Preparation of Aluminium Reinforced with Granite and Graphite – A Hybrid Metal Matrix Composite

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***Abstract*— Now-a-days composite materials have become more popular for its wide range of applications and design flexibility. Since the fuel costs are increasing day to day, most of the automobile industries are conducting various experiments to develop composites having less densities and superior mechanical and tribological properties which are equally cost effective. In view of the above, most of the research has been focused on improving mechanical and tribological properties of aluminium alloys by adding with ceramic reinforcements.**

Granite is a common type of igneous rock consists mainly of quartz and other minerals. It possesses high compressive strength, impervious and inflexible. Granite powder is most inexpensive as it comes as waste in granite cutting factories. Graphite is well known for its self-lubricating properties, which is a semi metal and an allotrope of carbon.

Research was done to improve the properties of aluminium using both graphite and granite as reinforcements separately. Till now, no work is done on the combination of both granite and graphite in a single composite.

Keywords*— *Aluminium alloy, Metal Matrix Composite (MMC)etc.,

I. INTRODUCTION

1.1 Composite Material

A composite is when two or more different materials are combined together to create a superior and unique material. A composite material is made by combining two or more materials – often ones that have very different properties. The two materials work together to give the composite unique properties. However, within the composite you can easily tell the different materials apart as they do not dissolve or blend into each other.

1.1.1 Natural Composites

Many of us may not be noticed that several, naturally formed materials around us are composites.Wood is a composite made from cellulose and lignin. The advanced forms of wood composites can be ply-woods. An excellent example of natural composite is muscles of human body. The muscles are present in a layered system consisting of fibers at different orientations and in different concentrations. These result in a very strong, efficient, versatile and adaptable structure. The muscles impart strength to bones and vice a versa. These two together form a structure that is unique. The bone itself is a composite structure. The bone contains mineral matrix material which binds the collagen fibres together.

The other examples include: wings of a bird, fins of a fish, trees and grass. A leaf of a tree is also an excellent example of composite structure. The veins in the leaf not only transport the food and water but also impart the strength to the leaf so that the leaf remains stretched with maximum surface area. This helps the plant to extract more energy from sun during photo-synthesis.

1.1.2 Man-Made Composites

These composites are made by artificial mixing of two or more materials in definite proportions under controlled conditions. Mud mixed straw to produce stronger mud mortar and bricks, Plywood, Chipboards, Decorative laminates, Fibre Reinforced Plastic (FRP), Carbon Composites, Concrete and RCC, Reinforced Glass etc. The composites exist in day to day life applications as well. The most common existence is in the form of concrete. The concrete is a composite made from gravel, sand and cement. Further, when it is used along with steel to form structural components in construction, it forms one further form of composite.

1.2 Why use composites?

The biggest advantage of modern composite materials is that they are light as well as strong. By choosing an appropriate combination of matrix and reinforcement material, a new material can be made that exactly meets the requirements of a particular application. Composites also provide design flexibility because many of them can be moulded into complex shapes.

1.3 History of Composites

The first uses of composites date back to the 1500s B.C. when early Egyptians and Mesopotamian settlers used a mixture on mud and straw to create strong and durable buildings. Straw continued to provide reinforcement to ancient composite products including pottery and boats.

Later, in 1200 BC, the Mongols invented the first composite bow. Using a combination of wood, bone, and animal glue, bows were pressed and wrapped with birch bark. These bows were extremely powerful and extremely accurate. Composite Mongolian bows provided

Genghis Khan with military dominance, and because of the composite technology, this weapon was the most powerful weapon on earth until the invention of gunpowder

As said, “Need is the mother of all inventions”, the modern composites, that is, polymer composites came into existence during the Second World War. During this period the fighter planes were the most advanced fighting means. The light weight yet strong materials were in high demand. Further, for application like housing of electronic radar equipment require non-metallic materials. Hence, the Glass Fibre Reinforced Plastics (GFRP’s) were first used in these applications.

Concrete is also a composite material, and is used more than any other man-made material in the world. As of 2006, about 7.5 billion cubic metres of concrete are made each year—more than one cubic metre for every person on Earth.

Woody plants, both true wood from trees and such plants as palms and bamboo, yield natural composites that were used prehistorically by mankind and are still used widely in construction and scaffolding.

Plywood 3400 BC by the Ancient Mesopotamians; gluing wood at different angles gives better properties than natural wood

Cartonnage layers of linen or papyrus soaked in plaster dates to the First Intermediate Period of Egypt c. 2181–2055 BC and was used for death masks

Cob (material) Mud Bricks, or Mud Walls, (using mud (clay) with straw or gravel as a binder) have been used for thousands of years.

Concrete was described by Vitruvius, writing around 25 BC in his Ten Books on Architecture, distinguished types of aggregate appropriate for the preparation of lime mortars. For structural mortars, he recommended pozzolana, which were volcanic sands from the sandlike beds of Pozzuoli brownish-yellow-gray in colour near Naples and reddish-brown at Rome Papier-mâché, a composite of paper and glue, has been used for hundreds of years.The first artificial fibre reinforced plastic was bakelite which dates to 1907, although natural polymers such as shellac predate itone of the most common and familiar composite is fiber glass in which small glass fiber are embedded within a polymeric material (normally an epoxy or polyester).the glass fiber is relatively strong and stiff (but also brittle),where as the polymer is ductile (but also weak and flexible).Thus the resulting fiberglass is relatively stiff, strong, flexible, and ductile.

