Enhancements in Mechanical Characteristics of Hybrid Aluminium Metal Matrix Composite ($Al7075/B_4C/SiC$)

A project report submitted in partial fulfilment of the requirement for the award of the degree of

BACHELOR OF TECHNOLOGY
IN
MECHANICALENGINEERING
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CERTIFICATE

This is to certify that the Project Report entitled "ENHANCEMENTS IN MECHANICAL CHARACTERISTICS OF HYBRID ALUMINUM METAL MATRIX COMPOSITE (AL7075/ B4C/SIC)" has been carried out by Ch Varshini Shreyesha (318126520073), Gadigatla Anudeep (318126520077), Kakara Karthik (318126520084), Moturu Sailesh (318126520098), Bejawada Hema Saranya (319126520L20), my guidance in partial fulfillment of the requirements of Degree of Bachelor of Mechanical Engineering of Andhra University, Visakhapatnam.

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ABSTRACT

Hybrid metal matrix composites (HMMC's) are required to meet unique specifications for specific components in the transportation, aerospace, marine, automobile and mineral processing industries, etc. Because of its demanding applications, such as light weight, high stiffness, high hardness, wear resistance, high energy absorption and damping capacity, low coefficient of friction and thermal expansion, aluminium hybrid metal matrix composites (Al-HMMC's) are most widely employed everywhere. In the present work, the composite is made by taking A17075 as matrix and B_4C (0.5%wt.) and SiC (1, 2, 3, 4% wt.) as reinforcements by the stir casting process. The mechanical properties like density, tensile strength, compression strength and hardness were tested and the best results were found at 7075 (95.5%) +B_4C (0.5%) SiC (4%) as 2.648 g/cm^3, 290 2MPa, 77.84 MPa and 110VHN respectively.

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CHAPTER 1

INTRODUCTION

1.INTRODUCTION

Aluminium Matrix Composites (AMC) finds applications in automobiles and aerospace fields as they bear better mechanical and physical properties. Compared to available traditional materials these composites are found to have improved wear, tensile and other similar properties due to the addition of reinforcements to the matrix. The property of base alloy gets improved when it gets mixed up with different reinforcements having various properties. The effects of addition of various reinforcements on aluminium alloy were given overview in this paper. It will have uniform distribution of matrix and reinforcement and ensure better bonding of fibre with matrix. It is obvious from investigations that the life and behaviour of composites are superior for Aluminium matrix composites than that of the traditionally available materials.

The studies show that because of reinforcement addition the mechanical properties of the AMC will have an average improvement of at least around 10% approximately while comparing with base material alone. Various methods are available for fabrication of composite materials and a researcher can select one among them depending on type of matrix and reinforcement chosen. Production methods are categorized into three namely solid, liquid and semi-solid phases of fabrication. Stir casting, compo casting, rheo-casting and liquid infiltration are some of the liquid processing techniques available. Out of various fabrication methods available, one of the less expensive methods is the stir casting method. Hence, it is used for bulk production of composites. Many researchers earlier have used stir casting technique and found to have improved wear and mechanical properties in the composites fabricated.

Melt stirring process is successful in achieving better bonding of matrix and particle, easy in controlling the structure of matrix, applicable for mass production, flexible, simple and inexpensive. On the other hand, non uniform distribution of reinforcement with matrix material and poor wettability are the quite common problems faced in stir casted Aluminium Matrix Composites (AMC). In order to overcome problems related with stir casting, few techniques were followed by the researchers. Wettability of reinforcement can be improved by pre heating of reinforcement particles before introducing into the molten metal melt. This method helps in adsorption of gases from the reinforcement surface.

Reinforcement particles, if injected with the help of inert carrier into metal melt will result in homogeneous distribution of particles into the melt. Wettability of reinforcement particle is found better with the three step stir casting method followed in the newly designed equipment Combining harder ceramic reinforcements with metallic matrix results in metal matrix composite(MMC). Less production cost and improved properties of Aluminium composites make them best suited for marine and aerospace applications. Properties like low density, ductility and formability of aluminium and its alloys make them to choose as matrix material for MMC. The performance of composite material depends mainly on its microstructure. Distribution of reinforcement in the alloy, fibre or particulate size and shape are some other essential parameters to be noted on which physical property of the resulting composite depends. For application of the fabricated composites in various areas, proper choice of matrix and reinforcement will play a prominent role. Reinforcements such as Sic, B4C, B4C and TiB2 are widely used in Aluminium composites as reinforcements. Most of the studies on casting analyse the mechanical properties like hardness, tensile, wear and similar other properties and evaluate the microstructure of the resulting specimens. Whereas Finite Element Analysis (FEA), Response Surface Methodology (RSM) and Artificial Neural Networking (ANN) are the methods used for analysing the performance of welded specimens. Behaviour of AMC on using different reinforcements were discussed and reviewed.

1.1 CONCEPT OF COMPOSITE

Fibres or particles embedded in matrix of another material are the best example of modern-day composite materials, which are mostly structural.

Laminates are composite material where different layers of materials give them the specific character of a composite material having a specific function to perform. Fabrics have no matrix to fall back on, but in them, fibres of different compositions combine to give them a specific character. Reinforcing materials generally withstand maximum load and serve the desirable properties.

Further, though composite types are often distinguishable from one another, no clear determination can be really made. To facilitate definition, the accent is often shifted to the levels at which differentiation take place viz., microscopic or macroscopic.

In matrix-based structural composites, the matrix serves two paramount purposes viz., binding the reinforcement phases in place and deforming to distribute the stresses among the constituent reinforcement materials under an applied force.

The demands on matrices are many. They may need to temperature variations, be conductors or resistors of electricity, have moisture sensitivity etc. This may offer weight advantages, ease of handling and other merits which may also become applicable depending on the purpose forwhich matrices are chosen.

Solids that accommodate stress to incorporate other constituents provide strong bonds for the reinforcing phase are potential matrix materials. A few inorganic materials, polymers and metals have found applications as matrix materials in the designing of structural composites, with commendable success. These materials remain elastic till failure occurs and show decreased failure strain, when loaded in tension and compression.

Composites cannot be made from constituents with divergent linear expansion characteristics. The interface is the area of contact between the reinforcement and the matrix materials. In some cases, the region is a distinct added phase. Whenever there is interphase, there has to be two interphases between each side of the interphase and its adjoint constituent. Some composites provide interphases when surfaces dissimilar constituents interact with each other. Choice of fabrication method depends on matrix properties and the effect of matrix on properties of reinforcements. One of the prime considerations in the selection and fabrication of composites is that the constituents should be chemically inert non-reactive. Figure helps to classify matrices.

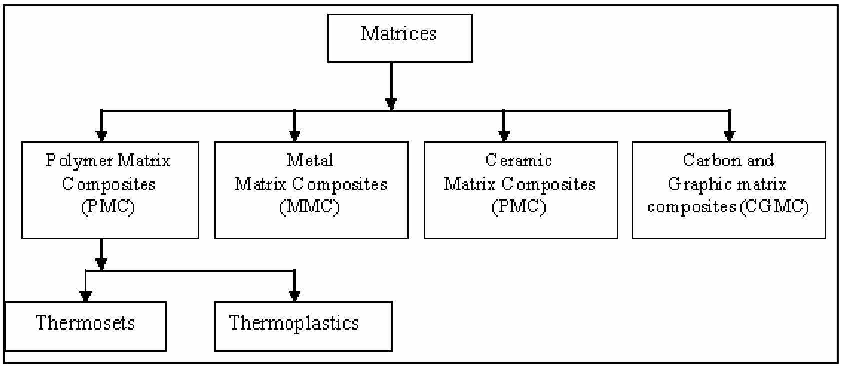

Figure1.1: Classification of Matrix Materials

1.1.1 CLASSIFICATION OF COMPOSITES

Composite materials are commonly classified at following two distinct levels:

- The first level of classification is usually made with respect to the matrix constituent. The major composite classes include Organic Matrix Composites (OMCs), Metal Matrix Composites (MMCs) and Ceramic Matrix Composites (CMCs). The term organic matrix composite is generally assumed to include two classes of composites, namely Polymer Matrix Composites (PMCs) and carbon matrix composites commonly referred to as carbon- carbon composites.
- The second level of classification refers to the reinforcement form - fibre **reinforced composites**, **laminar composites** and **particulate composites**. Fibre Reinforced composites (FRP) can be further divided into those containing discontinuous or continuous fibres.
- **Fibre Reinforced Composites** are composed of fibres embedded in matrix material. Such a composite is considered to be a discontinuous fibre or short fibre composite if its properties vary with fibre length. On the other hand, when the length of the fibre is such that any further increase in length does not further increase, the elastic modulus of the composite, the composite is considered to be continuous fibre reinforced. Fibres are small in diameter and when pushed axially, they bend easily although they have very good tensile properties. These fibres must be supported to keep individual fibres from bending and buckling.
- **Laminar Composites** are composed of layers of materials held together by matrix. Sandwich structures fall under this category.
- **Particulate Composites** are composed of particles distributed or embedded in a matrix body. The particles may be flakes or in powder form. Concrete and wood particle boards are examples of this category.

1.1.2 Organic Matrix Composites

Polymer Matrix Composites (PMC)/Carbon Matrix Composites/Carbon-Carbon Composites:

Polymers make ideal materials as they can be processed easily, possess lightweight, and desirable mechanical properties. It follows, therefore, that high temperature resins are extensively used in aeronautical applications.

Two main kinds of polymers are thermosets and thermoplastics. Thermosets have qualities such as a well-bonded three-dimensional molecular structure after curing. They decompose instead of melting on hardening. Merely changing the basic composition of the resin is enough to alter the conditions suitably for curing and determine its other characteristics. They can be retained in a partially cured condition too over prolonged periods of time, rendering Thermosets very flexible. Thus, they are most suited as matrix bases for advanced conditions fiber reinforced composites. Thermosets find wide ranging applications in the chopped fiber composites form particularly when a premixed or moulding compound with fibers of specific quality and aspect ratio happens to be starting material as in epoxy, polymer and phenolic polyamide resins.

Thermoplastics have one- or two-dimensional molecular structure and they tend to at an elevated temperature and show exaggerated melting point. Another advantage is that the process ofsoftening at elevated temperatures can reversed to regain its properties during cooling, facilitating applications of conventional compress techniques to mould the compounds.

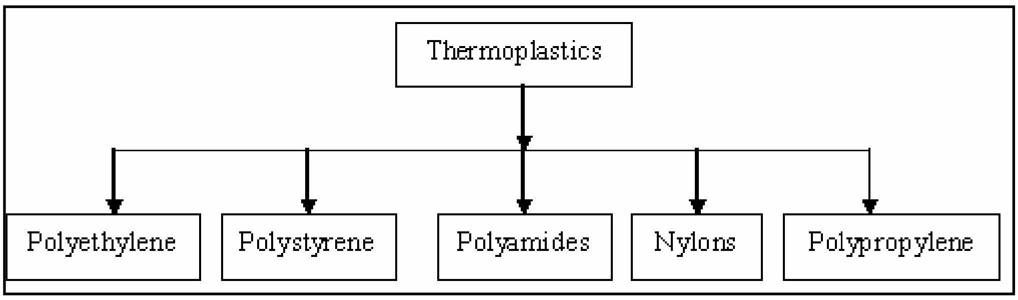

Figure1.2: Thermoplastics

Resins reinforced with thermoplastics now comprised an emerging group of composites. The theme of most experiments in this area to improve the base properties of the resins and extractthe greatest functional advantages from them in new avenues, including attempts to replace metals in die-casting processes. In crystalline thermoplastics, the reinforcement affects the morphology to a considerable extent, prompting the reinforcement to empower nucleation. Whenever crystalline or amorphous, these resins possess the facility to alter their creep over anextensive range of temperature. But this range includes the point at which the usage of resins is constrained, and the reinforcement in such systems can increase the failure load as well as creep resistance. Figure shows kinds of thermoplastics.

A small quantum of shrinkage and the tendency of the shape to retain its original form are also to be accounted for. But reinforcements can change this condition too. The advantage of thermoplastics systems over thermosets are that there are no chemical reactions involved, which often result in the release of gases or heat. Manufacturing is limited by the time required for heating, shaping and cooling the structures.

Thermoplastics resins are sold as moulding compounds. Fiber reinforcement is apt for these resins. Since the fibers are randomly dispersed, the reinforcement will be almost isotropic. However, when subjected to moulding processes, they can be aligned directionally.

There are a few options to increase heat resistance in thermoplastics. Addition of fillers raises the heat resistance. But all thermoplastic composites tend loose their strength at elevated temperatures. However, their redeeming qualities like rigidity, toughness and ability to repudiate creep, place thermoplastics in the important composite materials bracket. They are used in automotive control panels, electronic products encasement etc.

Newer developments augur the broadening of the scope of applications of thermoplastics. Huge sheets of reinforced thermoplastics are now available and they only require sampling and heating to be moulded into the required shapes. This has facilitated easy fabrication of bulky components, doing away with the more cumbersome molding compounds.

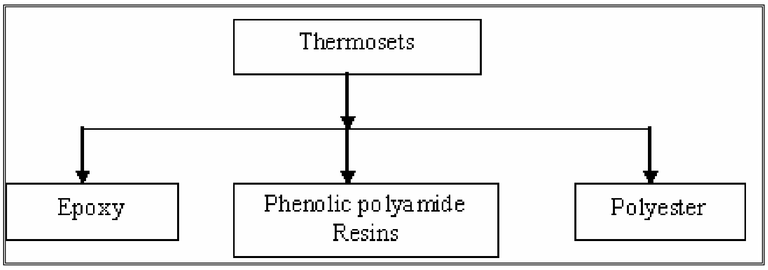

Figure1.3: Thermoset Materials

Thermosets are the most popular of the fiber composite matrices without which, research and development in structural engineering field could get truncated. Aerospace components, automobile parts, defence systems etc., use a great deal of this type of fiber composites. Epoxy matrix materials are used in printed circuit boards and similar areas. Figure below shows somekinds of thermosets.

Direct condensation polymerization followed by rearrangement reactions to form heterocyclic entities is the method generally used to produce thermoset resins. Water, a product of the reaction, in both methods, hinders production of void-free composites. These voids have a negative effect on properties of the composites in terms of strength and dielectric properties. Polyesters phenolic and Epoxies are the two important classes of thermoset resins.

Epoxy resins are widely used in filament-wound composites and are suitable for moulding prepress. They are reasonably stable to chemical attacks and are excellent adherents having slow shrinkage during curing and no emission of volatile gases. These advantages, however, make the use of epoxies rather expensive. Also, they cannot be expected beyond a temperature of140ºC. Their use in high technology areas where service temperatures are higher, as a result, is ruled out.

Polyester resins on the other hand are quite easily accessible, cheap and find use in a wide range of fields. Liquid polyesters are stored at room temperature for months, sometimes for years and the mere addition of a catalyst can cure the matrix material within a short time. They are used in automobile and structural applications.

The cured polyester is usually rigid or flexible as the case may be and transparent. Polyesters withstand the variations of environment and stable against chemicals. Depending on the formulation of the resin or service requirement of application, they can be used up to about 75ºC or higher. Other advantages of polyesters include easy compatibility with few glass fibers and can be used with verify of reinforced plastic accoutrey.

Aromatic Polyamides are the most sought after candidates as the matrices of advanced fiber composites for structural applications demanding long duration exposure for continuous service at around 200-250ºC .

