nomenclature of sample	HV 1	HV 2	HV 3	HV Average
1	Pure Al-5083	68	68	69	68
2	10% B4C-Al	69	70	69	69
3	15% B4C-Al	71	72	73	72
4	20% B4C-Al	73	74	73	73
5	25% B4C-Al	76	77	76	76

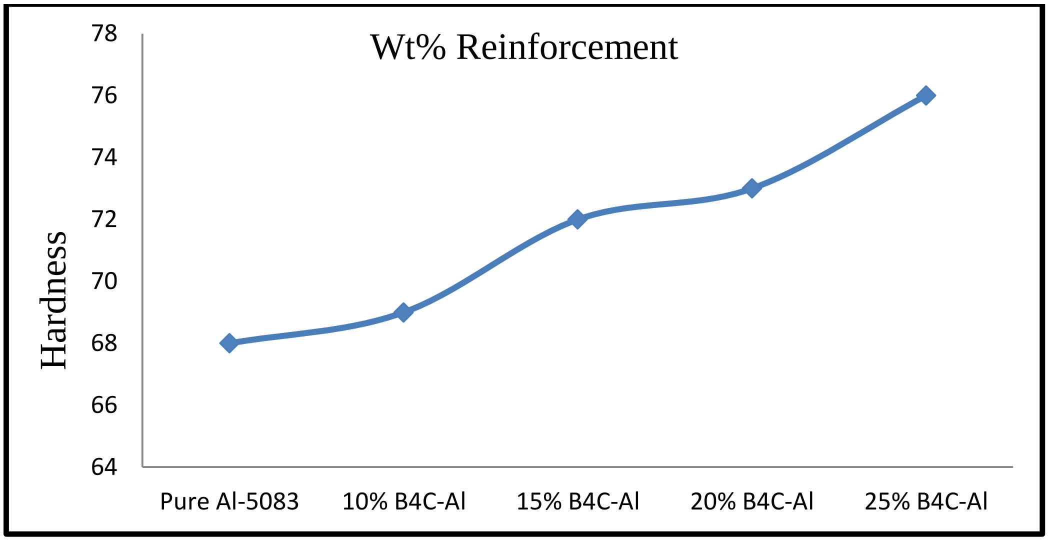


Fig. 5.7 Effect of %age Variations in the Hardness of Casted AMC's

Figure 5.7 describes the steady aviation in the slope of the hardness curve with increasing wt% of the B4C particles with respect to the base alloy which is due to increase in resistance to deformation after the addition of the ceramic particles in the aluminium alloy.

5.3 Tensile Strength Results

Fig. 5.8 Universal testing machine

Ultimate tensile strength (UTS), often shortened to tensile strength (TS) or ultimate strength, is maximum stress that a material can withstand while being stretched or pulled before necking phenomena which is when the specimen’s cress-section starts to contract significantly. To evaluate the mechanical behavior of the matrix alloy and composites, the tensile tests were done on the tensile samples machined. The flat specimens were prepared as per standard dimensions under test method BIS-IS 1608-2005.

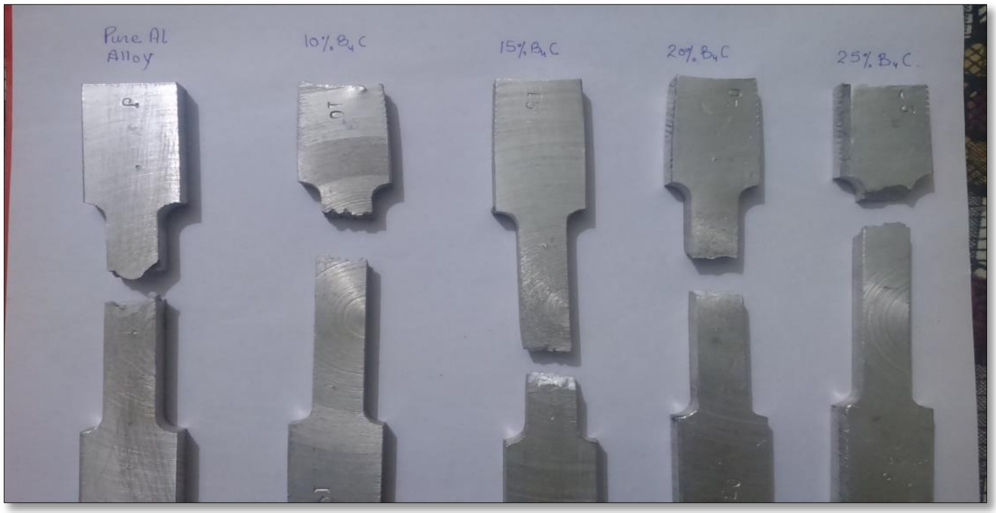


Fig. 5.9 Tensile test specimens after testing

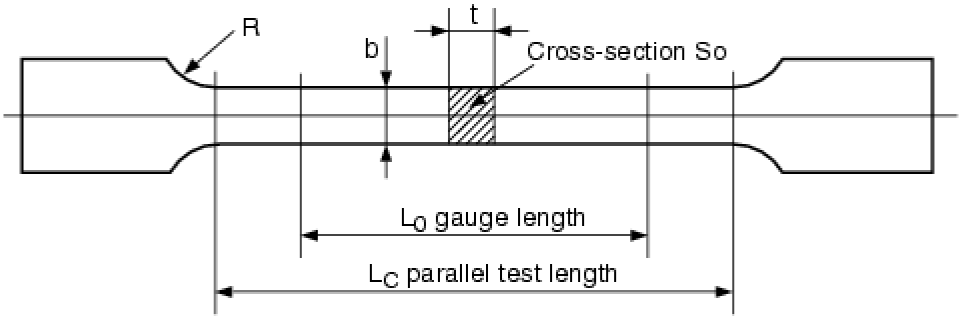


Fig. 5.10 Dimensions of Flat Tensile Test Specimen

where,

Lo= 52 mm

Lc= 65 mm

b = 10 mm

R = 0.7 mm

Table 5.3: Tensile Test Results

S.NO	Composition	UTS (N/mm²)	% Elongation	% Improve
1.	Pure Al-5083	138	8.38	-
2.	10% B4C	159	7.90	15.2
3.	15% B4C	168	7.30	21.7
4.	20% B4C	191	5.96	38.4
5.	25% B4C	195	5.40	41.3

5.3.1 Stress vs. Strain Curves

During tensile testing of a material sample, the stress-strain curve is a graphical representation of the relationship between stress, derived from measuring the load applied on the sample, and strain, derived from measuring the deformation of the sample, i.e elongation, compression, or distortion. The slope of stress-strain curve at any point is called the tangent modulus; the slope of elastic portion of the curve is a property used to characterize materials and is known as Young's modulus. The area under elastic portion of the curve is known as the modulus of resilience.

