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A Review on Processing of Particulate Metal Matrix Composites and its Properties

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Abstract:

In the past, materials are confined only to monolithic type, but for the better physical, chemical and triboloigical properties comparing to the monolithic materials composite materials are have been evolved. Metal matrix composites have evoked a keen interest in recent times for potential applications, because the characteristics of MMCs can be designed into the material, custom-made, dependent on the application. From this potential, metal matrix composites fulfill all the desired conceptions of the designer. Out of these Al/Al alloy based MMC's are gaining wider acceptance in many industries e.g. aerospace, automotive and automobile industries due to their superior properties such as light weight, low density, high strength to weight ratio, low cost, high quality and high performance etc. in structural materials. The aim of this paper is to review the current research and development of Al matrix based MMC and discusses the various existing and emerging processing techniques for the fabrication of Aluminium matrix composites. The vortex (or mixing) method continues to be the most popular processing method in use because of its operation, total production cost, and suitability, while the infiltration, compocasting, in-situ and spray atomization and co-deposition techniques receive less attention.

Keywords: Metal Matrix composites, Processing Techniques, Wettability, Uniform Distribution, Nano composites.

Introduction:

During the past few years, materials design has shifted emphasis to pursue light weight, environment friendliness, low cost, quality and performance. Parallel to this trend metal matrix composites (MMCs) have been attracting growing interest [1-3]. Metal matrix composite(MMC) is engineered combination of metal (Matrix) and hard particles (Reinforcement) to tailored properties, such as mechanical properties (tensile and compressive properties, creep, notch resistance and tribology) and physical properties (density, thermal expansion, thermal density) by the filler phase; the materials limitations are thermal fatigue, thermo chemical compatibility and low transverse creep resistance.

In recent years, particulate reinforced metal matrix composites have attracted attention of many researchers, engineers and designers as promising advanced engineering and structural material for automobile and advanced aerospace applications. Especially 6xxx series particulate reinforced aluminium metal matrix composites (AMCs) [4-6] have been studied extensively because of their relatively low cost, design flexibility, isotropic properties and ease of handling. Also the processing problems and commercial difficulties associated with continuously reinforced AMCs are contributory to the recent interest in the particulate composites.

In AMC aluminium/ aluminium alloy is termed as matrix phase, and the reinforcing phase is usually non-metallic and ceramic such as Silicon carbide, Titanium carbide, tungsten, boron, aluminium oxide, fly ash, Zirconium, titanium boride. The most common using ceramics such as SiC, Al_2O_3, TiB_2, boron and graphite. By varying the composition, size, shape and weight percentages of the reinforcement, properties of AMCs can be tailored.

The major advantages of AMCs compared to unreinforced materials re as follows:

- Low density
- Low coefficient of thermal expansion
- Higher service temperature
- Higher elastic modulus
- Increased strength
- Improved stiffness
- Improved wear and abrasive resistance
- High electrical and thermal conductivity
- High vacuum environmental resistance
- Improved damping capabilities
- Increase in creep resistance at higher temperatures
- Increase in fatigue strength
- Improvement of thermal shock resistance
- Minimum ductility.

The major disadvantages of metal matrix composites are relatively high cost of fabrication and of the reinforcement materials. This paper reviews recent studies on the existing and advanced processing techniques for MMC.

TYPES OF AMC

- AMCs can be classified into four types depending on the type of reinforcement. [7]
- Particulate-reinforced AMCs (PAMCs)
- Whisker-or short fibre-reinforced AMCs (SFAMCs)
- Continuous fibre-reinforced AMCs (CFAMCs)
- Mono filament-reinforced AMCs (MFAMCs)
- Hybrid AMCs(HAMCs)

Particulate Reinforced AMCs (PAMCs):
Particles used for reinforcing include ceramics and glasses such as small mineral particles, metal particles such as aluminum, and amorphous materials, including polymers and carbon black. Particles used to increase the modulus of the matrix to decrease the permeability and ductility of the matrix. PMMCs offer isotropic properties with an increase in strength and stiffness compared to unreinforced materials. These composites generally contain equiaxed ceramic reinforcements with an aspect ratio less than about 5. Common Ceramic reinforcements are generally oxides or carbides or borides (Al2O3 or SiC or TiB2) and present in volume fraction less than 30% when used for structural and wear resistance applications. However, in electronic packaging applications reinforcement volume fraction could be as high as 70%.

Whisker or Short Fibre-Reinforced AMCs (SFAMCs):
Intricate shapes can be formed with whisker or short fibers, which are not possible with, continuous fiber reinforcement. The reinforcement does not always serve a purely structural task (reinforcing the compound), but is also used to change physical properties such as wear resistance, friction coefficient, or thermal conductivity. These contain reinforcements with an aspect ratio of greater than 5. The most common reinforcing materials in this category are alumina and silicon carbide. Short fiber reinforced composites consist of a matrix reinforced by a dispersed phase in form of discontinuous fibers (length < 100*diameter).Short alumina fibre reinforced aluminium matrix composites is one of the first and most popular AMCs to be developed and used in pistons. The reinforcement will be either continuous or discontinuous as shown figure.