1.1.3 Metal Matrix Composites (MMC)

Metal matrix composites, at present though generating a wide interest in research fraternity, are not as widely in use as their plastic counterparts. High strength, fracture toughness andstiffness are offered by metal matrices than those offered by their polymer counterparts. They can withstand elevated temperature in corrosive environment than polymer composites. Most metals and alloys could be used as matrices and they require reinforcement materials which need to be stable over a range of temperature and non-reactive too. However the guiding aspect for the choice depends essentially on the matrix material. Light metals form the matrix for temperature application and the reinforcements in addition to the aforementioned reasons are characterized byhigh moduli.

Most metals and alloys make good matrices. However, practically, the choices for low temperature applications are not many. Only light metals are responsive, with their low density proving an advantage. Titanium, Aluminium and magnesium are the popular matrix metals currently in vogue, which are particularly useful for aircraft applications. If metallic matrix materials have to offer high strength, they require high modulus reinforcements. The strength-to- weight ratios of resulting composites can be higher than most alloys.

The melting point, physical and mechanical properties of the composite at various temperatures determine the service temperature of composites. Most metals, ceramics and compounds can be used with matrices of low melting point alloys. The choice of reinforcements becomes more stunted with increase in the melting temperature of matrix materials.

1.1.4 Ceramic Matrix Materials (CMM)

Ceramics can be described as solid materials which exhibit very strong ionic bonding in general and in few cases covalent bonding. High melting points, good corrosion resistance, stability at elevated temperatures and high compressive strength, render ceramic-based matrix materials a favourite for applications requiring a structural material that doesn't give way at temperatures above 1500ºC. Naturally, ceramic matrices are the obvious choice for high temperature applications.

High modulus of elasticity and low tensile strain, which most ceramics posses, have combined to cause the failure of attempts to add reinforcements to obtain strength improvement. This is because at the stress levels at which ceramics rupture, there is insufficient elongation of the matrix which keeps composite from transferring an effective quantum of load to the reinforcement and the composite may fail unless the percentage of fiber volume is high enough. A material is reinforcement to utilize the higher tensile strength of the fiber, to produce an increase in load bearing capacity of the matrix. Addition of high-strength fiber to a weaker ceramic has not always been successful and often the resultant composite has proved to be weaker.

The use of reinforcement with high modulus of elasticity may take care of the problem to some extent and presents pre-stressing of the fiber in the ceramic matrix is being increasingly resortedto as an option.

When ceramics have a higher thermal expansion coefficient than reinforcement materials, the resultant composite is unlikely to have a superior level of strength. In that case, the composite will develop strength within ceramic at the time of cooling resulting in micro-cracks extending from fiber to fiber within the matrix. Microcracking can result in a composite with tensile strength lower than that of the matrix.

1.2 CLASSIFICATION BASED ON REINFORCEMENTS

1.2.1 Introduction to Reinforcements

Reinforcements for the composites can be fibers, fabrics particles or whiskers. Fibers are essentially characterized by one very long axis with other two axes either often circular or near circular. Particles have no preferred orientation and so does their shape. Whiskers have a preferred shape but are small both in diameter and length as compared to fibers. Figure below shows types of reinforcements in composites.

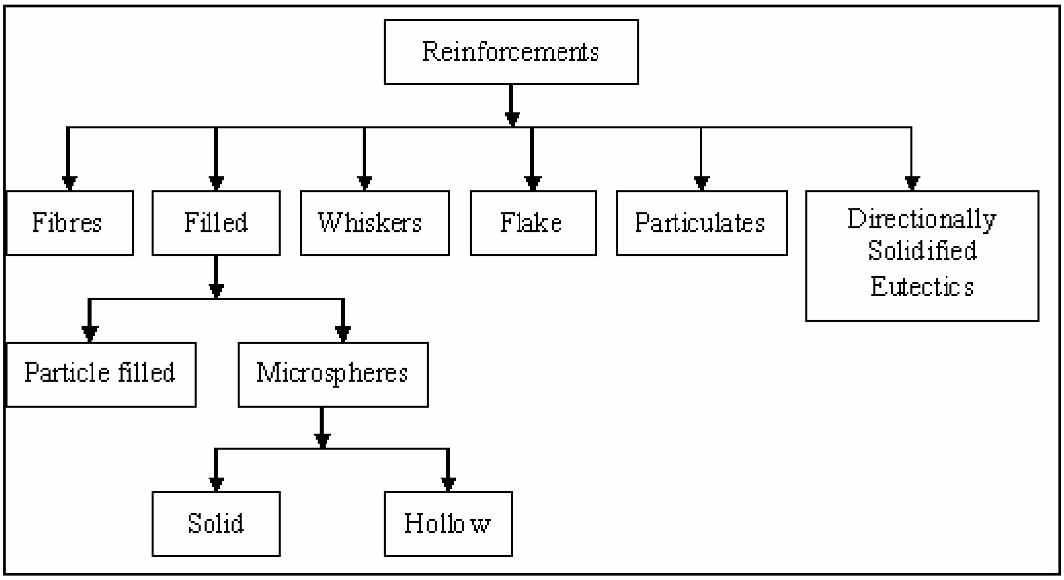

Figure1.4: Reinforcements

Reinforcing constituents in composites, as the word indicates, provide the strength that makesthe composite what it is. But they also serve certain additional purposes of heat resistance or conduction, resistance to corrosion and provide rigidity. Reinforcement can be made to perform all or one of these functions as per the requirements.

A reinforcement that embellishes the matrix strength must be stronger and stiffer than the matrix and capable of changing failure mechanism to the advantage of the composite. This means that the ductility should be minimal or even nil the composite must behave as brittle as possible.

1.2.2 Fiber Reinforced Composites/Fiber Reinforced Polymer (FRP) Composites

Fibers are the important class of reinforcements, as they satisfy the desired conditions and transfer strength to the matrix constituent influencing and enhancing their properties as desired.

Glass fibers are the earliest known fibers used to reinforce materials. Ceramic and metal fibers were subsequently found out and put to extensive use, to render composites stiffer more resistant to heat.

Fibers fall short of ideal performance due to several factors. The performance of a fiber composite is judged by its length, shape, orientation, and composition of the fibers and the mechanical properties of the matrix.

The orientation of the fiber in the matrix is an indication of the strength of the composite and the strength is greatest along the longitudinal directional of fiber. This doesn’t mean the longitudinal fibers can take the same quantum of load irrespective of the direction in which it is applied. Optimum performance from longitudinal fibers can be obtained if the load is applied along its direction. The slightest shift in the angle of loading may drastically reduce the strength of the composite.

Unidirectional loading is found in few structures and hence it is prudent to give a mix of orientations for fibers in composites particularly where the load is expected to be the heaviest.

Monolayer tapes consisting of continuous or discontinuous fibers can be oriented unidirectional stacked into plies containing layers of filaments also oriented in the same direction. Morecomplicated orientations are possible too and nowadays, computers are used to make projections of such variations to suit specific needs. In short, in planar composites, strength can be changed from unidirectional fiber oriented composites that result in composites with nearly isotropic properties.

Properties of angle-plied composites which are not quasi-isotropic may vary with the number of plies and their orientations. Composite variables in such composites are assumed to have a constant ratio and the matrices are considered relatively weaker than the fibers. The strength of the fiber in any one of the three axes would, therefore be one-third the unidirectional fiber composite, assuming that the volume percentage is equal in all three axes.

However, orientation of short fibers by different methods is also possible like random orientations by sprinkling on to given plane or addition of matrix in liquid or solid state before orafter the fiber deposition. Even three-dimensional orientations can achieve in this way.

There are several methods of random fiber orientations, which in a two-dimensional one, yield composites with one-third the strength of a unidirectional fiber-stressed composite, in the direction of fibers. In a 3-dimension, it would result in a composite with a comparable ratio,about less than one-fifth.

In very strong matrices, moduli and strengths have not been observed. Application of thestrength of the composites with such matrices and several orientations is also possible. The longitudinal strength can be calculated on the basis of the assumption that fibers have been reduced to their effective strength on approximation value in composites with strong matricesand non-longitudinally orientated fibers.

It goes without saying that fiber composites may be constructed with either continuous or short fibers. Experience has shown that continuous fibers (or filaments) exhibit better orientation, although it does not reflect in their performance. Fibers have a high aspect ratio, i.e., their lengths being several times greater than their effective diameters. This is the reason why filaments are manufactured using continuous process. This finished filaments.

Mass production of filaments is well known and they match with several matrices in different ways like winding, twisting, weaving and knitting, which exhibit the characteristics of a fabric.

Since they have low densities and high strengths, the fiber lengths in filaments or other fibers yield considerable influence on the mechanical properties as well as the response of composites to processing and procedures. Shorter fibers with proper orientation composites that use glass, ceramic or multi-purpose fibers can be endowed with considerably higher strength than thosethat use continuous fibers. Short fibers are also known to their theoretical strength.

The continuous fiber constituent of a composite is often joined by the filament winding process in which the matrix impregnated fiber wrapped around a mandrel shaped like the part over which the composite is to be placed, and equitable load distribution and favorable orientation of the fiber is possible in the finished product. However, winding is mostly confined to fabrication of bodies of revolution and the occasional irregular, flat surface.

Short-length fibers incorporated by the open- or close-mould process are found to be less efficient, although the input costs are considerably lower than filament winding.

Most fibers in use currently are solids which are easy to produce and handle, having a circular cross-section, although a few non-conventional shaped and hollow fibers show signs of capabilities that can improve the mechanical qualities of the composites.

Given the fact that the vast difference in length and effective diameter of the fiber are assets to a fiber composite, it follows that greater strength in the fiber can be achieved by smaller diameters due to minimization or total elimination of surface of surface defects.

After flat-thin filaments came into vogue, fibers rectangular cross sections have provided new options for applications in high strength structures. Owing to their shapes, these fibers provide perfect packing, while hollow fibers show better structural efficiency in composites that are desired for their stiffness and compressive strengths. In hollow fibers, the transverse compressive strength is lower than that of a solid fiber composite whenever the hollow portion is more than half the total fiber diameter. However, they are not easy to handle and fabricate.

1.2.3 Laminar Composites

Laminar composites are found in as many combinations as the number of materials. They can be described as materials comprising of layers of materials bonded together. These may be of several layers of two or more metal materials occurring alternately or in a determined order morethan once, and in as many numbers as required for a specific purpose.

Clad and sandwich laminates have many areas as it ought to be, although they are known to follow the rule of mixtures from the modulus and strength point of view. Other **intrinsic values** pertaining to metal-matrix, metal-reinforced composites are also fairly well known.

Powder metallurgical processes like roll bonding, hot pressing, diffusion bonding, brazing and so on can be employed for the fabrication of different alloys of sheet, foil, powder or sprayed materials. It is not possible to achieve high strength materials unlike the fiber version. But sheets and foils can be made isotropic in two dimensions more easily than fibers. Foils and sheets are also made to exhibit high percentages of which they are put. For instance, a strong sheet may useover 92% in laminar structure, while it is difficult to make fibers of such compositions. Fiber laminates cannot over 75% strong fibers.

The main functional types of metal-metal laminates that do not posses high strength or stiffness are single layered ones that endow the composites with special properties, apart from being cost- effective. They are usually made by pre-coating or cladding methods.

Pre-coated metals are formed by forming by forming a layer on a substrate, in the form of a thin continuous film. This is achieved by hot dipping and occasionally by chemical plating and electroplating. Clad metals are found to be suitable for more intensive environments where denser faces are required.

There are many combinations of sheet and foil which function as adhesives at low temperatures. Such materials, plastics or metals, may be clubbed together with a third constituent. Pre-painted or pre-finished metal whose primary advantage is elimination of final finishing by the user is the best known metal-organic laminate. Several combinations of metal-plastic, vinyl-metallaminates, organic films and metals, account for upto 95% of metal-plastic laminates known. They are made by adhesive bonding processes.

1.2.4 Particulate Reinforced Composites (PRC)

Microstructures of metal and ceramics composites, which show particles of one phase strewn in the other, are known as particle reinforced composites. Square, triangular and round shapes of reinforcement are known, but the dimensions of all their sides are observed to be more or less equal. The size and volume concentration of the dispersoid distinguishes it from dispersion hardened materials.

The dispersed size in particulate composites is of the order of a few microns and volume concentration is greater than 28%. The difference between particulate composite and dispersion strengthened ones is, thus, oblivious. The mechanism used to strengthen each of them is also different. The dispersed in the dispersion-strengthen materials reinforces the matrix alloy by arresting motion of dislocations and needs large forces to fracture the restriction created by dispersion.

In particulate composites, the particles strengthen the system by the hydrostatic coercion of fillers in matrices and by their hardness relative to the matrix.

Three-dimensional reinforcement in composites offers isotropic properties, because of the three systematically orthogonal planes. Since it is not homogeneous, the material properties acquire sensitivity to the constituent properties, as well as the interfacial properties and geometric shapes of the array. The composite's strength usually depends on the diameter of the particles, the inter-particle spacing, and the volume fraction of the reinforcement. The matrix properties influence the behaviour of particulate composite too.

1.3 CLASSIFICATION BASED ON REINFORCEMENTS AND MATRICES

There are two types of constituent materials: matrix and reinforcement. At least one portion (fraction) of each type is required. The matrix material surrounds and supports the reinforcement materials by maintaining their relative positions. The reinforcements impart special physical (mechanical and electrical) properties to enhance the matrix properties.

1.3.1 Classification Based On Matrices

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 as aluminium, magnesium, or titanium, and provides a compliant support for the reinforcement. In high temperature applications, cobalt and cobalt-nickel alloy matrices are common.

The composite materials are commonly classified based on matrix constituent. The major composite classes include Organic Matrix Composites (OMCs), Metal Matrix Composites (MMCs) and Ceramic Matrix Composites (CMCs). The term organic matrix composite is generally assumed to include two classes of composites, namely Polymer Matrix Composites (PMCs) and carbon matrix composites commonly referred to as carbon-carbon composites.

These three types of matrixes produce three common types of composites.

- Polymer matrix composites (PMCs), of which GRP is the best-known example, use ceramic fibers in a plastic matrix.

- Metal-matrix composites (MMCs) typically use silicon carbide fibers embedded in a matrix made from an alloy of aluminium and magnesium, but other matrix materials such as titanium, copper, and iron are increasingly being used. Typical applications of MMCs include bicycles, golf clubs, and missile guidance systems; an MMC made from silicon- carbide fibers in a titanium matrix is currently being developed for use as the skin (fuselage material) of the US National Aerospace Plane.

- Ceramic-matrix composites (CMCs) are the third major type and examples include silicon carbide fibers fixed in a matrix made from a borosilicate glass. The ceramic matrix makes them particularly suitable for use in lightweight, high-temperature components, such as parts for airplane jet engines.

1.3.1.1 Polymer Matrix Composites (PMC)/Carbon Matrix Composites/ Carbon-CarbonComposites (CCC)

Polymers make ideal materials as they can be processed easily, possess lightweight, and desirable mechanical properties. It follows, therefore, that high temperature resins are extensively used in aeronautical applications.

Two main kinds of polymers are thermosets and thermoplastics. Thermosets have qualities such as a well-bonded three-dimensional molecular structure after curing. They decompose instead ofmelting on hardening. Merely changing the basic composition of the resin is enough to alter the conditions suitably for curing and determine its other characteristics. They can be retained in a partially cured condition too over prolonged periods of time, rendering Thermosets very flexible. Thus, they are most suited as matrix bases for advanced conditions fiber reinforced composites. Thermosets find wide ranging applications in the chopped fiber composites form particularly when a premixed or moulding compound with fibers of specific quality and aspect ratio happens to be starting material as in epoxy, polymer and phenolic polyamide resins.