I. Stress vs. Strain Curve for Pure Al 5083

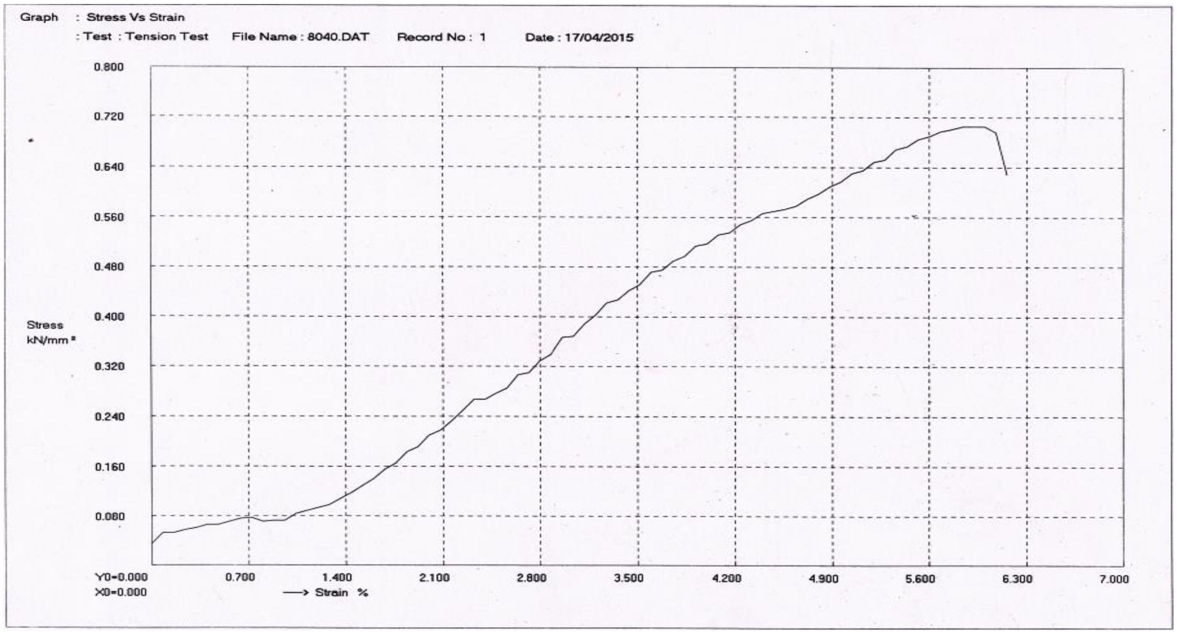


Fig. 5.11 Stress vs. Strain curve for Pure Al 5083

II. Stress vs. Strain Curve for 10% B4C

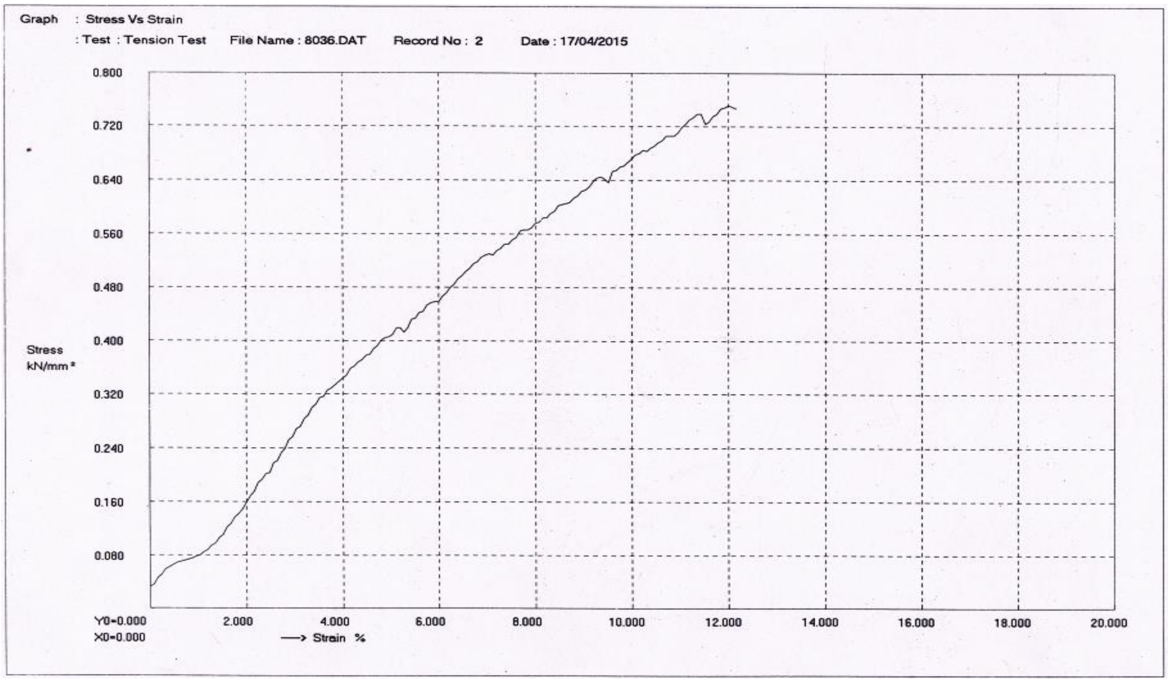


Fig. 5.12 Stress vs. Strain curve for 10% B4C

III. Stress vs. Strain Curve for 15% B4C

Fig. 5.13 Stress vs. Strain curve for 15% B4C

IV. Stress vs. Strain Curve for 20% B4C

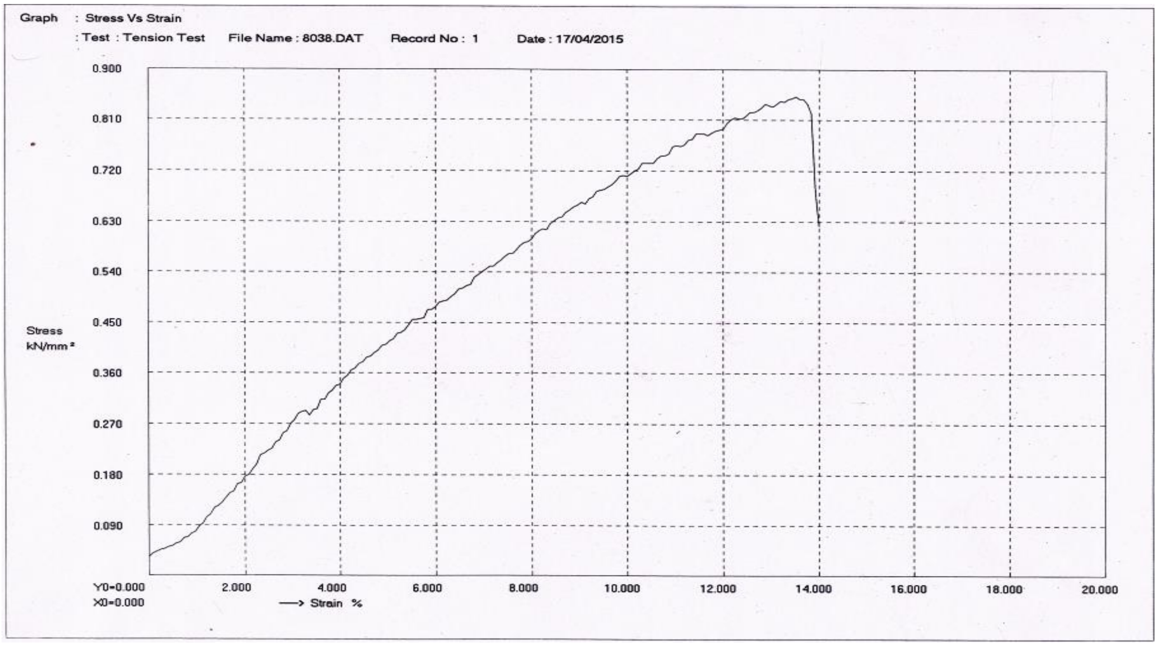


Fig. 5.14 Stress vs. Strain curve for 20% B4C

V. Stress vs. Strain Curve for 25% B4C

Fig. 5.15 Stress vs. Strain curve for 25% B4C

From above figures, it can be clearly seen that stress-strain is almost linearly rising throughout the process including the yield point and then gradually stabilizing upto ultimate tensile strength till fracture.

Now, as deformation takes place, the stress increases on account of strain hardening until it reached the ultimate strength. Until this point, the cross-sectional area decreases uniformaly because of poisson contractions. Both the ruptures, actual and visual are in same vertical line. The work hardening rate increases with increasing weight percent of reinforcement due to which lower ductility can be attributed to the earlier onset of void nucleation with increasing ratio of reinforcement.

5.3.2 Ultimate Tensile Strength

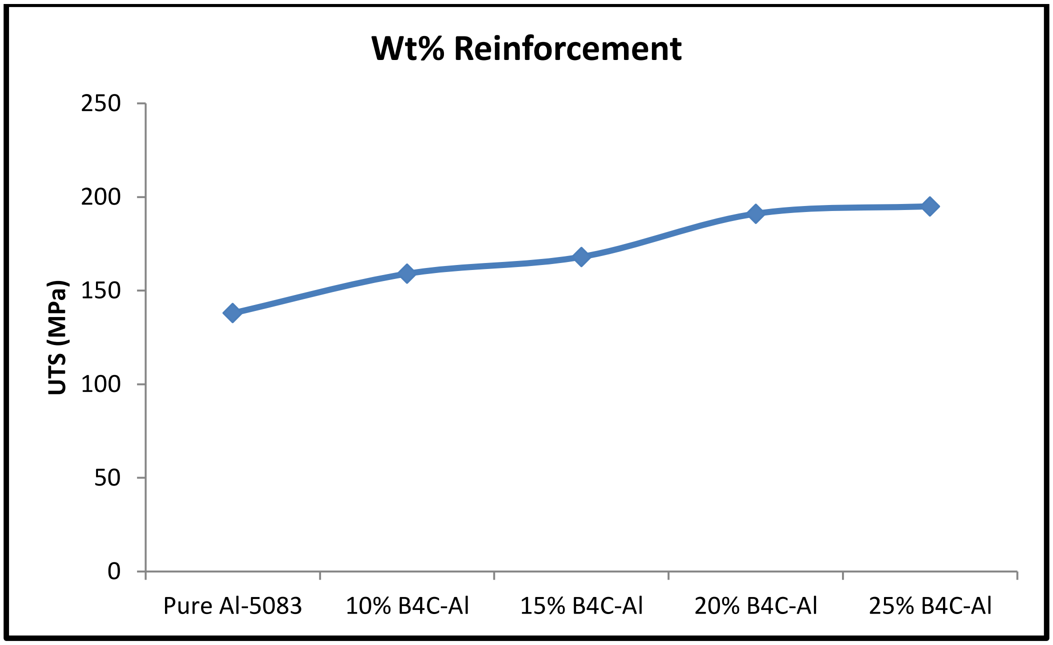


Fig. 5.16 Effect of Varying wt% of Reinforcement on Ultimate Tensile Strength

As shown in figure 5.16, evaluation reveals that on the account of increasing wt% of reinforcement, the ultimate strength also depicted certain improvement. This might be due to distribution of B4C particles which caused interference to the dislocation motion which results an increase in tensile strength of cast composite.

