Investigation of Mechanical Behavior on Al LM 24/Si_3N_4/Graphite Hybrid Composites

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Abstract- **Aluminium MMCs are preferred to other conventional materials in the fields of aerospace, automotive and marine applications owing to their improved properties like high strength to weight ratio, good wear resistance etc. In the present work an attempt has been made to synthesize metal matrix composite using Aluminium LM 24 as matrix material reinforced with silicon nitride (Si_3N_4) and graphite particulates using liquid metallurgy route in particular stir casting technique. The addition level of reinforcement is being varied from 10-11wt% in Si_3N_4 and 7% graphite. For each composite, reinforcement particles were preheated to a temperature of 2,256^{0}C and then dispersed in steps of three into the vortex of molten Aluminium LM 24 to improve wettability and distribution. Micro structural characterization was carried out for the above prepared composites by taking specimens from central portion of the casting to ensure homogeneous distribution of particles. Hardness and tensile properties of the prepared composite were determined before and after addition of Si_3N_4 graphite particulates to note the extent of improvement. Micro structural characterization of the composites has revealed fairly uniform distribution and some amount of grain refinement in the specimens. Further, the hardness and tensile properties are higher in case of composites when compared to commercial aluminium and mild steel bars.**

***Index Terms*—Metal Matrix Composite (MMC),LM 24,Si_3N_4,Graphite, Hardness.**

I.INTRODUCTION

Composite materials are materials made from two or more constituent materials with significantly different physical or chemical properties, that when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure. The new material may be preferred for many reasons: common examples include materials which are stronger, lighter or less expensive when compared to traditional materials. Composite materials are generally used for buildings, bridges and structures such as boat hulls, swimming pool panels, race car bodies, shower stalls, bathtubs, storage tanks, imitation granite and marble sinks and counter tops. The most advanced examples perform routinely on spacecraft in demanding environments.

Typical engineered composite materials include:

- Composite building materials such as cements, concrete.
- Reinforced plastics such as fiber-reinforced polymer
- Metal Composites.
- Ceramic Composites (composite ceramic and metal matrices).

In recent years, various types of high-end equipment have developed very urgent requirements for solid lubrication technology. The lubricating materials corresponding to the required conditions in these fields must be capable of working in extreme conditions for a long time. To improve the tribological performances of ceramic/metal materials, self-lubricating composites with additives of solid lubricants, have attracted a lot of research attention. The solid lubricant can be used to improve the tribiological performance of materials, demonstrating excellent self-lubricating properties in a wide range of temperatures[1].

Composites can also use metal fibers reinforcing other metals, as in metal matrix composites (MMC) or ceramic matrix composites (CMC), which includes bone (hydroxyl apatite reinforced with collagen fibers), cermet (ceramic and metal) and concrete. Ceramic matrix composites are built primarily for fracture toughness, not for strength.Nowadays, metal matrix composites (MMCs) are widely used for different industrial applications. They are suitable materials which combine the advantages of metals and ceramics. Ceramic materials like Al_2O_3, SiC, TiO_2 and clay are often added to the metallic matrices to provide unique mechanical properties.Such MMCs often inherit ductility and fracture toughness from the metallic matrix and creep resistance and high strength from the ceramic additives. Among the metals, the light alloys of Al, Ti and Mg are desirable to produce MMCs. This is because of the great tendency for light vehicles and structures in different industries. Moreover, the development of MMCs has resolved the lack of enough strength in light alloys. Having low density, good mechanical properties, desirable corrosion resistance and low cost, Al alloys have been the best choice for the manufacture of MMCs in automotive, military and aerospace industries.

Graphite, as a promising solid lubricant for self-lubricating ceramic/metal materials, has been intensively studied in tribology since its lamellar structure was first described. There are earlier reports from some investigators indicated that the aluminum-graphite composites containing a small amount of graphite exhibit superior wear properties over the base alloys. These materials with graphite exhibit excellent self-lubricating properties because that graphite can form lubricating and transferring films on the contact surfaces due to its lamellar structure providing suitable hear during sliding[2].

Our modern technologies many a times, demand materials with unusual and extra-ordinary combination of properties that can't be provided by the conventional metal alloys, ceramics, and polymeric materials. This is particularly to for materials required for aerospace, underwater and transportation applications.

Scientist and Engineers have ingeniously designed various composite materials by the combination of metals, ceramics and polymers to produce new generation of extra-ordinary materials having combination of superior mechanical characteristics such as hardness, toughness, stiffness and high temperature strength. In recent years there has been a considerable interest in metal matrix composites (MMCs)[3]. Metal-matrix composites (MMCS) have recently become candidates for critical structural applications because of their superior specific strength, stiffness and hardness properties. The need for hardness materials for high performance tribological applications has been one of the major incentives for the technological development of ceramic particulate reinforced aluminium LM24 during the last decade. Continuous progress in science and technology creates an increasing demand for improved structural materials.

Materials like cast iron with graphite or steel with high carbide content, as well as tungsten carbides, consisting of carbides and metallic binders, also belong to this group of composite materials. Metal matrix composites (MMCs) usually consist of a low-density metal, such as aluminium or magnesium, reinforced with particulate or fibers of a ceramic material, such as Boron carbide, silicon nitrate or graphite. Compared with unreinforced metals, MMCs offer higher specific strength and hardness, higher operating temperature, and greater wear resistance, as well as the opportunity to tailor these properties for a particular application. Metal composite materials have found application in many areas of daily life for quite some time. Substantial progress in the development of light metal matrix composites has been achieved in recent decades, so that they could be introduced into the most important applications such as in traffic engineering, especially in the automotive industry. However, despite the increased use of MMCs in recent years, the problems of poor fracture toughness and unsatisfactory fatigue properties have limited their application in certain fields. With hard particles dispersed in a relatively ductile matrix, aluminium LM24 matrix composites possess an ideal structure for hardness materials. These Al LM24 composites which are reinforced with ceramic particulates led to a new generation of tailor able engineering materials with improved specific properties. Most of the composites having actual or potential use as structural materials are manufactured by powder processing, liquid casting method.