Thermoplastics have one- or two-dimensional molecular structure and they tend to at an elevated temperature and show exaggerated melting point. Another advantage is that the process of softening at elevated temperatures can reversed to regain its properties during cooling, facilitating applications of conventional compress techniques to mold the compounds. Resins reinforced with thermoplastics now comprised an emerging group of composites. The theme of most experiments in this area to improve the base properties of the resins and extract the greatest functional advantages from them in new avenues, including attempts to replace metals in die-casting processes. In crystalline thermoplastics, the reinforcement affects the morphology to a considerable extent, prompting the reinforcement to empower nucleation.

Whenever crystalline or amorphous, these resins possess the facility to alter their creep over an extensive range of temperature. But this range includes the point at which the usage of resins is constrained, and the reinforcement in such systems can increase the failure load as well as creepresistance. Figure below shows kinds of thermoplastics.

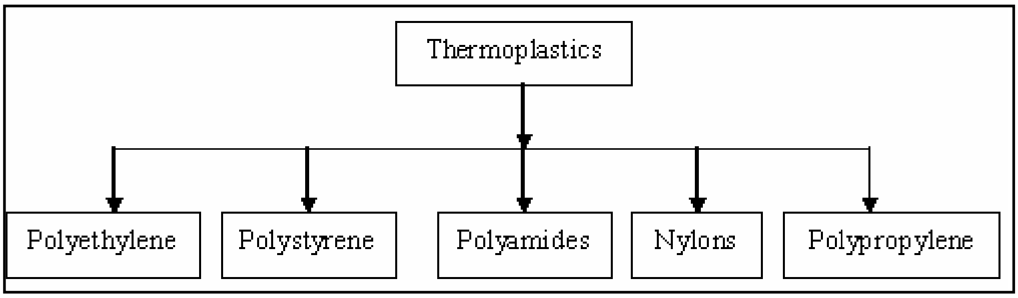

Figure1.5: Thermoplastics

A small quantum of shrinkage and the tendency of the shape to retain its original form are also to be accounted for. But reinforcements can change this condition too. The advantage of thermoplastics systems over thermosets are that there are no chemical reactions involved, which often result in the release of gases or heat. Manufacturing is limited by the time required for heating, shaping and cooling the structures.

Thermoplastics resins are sold as moulding compounds. Fiber reinforcement is apt for these resins. Since the fibers are randomly dispersed, the reinforcement will be almost isotropic. However, when subjected to moulding processes, they can be aligned directionally.

There are a few options to increase heat resistance in thermoplastics. Addition of fillers raises the heat resistance. But all thermoplastic composites tend lose their strength at elevated temperatures. However, their redeeming qualities like rigidity, toughness and ability to repudiate creep, place thermoplastics in the important composite materials bracket. They are used in automotive control panels, electronic products encasement etc.

Newer developments augur the broadening of the scope of applications of thermoplastics. Huge sheets of reinforced thermoplastics are now available and they only require sampling and heating to be moulded into the required shapes. This has facilitated easy fabrication of bulky components, doing away with the more cumbersome moulding compounds.

Thermosets are the most popular of the fiber composite matrices without which, research and development in structural engineering field could get truncated. Aerospace components, automobile parts, defence systems etc., use a great deal of this type of fiber composites. Epoxy matrix materials are used in printed circuit boards and similar areas. Figure below shows some kinds of thermosets.

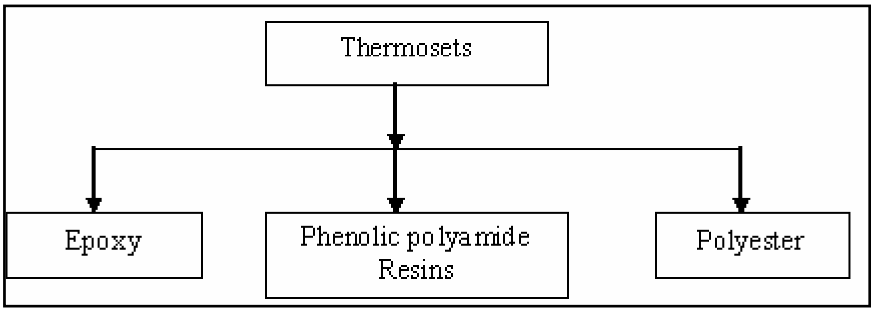

Figure1.6: Thermoset Materials

Direct condensation polymerization followed by rearrangement reactions to form heterocyclic entities is the method generally used to produce thermoset resins. Water, a product of the reaction, in both methods, hinders production of void-free composites.

These voids have a negative effect on properties of the composites in terms of strength and dielectric properties. Polyesters phenolic and Epoxies are the two important classes of thermoset resins.

Epoxy resins are widely used in filament-wound composites and are suitable for moulding prepress. They are reasonably stable to chemical attacks and are excellent adherents having slow shrinkage during curing and no emission of volatile gases. These advantages, however, make the use of epoxies rather expensive. Also, they cannot be expected beyond a temperature of 140ºC. Their use in high technology areas where service temperatures are higher, as a result, is ruled out.

Polyester resins on the other hand are quite easily accessible, cheap and find use in a widerange of fields. Liquid polyesters are stored at room temperature for months, sometimes foryears and the mere addition of a catalyst can cure the matrix material within a short time. They are used in automobile and structural applications.

The cured polyester is usually rigid or flexible as the case may be and transparent. Polyesters withstand the variations of environment and stable against chemicals. Depending on the formulation of the resin or service requirement of application, they can be used up to about 75ºC or higher. Other advantages of polyesters include easy compatibility with few glass fibers and can be used with verify of reinforced plastic accoutrey.

Aromatic Polyamides are the most sought after candidates as the matrices of advanced fiber composites for structural applications demanding long duration exposure for continuous service at around 200-250ºC .

1.3.1.2 Metal Matrix Composites (MMC)

Metal matrix composites, at present though generating a wide interest in research fraternity, are not as widely in use as their plastic counterparts. High strength, fracture toughness and stiffness are offered by metal matrices than those offered by their polymer counterparts. They can withstand elevated temperature in corrosive environment than polymer composites. Most metals and alloys could be used as matrices and they require reinforcement materials which need to be stable over a range of temperature and non-reactive too. However the guiding aspect for the choice depends essentially on the matrix material. Light metals form the matrix for temperature application and the reinforcements in addition to the aforementioned reasons are characterized by high moduli.

Most metals and alloys make good matrices. However, practically, the choices for low temperature applications are not many. Only light metals are responsive, with their low density proving an advantage. Titanium, Aluminium and magnesium are the popular matrix metals currently in vogue, which are particularly useful for aircraft applications. If metallic matrix materials have to offer high strength, they require high modulus reinforcements. The strength-to-weight ratios of resulting composites can be higher than most alloys.

The melting point, physical and mechanical properties of the composite at various temperatures determine the service temperature of composites. Most metals, ceramics and compounds can be used with matrices of low melting point alloys. The choice of reinforcements becomes more stunted with increase in the melting temperature of matrix materials.

1.3.1.3 Ceramic Matrix Materials (CMM)

Ceramics can be described as solid materials which exhibit very strong ionic bonding in general and in few cases covalent bonding. High melting points, good corrosion resistance, stability at elevated temperatures and high compressive strength, render ceramic-based matrix materials a favourite for applications requiring a structural material that doesn't give way at temperatures above 1500ºC. Naturally, ceramic matrices are the obvious choice for high temperature applications.

High modulus of elasticity and low tensile strain, which most ceramics posses, have combined to cause the failure of attempts to add reinforcements to obtain strength improvement. This is because at the stress levels at which ceramics rupture, there is insufficient elongation of the matrix which keeps composite from transferring an effective quantum of load to the reinforcement and the composite may fail unless the percentage of fiber volume is high enough. A material is reinforcement to utilize the higher tensile strength of the fiber, to produce an increase in load bearing capacity of the matrix. Addition of high-strength fiber to a weaker ceramic has not always been successful and often the resultant composite has proved to be weaker.

The use of reinforcement with high modulus of elasticity may take care of the problem to some extent and presents pre-stressing of the fiber in the ceramic matrix is being increasingly resortedto as an option.

When ceramics have a higher thermal expansion coefficient than reinforcement materials, the resultant composite is unlikely to have a superior level of strength. In that case, the composite will develop strength within ceramic at the time of cooling resulting in microcracks extending from fiber to fiber within the matrix. Microcracking can result in a composite with tensile strength lower than that of the matrix

1.4 CLASSIFICATION BASED ON REINFORCEMENTS

1.4.1 Introduction to Reinforcement

Reinforcements

A strong, inert woven and nonwoven fibrous material incorporated into the matrix to improve its metal glass and physical properties. Typical reinforcements are asbestos, boron, carbon, metal glass and ceramic fibers, flock, graphite, jute, sisal and whiskers, as well as chopped paper, macerated fabrics, and synthetic fibers. The primary difference between reinforcement and filler is the reinforcement markedly improves tensile and flexural strength, whereas filler usually does not. Also to be effective, reinforcement must form a strong adhesive bond with the resin.

The role of the reinforcement in a composite material is fundamentally one of increasing the mechanical properties of the neat resin system. All of the different fibres used in composites havedifferent properties and so affect the properties of the composite in different ways.

However, individual fibres or fibre bundles can only be used on their own in a few processessuch as filament winding. For most other applications, the fibres need to be arranged into some form of sheet, known as a fabric, to make handling possible. Different ways for assembling fibres into sheets and the variety of fibre orientations possible lead to there being many different types of fabrics, each of which has its own characteristics.

Reinforcements for the composites can be fibers, fabrics particles or **whiskers**. Fibers are essentially characterized by one very long axis with other two axes either often circular or near circular. Particles have no preferred orientation and so does their shape. Whiskers have a preferred shape but are small both in diameter and length as compared to fibers. Figure shows types of reinforcements in composites.

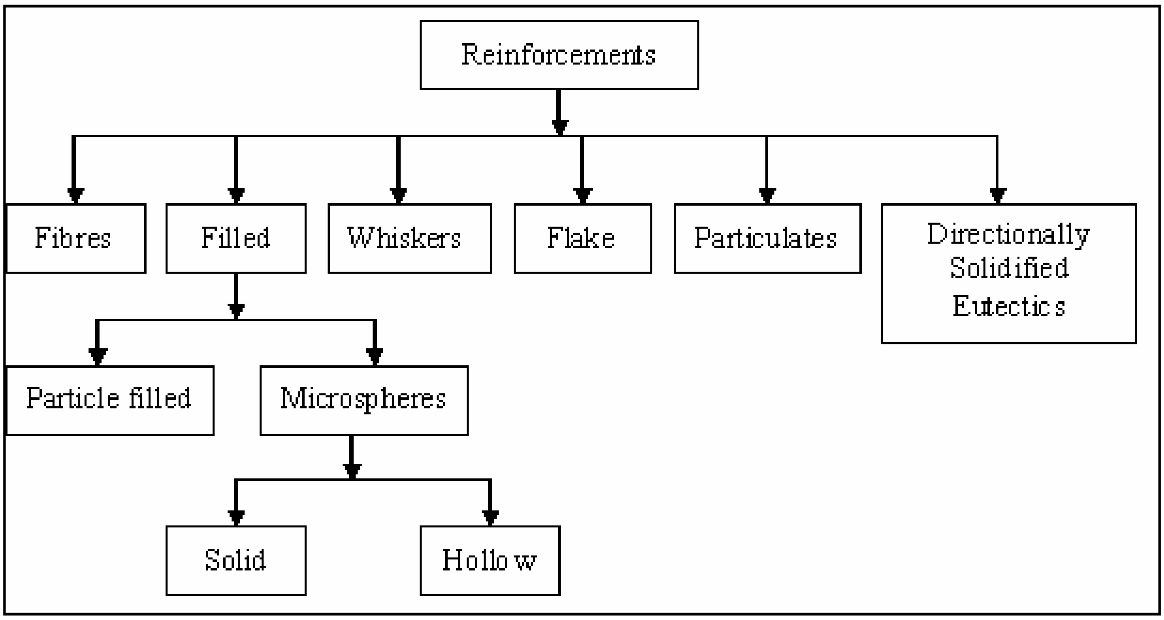

Figure1.7: Reinforcements

Reinforcing constituents in composites, as the word indicates, provide the strength that makes the composite what it is. But they also serve certain additional purposes of heat resistance or conduction, resistance to corrosion and provide rigidity. Reinforcement can be made to perform all or one of these functions as per the requirements.

A reinforcement that embellishes the matrix strength must be stronger and stiffer than the matrix and capable of changing failure mechanism to the advantage of the composite. This means that the ductility should be minimal or even nil the composite must behave as brittle as possible.

1.4.2 Fiber Reinforced Composites/Fiber Reinforced Polymer (FRP)

Composites

Fibers are the important class of reinforcements, as they satisfy the desired conditions and transfer strength to the matrix constituent influencing and enhancing their properties as desired.

Glass fibers are the earliest known fibers used to reinforce materials. Ceramic and metal fibers were subsequently found out and put to extensive use, to render composites stiffer more resistant to heat.

Fibers fall short of ideal performance due to several factors. The performance of a fibercomposite is judged by its length, shape, orientation, and composition of the fibers and the mechanical properties of the matrix.

The orientation of the fiber in the matrix is an indication of the strength of the composite and the strength is greatest along the longitudinal directional of fiber. This doesn’t mean the longitudinal fibers can take the same quantum of load irrespective of the direction in which it is applied. Optimum performance from longitudinal fibers can be obtained if the load is applied along its direction. The slightest shift in the angle of loading may drastically reduce the strength of the composite.

Unidirectional loading is found in few structures and hence it is prudent to give a mix of orientations for fibers in composites particularly where the load is expected to be the heaviest.

Monolayer tapes consisting of continuous or discontinuous fibers can be oriented unidirectional stacked into plies containing layers of filaments also oriented in the same direction. More complicated orientations are possible too and nowadays, computers are used to make projections of such variations to suit specific needs. In short, in planar composites, strength can be changed from unidirectional fiber oriented composites that result in composites with nearly isotropic properties.

Properties of angle-plied composites which are not quasi-isotropic may vary with the number of plies and their orientations. Composite variables in such composites are assumed to have a constant ratio and the matrices are considered relatively weaker than the fibers. The strength of the fiber in any one of the three axes would, therefore be one-third the unidirectional fiber composite, assuming that the volume percentage is equal in all three axes.

However, orientation of short fibers by different methods is also possible like random orientations by sprinkling on to given plane or addition of matrix in liquid or solid state before or after the fiber deposition. Even three-dimensional orientations can achieve in this way.

There are several methods of random fiber orientations, which in a two-dimensional one, yield composites with one-third the strength of an unidirectional fiber-stressed composite, in the direction of fibers. In a 3-dimension, it would result in a composite with a comparable ratio, about less than one-fifth.

In very strong matrices, moduli and strengths have not been observed. Application of thestrength of the composites with such matrices and several orientations is also possible. The longitudinal strength can be calculated on the basis of the assumption that fibers have been reduced to their effective strength on approximation value in composites with strong matricesand non-longitudinally orientated fibers.

It goes without saying that fiber composites may be constructed with either continuous or short fibers. Experience has shown that continuous fibers (or filaments) exhibit better orientation, although it does not reflect in their performance.