5.3.3 % Length Elongation

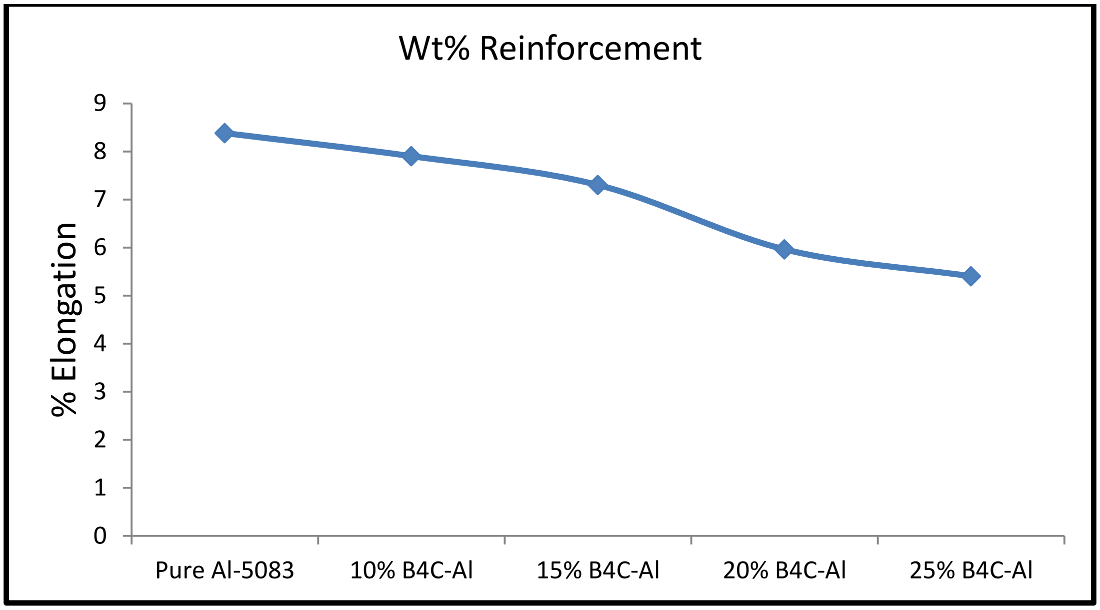


Fig. 5.17 Effect of Varying wt% of Reinforcement on Length Elongation

From above Figure, it is clear that with increasing ratio of weight fraction of B4C particles elongation decreases. This might be due to decrement in ductility on the account of enhanced tensile strength of composites.

5.4 Wear Test Results

A pin-on-disk tribometer is utilized to perform the wear test. The track disk used in the experiment was EN-31 carbon steel. The wear track, base alloy specimen and prepared composite samples are cleaned with acetone before each reading. Also every specimen is measured utilizing an electronic weighing machine having a precision of ±0.0001 gm. For proper contact of pin on the disk, each specimen is polished with an 80 grit size emery paper. After that the specimen is mounted on the pin holder of the tribometer prepared for wear test. For all trials, the sliding speed is conformed to 1.25 m/s, track diameter 80mm, applied load were 19.6N and 29.4N and aggregate time is 26 minutes under room temperature. All specimens were prepared under ASTM G99 standards with pin length of 30mm and 8mm dia.

Fig. 5.18 Pin on Disk Tribometer

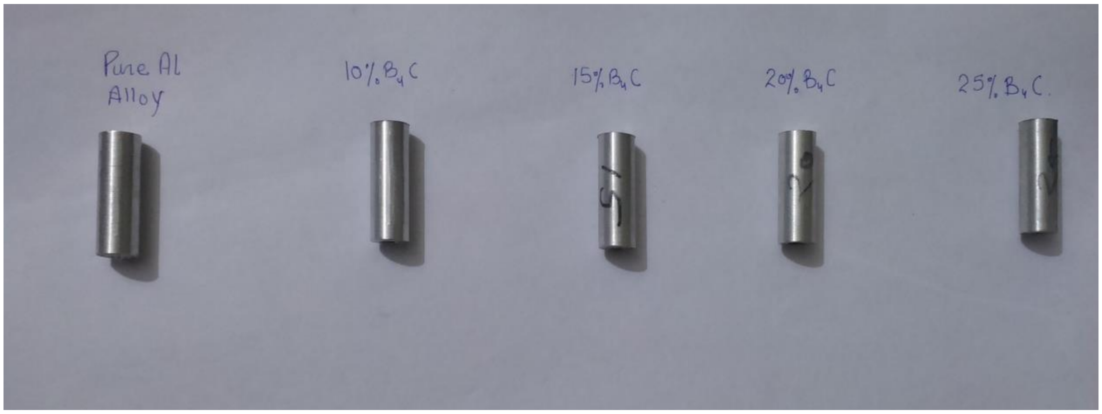


Fig. 5.19 Pin Specimens for Wear Test.

Furthermore, the wear rate is calculated form the volume loss in pin at each sliding distance:

$$Wear\ Rate = \frac{voulme\ loss}{sliding\ distance}\ mm^3/sec$$

where,

$$volume\ loss(mm^3)=\frac{mass\ loss(g)}{desnity(g/cm^3)}\ X\ 1000$$

$$sliding\ distance = \frac{\pi DNT}{60000}$$

where,

D=track diameter in mm

N=revolutions per min in rpm

T= Time in seconds.

5.4.1 Wear Test Results for Pure Al 5083

Readings for pure alloy sample at load 19.6N taken during the experiment are shown in table 5.4.

Table 5.4: Wear Test Results for Pure Al 5083 (Load 19.6N)

Applied Load:-	19.6N
Sliding speed:-	1.25m/s

	S.NO	Initial Wt.(gm)	Final Wt.(gm)	Mass loss(mg)	Time(sec)	Sliding distance(m)
Pure Al5083	1	6.1555	6.1547	0.8	180	200
	2	6.1547	6.1537	1.0	330	400
	3	6.1537	6.1521	1.6	480	600
	4	6.1521	6.1504	2.0	630	800

Readings for pure alloy sample at load 29.4N taken during the experiment are shown in table 5.5.

Table 5.5: Wear Test Results for Pure Al 5083 (Load 29.4N)

Applied Load:-	29.4N
Sliding speed:-	1.25m/s

	S.NO	Initial Wt.(gm)	Final Wt.(gm)	Mass loss(mg)	Time(sec)	Sliding distance(m)
Pure Al5083	1	6.1504	6.1495	0.9	180	200
	2	6.1495	6.1482	1.3	330	400
	3	6.1482	6.1465	1.7	480	600
	4	6.1465	6.1439	2.6	630	800

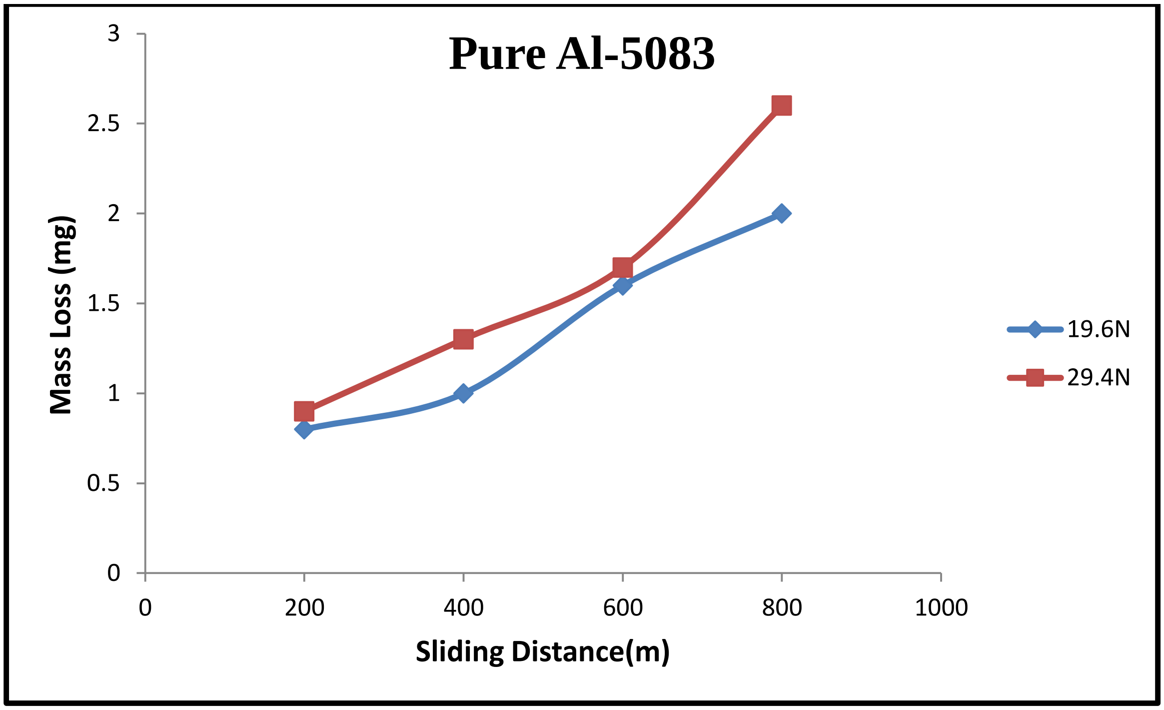


Fig. 5.20 Wear Mass Loss of Pure Al-5083 at varying Sliding Distance at 19.6N & 29.4N