1.4 Constituents of a Composite Material

In a composite, typically, there are two constituents. One of the constituent acts as a reinforcement and other acts as a matrix. Sometimes, the constituents are also referred as phases.

1.4.1 Matrix Phase

The primary phase, the monolithic material into which the reinforcement is embedded, and having a continuous character, is called matrix. Matrix is usually more ductile and less hard phase.

Classification of Matrix

The matrix in a composite material can be grouped based on the type of material as given below

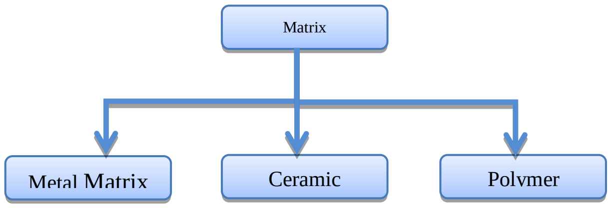

Fig.1.1 : Classification of Matrix

II. SELECTION OF COMPOSITES

2.1 Identification of Need

Usage of automobiles was increasing day to day. But at the same time, search for alternate fuels increased as the conventional non-renewable sources of petroleum getting depleted. Simultaneously, automotive industries promoting the development of lighter and fuel efficient vehicles considering the manufacturing costs and the life of the vehicle.

Composite materials have more advantages over steel in automobile manufacturing. Composites are being considered to make lighter, safer and more fuel-efficient vehicles. Affordability is an important issue in vehicle manufacturing, which includes factoring in the costs associated with a car’s complete life-cycle—including manufacturing, operating and disposal costs.

In view of developing less dense, low cost, highly durable materials for the automobile components, composites were the best choice for obtaining materials with such type of properties. Even though aluminium has replaced most of the ferrous based engine components like cylinder head, piston, cylinder block etc., its usage was restricted to very few applications due to very less wear resistance of aluminium alloys. This can be improved by pairing aluminium alloy with the materials having good tribological properties.

2.2 Selection of Matrix

Aluminium is a relatively soft, durable, lightweight, ductile and malleable metal. Aluminium is remarkable for the metal's ability to resist corrosion due to the phenomenon of passivation. Aluminium has a lower density of 2.7 g/cc compared to 7.8 g/cc of steel. Aluminium alloys are lightweight with good corrosion resistance, ductility and strength. The greater use of aluminium can decrease vehicle weight, improve its performance and reduce fuel costs.

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Pure aluminium possesses relatively poor casting features, for this reason castings are prepared from aluminium alloys. The main alloying elements are silicon, copper, magnesium, zinc, etc. Aluminium silicon alloys have good casting and corrosion resistance properties. The fluidity increases with silicon addition. The addition of copper to aluminium increases its strength and hardness. The aluminium copper alloys are heat treatable and possess good machinability. Nowadays, aluminium alloys are replacing the ferrous alloys in manufacturing of automobile components.

Even though aluminium alloys have such remarkable properties, usage of aluminium is limited to some components because, compared to ferrous alloys aluminium alloys possess less hardness and wear resistance which can be improved by mixing suitable reinforcement.

Among various aluminium alloys LM16 (Al – Si5CulMg0.5) is one of the most popular aluminium alloy used for water-cooled cylinder heads, valve bodies, water jackets, cylinder blocks, fire hose couplings, air compressor pistons, fuel pump bodies, aircraft supercharger covers and similar applications where leak-proof castings having the high strength produced by heat-treatment are required. The physical properties of composite materials are generally not isotropic (independent of direction of applied force) in nature, but rather are typically anisotropic (different depending on the direction of the applied force or load). For instance, the stiffness of a composite panel will often depend upon the orientation of the applied forces and/or moments. Panel stiffness is also dependent on the design of the panel.

2.2.1 Chemical Composition of LM16 Alloy

According to BS 1490; 1988 the chemical composition of LM16 alloy by weight is given below table 2.1.

Copper	1.0 - 1.5
Magnesium	0.4 - 0.6
Silicon	4.5 - 5.5
Iron	0.6 max
Manganese	0.5 max
Nickel	0.25 max
Zinc	0.1 max
Lead	0.1 max
Tin	0.05 max
Titanium	0.2 max
Aluminium	Remainder

2.2.1 Mechanical Properties of LM16 Alloy

According to BS 1490; 1988 the mechanical properties of LM16 alloy is as below

Tensile Stress (N/mm2)	270 – 280
Impact Resistance Izod (Nm)	1.4
Brinell Hardness	100 – 110
Modulus of Elasticity (x103 N/mm2)	71

Table .2.2. Mechanical properties

2.3 Types of Composite Materials

There are two classification systems of composite materials. One of them is based on the matrix material and the second is based on the reinforcing material structure:

2.3.1 Classification of Composites Based on Matrix Material

Since composite materials does not limit to any specific materials or metals, matrix can be any of the materials like plastics, glass, metals etc. all these materials were grouped based on the type of material. Error! Reference source not found. shows the classification of composites based on the matrix materials.