Mass production of filaments is well known and they match with several matrices in different ways like winding, twisting, weaving and knitting, which exhibit the characteristics of a fabric.

Since they have low densities and high strengths, the fiber lengths in filaments or other fibers yield considerable influence on the mechanical properties as well as the response of composites to processing and procedures. Shorter fibers with proper orientation composites that use glass, ceramic or multi-purpose fibers can be endowed with considerably higher strength than those that use continuous fibers. Short fibers are also known to their theoretical strength.

Short-length fibers incorporated by the open- or close-mould process are found to be less efficient, although the input costs are considerably lower than filament winding.

Most fibers in use currently are solids which are easy to produce and handle, having a circular cross-section, although a few non-conventional shaped and hollow fibers show signs of capabilities that can improve the mechanical qualities of the composites.

Given the fact that the vast difference in length and effective diameter of the fiber are assets to a fiber composite, it follows that greater strength in the fiber can be achieved by smaller diametersdue to minimization or total elimination of surface of surface defects.

After flat-thin filaments came into vogue, fibers rectangular cross sections have provided new options for applications in high strength structures. Owing to their shapes, these fibers provide perfect packing, while hollow fibers show better structural efficiency in composites that are desired for their stiffness and compressive strengths. In hollow fibers, the transverse compressive strength is lower than that of a solid fiber composite whenever the hollow portion ismore than half the total fiber diameter. However, they are not easy to handle and fabricate.

1.4.3 Fiber Reinforcements

Organic and inorganic fibers are used to reinforce composite materials. Almost all organic fibers have low density, flexibility, and elasticity. Inorganic fibers are of high modulus, high thermal stability and possess greater rigidity than organic fibers and notwithstanding the diverse advantages of organic fibers which render the composites in which they are used.

Mainly, the following different types of fibers namely, glass fibers, silicon carbide fibers, high silica and quartz fibers, aluminina fibers, metal fibers and wires, graphite fibers, boron fibers, aramid fibers and multiphase fibers are used. Among the glass fibers, it is again classified into E-glass, A-glass, R-glass etc.

There is a greater marker and higher degree of commercial movement of organic fibers.

The potential of fibers of graphite, silica carbide and boron are also exercising the scientific mind due to their applications in advanced composites.

1.4.3.1 Whiskers

Single crystals grown with nearly zero defects are termed whiskers. They are usually discontinuous and short fibers of different cross sections made from several materials like graphite, silicon carbide, copper, iron etc. Typical lengths are in 3 to 55 N.M. ranges. Whiskers differ from particles in that, whiskers have a definite length to width ratio greater than one. Whiskers can have extraordinary strengths upto 7000 MPa.

Whiskers were grown quite incidentally in laboratories for the first time, while nature has some geological structures that can be described as whiskers. Initially, their usefulness was overlooked as they were dismissed as incidental by-products of other structure. However, study on crystal structures and growth in metals sparked off an interest in them, and also the study of defects that affect the strength of materials, they came to be incorporated in composites using several methods, including power metallurgy and slip-casting techniques.

Metal-whisker combination, strengthening the system at high temperatures, has been demonstrated at the laboratory level. But whiskers are fine, small sized materials not easy to handle and this comes in the way of incorporating them into engineering materials to come out with a superior quality composite system.

Early research has shown that whisker strength varies inversely with effective diameter. When whiskers were embedded in matrices, whiskers of diameter upto 2 to 10μm yielded fairly good composites.

Ceramic material's whiskers have high moduli, useful strengths and low densities. Specific strength and specific modulus are very high and this makes ceramic whiskers suitable for low weight structure composites. They also resist temperature, mechanical damage and oxidation more responsively than metallic whiskers, which are denser than ceramic whiskers. However, they are not commercially viable because they are damaged while handling.

1.5 LAMINAR COMPOSITES/LAMINATE REINFORCED COMPOSITES

Laminar composites are found in as many combinations as the number of materials. They can be described as materials comprising of layers of materials bonded together. These may be of several layers of two or more metal materials occurring alternately or in a determined order more than once, and in as many numbers as required for a specific purpose.

Clad and sandwich laminates have many areas as it ought to be, although they are known to follow the rule of mixtures from the modulus and strength point of view. Other intrinsic values pertaining to metal-matrix, metal-reinforced composites are also fairly well known.

Powder metallurgical processes like roll bonding, hot pressing, diffusion bonding, brazing and so on can be employed for the fabrication of different alloys of sheet, foil, powder or sprayed materials. It is not possible to achieve high strength materials unlike the fiber version. But sheetsand foils can be made isotropic in two dimensions more easily than fibers. Foils and sheets are also made to exhibit high percentages of which they are put. For instance, a strong sheet mayuse over 92% in laminar structure, while it is difficult to make fibers of such compositions. Fiberlaminates cannot over 75% strong fibers.

The main functional types of metal-metal laminates that do not posses high strength or stiffness are single layered ones that endow the composites with special properties, apart from being cost-effective. They are usually made by pre-coating or cladding methods.

Pre-coated metals are formed by forming by forming a layer on a substrate, in the form of a thin continuous film. This is achieved by hot dipping and occasionally by chemical plating and electroplating. Clad metals are found to be suitable for more intensive environments where denser faces are required.

There are many combinations of sheet and foil which function as adhesives at low temperatures. Such materials, plastics or metals, may be clubbed together with a third constituent. Pre-painted or pre-finished metal whose primary advantage is elimination of final finishing by the user is the best known metal-organic laminate. Several combinations of metal-plastic, vinyl-metallaminates, organic films and metals, account for upto 95% of metal-plastic laminates known. They are made by adhesive bonding processes.

1.6 FLAKE COMPOSITES

Flakes are often used in place of fibers as can be densely packed. Metal flakes that are in close contact with each other in polymer matrices can conduct electricity or heat, while mica flakes and glass can resist both. Flakes are not expensive to produce and usually cost less than fibers.

But they fall short of expectations in aspects like control of size, shape and show defects in the end product. Glass flakes tend to have notches or cracks around the edges, which weaken the final product. They are also resistant to be lined up parallel to each other in a matrix, causing uneven strength. They are usually set in matrices, or more simply, held together by a matrix with a glue-type binder. Depending on the end-use of the product, flakes are present in small quantities or occupy the whole composite.

Flakes have various advantages over fibers in structural applications. Parallel flakes filled composites provide uniform mechanical properties in the same plane as the flakes. While angle- plying is difficult in continuous fibers which need to approach isotropic properties, it is not so in flakes. Flake composites have a higher theoretical modulus of elasticity than fiber reinforced composites. They are relatively cheaper to produce and be handled in small quantities.

1.7 FILLED COMPOSITES

Filled composites result from addition of filer materials to plastic matrices to replace a portion of the matrix, enhance or change the properties of the composites. The fillers also enhance strength and reduce weight.

Another type of filled composite is the product of structure infiltrated with a second-phase filler material. The skeleton could be a group of cells, honeycomb structures, like a network of open pores. The infiltrant could also be independent of the matrix and yet bind the components like powders or fibers, or they could just be used to fill voids. Fillers produced from powders arealso considered as particulate composite

In the open matrices of a porous or spongy composite, the formation is the natural result of processing and such matrices can be strengthened with different materials. Metal impregnates are used to improve strength or tolerance of the matrix. Metal casting, graphite, powder metallurgy parts and ceramics belong to this class of filled composites.

In the honeycomb structure, the matrix is not naturally formed, but specifically designed to a predetermed shape. Sheet materials in the hexagonal shapes are impregnated with resin or foam and are used as a core material in sandwich composites.

Fillers may be the main ingredient or an additional one in a composite. The filler particles may be irregular structures, or have precise geometrical shapes like polyhedrons, short fibers or spheres.

While their purpose is far from adding visual embellishment to the composites, they occasionallyimpart colour or opacity to the composite which they fill.

As inert additives, fillers can change almost any basic resin characteristic in all directions required, to tide over the many limitations of basic resins as far as composites are concerned. The final composite properties can be affected by the shape, surface treatment, blend of particle types, size of the particle in the filler material and the size distribution.

Filled plastics tend to behave like two different constituents. They do not alloy and accept the bonding. They are meant to develop mutually; they desist from interacting chemically with each other. It is vital that the constituents remain in co-ordination and do not destroy each other’s desired properties.

Matrix in a few filled composites provides the main framework while the filler furnishes almost all desired properties. Although the matrix forms the bulk of the composite, the filler material is used in such great quantities relatively that it becomes the rudimentary constituent.

The benefits offered by fillers include increase stiffness, thermal resistance, stability, strength and abrasion resistance, porosity and a favorable coefficient of thermal expansion.

However, the methods of fabrication are very limited and the curing of some resins is greatly inhibited. They also shorten the life span of some resins and are known to weaken a fewcomposites.

1.8 MICROSPHERES

Microspheres are considered to be some of the most useful fillers. Their specific gravity, stable particle size, strength and controlled density to modify products without compromising onprofitability or physical properties are it's their most-sought after assets.

Solid glass Microspheres, manufactured from glass are most suitable for plastics. Solid glass Microspheres are coated with a binding agent which bonds itself as well as the sphere's surface to the resin. This increases the bonding strength and basically removes absorption of liquids intothe separations around the spheres.

Solid Microspheres have relatively low density, and therefore, influence the commercial value and weight of the finished product. Studies have indicated that their inherent strength is carried over to the finished moulded part of which they form a constituent.

Hollow microspheres are essentially silicate based, made at controlled specific gravity. They are larger than solid glass spheres used in polymers and commercially supplied in a wider range of particle sizes. Commercially, silicate-based hollow microspheres with different compositions using organic compounds are also available. Due to the modification, the microspheres are rendered less sensitive to moisture, thus reducing attraction between particles. This is very vital in highly filled liquid polymer composites where viscosity enhancement constraints the quantum of filler loading.

Formerly, hollow spheres were mostly used for thermosetting resin systems. Now, several new strong spheres are available and they are at least five times stronger than hollow microspheresin static crush strength and four times long lasting in shear.

Recently, ceramic alumina silicate microspheres have been introduced in thermoplastic systems. Greater strength and higher density of this system in relation to siliceous microspheres and their resistance to abrasions and considerable strength make then suitable for application in high pressure conditions.

Hollow microspheres have a lower specific gravity than the pure resin. This makes it possible to use them for lightning resin dominant compounds. They find wide applications in aerospace and automotive industries where weight reduction for energy conservation is one of the main considerations.

But their use in systems requiring high shear mixing or high-pressure moulding is restricted as their crush resistance is in no way comparable to that of solid spheres. Fortunately, judicious applications of hollow spheres eliminate crazing at the bends in the poly-vinyl chloride plastisol applications, where the end component is subjected to bending stresses.

Microspheres, whether solid or hollow, show properties that are directly related to their spherical shape let them behave like minute ball bearing, and hence, they give better flow properties. They also distribute stress uniformly throughout resin matrices.

In spherical particles, the ratio of surface area to volume is minimal (smallest). In resin-rich surfaces of reinforced systems, the Microspheres which are free of orientation and sharp edges are capable of producing smooth surfaces.

1.9 PARTICULATE REINFORCED COMPOSITES

Microstructures of metal and ceramics composites, which show particles of one phase strewn in the other, are known as particle reinforced composites. Square, triangular and round shapes of reinforcement are known, but the dimensions of all their sides are observed to be more or less equal. The size and volume concentration of the dispersoid distinguishes it from dispersion hardened materials.

The dispersed size in particulate composites is of the order of a few microns and volume concentration is greater than 28%. The difference between particulate composite and dispersion strengthened ones is, thus, oblivious. The mechanism used to strengthen each of them is also different. The dispersed in the dispersion-strengthen materials reinforces the matrix alloy by arresting motion of dislocations and needs large forces to fracture the restriction created by dispersion. In particulate composites, the particles strengthen the system by the hydrostatic coercion of fillers in matrices and by their hardness relative to the matrix.

Three-dimensional reinforcement in composites offers isotropic properties, because of the three systematically orthogonal planes. Since it is not homogeneous, the material properties acquire sensitivity to the constituent properties, as well as the interfacial properties and geometric shapes of the array. The composite's strength usually depends on the diameter of the particles, the inter-particle spacing, and the volume fraction of the reinforcement. The matrix properties influence the behavior of particulate composite too.

1.9.1 Cermet's/Ceramal

The Cermet is an abbreviation for the "'ceramic" and "metal." A Cermet is a composite material composed of ceramic (Cer) and metallic (Met) materials. A Cermet is ideally designed to have the optimal properties of both a ceramic, such as high temperature resistance and hardness, and those of a metal, such as the ability to undergo plastic deformation. The metal is used as a binder for an oxide, boride, carbide, or alumina. Generally, the metallic elements used are nickel, molybdenum, and cobalt. Depending on the physical structure of the material, cermets can also be metal matrix composites, but cermets are usually less than 20% metal by volume.

It is used in the manufacture of resistors (especially potentiometers), capacitors, and other electronic components which may experience high temperatures.

Some types of cermet are also being considered for use as spacecraft shielding as they resist the high velocity impacts of micrometeoroids and orbital debris much more effectively than more traditional spacecraft materials such as aluminum and other metals.

One application of these materials is their use in vacuum tube coatings, which are key to solar hot water systems.

Cermets are also used in dentistry as a material for fillings and prostheses. Also it used in machining on cutting tools.

Cermets are one of the premier groups of particle strengthened composites and usually comprises ceramic grains of borides, carbides or oxides. The grains are dispersed in a refractory ductile metal matrix, which accounts for 20 to 85% of the total volume. The bonding between ceramic and metal constituents is the result of a small measure of mutual solutions.

Metal oxide systems show poor bonding and require additional bonding agents. Cermet structures are usually produced using power metallurgy techniques. Their potential properties are several and varied depending on the relative volumes and compositions and of the metal and ceramic constituents. Impregnation of a porous ceramic structure with a metallic matrix binder is another method used to produce cermets. Cermets may be employed as coating in a power form. The power is sprayed through a gas flame and fused to a base material. A wide variety of cermets have been produced on a small scale, but only a few have appreciable value commercially.

1.10 SOLIDIFICATION OF COMPOSITES/ DIRECTIONALLY SOLIDIFIED EUTECTICS

Directional solidification of alloys is adopted to produce in-situ fibers. They are really a part of the alloy being precipitated from the melt, while the alloy is solidifying. This comprises eutectic alloys wherein the molten material degenerates to form many phases at a steady temperature. When the reaction is carried out after ensuring the solidifying phases, directionally solidified eutectics result.

During the solidification of alloy, crystals nucleate from the mould or some relatively cooler region. A structure with many crystalline particles or grains results from this and grows into each other. When unidirectionallly solidified, random **coalescing** is not allowed to occur.