FABRICATION OF SAMPLES

Step 1

Pre heat and melting the Aluminium LM24 up to its melting point 490 C in the crucible furnace. Coal is used as a fuel for heating up the furnace.

Step 2

Reinforcements such as Graphite and silicon nitrate were preheated at a specified temperature 30 min in order to remove moisture or any other gases present within reinforcement. The preheating of also promotes the wettability of reinforcement with matrix. Reinforcements are added as 5% and 10% composition with Aluminium LM24. ThePreheating of Reinforcements in furnace is shown below.

Step 3

Pre heated materials are added and mixed up with the molten Aluminium manually and heating up for proper distribution with the Aluminium Matrix. The melting of the aluminium and boron carbide powder is carried out in thecrucible into the coal-fired furnace Pouring of preheated reinforcements at the semisolid stage of the matrix enhance the wettability of the reinforcement, reduces the particle settling at the bottom of the crucible. Reinforcements are pouredmanually with the help of conical hopper.

Step 4

Stirring up the molten aluminium with reinforcements at a constant rate which enhances the uniform distribution throughout the matrix phase which is necessary to adjoining the reinforcements with matrix material.

Step 5

While pouring the slurry in the Mold the flow of the slurry is kept uniform to avoid trapping of gas. Then it is quick quenched with the help of air to reduce the settling time of the particles in the matrix. After stirring molten slurry is poured into the desired Mold with preferred dimensions which would be facilitated for conduct various tests on it.In this project work Aluminium based metal matrix composite were produced in the laboratory by using stir casting method. Aluminium 2024 was selected as matrix material Reinforcement materials were Graphite and silicon nitrate[4].

The specimen pieces were casted for 5% and 10% following tests were conducted ,

1) Hardness Test
2) Microstructure Test
3) Strength Test

1.1 METAL MATRIX COMPOSITE

A metal matrix composite (MMC) is Composite material with at least two constituent parts, one being a metal necessarily; the other material may be a different metal or another material, such as a ceramic or organic compound. When at least three materials are present, it is called a hybrid composite. An MMC is complementary to a cermet.MMCs are made by dispersing a reinforcing material into a metal matrix. The reinforcement surface can be coated to prevent a chemical reaction with the matrix. For example, carbon fibers are commonly used in aluminium matrix to synthesize composites showing low density and high strength. However, carbon reacts with aluminium to generate a brittle and water-soluble compound AL4C3 on the surface of the fiber. To prevent this reaction, the carbon fibers are coated with nickel or titaniumboride[5].

1.2 LIQUID CASTING PROCESS

Casting is a manufacturing process in which a liquid material is usually poured into a mold, which contains a hollow cavity of the desired shape, and then allowed to solidify. The solidified part is also known as a casting, which is ejected or broken out of the mold to complete the process. Casting materials are usually metals or various cold setting materials that cure after mixing two or more components together; examples are metals, concrete, plaster and clay. Casting is most often used for making complex shapes that would be otherwise difficult or uneconomical to make by other methods, In metalworking, metal is heated until it becomes liquid and is then poured into a mold. The mold is a hollow cavity that includes the desired shape, but the mold also includes runners and risers that enable the metal to fill the mold. The mold and the metal are then cooled until the metal solidifies. The solidified part (the casting) is then recovered from the mold. Subsequent operations remove excess material caused by the casting process (such as the runners and risers).

1.3 STIR CASTING PROCESSES

It is a liquid state processing. It incorporation of ceramics particles into liquid aluminium melt and allowing the mixture of solidifying. The simplest and most commercially used technique is known as stir casting technique.The matrix material used for the present study is Aluminium LM 24. The chemical composition of matrix material. Si_3N_4 particles with size of 125µm and with varying amounts of 6, 9 and 12wt% are being used as reinforcing material in the preparation of composites. Stir casting technique has been used for the preparation of composites. Initially calculated amount Aluminium LM 24 was charged into graphite crucible and superheated to a temperature of 2256^0C in an electrical resistance furnace. The furnace temperature was controlled to an accuracy of 50^0C using a digital temperature controller. A novel three stage mixing combined with preheating of the reinforcing particles is followed. Ceramic Si_3N_4 particulates were preheated to a temperature of 200^0C in an oven to remove the adsorbed gases from the particle surface and to avoid high drop of temperature after addition of particulates.. Vortex is generated with the help of a zirconia coated steel impeller. The extent of incorporation of Si_3N_4 particles in the matrix alloy was achieved in steps of 3. Total amount of reinforcement required was calculated and is being introduced into the melt 3 times rather than introducing all at once. At every stage before and after introduction of reinforcement, mechanical stirring is carried out for a period of 10 min.

The stirrer was preheated before immersing into the melt, and is located approximately to a depth of 2/3 height of the molten metal from the bottom and run at a speed of 200 rpm. Composite mixture was poured into permanent cast iron moulds having diameter 12.5mm and length of 125mm at a pouring temperature of 750^0C. The prepared composites were characterized by microscopic studies. The density of the samples were measured by Archimedes' method while theoretical density is computed by taking densities of Aluminium LM 24 and Si_3N_4 particles as 2.7 and 3.9gm/cm3 respectively. To investigate the mechanical behavior of the composites the hardness and tensile tests were carried out using Zwick and computerized uni-axial tensile testing machine. Fig.1. Shows the dimensions of the mould and specimen used for tensile studies. The Micro-Vickers hardness values of the composites before and after addition of A Si_3N_4 particles were measured with a load of 20N using MVH-II digital micro hardness tester (Zwick/Roell indentec). The hardness value reported is the average value of 100 readings taken at various locations on the polished specimen. Similarly tensile tests were carried out before and after addition of Si_3N_4 particles and for each of the composite three tests were conducted and average value is reported[6].

II.LITERATURE REVIEW

2.1. Literature review

The sustained interest to develop engineering materials which could cope with the raised performance standards, resulted in emergence of a newer class of materials, called Metal Matrix Composites (MMCs). They constitute a family of customizable materials with customizable critical-property relationships. Such materials are known for their exceptional high modulus, stiffness, wear resistance, fatigue life, strength-to-weight ratios, tailor able coefficient of thermal expansion, etc. With these enhancements in properties, they pose for strong candidature for replacing conventional structural materials. The Aluminium metal matrix composite characteristic is observed in these following journals.