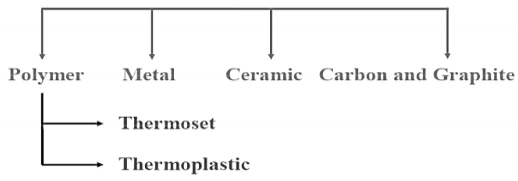

Fig.3.1. composite based matrix material

Metal Matrix Composites (MMC)

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

Ceramic Matrix Composites (CMC)

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

Polymer Matrix Composites (PMC)

Polymer Matrix Composites are composed of a matrix from thermoset (Unsaturated Polyester, Epoxy) or thermoplastic (Polycarbonate, Polyvinylchloride, Nylon, Polystyrene) and embedded glass, carbon, steel or Kevlar fibers (dispersed phase).

2.4 Selection of Reinforcements

Aluminium has very poor wear resistance compared to ferrous alloys. To improve the hardness and wear properties of aluminium alloy, reinforcement must possess relatively high hardness and wear resistance. Ceramics are the materials which stood in the top and well ahead of ferrous alloys. If a sound composite can be produced with ceramic reinforcement, then the composite may possess superior qualities equivalent or even better than some ferrous alloys.

2.5 Granite

Granite is a common type of intrusive, felsic, igneous rock. The word "granite" comes from the Latin granum, a grain, in reference to the coarse-grained structure of such a crystalline rock. This rock consists mainly of quartz, mica, and feldspar. Granites can be pink to gray in color, depending on their chemistry and mineralogy. Granite is usually found in the continental plates of the Earth's crust.

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2.5.1 Properties of granite

Granite is nearly always massive, hard and tough, and therefore it has gained widespread use as a construction stone. Its compressive strength usually lies above 200 MPa, and its melting temperature is 1215 - 1260 °C.

SiO_2 (Silica)	72.04
Al_2O_3 (Alumina)	14.42
K_2O	4.12
Na_2O	3.69
CaO	1.82
FeO	1.68
Fe_2O_3	1.22
MgO	0.71
TiO_2	0.30
P_2O_5	0.12
MnO	0.05

Table.2.3. Chemical composition of granite

2.5.2 Types of granite

The letter-based Chappell & White classification system was proposed initially to divide granites intoI-type granite (o1r igneous protolith) granite and S-type or sedimentary protolith granite. Both of these types of granite are formed by melting of high grade metamorphic rocks, either other granite orintrusive mafic rocks, or buried sediment, respectively. Derived granite was proposed later, to cover those granites which were clearly sourced from crystallized mafic magmas, generally sourced from the mantle. These are rare, because it is difficult to turn basalt into granite via fractional crystallisation.

A-type or androgenic granites are formed above volcanic "hot spot" activity and have peculiar mineralogy and geochemistry. These granites are formed by melting of the lower crust under conditions that are usually extremely dry. The rhyolites of the Yellowstone caldera are examples of volcanic equivalents of A-type granite.

H-type or hybrid granites are formed following a mixing of two granitic magmas from different sources, e.g. M-type and S-type. Most geologists today accept that a combination of these phenomena can be used to explain granite intrusions, and that not all granites can be explained entirely by one or another mechanism.

2.5.3 Applications of granite

- Antiquity
- Sculpture and memorials
- Buildings
- Engineering works

2.6 Graphite

The mineral graphite is an allotrope of carbon. Unlike diamond (another carbon allotrope), graphite is an electrical conductor, a semimetal. It is, consequently, useful in such applications as arc lamp electrodes. Graphite is the most stable form of carbon under standard conditions. Therefore, it is used in thermo chemistry as the standard state for defining the heat of formation of carbon compounds. Graphite may be considered the highest grade of coal, just above anthracite and alternatively called meta-anthracite, although it is not normally used as fuel because it is difficult to ignite.

Graphite and graphite powder are valued in industrial applications for their self-lubricating and dry lubricating properties. And hence, graphite may support granites hardness by providing a layer self-lubrication between contact surfaces resulting in increase of wear resistance.

2.6.1. Types of graphite

There are three principal types of natural graphite, each occurring in different types of ore deposit:

Crystalline flake graphite (or flake graphite for short) occurs as isolated, flat, plate-like particles with hexagonal edges if unbroken and when broken the edges can be irregular or angular;

Amorphous graphite: very fine flake graphite is sometimes called amorphous in the trade;

Lump graphite (also called vein graphite) occurs in fissureveinsor fractures and appears as massive platy intergrowths of fibrous or acicular crystalline aggregates, and is probably hydrothermal in origin.

2.6.2. Properties of graphite

Graphite has a layered, planar structure. 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..

The two known forms of graphite, alpha (hexagonal) and beta (rhombohedra), have very similar physical properties, except the graphene layers stack slightly differently. The hexagonal graphite may be either flat or buckled.[10] The alpha form can be converted to the beta form through mechanical treatment and the beta form reverts to the alpha form when it is heated above 1300 °C.