1.11 COMMON CATEGORIES OF COMPOSITE MATERIALS BASED ON FIBER LENGTH

Based on the form of reinforcement, common composite materials can be classified as follows:

1. Fibers as the reinforcement (Fibrous Composites):
   a. Random fiber (short fiber) reinforced composites

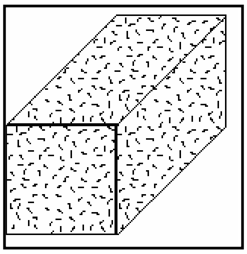

Figure1.8: Short-fiber reinforced composites

   b. Continuous fiber (long fiber) reinforced composites

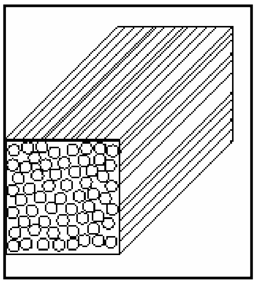

***Figure1.9: Long- fiber reinforced composite*s**

2. Particles as the reinforcement (Particulate composites):

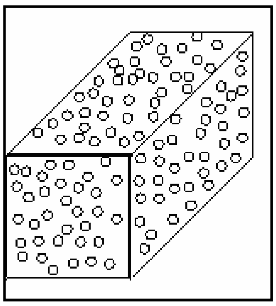

Figure1.10: Particulate Composites

3. Flat flakes as the reinforcement (Flake composites):

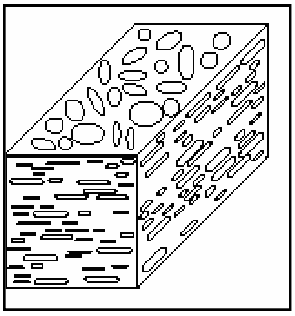

Figure1.11: Flake Composites

4. Fillers as the reinforcement (Filler composites):

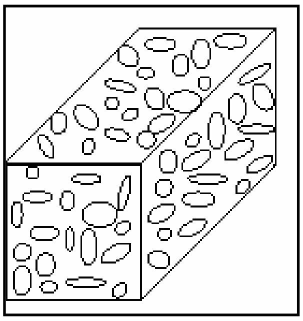

Figure1.12: Filler Composites

1.11.1 Examples for composite materials

- Fibre reinforced plastics:
    - Classified by type of fiber:
        - Wood (cellulose fibers in a lignin and hemicellulose matrix)
        - Carbon-fibre reinforced plastic (CRP)
        - Glass-fibre reinforced plastic (GRP) (informally, "fiberglass")
- Classified by matrix:
    - Thermoplastic Composites
        - short fiber thermoplastics
        - long fiber thermoplastics or long fiber reinforced thermoplastics
        - glass mat thermoplastics
        - continuous fiber reinforced thermoplastics
        - Thermoset Composites

- Metal matrix composites (MMCs):
    - White cast iron
    - Hardmetal (carbide in metal matrix)
    - Metal-intermetallic laminate
- **Ceramic matrix composites**:
    - Bone (hydroxyapatite reinforced with collagen fibers)
    - Cermet (ceramic and metal)
    - Concrete
- **Organic matrix/ceramic aggregate composites:**
    - Asphalt concrete
    - Dental composite
    - Syntactic foam
    - Mother of Pearl
- **Engineered wood**
    - Plywood
    - Oriented strand board
    - Wood plastic composite (recycled wood fiber in polyethylene matrix)
    - Pykrete (sawdust in ice matrix)
- **Plastic-impregnated or laminated paper or textiles**
    - Arborite
    - Formica (plastic)

1.12 ROLE AND SELECTION OF FIBERS

The points to be noted in selecting the reinforcements include compatibility with matrix material, thermal stability, density, melting temperature etc. The efficiency of discontinuously reinforced composites is dependent on tensile strength and density of reinforcing phases. The compatibility, density, chemical and thermal stability of the reinforcement with matrix material is important for material fabrication as well as end application. The thermal discord strain between the matrix and reinforcement is an important parameter for composites used in thermal cycling application. It is a function of difference between the coefficients of thermal expansion of the matrix and reinforcement. The manufacturing process selected and the reinforcement affects the crystal structure.

Also the role of the reinforcement depends upon its type in structural Composites. In particulate and whisker reinforced Composites, the matrix are the major load bearing constituent. The role of the reinforcement is to strengthen and stiffen the composite through prevention of matrix deformation by mechanical restraint. This restraint is generally a function of the ratio of inter- particle spacing to particle diameter. In continuous fiber reinforced Composites, the reinforcement is the principal load-bearing constituent. The metallic matrix serves to hold the reinforcing fibers together and transfer as well as distribute the load. Discontinuous fiber reinforced Composites display characteristics between those of continuous fiber and particulate reinforced composites. Typically, the addition of reinforcement increases the strength, stiffness and temperature capability while reducing the thermal expansion coefficient of the resulting MMC. When combined with a metallic matrix of higher density, the reinforcement also serves to reduce the density of the composite, thus enhancing properties such as specific strength.

1.13 MATRIX MATERIALS

Introduction

Although it is undoubtedly true that the high strength of composites is largely due to the fiber reinforcement, the importance of matrix material cannot be underestimated as it provides support for the fibers and assists the fibers in carrying the loads. It also provides stability to the composite material. Resin matrix system acts as a binding agent in a structural component in which the fibers are embedded. When too much resin is used, the part is classified as resin rich. On the other hand if there is too little resin, the part is called resin starved. A resin rich part is more susceptible to cracking due to lack of fiber support, whereas a resin starved part is weaker because of void areas and the fact that fibers are not held together and they are not well supported.

1.13.1 Matrix Selection

Thermodynamically stable dispersions are essential for the use of metal matrix composites for high temperature applications. This can be done by using an alloy dispersoid system in which solid state diffusivity, interfacial energies and elemental solubility are minimized, in turn reducing coarsening and interfacial reactions. Aluminium and magnesium alloys are regarded as widely used matrices due to low density and high thermal conductivity. Composites with low matrix alloying additions result in attractive combinations of ductility, toughness and strength. In discontinuous reinforced metal matrix composites minor alloying elements, used in wrought alloys as grain refiners, are not required. These additions should be avoided since coarse inter-metallic compounds get formed during consolidation, thus, reducing the tensile ductility of the composite.

1.13.2 Role of matrix materials

The choice of a matrix alloy for an MMC is dictated by several considerations. Of particular importance is whether the composite is to be continuously or discontinuously reinforced. The use of continuous fibers as reinforcements may result in transfer of most of the load to the reinforcing filaments and hence composite strength will be governed primarily by the fiber strength. The primary roles of the matrix alloy then are to provide efficient transfer of load to the fibers and to blunt cracks in the event that fiber failure occurs and so the matrix alloy for continuously reinforced composites may be chosen more for toughness than for strength. On this basis, lower strength, more ductile, and tougher matrix alloys may be utilized in continuously reinforced composites. For discontinuously reinforced composites, the matrix may govern composite strength. Then, the choice of matrix will be influenced by consideration of the required composite strength and higher strength matrix alloys may be required.

Additional considerations in the choice of the matrix include potential reinforcement/matrix reactions, either during processing or in service, which might result in degraded composite performance; thermal stresses due to thermal expansion mismatch between the reinforcements and the matrix; and the influence of matrix fatigue behavior on the cyclic response of the composite. Indeed, the behavior of composites under cyclic loading conditions is an arearequiring special consideration. In composites intended for use at elevated temperatures, an additional consideration is the difference in melting temperatures between the matrix and the reinforcements. A large melting temperature difference may result in matrix creep while the reinforcements remain elastic, even at temperatures approaching the matrix melting point. However, creep in both the matrix and reinforcement must be considered when there is a small melting point difference in the composite.

1.13.3 Functions of a Matrix

In a composite material, the matrix material serves the following functions:

- Holds the fibres together.
- Protects the fibres from environment.
- Enhances transverse properties of a laminate.
- Improves impact and fracture resistance of a component.
- Helps to avoid propagation of crack growth through the fibres by providing alternate failure path along the interface between the fibres and the matrix.
- Carry inter-laminar shear.

The matrix plays a minor role in the tensile load-carrying capacity of a composite structure. However, selection of a matrix has a major influence on the interlaminar shear as well as in- plane shear properties of the composite material. The interlaminar shear strength is an important design consideration for structures under bending loads, whereas the in-plane shear strength is important under torsion loads. The matrix provides lateral support against the possibility of fibre buckling under compression loading, thus influencing to some extent the compressive strength of the composite material. The interaction between fibres and matrix is also important in designing damage tolerant structures. Finally, the process ability and defects in a composite material depend strongly on the physical and thermal characteristics, such as viscosity, melting point, and curing temperature of the matrix.

1.13.4 Desired Properties of a Matrix

The needs or desired properties of the matrix which are important for a composite structure areas follows:

- Reduced moisture absorption.
- Low shrinkage.
- Low coefficient of thermal expansion.
- Good flow characteristics so that it penetrates the fibre bundles completely and eliminatesvoids during the compacting/curing process.
- Reasonable strength, modulus and elongation (elongation should be greater than fibre).
- Must be elastic to transfer load to fibres.
- Strength at elevated temperature (depending on application).
- Low temperature capability (depending on application).
- Excellent chemical resistance (depending on application).
- Should be easily processable into the final composite shape.
- Dimensional stability (maintains its shape).

As stated above, the matrix causes the stress to be distributed more evenly between all fibres by causing the fibres to suffer the same strain. The stress is transmitted by shear process, which requires good bonding between fibre and matrix and also high shear strength and modulus for thematrix itself. One of the important properties of cured matrix system is its glass transition temperature (Tg) at which the matrix begins to soften and exhibits a decrease in mechanical properties. The glass transition temperature is not only an important parameter for dimensional stability of a composite part under influence of heat, but it also has effect on most of the physical properties of the matrix system at ambient temperature.

As the load is primarily carried by the fibres, the overall elongation of a composite material is governed by the elongation to failure of the fibres that is usually 1-1.5%. A significant property of the matrix is that it should not crack. The function of the matrix in a composite material will vary depending on how the composites are stressed. For example, in case of compressive loading the matrix prevents the fibers from buckling and is, therefore, a very critical part of the composite since without it; the reinforcement could carry no load. On the contrary, a bundle of fibers could sustain high tensile loads in the direction of the filaments without a matrix. Some of the physical properties of the matrix which influence the behaviour of composites are:

- Shrinkage during cure,
- Modulus of elasticity,
- Ultimate elongation,
- Strength (tensile, compressive and shear)
- Fracture toughness.

1.13.5 Factors considered for Selection of Matrix

In selecting matrix material, following factors may be taken into consideration:

- The matrix must have a mechanical strength commensurate with that of the reinforcement i.e. both should be compatible. Thus, if a high strength fibre is used as the reinforcement, there is no point using a low strength matrix, which will not transmit stresses efficiently to the reinforcement.
- The matrix must stand up to the service conditions, viz., temperature, humidity, exposure to ultra-violet environment, exposure to chemical atmosphere, abrasion by dust particles, etc.
- The matrix must be easy to use in the selected fabrication process.
- Smoke requirements.
- Life expectancy.
- The resultant composite should be cost effective.

The fibers are saturated with a liquid resin before it cures to a solid. The solid resin is then saidto be the matrix for the fibers.

1.14 Advantages and Limitations of Composites Materials

1.14.1Advantages of Composites

Summary of the advantages exhibited by composite materials, which are of significant use inaerospace industry are as follows:

- High resistance to fatigue and corrosion degradation.
- High ‘strength or stiffness to weight’ ratio. As enumerated above, weight savings are significant ranging from 25-45% of the weight of conventional metallic designs.
- Due to greater reliability, there are fewer inspections and structural repairs.
- Directional tailoring capabilities to meet the design requirements. The fibre pattern can be laid in a manner that will tailor the structure to efficiently sustain the applied loads.
- Fibre to fibre redundant load path.
- Improved dent resistance is normally achieved. Composite panels do not sustain damage as easily as thin gage sheet metals.
- It is easier to achieve smooth aerodynamic profiles for drag reduction. Complex double-curvature parts with a smooth surface finish can be made in one manufacturing operation.
- Composites offer improved torsional stiffness. This implies high whirling speeds, reduced number of intermediate bearings and supporting structural elements. The overall part count and manufacturing & assembly costs are thus reduced.
- High resistance to impact damage.
- Thermoplastics have rapid process cycles, making them attractive for high volume commercial applications that traditionally have been the domain of sheet metals. Moreover, thermoplastics can also be reformed.
- Like metals, thermoplastics have indefinite shelf life.

- Composites are dimensionally stable i.e. they have low thermal conductivity and low coefficient of thermal expansion. Composite materials can be tailored to comply with a broad range of thermal expansion design requirements and to minimise thermal stresses.
- Manufacture and assembly are simplified because of part integration (joint/fastener reduction) thereby reducing cost.
- The improved weather ability of composites in a marine environment as well as their corrosion resistance and durability reduce the down time for maintenance.
- Close tolerances can be achieved without machining.
- Material is reduced because composite parts and structures are frequently built to shape rather than machined to the required configuration, as is common with metals.
- Excellent heat sink properties of composites, especially Carbon-Carbon, combined with their lightweight have extended their use for aircraft brakes.
- Improved friction and wear properties.
- The ability to tailor the basic material properties of a Laminate has allowed new approaches to the design of aero elastic flight structures.

The above advantages translate not only into airplane, but also into common implements and equipment such as a graphite racquet that has inherent damping, and causes less fatigue and pain to the user.

1.14.2 Limitations of Composites

Some of the associated disadvantages of advanced composites are as follows:

- High cost of raw materials and fabrication.
- Composites are more brittle than wrought metals and thus are more easily damaged.
- Transverse properties may be weak.
- Matrix is weak, therefore, low toughness.
- Reuse and disposal may be difficult.
- Difficult to attach.

- Repair introduces new problems, for the following reasons:
- Materials require refrigerated transport and storage and have limited shelf life.
- Hot curing is necessary in many cases requiring special tooling.
- Hot or cold curing takes time.
- Analysis is difficult.
- Matrix is subject to environmental degradation.

However, proper design and material selection can circumvent many of the above disadvantages.

New technology has provided a variety of reinforcing fibres and matrices those can be combined to form composites having a wide range of exceptional properties. Since the advanced composites are capable of providing structural efficiency at lower weights as compared to equivalent metallic structures, they have emerged as the primary materials for future use.

In aircraft application, advanced fibre reinforced composites are now being used in many structural applications, viz. floor beams, engine cowlings, flight control surfaces, landing gear doors, wing-to-body fairings, etc., and also major load carrying structures including the vertical and horizontal stabiliser main torque boxes.

Composites are also being considered for use in improvements to civil infrastructures, viz., Earthquake proof highway supports, power generating wind mills, long span bridges, etc.

CHAPTER 2

LITERATURE REVIEW

2.LITERATURE REVIEW

U.S. Ramakanth and putti.Srinivasa rao [1] had studied the influence of sic and fly ash on the wear behaviour of aluminum 7075 and the weight percentage of the hybrid complex. Aluminum alloy 7075 strengthened with sic-fly ash was examined. The effectiveness of the integration of SiC in the composite for obtaining wear reduction was investigated in this study.

Sweety Mabanta, M.Chandrasekaran et al. [2] had studied the hybrid metal matrix Nano composites (MMNC) having AL7075 matrix alloy reinforced with (1.5 wt. %) and fly ash (0.5, 1.0 and 1.5 wt. %) nanoparticles were produced by ultrasonic stir casting method. A good enhancement in the wear properties of all combinations of reinforcements in AL-7075 hybrid Nano composites is observed. The hybrid Nano composites having 1.5 wt. % of B_4C and 1.5 wt. % of fly ash exhibited the maximum wear resistance.

Balasubramani Subramaniam, Balaji Natarajan, et al. [3] study involves dry sliding wear behavior of AL7075 hybrid composites by pin-on-disc wear tester. The experimental research work is carried out in material of AL7075 hybrid composite manufactured through stir casting. Wear specimen of AL7075 alloy hybrid composites are manufactured with varying weight percentage of (0, 3, 6, 9 and 12 wt. %) B_4C with 3 wt. % FA composite. These experimental results exposed that the addition of hard reinforcements such as B_4C and agro based waste material as a reinforcement of CSFA particles have greater improvement in wear resistance.