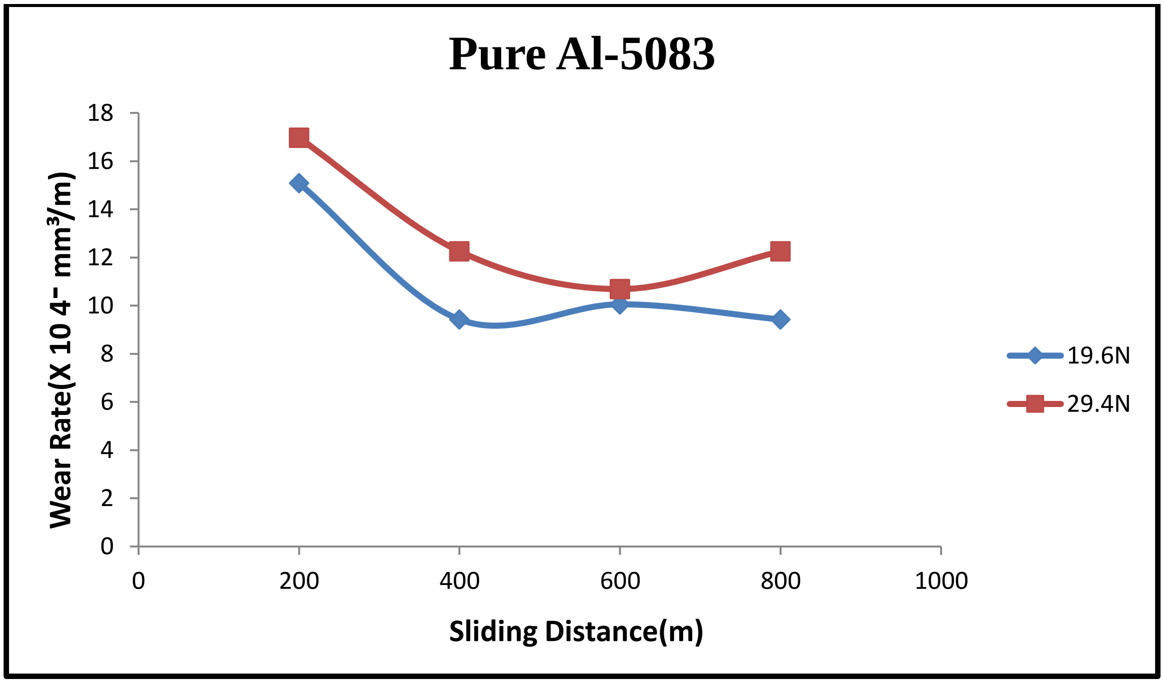


Fig. 5.21 Wear Rate of Pure Al-5083 at varying Sliding Distance at 19.6N & 29.4N

5.4.2 Wear Test Results for 10% B4C-Al

Readings for 10% B4C-Al sample taken during the experiment are shown in table 5.6.

Table 5.6: Wear Test Results for 10% B4C-Al (Load 19.6N)

Applied Load:-	19.6N
Sliding speed:-	1.25m/s

	S.NO	Initial Wt.(gm)	Final Wt.(gm)	Mass loss(mg)	Time(sec)	Sliding distance(m)
10% B4C-Al	1	6.4423	6.4417	0.6	180	200
	2	6.4417	6.4410	0.7	330	400
	3	6.4410	6.4400	1.0	480	600
	4	6.4400	6.4387	1.3	630	800

Readings for 10% B4C-Al sample taken during the experiment are shown in table 5.7.

Table 5.7: Wear Test Results for 10% B4C-Al (Load 29.4N)

Applied Load:-	29.4N
Sliding speed:-	1.25m/s

	S.NO	Initial Wt.(gm)	Final Wt.(gm)	Mass loss(mg)	Time(sec)	Sliding distance(m)
10% B4C-Al	1	6.4387	6.4380	0.7	180	200
	2	6.4380	6.4373	0.7	330	400
	3	6.4373	6.4360	1.3	480	600
	4	6.4360	6.4344	1.6	630	800

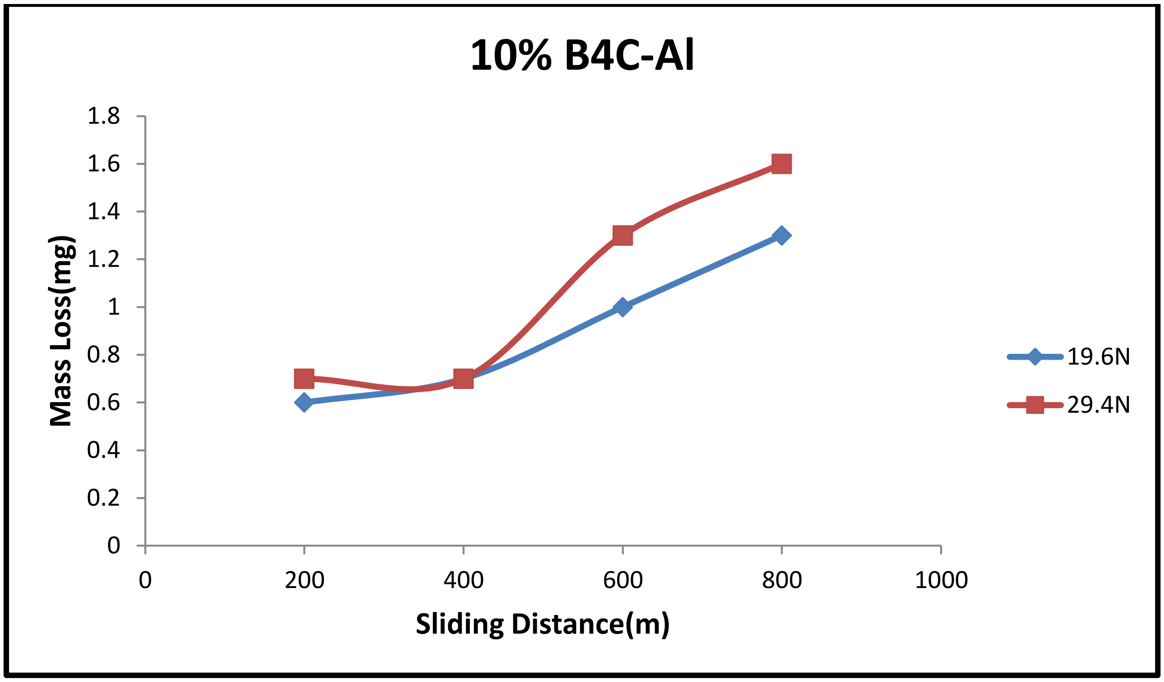


Fig. 5.22 Wear Mass Loss of 10% B4C-Al at varying Sliding Distance at 19.6N & 29.4N

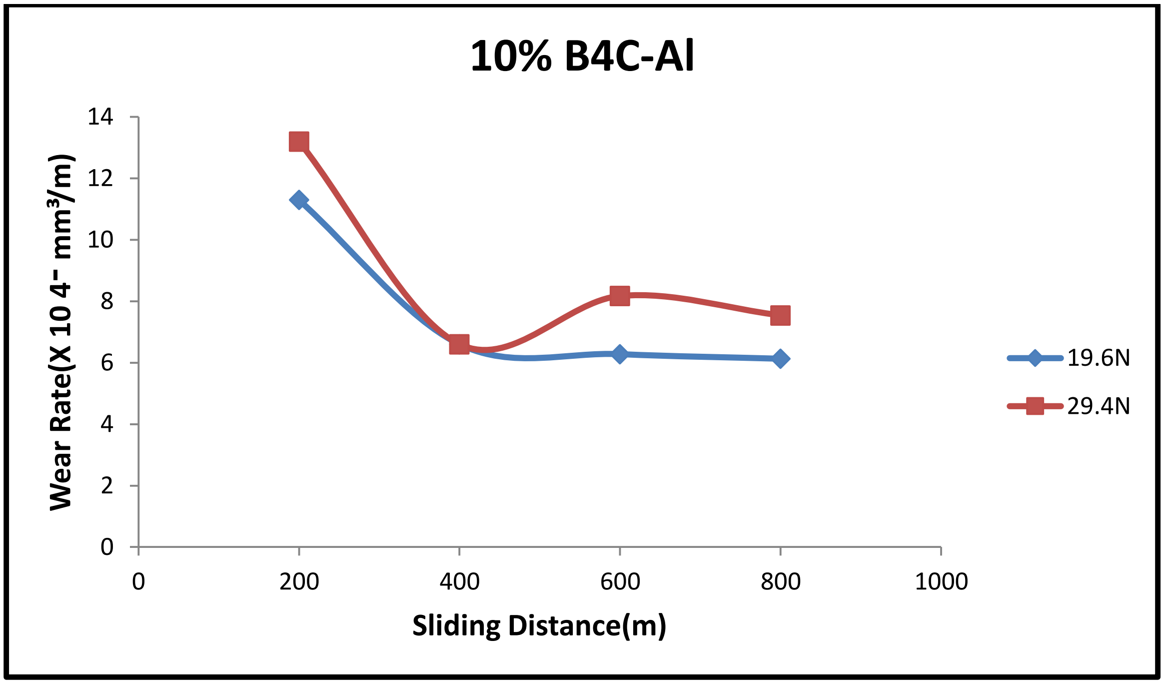


Fig. 5.23 Wear Rate of 10% B4C-Al at varying Sliding Distance at 19.6N & 29.4N

5.4.3 Wear Test Results for 15% B4C-Al

Readings for 15% B4C-Al sample taken during the experiment are shown in table 5.8.

Table 5.8: Wear Test Results for 15% B4C-Al (Load 19.6N)

Applied Load:-	19.6N
Sliding speed:-	1.25m/s

	S.NO	Initial Wt.(gm)	Final Wt.(gm)	Mass loss(mg)	Time(sec)	Sliding distance(m)
15% B4C-Al	1	6.3018	6.3015	0.3	180	200
	2	6.3015	6.3010	0.5	330	400
	3	6.3010	6.3001	0.9	480	600
	4	6.3001	6.2989	1.2	630	800

Readings for 15% B4C-Al sample taken during the experiment are shown in table 5.9.