Graphite is an electric conductor, consequently, useful in such applications as arc lamp electrodes. It can conduct electricity due to the vast electron delocalization with in the carbon layers (a phenomenon called aromaticity). These valence electrons are free to move, so are able to conduct electricity. However, the electricity is primarily conducted within the plane of the layers. The conductive properties of powdered graphite allows its use as pressure sensor in carbon microphones.

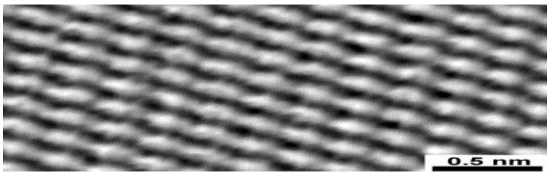

Fig .2.6. Graphite structure

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2.6.3. Applications of graphite

- Batteries
- Steelmaking
- Brake linings
- Foundry facings and lubricants
- Pencils

2.7. Selection of Process

There are many advanced processes for producing metal matrix composites with discontinuous particulate reinforcement. Among all the processes, stir casting route by producing vortex in the crucible by means of mechanical stirring is the most suitable and cost effective method for producing larger components with homogeneous mixture of metal-ceramic particulates .

2.7. Selection of Optimal Composition

It is obvious that the properties of the final composite depend on the optimal composition of the Granite and Graphite. According to various studies conducted on Al-Gr MMC's, better properties were obtained up to 4% of Graphite in the Al matrix and the grain size of Graphite particulates varies from 40 to 150 microns based on process parameters.

III.PREPARATION OF METAL MATRIX COMPOSITES

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 cermets.

3.1. Composition

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 fiber 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 Al_4C_3 on the surface of the fibre. To prevent this reaction, the carbon fibres are coated with nickel or titanium boride.

3.1.1. Matrix

The matrix is the monolithic material into which the reinforcement is embedded, and is completely continuous. This means that there is a path through the matrix to any point in the material, unlike two materials sandwiched together. In structural applications, the matrix is usually a lighter metal such asaluminium ,magnesium, or titanium, and provides a compliant support for the reinforcement. In high-temperature applications, cobalt and cobalt–nickel alloy matrices are common.

3.1.2. Reinforcement

The reinforcement material is embedded into a matrix. The reinforcement does not always serve a purely structural task (reinforcing the compound), but is also used to change physical properties 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 worked with standard metalworking techniques, such as extrusion, forging, or rolling. In addition, they may be machined using conventional techniques, but commonly would need the use of polycrystaline diamond tooling (PCD).

Classification of Composites Based on Reinforcing Material

Reinforcing material in composites can be of different materials or the combination of two or more materials (Hybrid Composites). One simple schema for the classification of composites bases on reinforcing material.

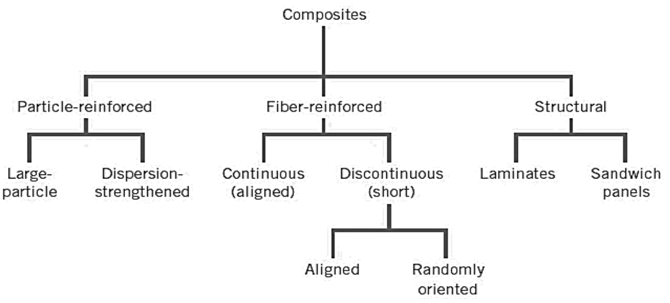

Fig 3.1. Classification of Composites Based on Reinforcements

Particulate Composites

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

- Composites with random orientation of particles.
- Composites with preferred orientation of particles. Dispersed phase of these materials consists of two-dimensional flat platelets (flakes), laid parallel to each other.

Fibrous Composites

- Short-fiber reinforced composites. Short-fiber reinforced composites consist of a matrix reinforced by a dispersed phase in form of discontinuous fibers.
    - Composites with random orientation of fibers.
    - Composites with preferred orientation of fibers.

3.2. Manufacturing and forming methods of MMC

MMC manufacturing can be broken into three types—solid, liquid, and vapour.

3.2.1. Liquid state methods

Stir casting: Discontinuous reinforcement is stirred into molten metal, which is allowed to solidify.
Electroplating and electroforming: A solution containing metal ions loaded with reinforcing particles is co-deposited forming a composite material.
Squeeze casting: Molten metal is injected into a form with fibers pre-placed inside it.
Spray deposition: Molten metal is sprayed onto a continuous fiber substrate.
Reactive processing: A chemical reaction occurs, with one of the reactants forming the matrix and the other the reinforcement.

3.2.2. Solid state methods

Powder blending and consolidation (powder metallurgy): Powdered metal and discontinuous reinforcement are mixed and then bonded through a process of compaction, degassing, and thermo-mechanical treatment (possibly via hot isostatic pressing (HIP) or extrusion).Foil diffusion bonding: Layers of metal foil are sandwiched with long fibers, and then pressed through to form a matrix.

3.2.3. Semi-solid state methods

Semi-solid powder processing: Powder mixture is heated up to semi-solid state and pressure is applied to form the composites.

3.2.4. Vapour deposition

Physical vapour deposition: The fiber is passed through a thick cloud of vaporized metal, coating it.