V.Balajia, N.Sateeshb, M.ManzoorHussainc, "Manufacture of Aluminium Metal Matrix Composite (Al7075-SiC) by Stir Casting Technique" (2015) – The work focused on the manufacturing of gear with AMMC material using stir casting process. The various tests have been conducted on AMMC material to know the various properties (Tensile strength and hardness) and it was observed that there is an increase in strength and hardness by 10 percent compared to Al6061. From Micro structure analysis conducted on the material reveals that uniform distribution of SiC particles in the metal matrix system. The performance test was conducted on the manufactured gear to analyses wear resistance of the matrix material. Stir casting method used in the matrix preparation is best economical method to produce the matrix. Al 7075-SiC matrix has been selected for the manufacture since it has potential applications in aircraft and space industries because of higher strength to weight ratio, high wear resistance and creep resistance. From the studies in overall it can be concluded that Al7075-SiC exhibits superior mechanical and tribological properties.

Anthony Xavior Ma*., Ajith Kumar J Pb "Machinability of Hybrid Metal Matrix Composite - A Review" (2017)- Machining operations generally requires minimum tool wear rate and good surface finish with lowest energy requirement. Hard metal, ceramic and oxide reinforcements in the composite increase the tool wear and machining cost. To improve tool life and increase the metal removal rate significant care is needed for the selection of optimum cutting parameters and cutting conditions. This review focuses on the influence of reinforcement particle's types, shape, size and volume fractions on the machinability issues like the cutting force, tool wear, chip formation and surface roughness. Further, the role of various cutting parameters like cutting speed, feed, depth of cut and tool material, tool geometry and cutting conditions during turning of hybrid metal matrix composites are critically reviewed.

Ion Badoia*, Dan M. Constantinescua,(2017)- "Wear behavior of metal matrix composites in comparison to sintered metal carbides" (2016)- Substantial progress in the development of aluminum and steel matrix composites achieved in the last years introduced these materials into the most important industrial applications. The possibility of combining various materials systems (metal-ceramic particles) gives opportunity for unlimited properties. The advantages of the composite materials are put in value when the cost - performance relation is optimum. One way to produce these advanced materials as having low cost and optimal wear properties is powder metallurgy. The objective of this work is to characterize the wear properties of Functionally Graded Composite Materials (FGCMs) achieved in three layers in which one layer of the system is Metal Matrix Composites (MMCs), in comparison to Sintered Metal Carbides (SMCs) of types K 20 (85%WC + 15%Co) and M 20 (75%WC + 16%TiC + 9%Co).

Rupinder Singh∗, Gagandeep Singh "Investigations of Al–SiC AMC prepared by vacuum moulding assisted stir casting" (2015)- The dry sliding wear is one of the most important properties of metal matrix composite to highlight the performance of the material. In this research work an attempt has been made for improving dry sliding wear properties of aluminium matrix composite (AMC) consisting of Al-6063 matrix and SiC reinforcement prepared through vacuum moulding assisted stir casting (VMASC) as process development for various industrial applications. The study of VMASC for preparing AMC highlights the novel method (being a green process) for improving the material performance. The controllable process parameters of stir casting (namely: particle size of solute (SiC), proportion of SiC) and vacuum moulding process (namely: vacuum pressure and sand grain size) were studied to find out their affect on wear properties of AMC. Wear was examined on 'pin-on-disc type tribological tester'. The results of the study highlights that as regards to dry sliding wear; sand grain size, vacuum pressure, particle size, and proportion of SiC; have contributed 5.95%, 10.14%, 10.71% and 73.2%, respectively. The improvement in material performance of the AMC prepared by using VMASC was counter verified with microstructure analysis.

Yunfeng Su a,b, Yongsheng Zhang a,n, Junjie Song a,b, LitianHua "Tribological behavior and lubrication mechanism of self-lubricating ceramic/metal composites: The effect of matrix type on the friction and wear properties" (2017)- This study aim sat revealing the mechanisms of how matrix type and lubricant content affect the lubricating properties of graphite depend self-lubricating composites. Self-lubricating mechanism and tribological properties of three kinds of lubricating material shaving different matrix-types(copper alloy, zirconia and alumina)are investigated.

III. MATERIAL PROPERTIES

3.1 Aluminium LM24

Aluminium or aluminum (in North American English) is a chemical element in the boron group with symbol Al and atomic number 13. It is a silverywhite, soft, nonmagnetic, ductile metal. By mass, aluminium makes up about 8% of the Earth's crust; it is the third most abundant element after oxygen and silicon and the most abundant metal in the crust, though it is less common in the mantle below. Aluminium metal is so chemically reactive that native specimens are rare and limited to extreme reducing environments. Instead, it is found combined in over 270 different minerals. The chief ore of aluminium is bauxite. Aluminium is remarkable for the metal's low density and its ability to resist corrosion through the phenomenon of passivation. Aluminium and its alloys are vital to the aerospace industry and important in transportation and structures, such as building facades and window frames. The oxides and sulfates are the most useful compounds of aluminium. Despite its prevalence in the environment, no known form of life uses aluminium salts metabolically, but aluminium is well tolerated by plants and animals. Because of these salts' abundance, the potential for a biological role for them is of continuing interest, and studies continue.Aluminium is a relatively soft, durable, lightweight, ductile, and malleable metal with appearance ranging from silvery to dull gray, depending on the surface roughnessIt is easily machined, cast, drawn and extruded.Corrosion resistance can be excellent because a thin surface layer of aluminium oxide forms when the bare metal is exposed to air, effectively preventing further oxidation, in a process termed passivation. The strongest aluminium alloys are less corrosion resistant due to galvanic reactions with alloyed copper. This corrosion resistance is greatly reduced by aqueous salts, particularly in the presence of dissimilar metals[7].