M. H.Faisal and S.Prabagaran [4] performed mechanical and wear tests on AL7075/B_4C, AL7075/ B_4C /Gr and AL7075/ B_4C /Fly ash composites. By adding boron carbide and Fly ash in the AL7075 Aluminum matrix, the hardness of the produced composites gets raised. In the case of tribological properties like wear, coefficient of friction and frictional force, a decline was observed with the addition of boron carbide and Fly ash.

SD.Saravanan, M.Senthil Kumar et al. [5] studied the properties of the AISI10Mg alloy with RHA reinforcements and found that the tensile Strength and compressive

Strength increased with an increase in the weight percentage of rice husk ash. Hardness of the composite linearly increasing with the increase in weight fraction of the rice husk ash particles.

P.Anitha, U.Shrinivas Balraj et al. [6] studied the dry sliding wear performance of Alumina- A1203 and graphite-Gr particles reinforced with AL7075 (aluminum alloy 7075) hybrid metal matrix composites is studied using a pin-on-disc tribometer. Wear decreases with the increase of Al2O3% reinforcement and increases with the increase of applied load. Whereas, coefficient of friction is mainly influenced by Gr% reinforcement and the applied load. Applied load significantly affects both wear and coefficient of friction, whereas sliding distance has an insignificant effect on both.

N.Sathish Kumar [7] studied the fabrication and characterization of high-performance Aluminum composite material with agro-waste reinforcements. The base material selected for the composite development is Aluminum 7075, whereas rice husk ash (RHA) and mica is preferred as reinforcement and fabricated by squeeze casting. The manufactured composite is economical and harder than the base material and I possess high toughness and tensile strength

Ashiwani Kumar [8] studied the mechanical and dry sliding behaviour of AL7075-B_4C rice husk ash (RHA) hybrid alloy composite. The specimens of AL7075 with 0, 2, 4, 6, 8 wt.% of B_4C mixed with 0, 2, 4, 6 and 8 wt.% rice husk ash (RHA) are prepared using high vacuum casting machining. The addition of 8 wt. % B_4C -8 wt. % of RHA has reduced wear rate of composite greatly even with increasing sliding velocity and the applied load. Thus, the wear resistance of composite improves at 8 wt. % B_4C -8 wt. % of RHA.

Namdev A.Patil et al. [9] used friction stir processing (FSP) to fabricate ice houde ssh (RHA) reinforced aluminum 7075 alloy (AL7075) surface composites (SC). The deposition method of RHA into AL7075 substrate has been taken as variable and its effects on microstructure, micro hardness and tensile properties of resultant SCs were analysed.

Nishant Verma [10] had studied the mechanical behaviour of AA 7075- B_4C -Rice Husk Ash (RHA) hybrid composite. The samples AA 7075 and 5 wt. % of B_4C and 3, 5 wt. % of RHA are prepared using the Stir Casting technique. The highest hardness is 121 HV at 5 wt. % of B_4C and 5 wt. % of RHA. The highest tensile strength is 260 MPa at 5 wt. % of B_4C.

Rajeshkumar Gangaram Bhandare, Parshuram M.Sonawane [11] The “composite material” is composed of a discrete reinforcement & distributed in a continuous phase of matrix, In Aluminium matrix composite (AMC) one constitutes is aluminium which forms network i.e. matrix phase and another constitute serve as reinforcement which is generally ceramic or non-metallic hard material. The basic reason of metals reinforced with hard ceramic particles or fibers are improved properties than its original material like strength, stiffness etc. Stir casting process is mainly used for manufacturing of particulate reinforced metal matrix composite (PMMC). Manufacturing of aluminum alloy based casting composite by stir casting is one of the most economical methods of processing MMC. Properties of these materials depend upon many processing parameters and selection of matrix and reinforcements. This paper presents an overview of stir casting process, process parameter, & preparation of AMC material by using aluminium as matrix form and SiC, Al2O3, graphite as reinforcement by varying proportion.

Suman Kant and Ajay Singh Verma [12] The enhancement of manufacturing sector has somewhere advance to the increase in the use of particulate aluminium metal matrix composites (PAMMCs). PAMMCs are attracting considerable interest worldwide for automotive, architectural and aerospace sectors because of their superior mechanical and tribological properties. PAMMCs possess high specific strength, greater strength to weight ratio at elevated temperature, greater wear resistance as compare to matrix phase. Numerous types of reinforcements in particulate like SiC, Al2O3, B_4C, TiC and ZrSiO4 is used to improve the metallurgical as well as mechanical properties as compared to its base matrix. Besides, authors also used industrial and agro waste like fly ash, bauxite residue, groundnut shell, rice husk ash and bagess ash as reinforcement in matrix phase. Various fabrication processes like solid state (Powder Metallurgy) and liquid state processes (Stir casting, Compo-casting, Squeeze Casting, in situ casting routes) were adopted by authors to fabricate PAMMCs.Among these processes stir casting is cheapest and simple route for fabrication of AMMCs. This review article elaborate the latest trend in stir cast process to fabricate different types of PMMCs.

CHAPTER 3

EXPERIMENTAL DETAILS & METHODOLOGY

3. EXPERIMENTAL DETAILS & METHODOLOGY

3.1 SELECTION OF MATERIAL

The matrix material utilized in the current study is Al7075. The distinctive alloying parts are magnesium, copper, manganese, element, and atomic number 30. It belongs to a gaggle of hypo mixture Al-Si alloys and includes a wide field of application within the automotive and aeronautics industries. Besides this, the Al7075 alloy is employed as a matrix for getting composites that have Associate in Nursing increased wear resistance, favourable mechanical properties at temperature, and increased mechanical properties at elevated temperatures. Al7075 alloys naturally have Associate in nursing modulus of elasticity of regarding 70GPa. In general, stiffer and lighter styles are achieved with Al7075 alloys than is feasible with steels.

Applications of Al7075:

It is typically used in

- Truck frames
- Rail coaches
- Military and commercial bridges
- Ship building operations
- Towers and pylons
- Rivets
- Aerospace applications (i.e., helicopter rotor skins)
- Transport operations.

Table 3.1 Al7075 Chemical Composition

Elements	Cu	Mg	Si	Fe	Mn	Cr	Zn
Wt %	1.5	2.5	0.4	0.5	0.3	0.23	5.6

Table 3.2 Al7075 Mechanical Properties

Base Material	Al7075
Density value	2.81 g/cm^3
Young's modulus value	71.7Gpa
Tensile strength value	572Mpa
Elongation at break value	11%
Poisson's ratio value	0.33
Melting temperature value	477°c
Thermal conductivity value	130-150 W/(m-k)
Linear thermal expansion coefficient value	$2.36X10^{-5}$
Specific heat capacity value	714.8 J/(kg-k)

3.2 REINFORCEMENTS

3.2.1 Silicon Carbide

Silicon Carbide is that the sole matter of carbon and component. It was made by the warmth electro-substance response of sand and carbon. Nowadays the texture has been formed into a top-quality specialized grade fired with wonderful mechanical properties. Compared with carbon fiber, carbide fiber will maintain sensible performance beneath extreme conditions.

Silicon carbide fibre has sensible properties in these aspects, additionally pretty much as good compatibility with ceramics and metal matrix, therefore it is employed to strengthen composite materials.

Table: 3.3 Chemical Composition of SiC

Element	Si	SiO_2	Fe	Al	C
%	0.3	5	0.08	0.1	0.3

Fig. 3.1 SiC Powder

Properties:

1. Density – 3.1 g/cm^3
2. Tensile strength - 240MPa
3. Young's modulus – 129.9GPa

Key properties of SiC

1. High hardness
2. Low thermal expansion
3. High thermal consistency
4. Good resistance at high temperatures
5. Electrical conductivity
6. Non-linear electrical resistance

3.2.2 Boron Carbide

- Boron carbon is an extremely hard boron carbon ceramic and covalent material produced in tonnage quantities. It is mainly produced by reacting carbon with B_2O_3 in an electric arc furnace, through carbothermal reduction or by gas phase reactions:

$$2\ B_2O_3 + 7\ C \rightarrow B_4C + 6\ CO$$

- It has good chemical resistance, good nuclear properties, extreme hardness and low density.
- Boron carbide (B_4C) used as reinforcement in aluminium Matrix composites because of low density, high-strength, exceptionally high hardness, good chemical stability and neutron absorption capability.

Table: 3.4 Chemical Composition of B_4C

Element	Si	O	Fe	Al	C
%	0.15	1	0.05	0.05	21.8

Fig. 3.2 B_4C Powder

Properties:

1. Density – 2.3 g/cm^3
2. Tensile strength - 261MPa
3. Young's modulus – 362GPa

Key properties of B_4C

1. High Hardness
2. High Melting point
3. High Young's Modulus (it's a very stiff material)
4. Relatively low thermal expansion and conductivity

3.3 MUFFLE-FURNACE

A furnace is one of the most elements of your HVAC system. Once you set your thermostat, you activate the chamber to start heating air. a disciple switches on and circulates this heated air through your home. However, the warmth is transferred to the air depends on the kind of furnace.

A muffle furnace or muffle oven (sometimes retort furnace in historical usage could be a chamber inside which the theme material is segregated from the fuel and all of the product of burning, just as gases and flying debris. at the point when the occasion of high-temperature warming parts and boundless charge in created nations, new mute heaters immediately delighted to electrical styles.

Fig: 3.3 Muffle Furnace

One will set the desired temperature by pressing red colour push by finger, hold a similar in pressing position and temporary worker by rotating coarse, fine knobs and unharness the finer from the push. When emotional push, junction rectifier show of controller indicates an actual temperature of **furnace.** There are four main styles of furnaces: gas, oil, electric, and fuel. Electrical furnaces will heat the air by exposing heated parts, whereas alternative styles of furnaces generally need a device or chamber that warms the encompassing air.

3.4. ELECTRIC ARC FURNACE

An Electric arc furna**ce** (**EAF**) is a furnace that heat charged material by means that of an electrical arc. Mechanical circular segment heaters place size from small units of around one-ton ability (utilized in foundries for assembling fashioned iron items) as much as 400 ton units utilized for optional steelmaking. Circular segment heaters used in investigation research centres and by dental specialists may have a capacity of exclusively around dozen grams. Modern flash chamber temperatures will reach one,800 °C (3,272 °F), while research centre units will surpass three,000 °C (5,432 °F). Circular segment heaters differ from enlistment heaters, in this, the charged material is straightforwardly presented to an electrical bend, and furthermore the flow inside the chamber terminals goes through the charged material.

Fig: 3.4 Electric Arc Furnace

3.5. FABRICATION and METHADOLOGY

3.5.1. PRE-HEATING

Preheating of Reinforcement ought to be exhausted to get rid of agglomeration, wetness, and gases conferred in it. Assault and B4C are preheated in a Muffle chamber at a temperature of 3500c for one day. A six-finger die is preheated for one hour at 400^{o}c in Arc chamber such, the liquefied metal doesn't get solid quick.

3.5.2. STIR CASTING

Stir casting could be a liquid state technique for the manufacture of composite materials, within which a dispersed particle is combined with a liquefied metal matrix by means that of mechanical stirring. Stir Casting is that the simple technique of liquid state fabrication

It is one of all the foremost appropriate techniques for manufacturing metal matrix composites for various combinations of ceramic and metals.

It could be a sort of easy operation, lower price of production and production capabilities created this system versatile.

In recent past composites as well as steel and titanium-based alloys have additionally been rumoured. The hybrid composites are a brand new age of metal framework composites to achieve desired properties at a nearer approximation of real desires. These might have the potential of satisfying the recent demands of advanced engineering applications.

Fig: 3.5. Stir Casting Furnace

The Aluminium 6061 is placed within the vessel nearly 800gm-1000gm as per our demand of dying as shown in fig. shut the lid on the vessel and wait until the bottom material turns into liquid and add the reinforcements I Chronicles, 2% consistent with the load of the Al-6061 within the chamber.

3.5.3. CRUCIBLE

Crucible is that the instrumentality within which the metal is molten then poured into a mould to perform casting. The fabric of mould ought to have a more freezing point, more strength {and ought to |and will| and may} be a sensible conductor of warmth so that heat loss should be low. They are many materials on the market for this purpose like SiC, solid steel, and atomic number 6. For our necessities, the SiC vessel is good for suited, but the price is incredibly high therefore can't be afforded. We have got taken here an atomic number 6 vessel that serves our functions as its melting temperature is 2700°C that is way on top of operating temperature. The vessel is formed in an exceedingly form of a cylinder with decrease diameter so that the high portion remains a cylinder but the lowest half takes the form of a hemisphere. A handle is connected to the aspect of the vessel to carry it whereas putting it within the chamber and whereas gushing hot metal into the mould cavity. It will face up to terribly high temperatures and is employed for metal, glass, and for pigment production additionally as a variety of newly laboratory processes.

Fig: 3.6. Al7075 in Crucible

3.5.4. STIRRER

The strategy used in the manufacture of MMC needs the scattered particles that are the ceramic particles (SiC) to be blended in a strong state inside the fluid metal. Consequently for the uniform blend of the ceramic particles inside the fluid metal, it's necessary that the combination be mixed well. Thus, a stirrer is required which might withstand the warm temperature and doesn't affect the virtue of the composite. The stirrer is made of a chrome steel pole whose face is associated with a nuclear number 6 fan. It's driven by a ½ H.P. AC engine and pivots at a disturbing 400 rates. The stirrer is embedded upward into the vessel concerning 33% of its tallness once adding the fired particles. Here we've given approaches to mixing through outside mediums that might be associated with the chamber at any reason through the most elevated.

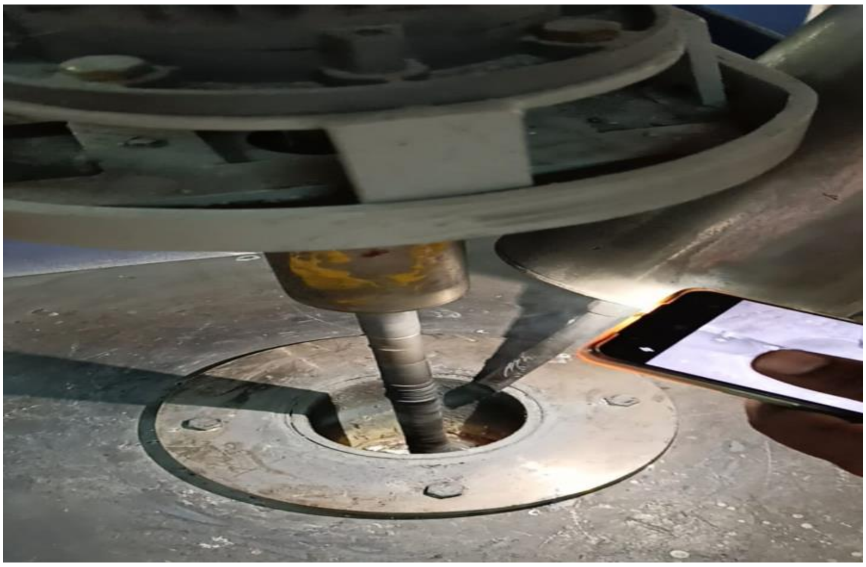

Fig: 3.7. Adding of Reinforcement according to their Percentages

CHAPTER 4

TESTING TOOLS AND MACHINES

4. TESTING TOOLS AND MACHINES

4.1. CAST IN THE MOULD

The 4 finger die was opened after the mould poured in the die gets solidify and then we get the shape of the die with cast of aluminium with mixture of the reinforcements as shown in figure 4.1.