3.2.5. In situ fabrication technique

Controlled unidirectional solidification of a eutectic alloy can result in a two-phase microstructure with one of the phases, present in lamellar or fiber form, distributed in the matrix.

3.2.6. Metals and metal matrix composites

Polymer composites are used normally up to 1800C, but rarely beyond 3500C. The high temperature capabilities of inorganic reinforcements cannot be realized, when polymers are employed as matrix materials. Metal matrices, on the other hand, can widen the scope of using composites over a wide range of temperatures. Besides, metal matrix composites allow tailoring of several useful properties that are not achievable in conventional metallic alloys. High specific strength and stiffness, low thermal expansion, good thermal stability and improved wear resistance are some of the positive features of metal matrix composites. The metal composites also provide better transverse properties and higher toughness compared to polymer composites.

Matrix	Reinforcements
Aluminium and alloys	C, Be, SiO2, B, SiC, Al2O3, Steel, B4C, Al3Ni, Mo, W, ZrO2
Titanium and alloys	B, SiC, Mo, SiO2, Be,ZrO2
Nickel and alloys	C, Be, Al2O3,SiC, Si3N4, steel, W, Mo, B
Magnesium alloys	C, B, glass, Al2O3
Molebdenum and alloys	B, ZrO2
Iron and Steel	Fe, Steel, B, Al2O3, W, SiO2,ZrO2
Copper and alloys	C,B, Al2O3, E-glass

Table 3.1. Metal matrices and reinforcements

The reinforcements can be in the form of either particulates, or short fibres or continuous fibres. Cermets constitute an important group of metal matrix composites in which ceramic grains of sizes greater than 1 am are dispersed in the refractory metal matrix. A typical example is the titanium carbide cermet which comprises of 70% TiC particles and 30% nickel matrix and exhibits high specific strength and stiffness at very high temperatures. The thermo-mechanical properties of some common matrices are presented in Table 2.8. The aluminium matrices include several alloys such as AA 1100, AA 2014, AA6061, AA 7075, AA5052, etc. The composites with aluminium matrices are relatively lightweight, but their applications are limited to the lower temperature range

3.3. COMPOSITE MATERIALS WITH METAL MATRIX

Particulate composites consist of particles immersed in matrices such as alloys and ceramics. They are usually isotropic since the particles are added randomly. Particulate composites have advantages such as improved strength, increased operating temperature and oxidation resistance etc. Typical examples include use of aluminium particles in rubber, silicon carbide particles in aluminium, and gravel sand, cement to make concrete.

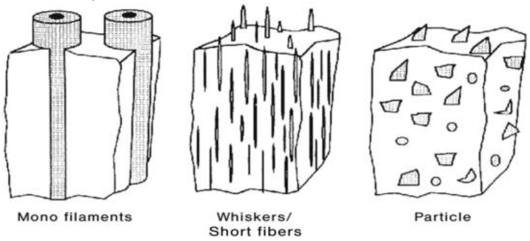

Fig 3.2. Composite Materials with Metal Matrices

3.4. APPLICATIONS OF MMC'S

Carbide drills are often made from a tough cobalt matrix with hard tungsten carbide particles inside.

Some tank armors may be made from metal matrix composites, probably steel reinforced with boron nitride, which is a good reinforcement for steel because it is very stiff and it does not dissolve in molten steel.

Some automotive disc brakes use MMCs. Early Lotus Elise models used aluminum MMC rotors, but they have less than optimal heat properties and Lotus has since switched back to cast-iron. Modern high-performance sport cars, such as those built by Porsche, use rotors made of carbon fiber within a silicon carbide matrix because of its high specific heat and thermal conductivity. 3M sells a preformed aluminium matrix insert for strengthening cast aluminium disc brake callipers, allowing them to weigh as much as 50% less while increasing stiffness. 3M has also used alumina performs for AMC pushrods.

IV.EXPERIMENTAL WORK

4.1. Introduction of Furnace

A furnace is a device used for heating. The name derives from Latin fornax, oven. In American English and Canadian English usage, the term furnace on its own refers to the house hold heating systems based on a central furnace (known either as a boiler or a heater in British English), and sometimes as a synonym for kiln, a device used in the production of ceramics. In British English, a furnace is an industrial furnace used for many things, such as the extraction of metal from ore (smelting) or in oil refineries and other chemical plants, for example as the heat source for fractional distillation columns. The term furnace can also refer to a direct fired heater, used in boiler applications in chemical industries or for providing heat to chemical reactions for processes like cracking, and are part of the Standard English names for many metallurgical furnaces worldwide.

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The heat energy to fuel a furnace may be supplied directly by fuel combustion, by electricity such as the electric arc furnace, or through induction heating in induction furnaces. A furnace is a device that produces heat. Not only are furnaces used in the home for warmth, they are used in industry for a variety of purposes such as making steel and heat treating of materials to change their molecular structure. Central heating with a furnace is an idea that is centuries old. In this venteenth century, coal began to replace wood as a primary fuel. Coal was used until the early 1940s when gas became the primary fuel. In the 1970s, electric furnaces started to replace gas furnaces because of the energy crisis.