Stable aluminium is created when hydrogen fuses with magnesium, either in large stars or in supernovae. It is estimated to be the 14th most common element in the Universe, by massfraction. However, among the elements that have odd atomic numbers, aluminium is the third most abundant by mass fraction, after hydrogen and nitrogen. In the Earth's crust, aluminium is the most abundant (8.3% by mass) metallic element and the third most abundant of all elements (after oxygen and silicon). The Earth's crust has a greater abundance of aluminium than the rest of the planet, primarily in aluminium silicates. In the Earths mantle, which is only 2% aluminium by mass, these aluminium silicate minerals are largely replaced by silica and magnesium oxides. Overall, the Earth is about 1.4% aluminium by mass (eighth in abundance by mass)[8].

Table: 3.1 - Properties of Aluminium LM24

Hardness, Brinell	150 BHN
Hardness, Knoop	191
Hardness, Rockwell A	53.3 RHN

Hardness, Rockwell B	87 RHN
Ultimate Tensile Strength	572 MPa
Tensile Yield Strength	503 MPa
Shear Strength	331 MPa
Density	2.81 g/cc
Modulus of El Asticity	71.7 GPa

3.2Silicon nitrate

Silicon nitride is a chemical compound of the elements silicon and nitrogen, with the formula Si_3N_4. It is a white, high melting point solid that is relatively chemically inert, being attacked by dilute HF and hot H_2SO_4. It is very hard (8.5 on the mohs scale).It is the most thermodynamically stable of the silicon nitrides.Hence, Si_3N_4 is the most commercially important of the silicon nitrides and is generally understood as what is being referred to where the term "silicon nitride" is used.Silicon nitride is difficult to produce as a bulk material—it cannot be heated over 1850 °C, which is well below its melting point, due to dissociation to silicon and nitrogen. Therefore, application of conventional hot press sintering techniques is problematic. Bonding of silicon nitride powders can be achieved at lower temperatures through adding additional materials (sintering aids or "binders") which commonly induce a degree of liquid phase sintering. A cleaner alternative is to use spark plasma sintering where heating is conducted very rapidly (seconds) by passing pulses of electric current through the compacted powder. Dense silicon nitride compacts have been obtained by this techniques at temperatures 1500–1700 °C[9].

Silicon nitride has long been used in hightemperature applications. In particular, it was identified as one of the few monolithic ceramic materials capable of surviving the severe thermal shock and thermal gradients generated in hydrogen/oxygen rocket engines. To demonstrate this capability in a complex configuration, NASA scientists used advanced rapid prototyping technology to fabricate a oneinchdiameter, singlepiece combustion chamber/nozzle (thruster) component. The thruster was hotfire tested with hydrogen/oxygen propellant and survived five cycles including a 5minute cycle to a 1320 °C material temperature.The first major application of Si_3N_4 was abrasive and cutting tools. Bulk, monolithic silicon nitride is used as a material for cutting tools, due to its hardness, thermal stability, and resistance to wear. It is especially recommended for high speed machining of cast iron. Hot hardness, fracture toughness and thermal shock resistance mean that sintered silicon nitride can cut cast iron, hard steel and nickel based alloys with surface speeds up to 25 times quicker than those obtained with conventional materials such as tungsten carbide. The use of Si_3N_4 cutting tools has had a dramatic effect on manufacturing output. For example, face milling of gray cast iron with silicon nitride inserts doubled the cutting speed, increased tool life from one part to six parts per edge, and reduced the average cost of inserts by 50%, as compared to traditional tungsten carbide tools.

3.3 Graphite

Graphite is an excellent conductor of heat and electricity and has the highest natural strength and stiffness of any material. It maintains its strength and stability to temperatures in excess of 3,600°C and is very resistant to chemical attack. At the same time it is one of the lightest of all reinforcing agents and has high natural lubricate.Graphite (pronunciation: /ˈgraphite /), archaically referred to as plumbago, is a crystalline form of carbon, a semimetal, a native element mineral, and one of the allotropes of carbon. Graphite is the most stable form of carbon under standard conditions. Therefore, it is used in thermochemistry as the standard state for defining the heat of formation of carbon compounds [10].

Graphite has a layered, planar structure. The individual layers are called graphene. In each layer, the carbon atoms are arranged in a honeycomb lattice with separation of 0.142 nm, and the distance between planes is 0.335 nm. Atoms in the plane are bonded covalently, with only three of the four potential bonding sites satisfied. The fourth electron is free to migrate in the plane, making graphite electrically conductive. However, it does not conduct in a direction at right angles to the plane. Bonding between layers is via weak van der Waals bonds, which allows layers of graphite to be easily separated, or to slide past each other.

IV. TESTING PROCESS

4. Hardness testing process

Hardness is the property of a material that enables it to resist plastic deformation, usually by penetration. However, the term hardness may also refer to resistance to bending, scratching, abrasion or cutting.

4.1The Rockwell hardness testing

The Rockwell hardness test method consists of indenting the test material with a diamond cone or hardened steel ball indenter. The indenter is forced into the test material under a preliminary minor load $F0$ (Fig. 1A) usually 10 kgf. When equilibrium has been reached, an indicating device, which follows the movements of the indenter and so responds to changes in depth of penetration of the indenter is set to a datum position. While the preliminary minor load is still applied an additional major load is applied with resulting increase in penetration (Fig. 1B). When equilibrium has again been reach, the additional major load is removed but the preliminary minor load is still maintained. Removal of the additional major load allows a partial recovery, so reducing the depth of penetration (Fig. 1C). The permanent increase in depth of penetration, resulting from the application and removal of the additional major load is used to calculate the Rockwell hardness number.

Advantages of the Rockwell hardness method include the direct Rockwell hardness number readout and rapid testing time. Disadvantages include many arbitrary non-related scales and possible effects from the specimen support anvil (try putting a cigarette paper under a test block and take note of the effect on the hardness reading! Vickers and Brinell methods don't suffer from this effect).