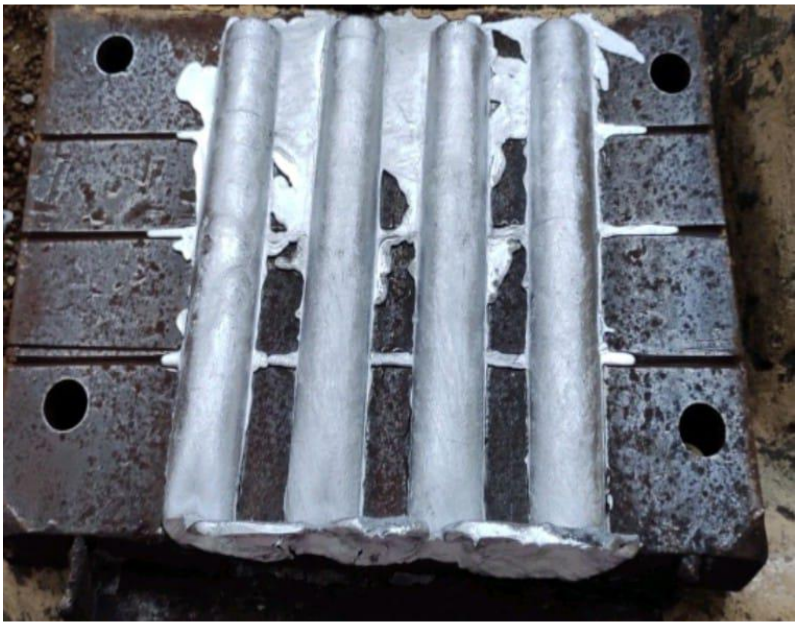

Fig: 4.1 After Casting

4.1.1. MACHINING

Machining is any of different cycles where a piece of crude material is cut into an ideal last shape and size by a controlled material-expulsion measure. The cycles that have this normal topic, controlled material evacuation, are today all in all known as subtractive assembling, in qualification from cycles of controlled material expansion, which are known as added substance fabricating. Precisely what the "controlled" a piece of the definition infers can shift, however it quite often suggests the utilization of machine instruments (notwithstanding power apparatuses and hand devices). Machining is a piece of the assembling of many metal items, however it can likewise be utilized on materials like wood, plastic, artistic, and composites. An individual who has some expertise in machining is known as a mechanical engineer. A room, building, or organization where by PC mathematical control (CNC), in which PCs are utilized to control the development and machining is done is known as a machine shop. Quite a bit of present day machining is completed activity of the plants, machines, and other cutting machines.

In turning, a cutting instrument with a solitary forefront is utilized to eliminate material from a pivoting work piece to create a round and hollow shape. The essential movement is given by turning the work piece, and the feed movement is accomplished by moving the cutting instrument gradually toward a path corresponding to the hub of revolution of the work piece.

Fig: 4.2 During Machining

A cutting device has at least one sharp front lines and is made of a material that is more enthusiastically than the work material. The state of the art serves to isolate chip from the parent work material. Associated with the forefront are the two surfaces of the apparatus:

- The rake face; and
- The flank.

The rake face which coordinates the progression of recently shaped chip, is arranged at a specific point is known as the rake point "α". It is estimated comparative with the plane opposite to the work surface. The rake point can be positive or negative. The flank of the instrument gives a leeway between the device and the recently shaped work surface, hence shielding the surface from scraped area, which would debase the completion. This point between the work surface and the flank surface is known as the help point. There are two essential kinds of cutting instruments:

- Single point device; and
- Multiple-state of the art device

A solitary point device makes them cut edge and is utilized for turning, exhausting and arranging. During machining, the place of the device infiltrates underneath the first work surface of the work part. The fact is in some cases adjusted to a specific range, called the nose sweep.

Different state of the art devices have more than one forefront and typically accomplish their movement comparative with the work part by turning. Penetrating and processing use pivoting numerous state of the art apparatuses. Albeit the states of these instruments are unique in relation to a solitary point device, numerous components of hardware math are comparative.

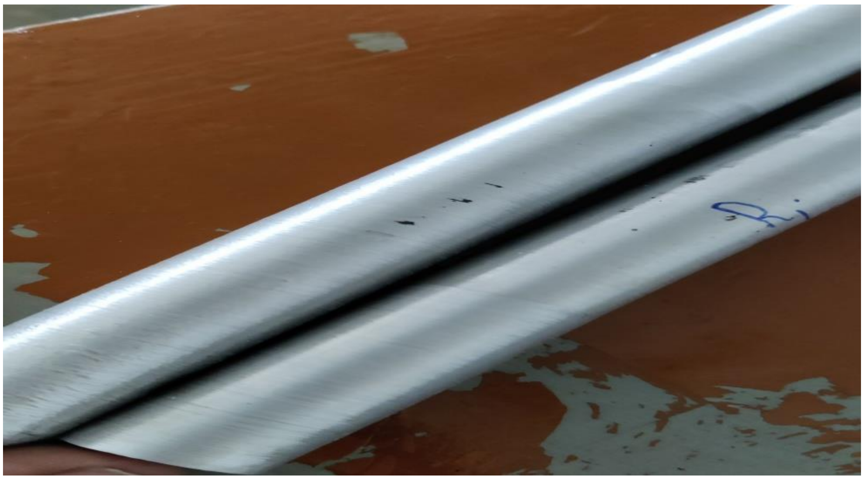

Fig: 4.3. After Machining

4.2. TESTS CONDUCTED

- Density
- Tensile
- Compression
- Hardness
- Impact

4.2.1. DENSITY

The density of the composites was gotten by the Archimedean strategy for gauging little pieces cut from the composite chamber first in air and afterward in water, while the hypothetical density was determined utilizing the blend rule as per the weight part of the molecule.

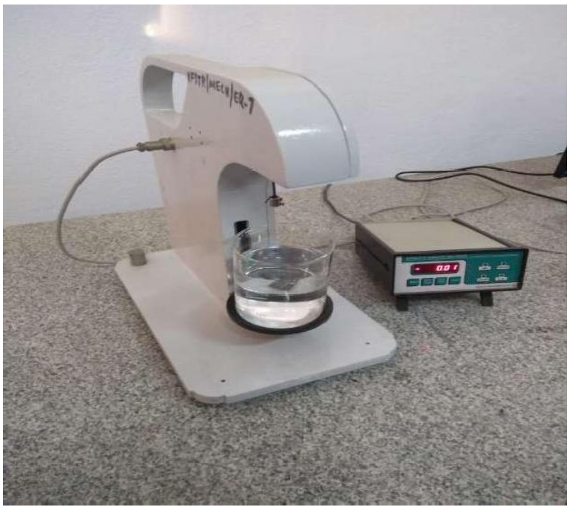

Fig 4.4 Density Measurement Apparatus

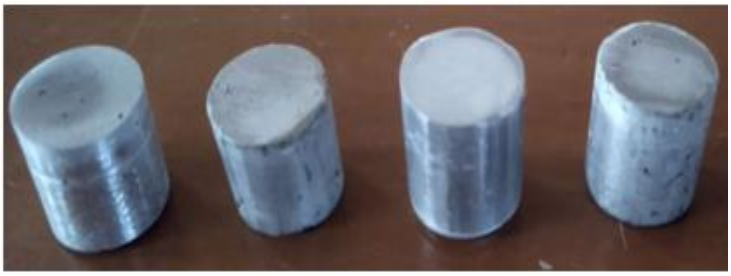

Fig 4.5 Density Measurement Tested Specimens

4.2.2. TENSILE TEST

One material property that is broadly utilized and perceived is the strength of a material. In any case, what does "strength" mean? "Strength" can have numerous implications, so let us investigate what is implied by the strength of a material. We will take a gander at an exceptionally simple test that gives heaps of data about the strength or the mechanical conduct of a material, called the malleable test.

Fig 4.6 Tensile Pieces after Machining

The fundamental thought of a pliable test is to put an example of a material between two installations called "grasps" which clasp the material. The material has known measurements, similar to length and cross-sectional region. We then, at that point start to apply weight to the material held toward one side while the opposite end is fixed. We continue to expand the weight (frequently called the heap or power) while simultaneously estimating the adjustment of length of the example.

Fig. 4.7 Universal Testing Machine (UTM)

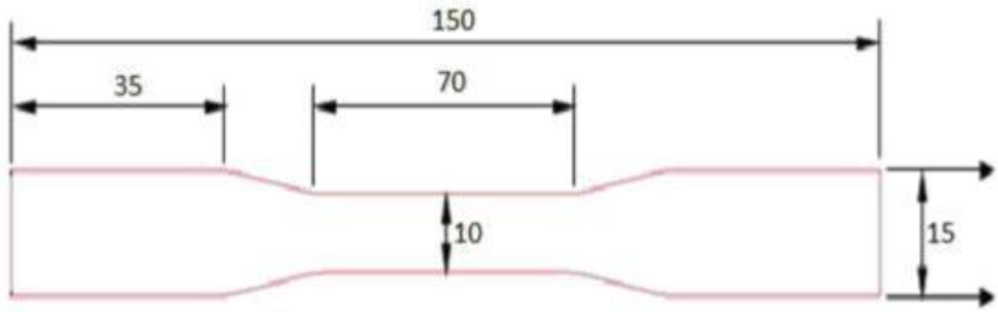

Fig 4.8 Tensile Test Specimen

Fig 4.9 Tensile Test Specimen after testing

4.2.3. COMPRESSION TEST

A compression test is any test wherein a material encounters contradicting powers that push internal upon the example from inverse sides or is generally packed, "crushed", squashed, or smoothed.

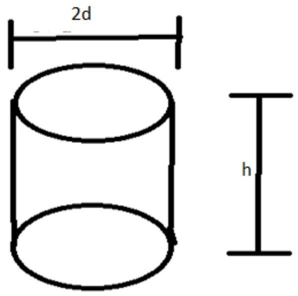

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Fig 4.10 Compression test Specimen

The test is for the most part positioned in the middle of two plates that disseminate the applied burden across the whole surface space of two inverse countenances of the test and afterward the plates are moved together by a widespread test machine making the example level. A compacted test is typically abbreviated toward the applied powers and extends toward the path opposite to the power. A pressure test is basically something contrary to the more normal strain test.

Fig 4.11 Compression Pieces after Machining

Fig 4.12 Compression Pieces after testing

4.2.4. VICKERS HARDNESS TEST

`The hardness of a material can be determined by Brinell Rockwell and Vickers hardness test. In Vickers hardness test, diamond indentation is used to determine the hardness. Vickers test decides the hardness by the estimation of the profundity of infiltration of an indenter under load more than contrasted with the entrance made by a preload. There are various scales, meant by a solitary letter, that utilization various burdens or indenters.

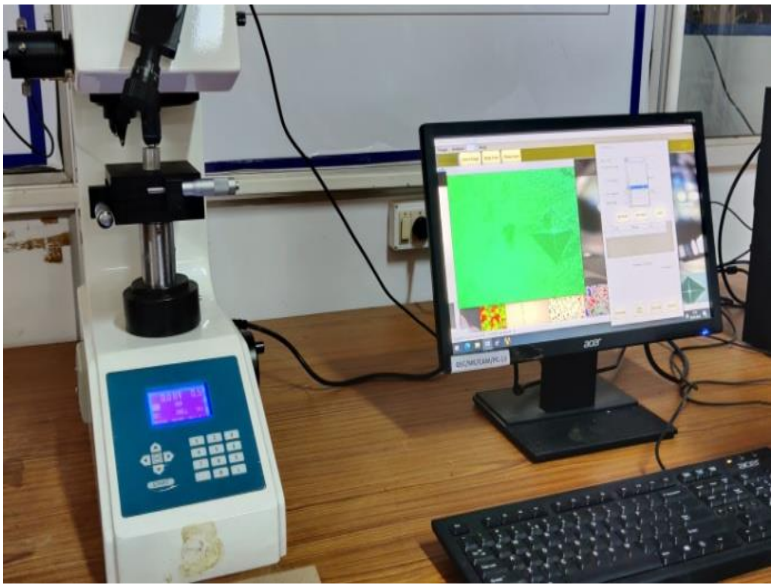

Fig 4.13 Vickers Hardness Testing Machine

The hardness of the AL7075 alloy and composites was determined with Vickers Micro Hardness Tester (LECOAT700 Micro hardness Tester). The dimension of each specimen for hardness testing was 20x10mmand each specimen was grinded and polished to obtain a flat smooth surface. During the testing, a load of 100gm. was applied for 10s on the specimen through square based diamond indenter and the hardness readings taken in a standard manner.

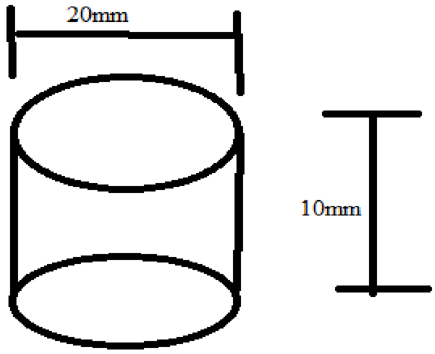

Fig 4.14 Hardness test Specimen dimensions

Fig 4.15 Hardness test Specimens after testing

4.2.5 IMPACT TEST

1. The behaviour of the material under dynamic loading is entirely different from the behaviour of the material under the static loading. The material may have high strengths but when it comes to dynamic loading (impact loads or the shock loads), they may not be suitable and they eventually fail. The capacity of the material to withstand the shock load or the impact loads are known as the **impact strength**. So static testing is not suitable to determine the Impact strength of the material. so we have to proceed with the Dynamic load testing.

2. In engineering, Impact test is mostly used to determine the impact strength, toughness and the notch sensitivity of the material. A specimen with a notch used in Impact testing. There are two different types of Impact tests, they are

   I. Charpy Impact Test
   II. Izod Impact Test

4.2.5.1 CHARPY IMPACT TEST

Impact Test to be carried out over Charpy Impact Testing Machine. The test specimens are prepared from the casting materials and machined as per ASTM E-23standard size. Square cross sections of size (10mmX10mmX55mm) with single V-notches are planned for experiment. The size of V-notches is 45o and 2mm depth. The impact roughness factor was determined when fracture is occurs.

4.2.5.2 IZOD IMPACT TEST

The **Izod impact strength test** is an ASTM standard method of determining the impact resistance of materials. A pivoting arm is raised to a specific height (constant potential energy) and then released. The arm swings down hitting a notched sample, breaking the specimen. The energy absorbed by the sample is calculated from the height the arm swings to after hitting the sample. A notched sample is generally used to determine impact energy and notch sensitivity.

CHAPTER 5

RESULTS AND DISCUSSION

5. RESULTS AND DISCUSSIONS

5.1 DENSITY TEST

The test performed on the specimens with SiC and B_4C (mixture of both SiC and B_4C with equal %) reinforcement.