Table 5.9: Wear Test Results for 15% B4C-Al (Load 29.4N)

Applied Load:-	29.4N
Sliding speed:-	1.25m/s

	S.NO	Initial Wt.(gm)	Final Wt.(gm)	Mass loss(mg)	Time(sec)	Sliding distance(m)
15% B4C-Al	1	6.2989	6.2983	0.6	180	200
	2	6.2983	6.2975	0.8	330	400
	3	6.2975	6.2965	1.0	480	600
	4	6.2965	6.2953	1.4	630	800

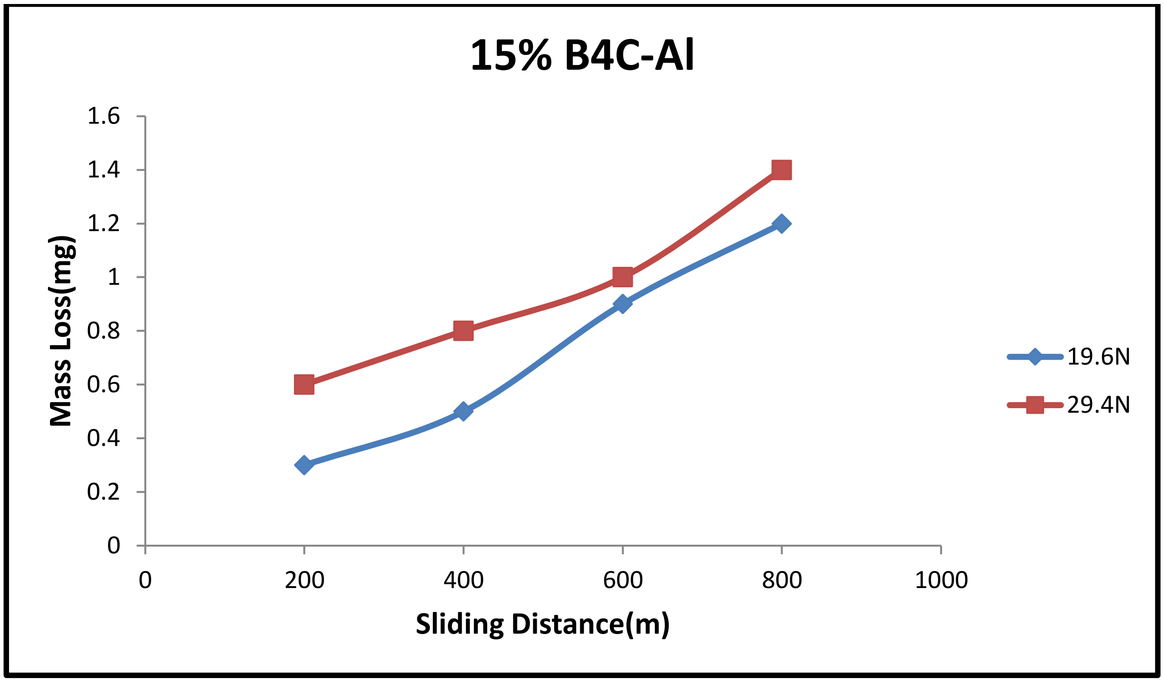


Fig. 5.24 Wear Mass Loss of 15% B4C-Al at varying Sliding Distance at 19.6N & 29.4N

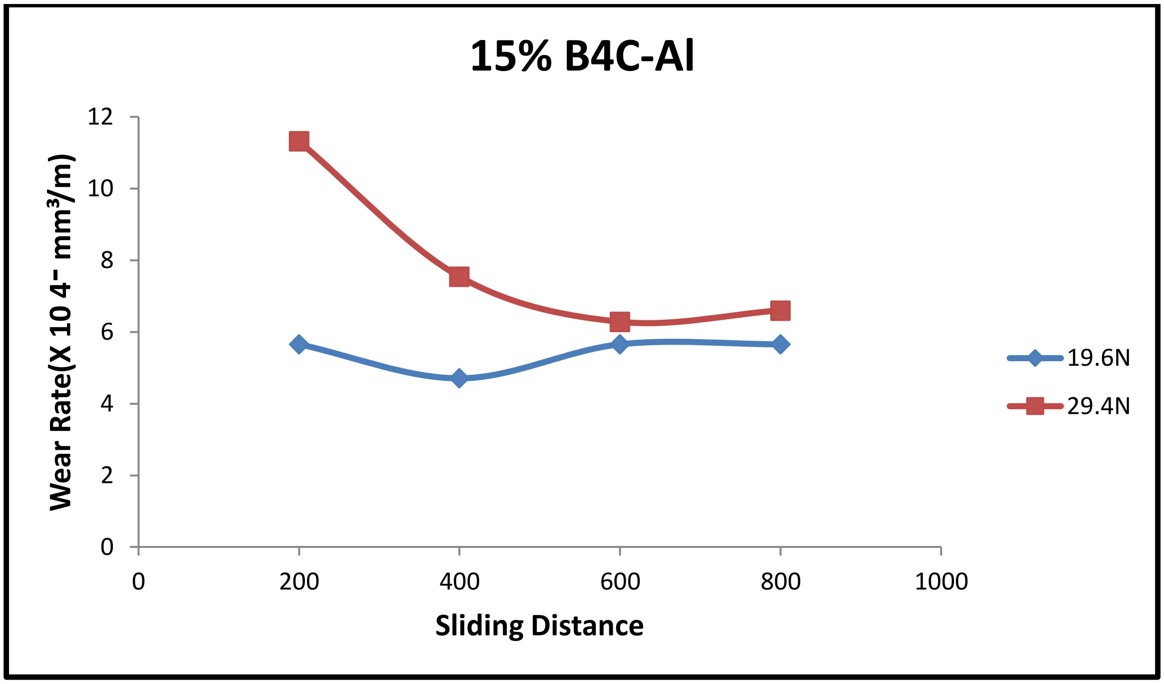


Fig. 5.25 Wear Rate of 15% B4C-Al at varying Sliding Distance at 19.6N & 29.4N

5.4.4 Wear Test Results for 20% B4C-Al

Readings for 20% B4C-Al sample taken during the experiment are shown in table 5.10.

Table 5.10: Wear Test Results for 20% B4C-Al (Load 19.6N)

Applied Load:-	19.6N
Sliding speed:-	1.25m/s

	S.NO	Initial Wt.(gm)	Final Wt.(gm)	Mass loss(mg)	Time(sec)	Sliding distance(m)
20% B4C-Al	1	6.1250	6.1248	0.2	180	200
	2	6.1248	6.1244	0.4	330	400
	3	6.1244	6.1236	0.8	480	600
	4	6.1236	6.1225	1.1	630	800

Readings for 20% B4C-Al sample taken during the experiment are shown in table 5.11.

Table 5.11: Wear Test Results for 20% B4C-Al (Load 29.4N)

Applied Load:-	29.4N
Sliding speed:-	1.25m/s

	S.NO	Initial Wt.(gm)	Final Wt.(gm)	Mass loss(mg)	Time(sec)	Sliding distance(m)
20% B4C-Al	1	6.1225	6.1221	0.4	180	200
	2	6.1221	6.1214	0.7	330	400
	3	6.1214	6.1205	0.9	480	600
	4	6.1205	6.1193	1.2	630	800

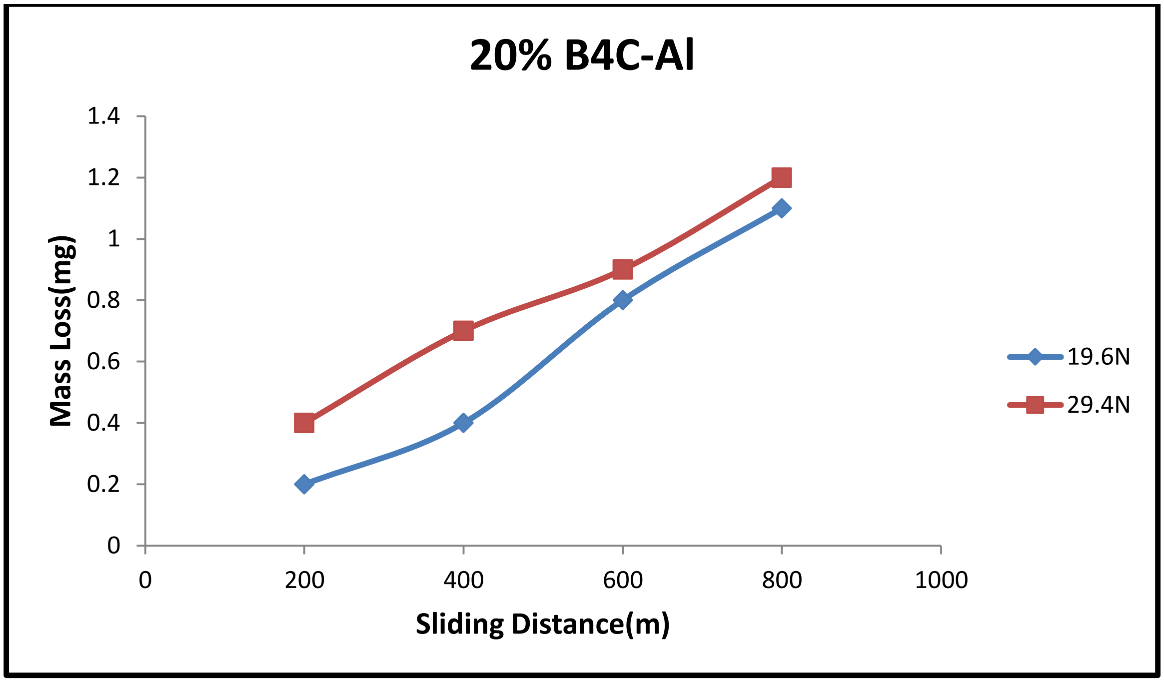


Fig. 5.26 Wear Mass Loss of 20% B4C-Al at varying Sliding Distance at 19.6N & 29.4N