F : Total load in kgf
e :permanent increase in depth of penetration due to major load F1 measured in units of 0.002 mm
E : A constant depending on form of indenter: 100 units for diamond indenter, 130 units for steel ball indenter
HR : Rockwell hardness number
D :Diameter of steel ball

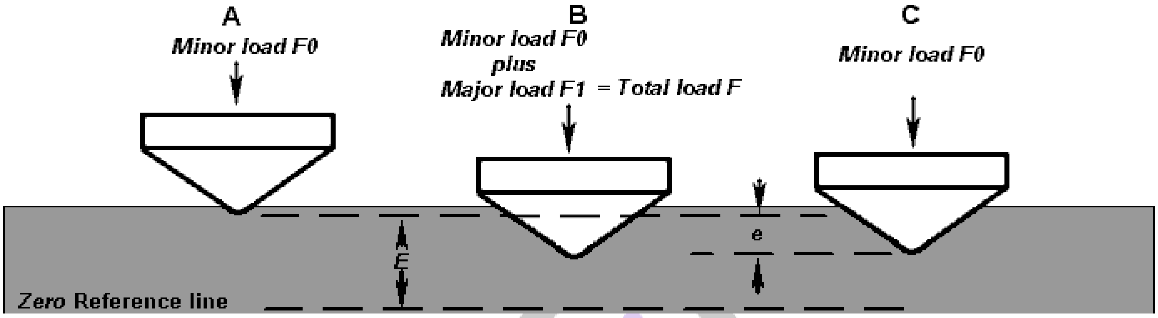
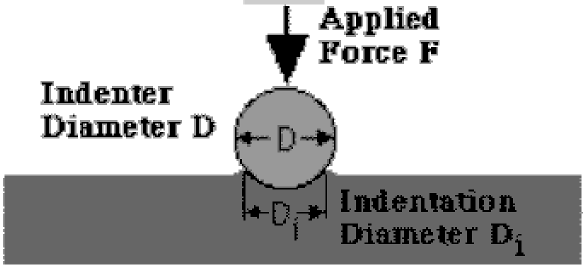


Fig. 4.1.Rockwell Principle

4.2. The Brinell hardness Test

The Brinell hardness test method consists of indenting the test material with a 10 mm diameter hardened steel or carbide ball subjected to a load of 3000 kg. For softer materials the load can be reduced to 1500 kg or 500 kg to avoid excessive indentation. The full load is normally applied for 10 to 15 seconds in the case of iron and steel and for at least 30 seconds in the case of other metals. The diameter of the indentation left in the test material is measured with a low powered microscope. The Brinell harness number is calculated by dividing the load applied by the surface area of the indentation.

The diameter of the impression is the average of two readings at right angles and the use of a Brinell hardness number table can simplify the determination of the Brinell hardness. A well-structured Brinell hardness number reveals the test conditions, and looks like this, "75 HB 10/500/30" which means that a Brinell Hardness of 75 was obtained using a 10mm diameter hardened steel with a 500 kilogram load applied for a period of 30 seconds. On tests of extremely hard metals a tungsten carbide ball is substituted for the steel ball. Compared to the other hardness test methods, the Brinell ball makes the deepest and widest indentation, so the test averages the hardness over a wider amount of material, which will more accurately account for multiple grain structures and any irregularities in the uniformity of the material. This method is the best for achieving the bulk or macro-hardness of a material, particularly those materials with heterogeneous structures.



$$\mathrm{BHN} = \frac{F}{\frac{\pi}{2} D \cdot \left(D - \sqrt{D^2 - D_i^2}\right)}$$

Fig. 4.2.Brinell Principle

Scanning Electron Microscopy testing

A micro structural analysis is performed in order to evaluate the microstructure in a metal alloy. The observation is made at different magnifications depending on the observation to be made.


Fig. 4.3 Testing machine

Fig. 4.4 Tested specimen

The microstructure of a material allows evaluating the state of supply and the possible presence of metallurgical defects. The sample should be collected from a section of the piece under analysis in order to include both an observation at core and on the surface; the ideal would be to obtain multiple sections in massive and thin areas in order to observe how the characteristics vary as a function of thickness.To perform this analysis it is sufficient to have samples of small dimensions (a few mm2), although it would be ideal performing the test on most representative areas.

V.MATERIALS COMPOSITE

Table 5.1 Composition

S. NO	MATERIALS	SPECIMEN
1.	AL LM 24	600gm
2.	Silicon nitrate	60gm (10%)
3.	Graphite	6gm (1%)

VI.RESULT AND DISCUSSION

6.1.Scanning Electron Microscopy (SEM)

The scanning electron microscope (SEM) uses a focused beam of high-energy electrons to generate a variety of signals at the surface of solid specimens. The signals that derive from electron-sample interactions reveal information about the sample including external morphology (texture), chemical composition, and crystalline structure and orientation of materials making up the sample. In most applications, data are collected over a selected area of the surface of the sample, and a 2-dimensional image is generated that displays spatial variations in these properties. Areas ranging from approximately 1 cm to 5 microns in width can be imaged in a scanning mode using conventional SEM techniques (magnification ranging from 20X to approximately 30,000X, spatial resolution of 50 to 100 nm). The SEM is also capable of performing analyses of selected point locations on the sample; this approach is especially useful in qualitatively or semi-quantitatively determining chemical compositions (using EDS), crystalline structure, and crystal orientations (using EBSD). The design and function of the SEM is very similar to the EPMA and considerable overlap in capabilities exists between the two instruments.