4.2. WHAT IS FURNANCE AND CLASSIFICATIONS

A furnace is an equipment to melt metals for casting or heat materials for change of shape (rolling, forging etc.) or change of properties (heat treatment).

4.2.1 Types and Classification of Different Furnaces

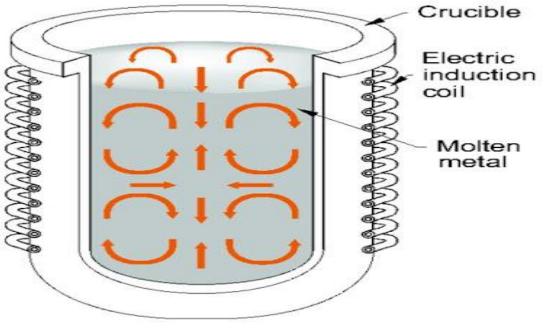
Based on the method of generating heat, furnaces are broadly classified into two types. Namely combustion type (using fuels) and electric type. In case of combustion type furnace, depending upon the kind of combustion, it can be broadly classified as oil fired, coal fired or gas fired. In case of electricity type furnace, depending up on the kind of electricity, it can be broadly classified as electric arc furnace, induction furnace and electric induction furnaces. And also another classification is house hold furnaces..

4.2.2 Types of furnaces

Common types of metal melting furnaces(Types)	Raw material	Outputs	process
INDUCTION FURNACE	Scrap iron(or) non-ferrous metals.	Molten iron or Non-ferrous metals.	Induction furnaces are the most common type used by both ferrous and non-ferrous foundries. Copper coils heat the metal using alternating currents. the flux reacts with impurities.
ELECTRICAL FURNACE	Scrap iron, flux	Molten iron and steel	Electric arcs from carbon electrodes melt the scrap metal. The flux reacts with impurities.
CUPOLA FURNACE	Iron ore, scrap iron, lime, cock	Molten iron	Alternative layers of metal and cock are fed into the top of the furnace. The metal is melted by the hot gases from the cock combustion. Impurities react with the lime and are separated.
OPEN HEARTH	Non-ferrous metals, flux	Molten non-ferrous metals	Reverberatory furnaces melt metals I n batches using a pot-shaped crucible that holds the metal over an electric heater or fuel free burner. The flux reacts with impurities.

4.3. Induction Furnace

An induction furnace is a electrical furnace in which heat is applied by induction heating of metal. Induction heating is the process of heating an electrically conducting object (usually a metal) by electromagnetic induction, through heat generated in the object by eddy currents (also called Foucault currents). An induction heating consists of an electromagnet (a coil of copper wire around or near the object to be heated), and an electronic oscillator which passes a high-frequency alternating current (AC) through the wire.



1-Melting metal, 2-ceramic wool, Inner part of the induction furnace
3. yokes, 4.crusible

Fig.4.1 Induction furnace

The rapidly alternating magnetic field produced by the coil penetrates the object, generating circular electric currents inside the conductor is called eddy currents. The eddy currents flowing through the resistance of the material heat it by joule heating. In ferromagnetic materials like iron, heat may also be generated by magnetic hysteresis losses. The frequency of current used depends on the object size, material type, coupling (between the work coil and the object to be heated) and the penetration depth.

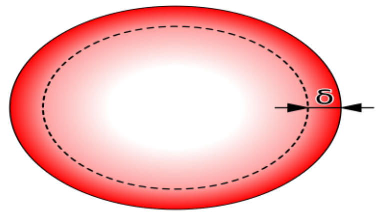


Fig.4.2. Skin depth (crusible)

Operating frequencies range from utility frequency (50 or 60 Hz) to 400 KHz or higher, usually depending on the material being melted, the capacity (volume) of the furnace and the melting speed required. Generally, the smaller the volume of the melts, the higher frequency of the furnace used, this is due to the skin depth which is a measure of the distance an alternating current can penetrate beneath the surface of a conductor. For the sane conductivity, the higher frequencies have a shallow skin depth-that is less penetration into the melt. Lower frequencies can generate stirring or turbulence in the metal.

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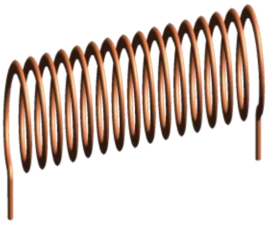
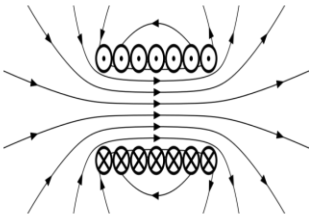


An insulation of a solanaid



Magnetic field created by a Seven-loop solenoid

Fig.4.3. Alternating current solanaids

4.3. Stir Casting

It is a liquid state method of composite materials fabrication, in which a dispersed phase (ceramic particles, short fibers)mixed with a molten matrix metal means of mechanical steering.Stir casting is the simplest and the most cost effective method of liquid state fabrication.The liquid composite material is than cast by conventional casting methods and may also be processed by conventional metal forming technology.

4.3.1. Construction of Stir Casting Furnace

For the present work we require a stir casting furnace with 3 blade graphite stirrer. Since stir casting is not a conventional casting method we have to design a suitable one. Even though some stir casting furnaces are readily available in the market, a custom made conventional stir casting furnace is a lot cheaper and is best suited for the present work to vary process parameters according the requirements.