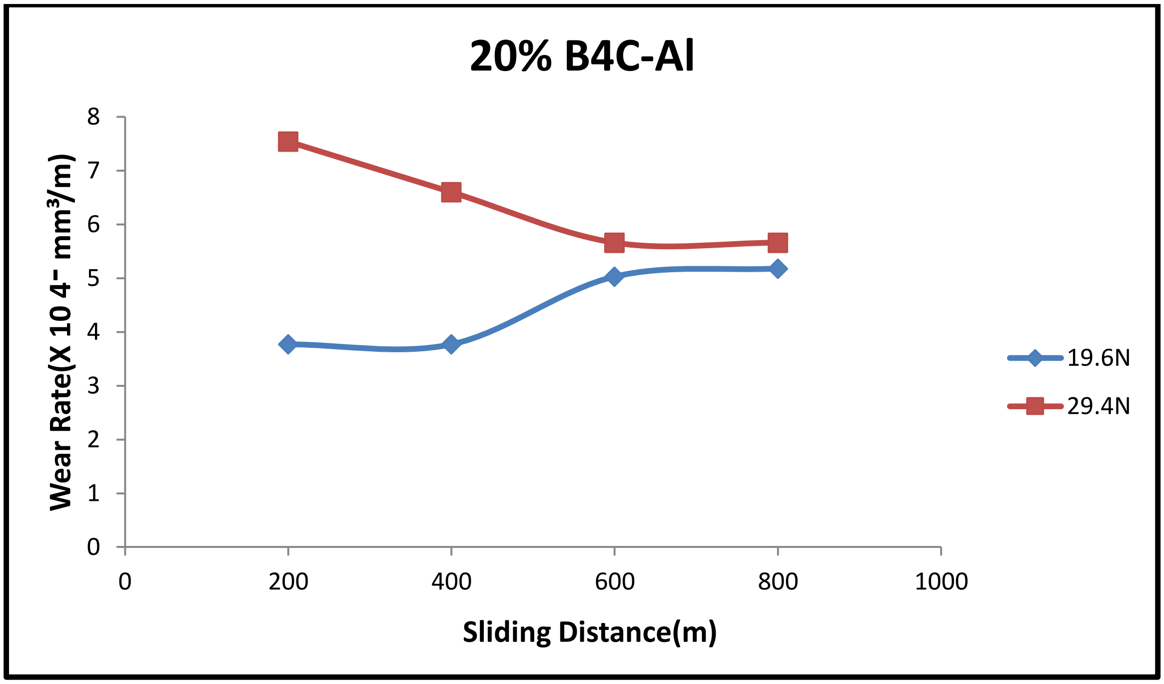


Fig. 5.27 Wear Rate of 20% B4C-Al at varying Sliding Distance at 19.6N & 29.4N

5.4.5 Wear Test Results for 25% B4C-Al

Readings for 25% B4C-Al sample taken during the experiment are shown in table 5.12.

Table 5.12: Wear Test Results for 20% B4C-Al (Load 19.6N)

Applied Load:-	19.6N
Sliding speed:-	1.25m/s

	S.NO	Initial Wt.(gm)	Final Wt.(gm)	Mass loss(mg)	Time(sec)	Sliding distance(m)
25% B4C-Al	1	6.5986	6.5984	0.2	180	200
	2	6.5984	6.5981	0.3	330	400
	3	6.5981	6.5975	0.6	480	600
	4	6.5975	6.5966	0.9	630	800

Readings for 25% B4C-Al sample taken during the experiment are shown in table 5.13.

Table 5.13: Wear Test Results for 25% B4C-Al (Load 29.4N)

Applied Load:-	29.4N
Sliding speed:-	1.25m/s

	S.NO	Initial Wt.(gm)	Final Wt.(gm)	Mass loss(mg)	Time(sec)	Sliding distance(m)
25% B4C-Al	1	6.5966	6.5964	0.2	180	200
	2	6.5964	6.5959	0.5	330	400
	3	6.5959	6.5951	0.8	480	600
	4	6.5951	6.5940	1.1	630	800

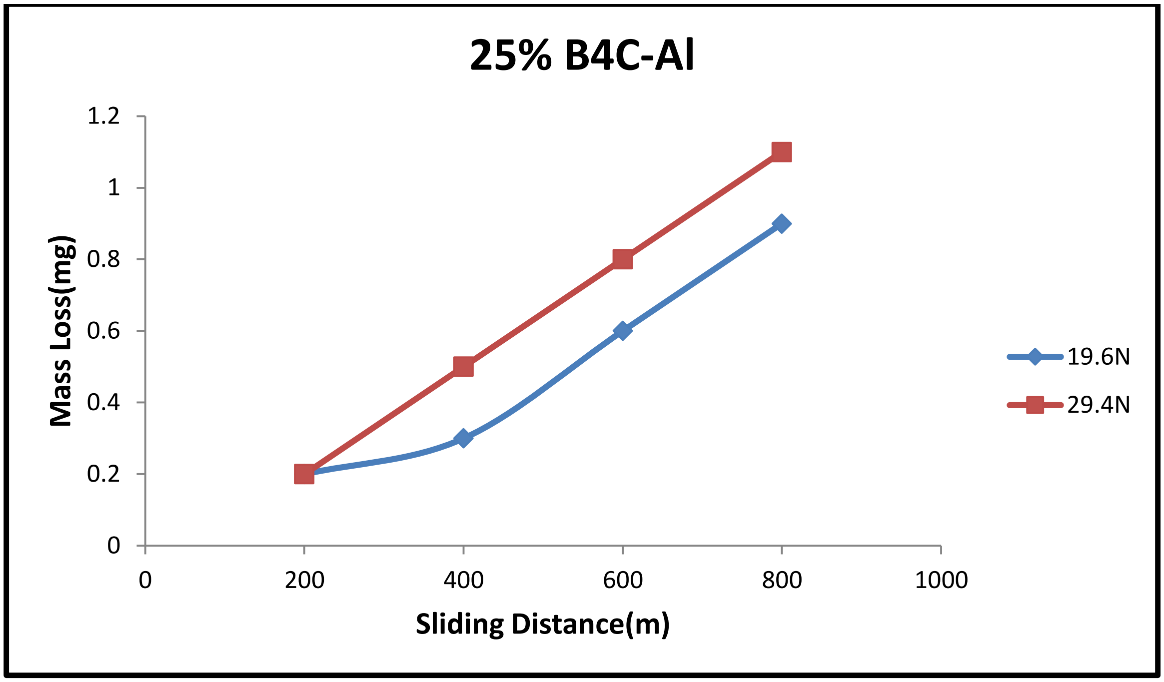


Fig. 5.28 Wear Mass Loss of 25% B4C-Al at varying Sliding Distance at 19.6N & 29.4N

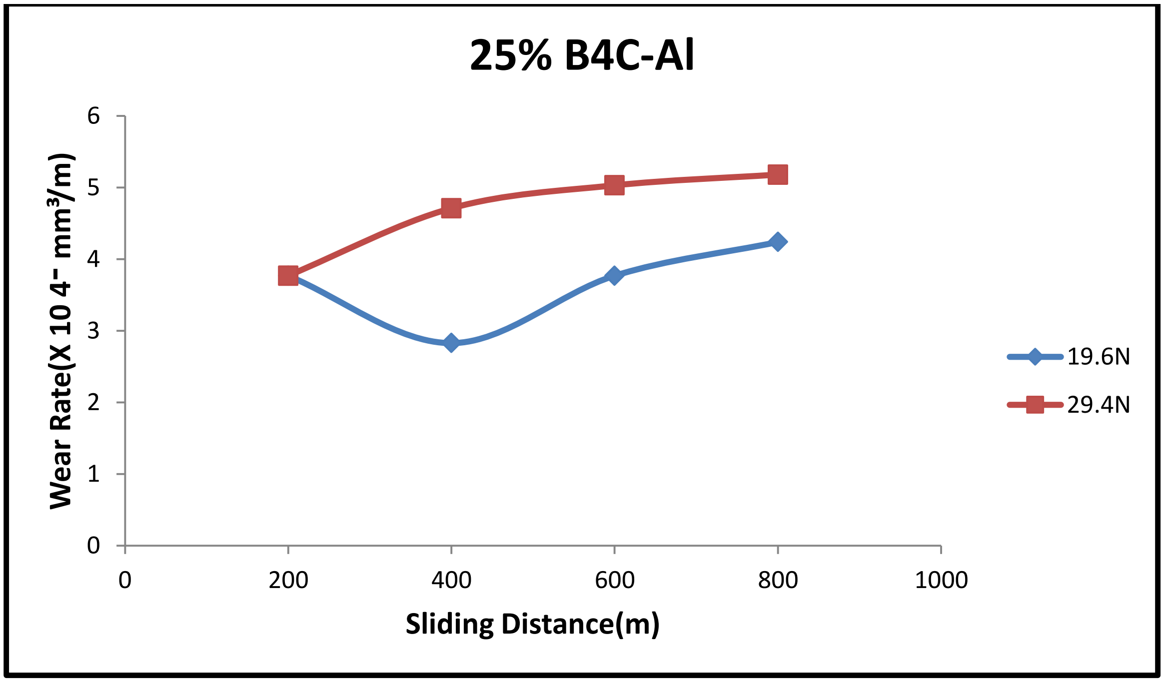


Fig. 5.29 Wear Rate of 25% B4C-Al at varying Sliding Distance at 19.6N & 29.4N

5.4.6 Wear Mass Loss at varying wt% of Reinforcements

Below is the comparative influence of the varying weight percentage of B4C particles on the wear of composite samples w.r.t to the base alloy.