Table 5.1 Density Varying with SiC & B_4C

S.no	Sample	Measured
1	Al7075	2.69 g/cm^3
2	Al7075 +1.5% (B_4C + SiC)	2.678 g/cm^3
3	Al7075 + 2.5 %(B_4C + SiC)	2.67 g/cm^3
4	Al7075 + 3.5 %(B_4C + SiC)	2.662 g/cm^3
5	Al7075 + 4.5 %(B_4C + SiC)	2.648 g/cm^3

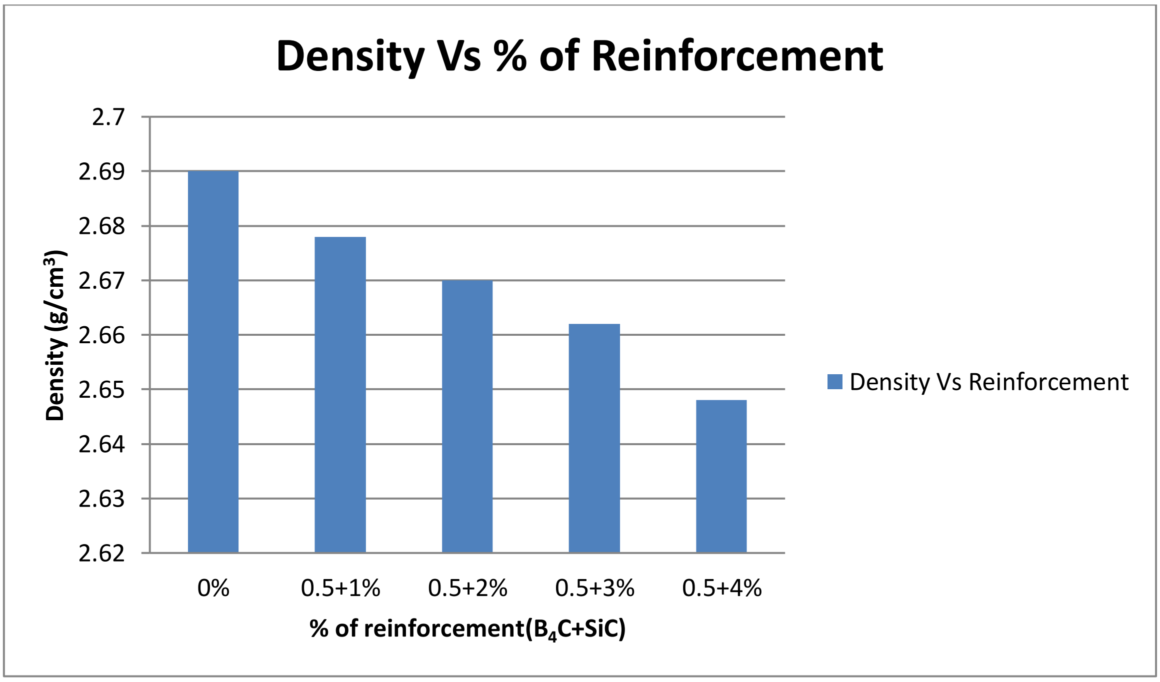

Fig: 5.1 Density v/s % of Reinforcement

5.2 TENSILE TEST

The test performed on the specimens with SiC and B_4C (mixture of both SiC and B_4C with equal %) reinforcement.

Table 5.2 Tensile Strength

S.No	% of reinforcement	Avg. Tensile strength (MPa)
1	0	230.2
2	1.5	254.5
3	2.5	266.3
4	3.5	273.5
5	4.5	290.2

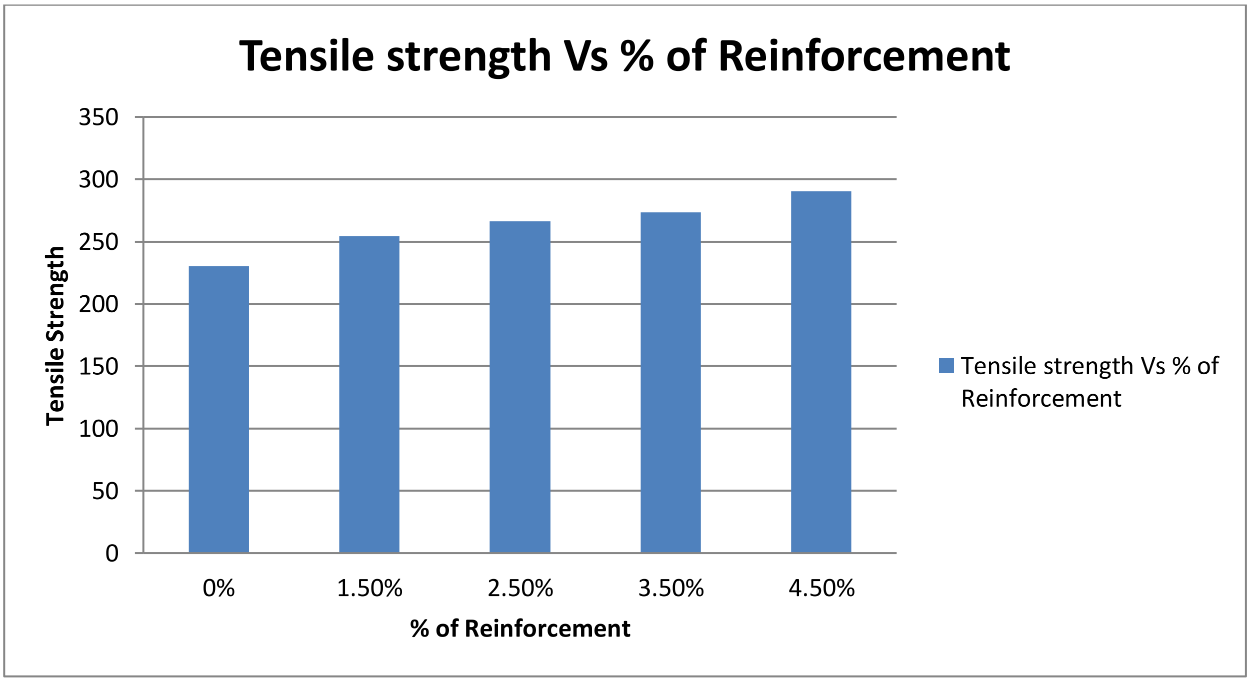

Fig 5.2 Tensile Strength v/s% of Reinforcement

5.3 COMPRESSION TEST

The test performed on the specimens with SiC and B_4C (mixture of both SiC and B_4C with equal %) reinforcement.

Table 5.3 Compressive Strength

S.No	% of Reinforcement	Avg . Compressive strength (Mpa)
1	0	50.79
2	1.5	57.29
3	2.5	59.95
4	3.5	66.29
5	4.5	77.84

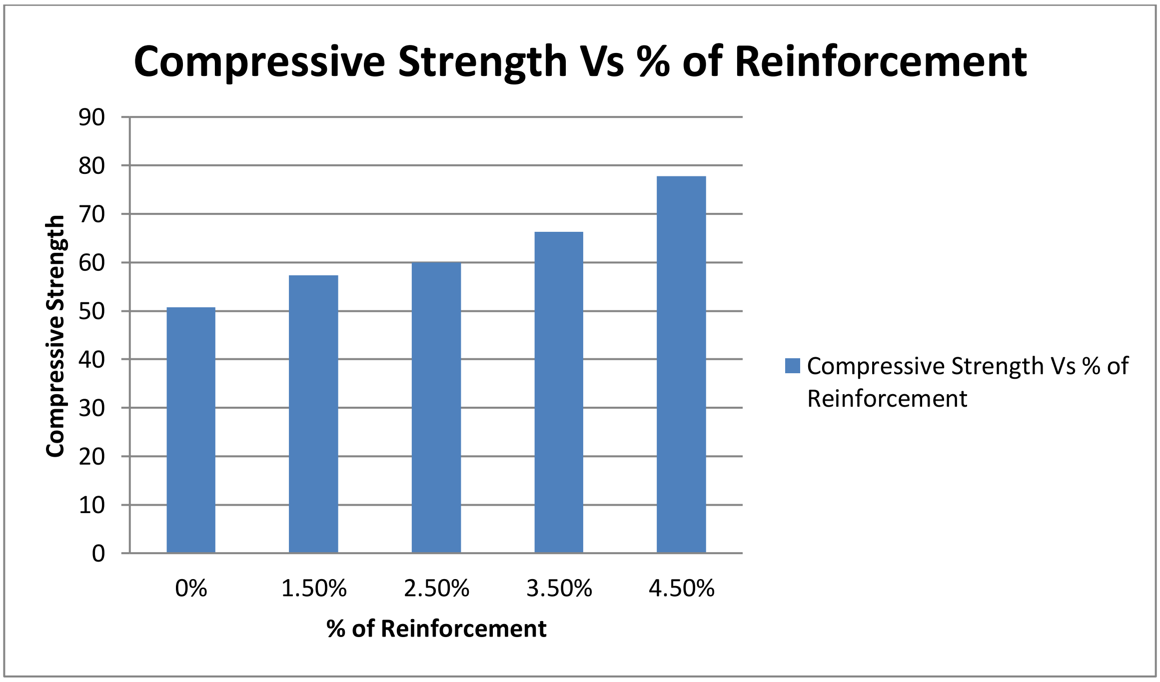

Fig: 5.3 Compression Strength v/s % of Reinforcement

5.4 HARDNESS TEST

The hardness test performed on the specimens with SiC and B_4C (mixture of both SiC and B_4C with equal %) reinforcement.

Table 5.4 Vickers's Hardness

S.No	%of reinforcement	Avg. VHN
1	0	91
2	1.5	101
3	2.5	105
4	3.5	108
5	4.5	110

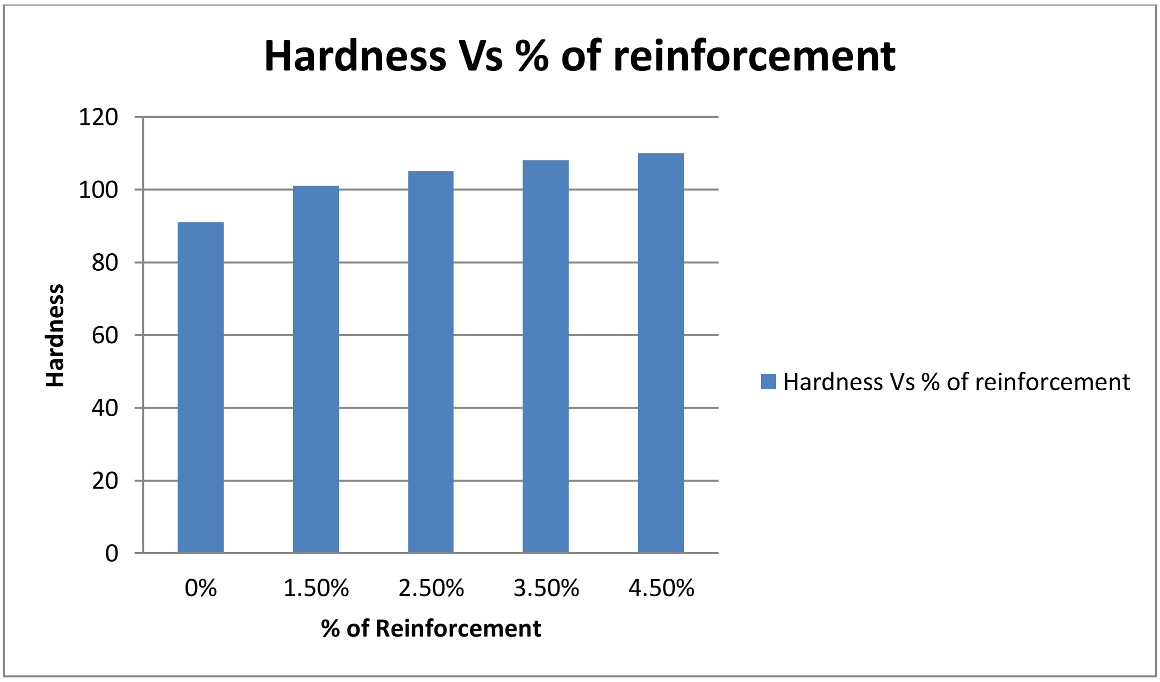

Fig 5.4 Hardness v/s % of Reinforcement

5.5 IMPACT TEST

The Impact test performed on the specimens with SiC and B_4C (mixture of both SiC and B_4C with equal %) reinforcement.

Table 5.5 Impact strength

S.No	%of reinforcement	Avg . Impact strength
1		1.96
2	1.5	2.3
3	2.5	2.65
4	3.5	3.01
5	4.5	3.4

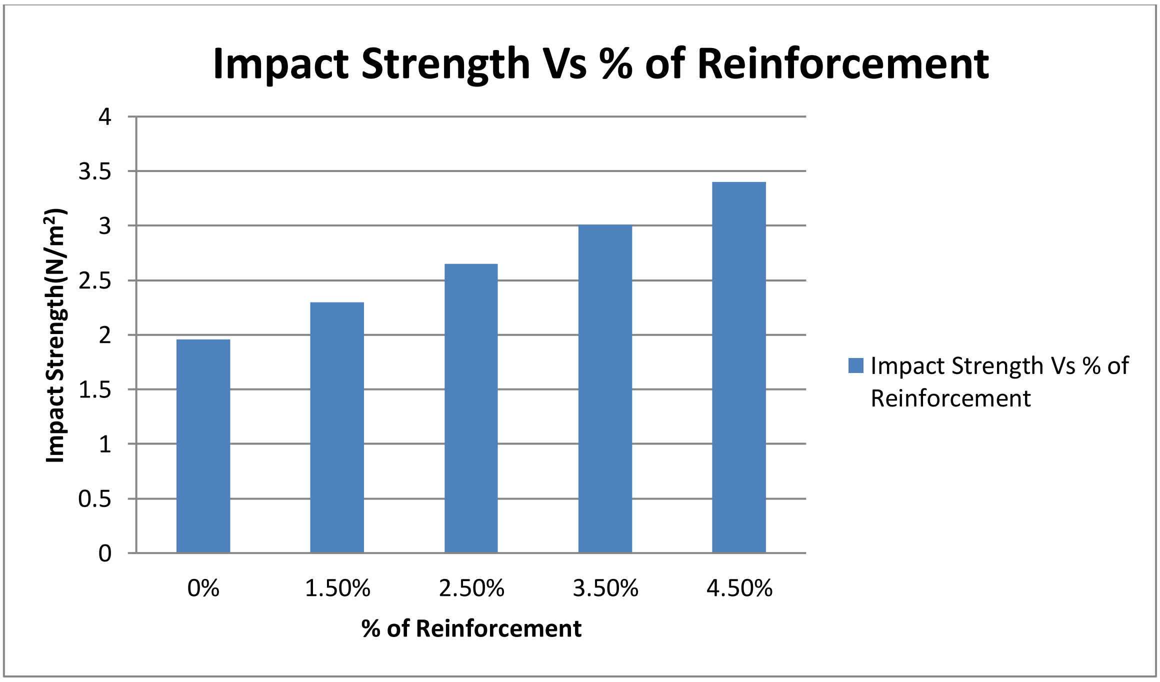

Fig 5.5 Impact Strength v/s % of Reinforcement

CHAPTER 6

CONCLUSIONS

6. CONCLUSIONS

Aluminium Metal matrix hybrid composites reinforced with B_4C and SiC are fabricated by stir casting technique. Composites are made at three different weight fractions of reinforcements for density, micro structure, tensile test, and compression test and hardness measurement. The micro structural studies revealed that there is a fairly uniform distribution of SiC particles and somewhat non uniform distribution B_4C in the AL7075 Metal matrix composites.

- The tensile strength has improved with increase in SiC and B_4C reinforcements.
- The compression strength also increases by increasing SiC and B_4C reinforcements
- The Density of the material decreased with increasing the SiC and B_4C reinforcements.
- Hardness of the pure Aluminium is up to 80 HB but our composite having more Hardness number.

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