A conventional stir casting furnace consists of the following basic components.

- Furnace
- Muffle
- Crucible
- Temperature Controller
- Stirring Equipment

4.3.2. Preparation of Furnace

A furnace is prepared by using a cylindrical thick sheet metal drum. The inner wall of furnace is lined with refractory ceramic material to prevent heat losses and is sealed with glass wool material which is prepared form glass.

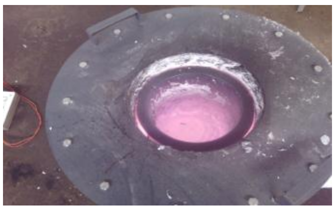


Fig. 4.5.Furnace

Total furnace was made with kanthaal wire. It is applicable to produce heat upto 13500C. It is protected by 15mm thickness of ceramic material integrated with 10% of iron.

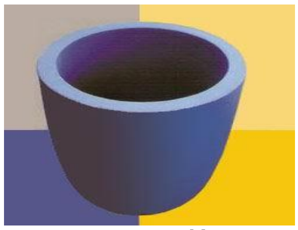


Fig.4.6.crusible

All crucibles should be handled with properly fitting tongs (lifting tool). Improper tongs can cause damage or complete failure of crucible at the worst possible time.

4.4. Preparation of furnace body

A furnace body is prepared by using different types of materials and sizes depend up on the requirement. Actual furnaces bodies are heavy weight and thick. In all types of furnaces body is the main thing, it hold's the total set up except temperature controller. So it is very expensive and cost also. In this process preparation of body is low weight and low cost and expensive. It can withstands the high temperature depends on giving temperature. This type of furnaces are easily to maintain, controllable and moving one place to another place is very easily, because it is low weight and convenient to moving. the specifications of the furnace body is discussed below.

Fig.4.7. Preparation of furnace body diagram

4.4.2. Preparation of Stirrer

A 1200 rpm high torque reversible motor is taken and connected with a potentiometer for varying speeds as per the requirement. The motor shaft is coupled to a stainless steel rod and the other end is connected to a graphite three-blade impeller and is tested by stirring water in the crucible and grinded to the desired angle for producing vortex.

Fig 4.8.Stirrer

4.5.3. Assembly of stir casting

Stir Casting is a liquid state method of composite materials fabrication, in which a discontinuous reinforcement is mixed with a molten matrix metal by means of mechanical stirring. The layout of conventional Stir Casting.

4.7. Sample Preparation

A standard test bar die (Permanent mould) is barrowed from Sibar Auto Parts Ltd. which will produce 27 mm diameter cylindrical rod with large riser on it to avoid shrinkage. It was tested that the test bar casting consumes 1 kg of molten metal.

Metal is melted in a separate furnace and is transferred to the stir casting furnace using a standard ladle which will carry 1.5 kg of molten aluminium. The metal is maintained at 700oC temperature in the stir casting furnace. A sample is taken with no reinforcements directly before transferring to the stir casting furnace.

After the desired speed is maintained in the crucible reinforcements were added slowly to the vortex and after completely adding the reinforcements the stirrer is further allowed to rotate for ten more minutes for uniform distribution of particulates.

Fig 5.11. Test Sample with Riser

After stirring, molten metal from the crucible is poured into the die cavity using ladle and allowed to cure for about two minutes and removed from the die. The remaining metal in the crucible is also used for taking the test samples. Same procedure is followed for producing samples of 4 % graphite and 10% granite. All the samples were grouped and marked based on the composition of reinforcements and is sent to heat treatment process.

4.8. Experimental Procedure

After heat treatment of samples the following operations were performed.Specimens were analysed for variation in density as per Archimedes principle.

V TEST CONDUCTED

5.1 PHYSICAL TESTS

5.1.1 Density

The density, or more precisely, the volumetric mass density, of a substance is its mass per unit volume. The symbol most often used for density is ρ (the lower case Greek letter rho). Mathematically, density is defined as mass divided by volume:

$$\rho = \frac{m}{V},$$

The density of a material varies with temperature and pressure. This variation is typically small for solids and liquids but much greater for gases. Increasing the pressure on an object decreases the volume of the object and thus increases its density. Increasing the temperature of a substance (with a few exceptions) decreases its density by increasing its volume. In most materials, heating the bottom of a fluid results in convection of the heat from the bottom to the top, due to the decrease in the density of the heated fluid. This causes it to rise relative to more dense unheated material.