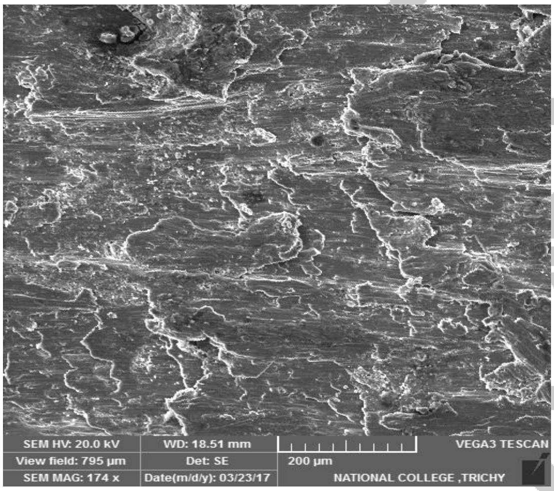


Fig. 6.1Testing Result SEM

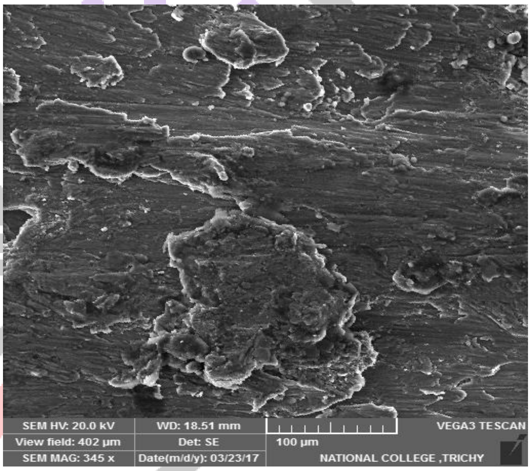


Fig. 6.2Testing Result SEM

The above figure shows the microstructure of specimen 1 composition. In that there are long black spots are the boron carbide and the black points are the graphite and other white surface is aluminium alloy 7075.The specimen 1 have an aluminium alloy 7075 at 95 wt. %, boron carbide 2 wt. % and graphite 3 wt. %.

6.2 ***Rockwell hardness test***

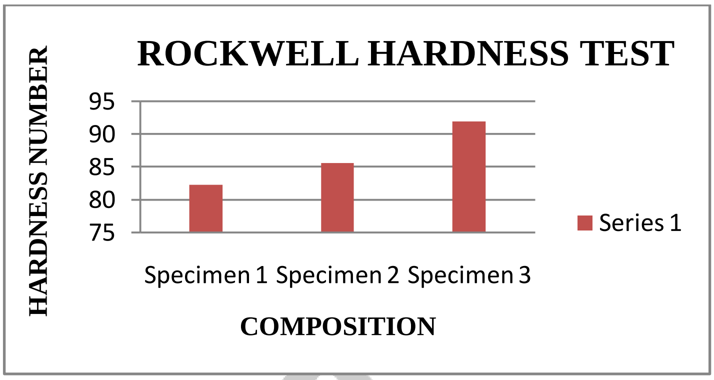
Apparatus required

- Rockwell hardness tester,
- Specimen,
- Ball indicator,
- Diamond indenter.

TabulationTable 6.1 Composition

S.NO	**Composition**	**I**	**II**	**III**	**Hardness number**
1.	Specimen	89	79	79	82.3 RHN

Load at 60 kg *Chart*



Graph: 6.1 Rockwell Hardness Test

6.3 Brinell hardness test

Fig.6.3 Testing Machine

TabulationTable 6.2 Composition

s.no	Composition	Indenter Diameter (mm)		**BHN**
		5	10	
		Load (kgf)		
		1000	2000	
		Indentation diameter (mm)		
1.	Sp. 1	3	3.9	142.25

Formula:

BHN = [Load of bar / Area of indenter] =$\frac{P}{\pi\left(\frac{D}{2}\right)(D2-d2)}$

P - Load applied
D - Indentation diameter
d - Indenter Diameter

SPECIMEN 1

P=1000kgf , 2000kgf
D=5mm & 10mm
d=3mm& 3.9 mm

BHN=1000/π (5/2) (5-$\sqrt{52 - 32)}$ = 127.32
BHN=2000/π (10/2) (10-$\sqrt{102 - 3.92)}$ = 157.23
BHN=127.32+157.23=142.25

SPECIMEN 2

P=1000kgf & 2000kgf

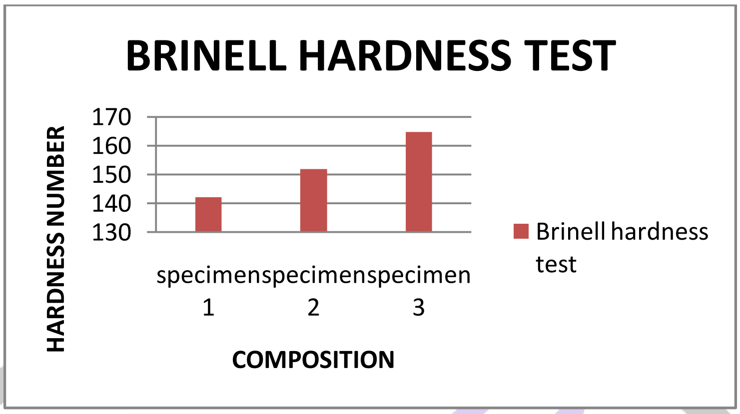
D=5mm & 10mm
d=2.7mm &3.79mm

$$\textbf{BHN}=1000/\pi\ (5/2)\ (5-\sqrt{52-2.72}) = 145.47$$
$$\textbf{BHN}=2000/\pi\ (10/2)\ (10-\sqrt{102-3.792}) = 158.32$$
$$\textbf{BHN}=145.47+158.32=151.89$$

SPECIMEN 3

P=1000kgf & 2000kgf
D=5mm & 10mm
d=2.7mm &3.8mm

$$\textbf{BHN}=1000/\pi\ (5/2)\ (5-\sqrt{52-2.72}) = 160.20$$
$$\textbf{BHN}=2000/\pi\ (10/2)\ (10-\sqrt{102-3.82}) = 169.15$$
$$\textbf{BHN}=160.82+169.73=164.67$$



Graph: 6.2 Brinell Hardness Test

*6.4. **Microstructure study***

Microstructure for different samples was studied using scanning electron microscope. Where microstructure was viewed under scanning electron microscope.The distribution of B4C particulates in specimens and it can be observed that there is fairly uniform distribution of particles. Excellent bonding between the matrix and the reinforcement is observed.The microstructure study is very useful for the analysis of properties and proportion of mixing in the aluminum matrix.In that the microstructure reveals the strength of materials. A carefully prepared specimen and magnification areneeded for microscopic examination.Proper preparation ofthe specimen and the material's surface requires that a rigidstep-by-step process be followed.The first step is carefully selecting a small sample of the material to undergomicrostructure analysis with consideration given to locationand orientation.This step is followed by sectioning,mounting, grinding, polishing and etching to reveal accuratemicrostructure and content.