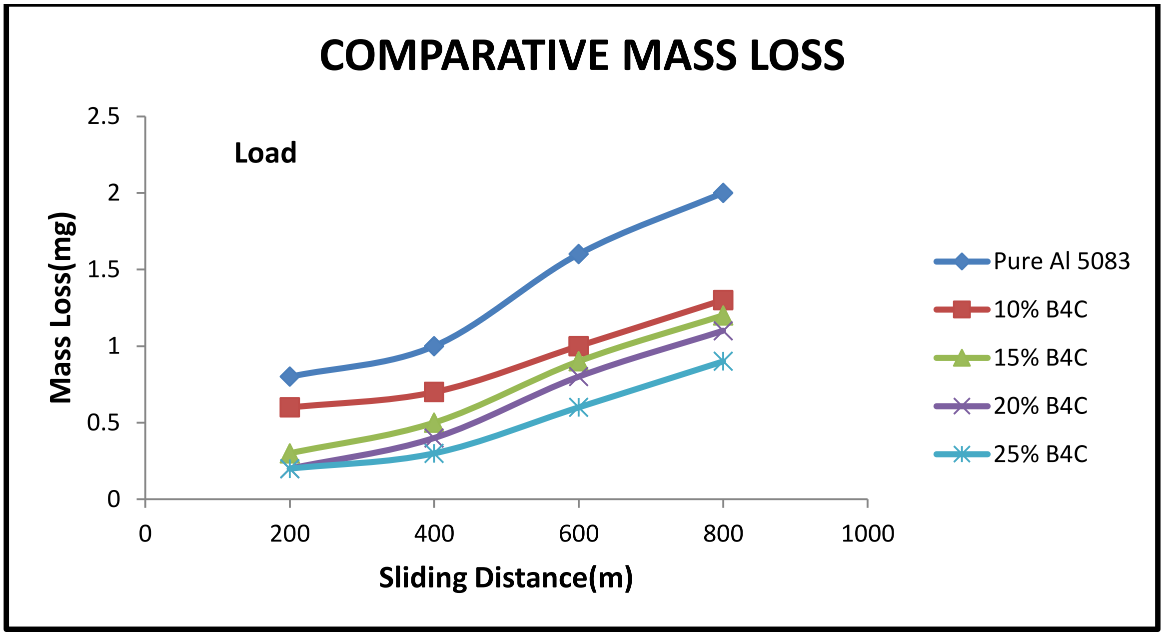


Fig. 5.30 Wear Mass Loss at varying wt% of Reinforcements at Load 19.6N

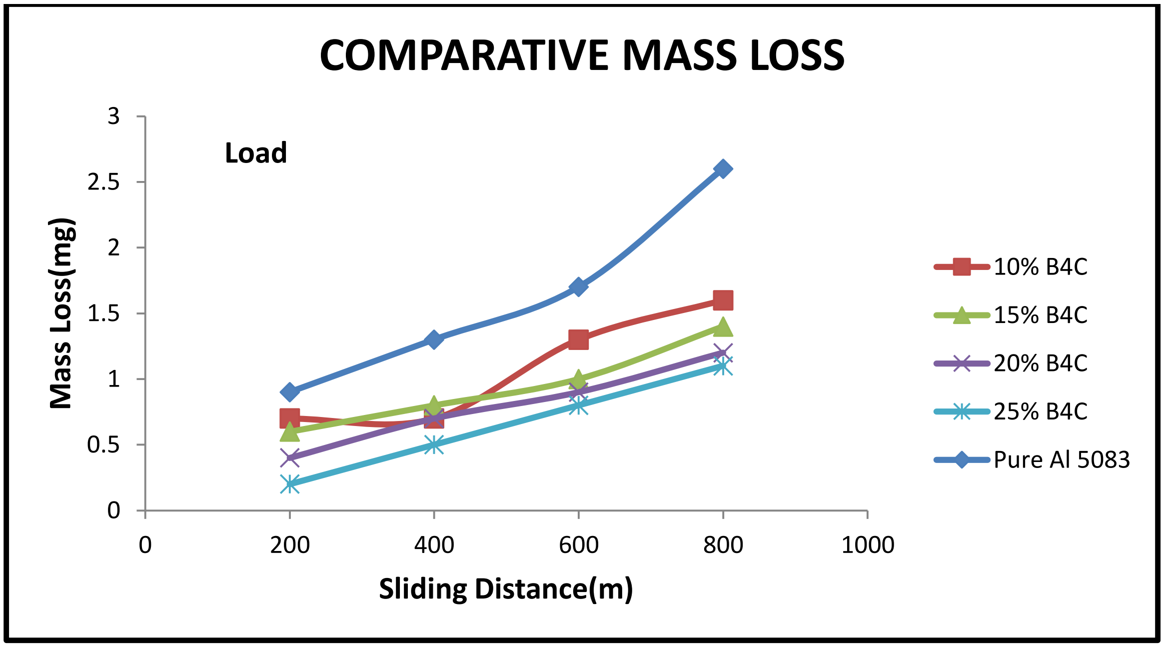


Fig. 5.31 Wear Mass Loss at varying wt% of Reinforcements at Load 29.4N

Figure 5.30 & 5.31 shows the mass loss at varying wt% of reinforcements at load 19.6N & 29.4N in which base alloy i.e. pure Al5083 has shown an increasing mass loss w.r.t to the composite samples. Moreover, maximum mass loss is only 0.9 mg in 25% B4C reinforced composite which is far less than that of pure Al 5083. This may be due to resistance to abrasion by the hard boron carbide particles in the ploughing action caused by track disk during the wear test.

5.4.7 Wear Rate at varying wt% of Reinforcements

Below is the comparative influence of the varying weight percentage of B4C particles on the Wear Rate of composite samples w.r.t to the base alloy.