5.1.2 Modulus of Elasticity

An elastic modulus, or modulus of elasticity, is a number that measures an object or substance's resistance to being deformed elastically (i.e., non-permanently) when a force is applied to it. The elastic modulus of an object is defined as the slope of its stress–strain curve in the elastic deformation region: A stiffer material will have a higher elastic modulus. An elastic modulus has the form.

$$\lambda \stackrel{\text{def}}{=} \frac{\text{stress}}{\text{strain}}$$

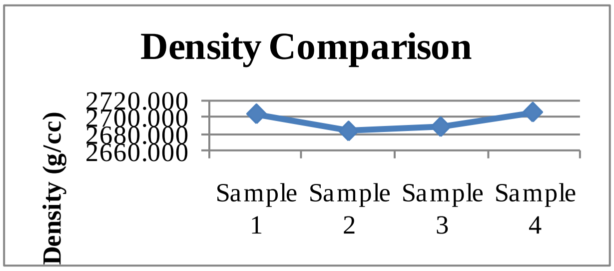
VI RESULTS AND DISCUSSIONS

After heat treatment of all samples, each sample was separately tested for the density, hardness and tensile strength and the average values were analysed by comparing with the zero sample. The results in various tests were discussed below.

For convenience of presentation and plotting, from here onwards pure LM-16 alloy samples were referred as sample 1 , LM-16 with 4% Graphite and 5% Granite samples were referred as sample 2 and LM-16 with 4% Graphite and 10% Granite samples were referred as sample 3 and LM-16 with 4% Graphite and 15% Granite samples were referred as sample 4.

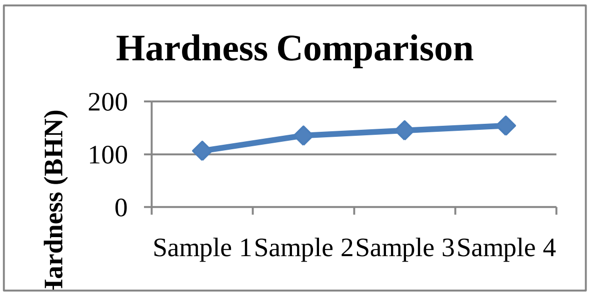
6.1. Physical Properties of Samples

Density



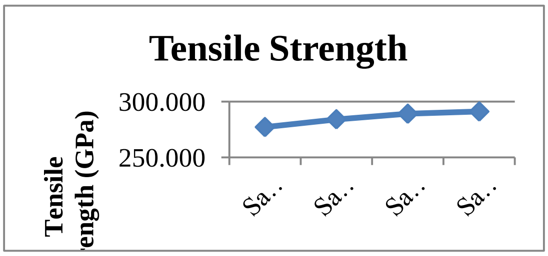
- Density of each sample was measured based on Archimedes principle in a calibrated glass jar. In figure 7.4, it can be noticed that the density of sample 1 is less compared to the other groups because the density of graphite powder is less compared to aluminium and granite. Further, the density of sample 2 is increased because of the increase of granite composition in the composite but not more than the density of sample 1, which may be due to the volume occupation by the 4% graphite particles in the composite.

Hardness



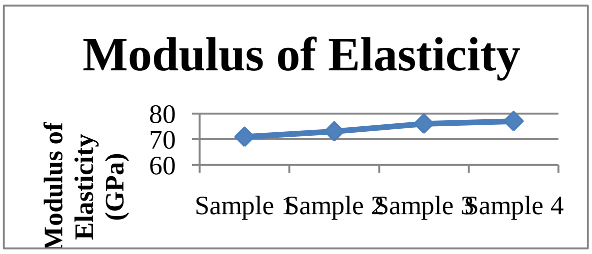
- Since the granite is superior to aluminium and graphite, in general it can be expected that the dominance of granite in increase of hardness of the composite. The practical observations revealed that the hardness of the composite increased considerably. It was noticed that the increase of hardness from Group 0 to sample 1 is form 108 BHN to 136 BHN has a difference of 28 BHN and the increase form sample 1 to sample 2 is from 136 BHN to 148 BHN has a difference of only 12 BHN (see Figure 6.5)

TensileStrength



- ***Yield strength*** - The stress a material can withstand without permanent deformation. This is not a sharply defined point. Yield strength is the stress which will cause a permanent deformation of 0.2% of the original dimension.
- As it was the maximum stress that a material can withstand while being stretched, interfacial bonds may affect greatly on the tensile strength of the composite. In Figure 7.5, we can see that the tensile strength was increased in the composites but doesn't have comparable variation. Weak interfacial bonds may result in decrease in tensile strength of the composite, but here the increase of tensile strength shows that there was good interfacial strength.

Modulus of Elasticity



- Modulus of elasticity shows linear relation with tensile strength as same as conventional materials. In Figure 7.7, we can observe that the modulus of elasticity was increased but not greatly as same as tensile strength. The elongation of material is similar to the base alloy, almost negligible amount of elongation for all the groups. Since all the samples are fully heat treated, the samples will gain brittleness and hardness losing ductility which might be resulted in tendency of brittle failure.

VII CONCLUSION

- From the experimental and analysis of present work the following conclusions are drawn.
- Addition of granite will increase the mechanical properties of the composite.
- By comparing with amount of granite in the composite LM-16 with 4% graphite and 5% granite is most suitable for regular casting process.
- Hardness of the composite increased by 25.9% for 5% Granite and 37% for 10%Granite.
- It was noticed that the density of the composite is slightly reduced due to less density of graphite.
- From the analysis the total deformation has been decreased by 5.7% for 5% Granite and 8.7% for 10% Granite.
- So, it can be concluded that this composite material in engine cylinders can be used for higher capacities than that of which they are now using.

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