Specimen 1

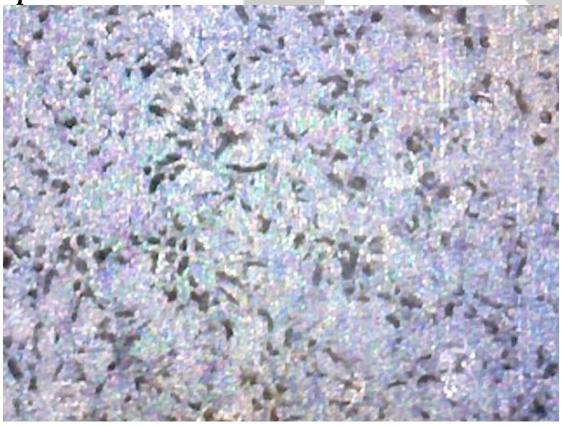


Fig. 6.4 Tested specimen

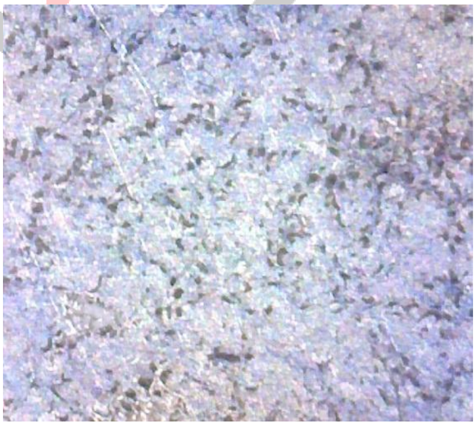


Fig.6.5Tested specimen

The above figure shows the microstructure of specimen 1 composition. In that there are long black spots are the boron carbide and the black points are the graphite and other white surface is aluminium alloy 7075.The specimen 1 have an aluminium alloy 7075 at 95 wt. %, boron carbide 2 wt. % and graphite 3 wt. %.

Specimen 2

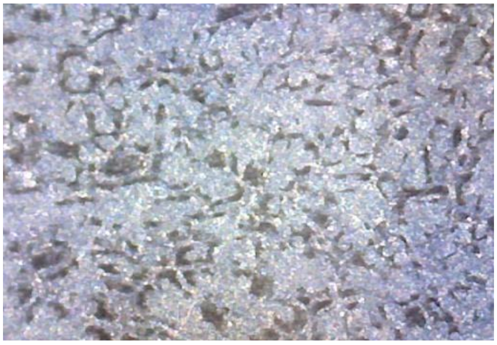


Fig. 6.5 Tested specimen

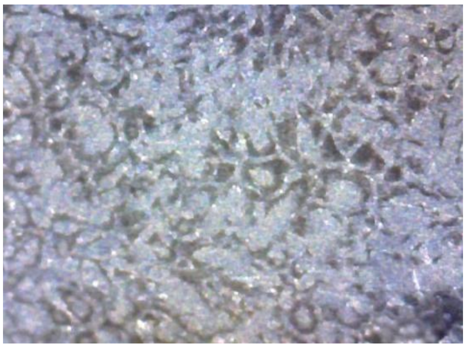


Fig. 6.6 Tested specimen

The above figure shows the microstructure of specimen 2 composition. In that there are long black spots are the boron carbide and the black points are the graphite and other white surface is aluminium alloy 7075.

The specimen 1 have an aluminium alloy 7075 at 95 wt. %, boron carbide 2.5 wt. % and graphite 2.5 wt. %.

Specimen 3

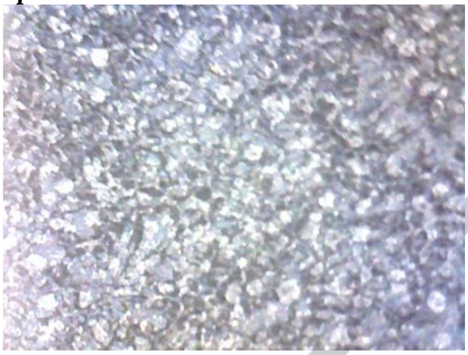


Fig. 6.7 Tested specimen

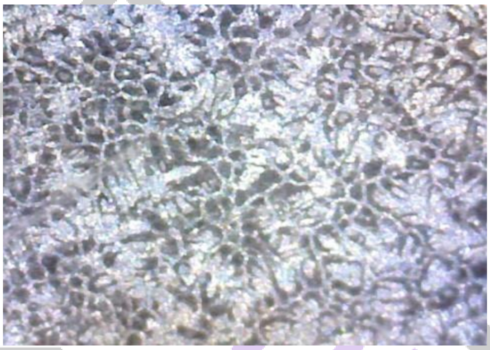


Fig. 6.8Tested specimen

The above figure shows the microstructure of specimen 3 composition. In that there are long black spots are the boron carbide and the black points are the graphite and other white surface is aluminium alloy 7075.The specimen 1 have an aluminium alloy 7075 at 95 wt. %, boron carbide 3 wt. % and graphite 2 wt. %.