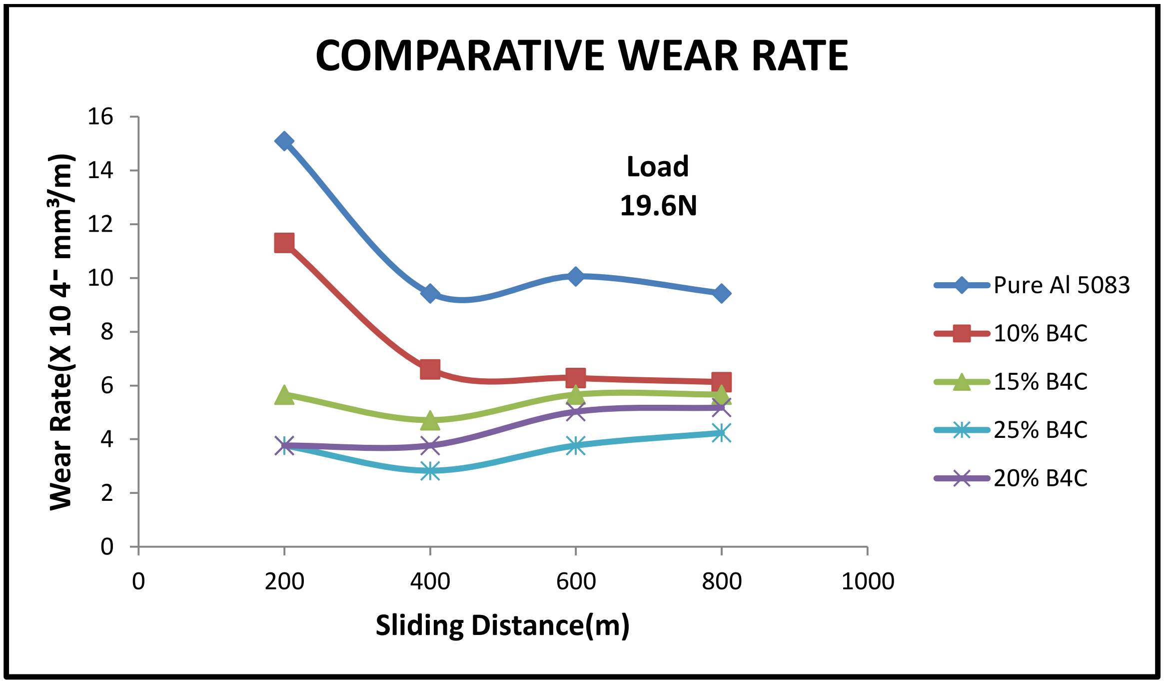


Fig. 5.32 Wear Rate at varying wt% of Reinforcements at Load 19.6N

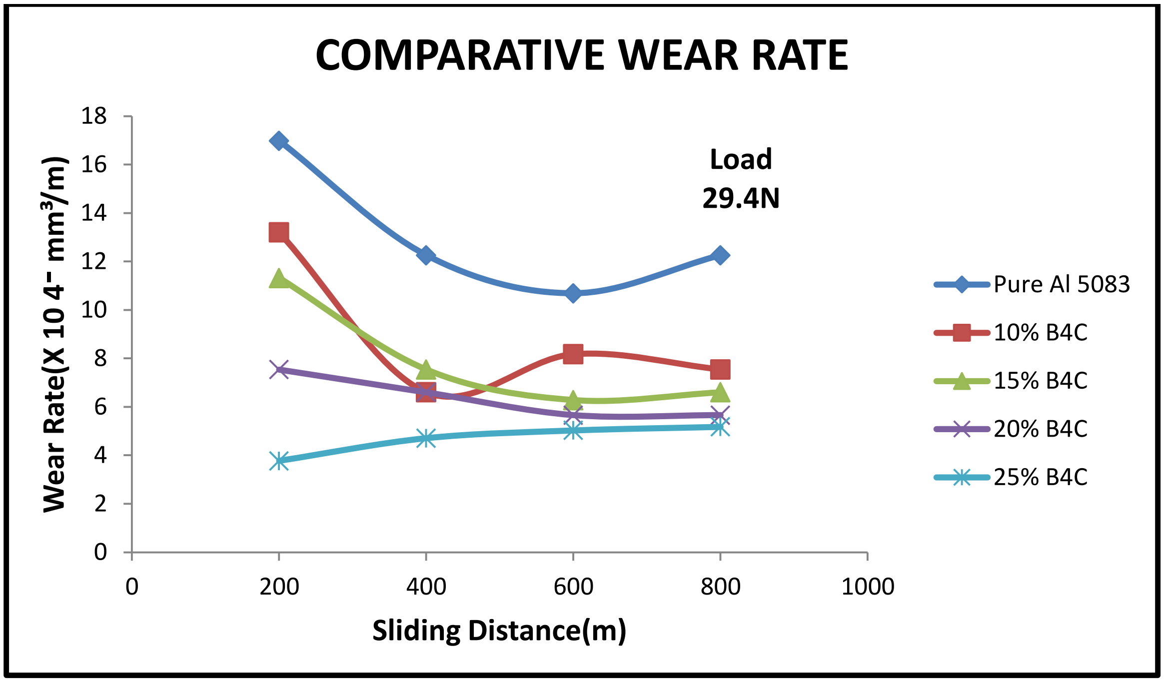
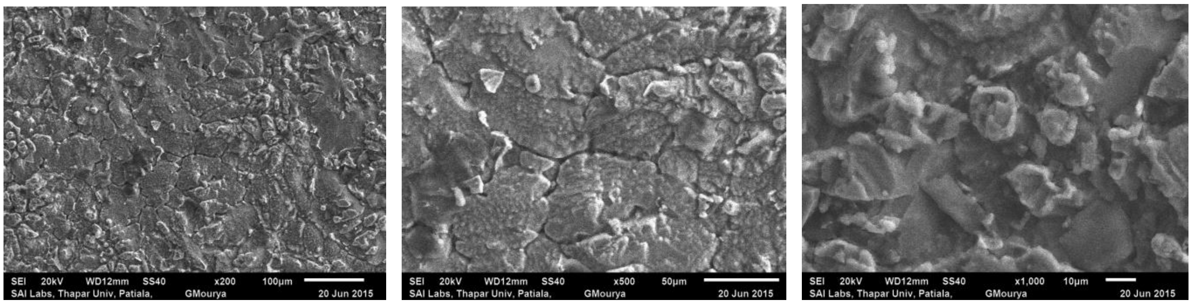


Fig. 5.33 Wear Rate at varying wt% of Reinforcements at Load 29.4N

From figure 5.32 & 5.33, it is clear that initial wear is more at the starting phase of the test which steadily decreased to some extent w.r.t to sliding distance and then kept stationary for further span of time. Moreover, pure Al 5083 sample depicts a clear picture of gradual decline to increment in the wear rate and is more than that of the composite samples. Hence, there is improvement noticed with the increasing weight percentage of the boron carbide particle as reinforcement.

5.5 SEM Results

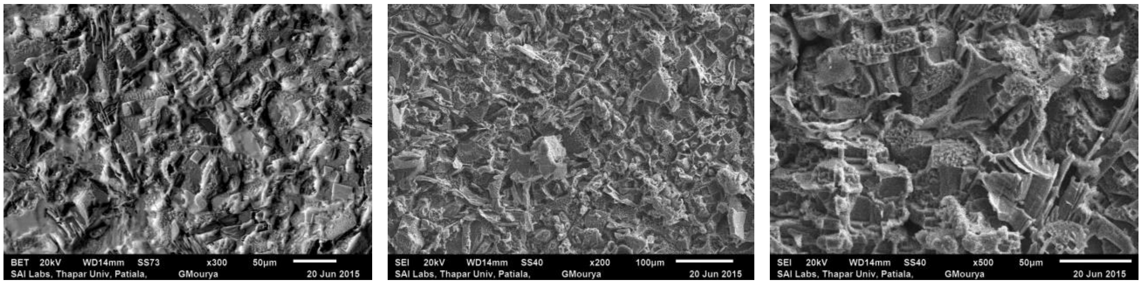
I. 10% B4C mixed with Al-5083



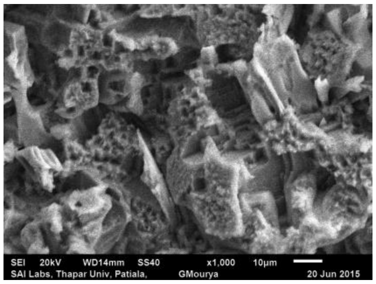
200X **500X** **1000X**

Fig. 5.34 Microstructural view of 10% B4C reinforced with Al-5083

II. 15% B4C mixed with Al-5083



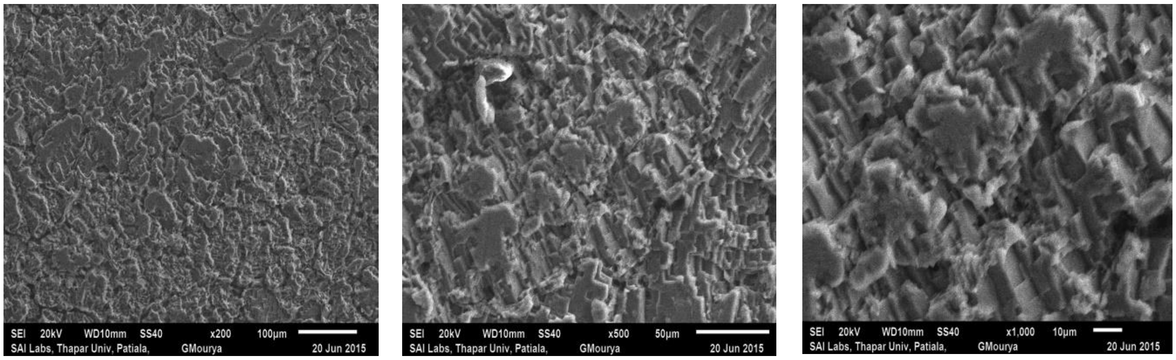
BET (300X) **SEI (200X)** **500X**



1000X

Fig. 5.35 Microstructural view of 15% B4C reinforced with Al-5083

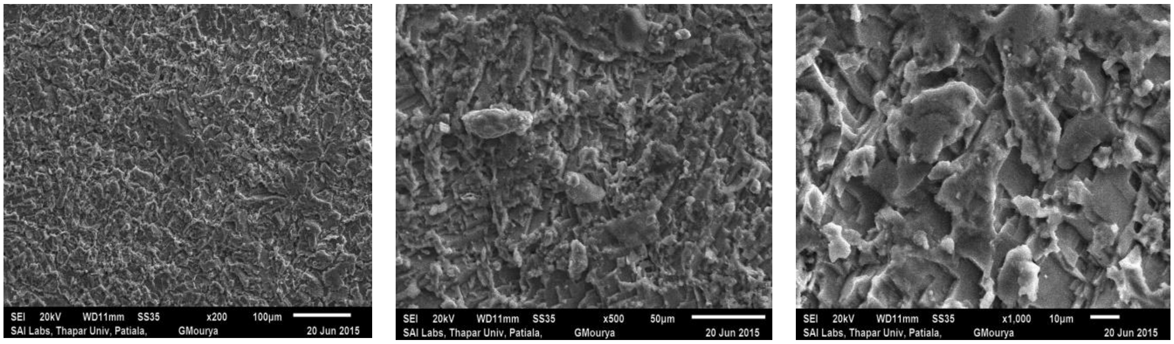
III. 20% B4C mixed with Al-5083



200X **500X** **1000X**

Fig. 5.36 Microstructural view of 20% B4C reinforced with Al-5083

IV.25% B4C mixed with Al-5083



200X **500X** **1000X**

Fig. 5.37 Microstructural view of 25% B4C reinforced with Al-5083

In the figures 5.34, 5.35, 5.36 & 5.37 are the microstructural view of cast Al 5083-B4C composite samples with different weight ratios respectively. It can be seen that the dispersion of reinforcements in the matrix is fairly equal which is due to the increase in metallic bonding between B4C and Al by Al-Ti compounds. As a result, the cast composites are certainly homogenous in nature.

CHAPTER 6

CONCLUSIONS AND FUTURE SCOPE

6.1 Conclusions

The conclusions extracted from the present research are as follows:

1. The evaluations clearly assures that the stir cast Al 5083 reinforced with boron carbide(B4C) is much more improved than pure Al 5083 in mechanical properties like Tensile Strength, Hardness, Impact and Wear.
2. Addition of Boron Carbide (B4C) in more weight fractions has certainly increased the hardness of the matrix material.
3. Impact strength has also been improved with the addition of B4C as reinforcement.
4. Wear character has also showed a positive result with increasing weight fractions and best at 25% addition of reinforcement. Furthermore, it has been noticed that initial wear rate was surprisingly more w.r.t sliding distance but as it increased wear rate tends to decrease and become stationary for a span of time.
5. It is concluded that with increasing weight percentage of particles, elongation tends to decrease which assures that addition of hard particles (B4C) increases the brittle behavior.
6. Moreover, tensile strength has been improved to a great extent with approximately 42% increase at 25% B4C addition in the matrix.
7. SEM results showed the fair distribution of B4C particles in the matrix alloy and other compounds(Al-Ti) scattered throughout in the matrix. Hence, strengthening the composites.
8. In the Stir casting method, stirring speed ,position and time, preheating temperature, particle mixing rate etc. are some important functions.

6.2 Scope of the Future Work

1. The research can be further extended by forming hybrid composite using alumina or titanium carbide as another reinforcement in addition with boron carbide. Thus, comparison can be done between the hybrid and the latter.
2. Heat treatments can be done to improve the properties further.
3. Evaluation can be done by varying the grain size of the reinforcements.

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