6.5 Rockwell hardness test:

Apparatus required

- Rockwell hardness tester,
- Specimen,
- Ball indicator,
- Diamond indenter.\

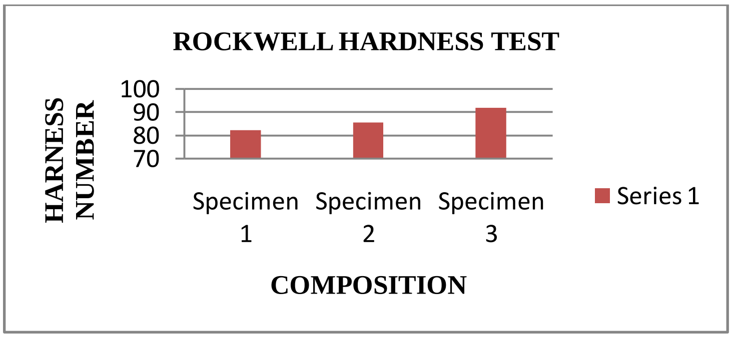
Table

Table6.3 Composition

S	**Composition**	**I**	**II**	**III**	**Hardness number**
1.	Specimen 1	89	79	79	82.3 RHN
2.	Specimen 2	83	88	86	85.6 RHN
3.	Specimen 3	92	94	90	92 RHN

Load at 60 kg

Chart



Graph: 6.3 Rockwell Hardness Test

6.6 Brinell hardness test

TabulationTable 6.4 Composition

s.no	Composition	Indenter Diameter (mm)		**BHN**
		5	10	
		Load (kgf)		
		1000	2000	
		Indentation diameter (mm)		
1.	Sp. 1	3	3.9	142.25
2.	Sp. 2	2.7	3.7	151.89
3.	Sp. 3	2.8	3.8	164.67

Formula

BHN = [Load of bar / Area of indenter] =$\frac{P}{\pi\left(\frac{D}{2}\right)(D2-d2)}$

P - Load applied
D - Indentation diameter
d - Indenter Diameter

SPECIMEN 1

P=1000kgf , 2000kgf
D=5mm & 10mm
d=3mm & 3.9 mm

BHN=1000/π (5/2) (5-$\sqrt{52-32)}$ = 127.32
BHN=2000/π (10/2) (10-$\sqrt{102-3.92)}$ = 157.23
BHN=127.32+157.23=142.25

SPECIMEN 2

P=1000kgf & 2000kgf
D=5mm & 10mm
d=2.7mm & 3.79mm

BHN=1000/π (5/2) (5-$\sqrt{52-2.72)}$ = 145.47

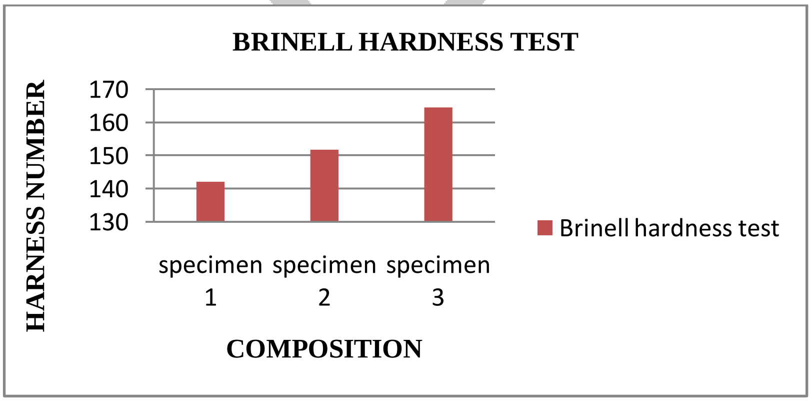
BHN=2000/π (10/2) (10-$\sqrt{102-3.792)}$ = 158.32

BHN=145.47 +158.32=151.89

SPECIMEN 3

P=1000kgf & 2000kgf
D=5mm & 10mm
d=2.7mm & 3.8mm

BHN=1000/π (5/2) (5-$\sqrt{52-2.72)}$ = 160.20
BHN=2000/π (10/2) (10-$\sqrt{102-3.82)}$ = 169.15
BHN=160.82+169.73=164.67



Graph:6.4 Brinell Hardness Test

6.7.Double shear stress

Shear strength= Load/Area

Table 6.5 Double shear stress

s.no	Material	Diameter (mm)	Max. load applied	shear strength
1.	Sp. 1	8	10.42	103.65
2.	Sp. 2	8	11.82	117.57
3.	Sp. 3	8	12.53	124.67

ADVANTAGES

- The advent of advanced fiber reinforced composite materials has been called the biggest technical revolution since the jet engine.
- The impact on commercial aviation is even more striking because the airline switched from propeller driven planes to all jet fleets within the span of just a few years because of superior performance and lower maintenance cost.
- The adjectives advanced in advanced fiber reinforced composite materials are used to distinguish composite material with ultrahigh strength and hardness materials as boron and graphite from some of more familiar.
- Such advanced composite materials have two major advantages, among many others: improve strength and hardness, especially when compared with others materials on unit Wight basis.
- For example, composite materials can have made that have the same hardness and strength as high strength steel, yet are 70% lighter.
- Other advanced composite materials are as much as three times as strong as aluminium; the common aircraft structure material, yet weigh only 60% as much.
- Expecially in this project the aluminium alloy 7075 have more advantages.
- Reinforcing the composite material in the aluminium alloy 7075 we can obtained even more hardness.
- The reinforcement of boron carbide and graphite in the aluminium alloy 7075 that increases the hardness of material.
- Boron Carbide is one of the hardest materials known, ranking third behind diamond and cubic boron nitride.
- It is the hardest material produced in tonnage quantities.
- Graphite is an excellent conductor of heat and electricity and has the highest natural strength and stiffness of any material.
- At the same time it is one of the lightest of all reinforcing agents and has high natural lubricate.

Applications

The SEM is routinely used to generate high-resolution images of shapes of objects (SEI) and to show spatial variations in chemical compositions:

1) acquiring elemental maps or spot chemical analyses using EDS,

2)discrimination of phases based on mean atomic number (commonly related to relative density) using BSE,

3) compositional maps based on differences in trace element "activitors" (typically transition metal and Rare Earth elements) using CL.

VII.CONCLUTION

Hence we have finished our project under casting method with powder form of aluminium LM24, silicon nitrate, graphite. In this work the experiment and analysis on the fabricated composite materials has been done successfully. The results of the composite materials which is fabricated by using stir casting technique to determine Hardness test has been taken to find out the microstructure and strength test has been taken in the reinforcement particles of the silicon nitrate and graphite in different composition. We have the specimen and the results thus the report is compared with specimen A, B, C of our project and verify that the specimen C is have more hardness. So we sudjuced that specimen C – (92% - 3%-5%)is the best composition for air craft window frame works.This will increase the hardness of the aluminiumLM24. It is observed that the investigational results meet the confidence limits.

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