Mono Filament-Reinforced AMCs (MFAMCS):
Monofilaments are large diameter (100 to 150 µm) fibres of either SiC or B into a core of carbon fibre or W wire, usually produced by chemical vapor deposition (CVD). Bending flexibility of monofilaments is low compared to multi-filaments. The term multi filament refers to relatively small diameter fibres about 5 - 30 µm. Monofilament reinforced aluminium matrix composites are produced by diffusion bonding techniques, and is limited to super plastic forming aluminium alloy matrices.

Continuous Fibre-Reinforced AMCs (CFAMCs)
Continuous fibre reinforced composites consist of a matrix reinforced by a dispersed

phase in form of continuous fibres, such as alumina, SiC or carbon with a diameter less than 20 µm. The fibres can either be parallel or pre woven, braided prior to the production of the composite. AMCs having fibre volume fraction up to 40% are produced by squeeze infiltration technique. These composites are produced by pressure infiltration route.

Hybrid AMC (HAMC)

In addition to four types of AMCs described above, another variant of AMCs known as hybrid AMCs have been developed and are in use to some extent. Hybrid AMCs essentially contain more than one type of reinforcement. For example, mixture of particle and whisker, or mixture of fibre and particle or mixture of hard and soft reinforcements. Aluminium matrix composite containing mixture of carbon fibre and alumina particles used in cylindrical liner applications is an example of hybrid composite.

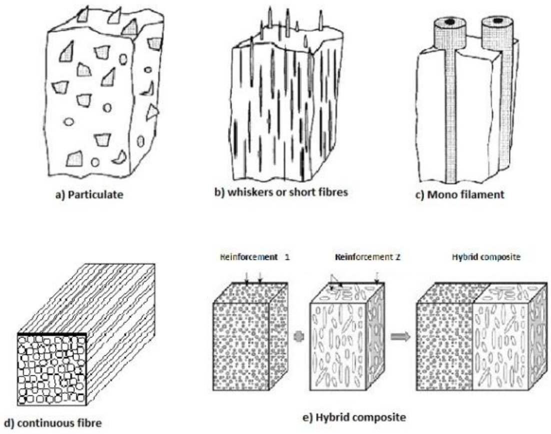

Fig 1. Types of AMCs

PROCESSING TECHNIQUES FOR AMMCs:

There are many processes viable to fabricate AMMCs, and the objectives of the processing techniques are to homogeneously distribute the reinforcement phases to achieve a defect free micro-structure as well as economical efficient.

Primary processing of AMCs

1. Liquid state processing techniques: Stir casting, compocasting (Rheocasting), squeeze casting.
2. Solid state processing techniques: Diffusion bonding, powder metallurgy.
3. Deposition process: Spray co-deposition or Osprey process, Disintegrated melt deposition (DMD) process.
4. Vapour state processing: Physical Vapour deposition, Chemical Vapour deposition.

Stir casting process:

Stir casting of metal matrix composites was initiated in 1968, Lloyd (1999) reports that vortex-mixing technique for the preparation of ceramic particle dispersed aluminium matrix composites was originally developed by Surappa & Rohatgi (1981) at the Indian Institute of Science.

This process involves incorporation of ceramic particulate (reinforcing phase) into liquid aluminium melt (Matrix) by mechanical stirring and allowing the mixture to solidify. It is simplest and most commercially used technique and also known as vortex technique [13-17]. The vortex technique involves the introduction of ceramic particles into the vortex of molten alloy created by the rotating impeller and the resultant alloy then be used for die casting, permanent mold casting or sand casting. The cast composites further extruded to reduce porosity, refine the microstructure and homogenize the distribution of the reinforcement.

The important features of stir casting are as follows:[8]

1. Dispersion of reinforcement is limited to 30 % of weight of the composite.
2. The reinforcement is not homogeneous, throughout the matrix if the reinforcing phase is more than 30 % of weight of the composite.
3. Clustering takes place which cannot be removed by conventional means.
4. It is a low cost process.

Irregular distribution of particles in the melt takes place: [9]

1. At the time of mixing while the melt is being continuously heated and stirred.
2. At the time of pouring into the mold there has been observed irregular flow of the melt.
3. At the time of solidification, stirring is impossible the molds.

The challenging task of the stir casting process is to maintain wettability. Wettability can be defined as the ability of a liquid to spread on a solid surface, and is represents the extent of intimate contact between a liquid and a solid. This shows a challenge of producing MMCs without poor distribution of the particles, high porosity and low mechanical properties.

The various methods by which wettability can be achieved as follows: [10-12]

- Surface coating of the particles before introduction into the melt.
- Using of wetting agents.
- Decreasing the solidification time.
- Preheating the particles to remove Absorbed gases from particle surfaces.
- By making fine sized reinforcement, wettability can be increased.
- Decreasing the surface tension of the alloy by heating at higher temperature
- Adding metallic element, by reducing the surface tension.

Another difficulty associated with the casting process is their segregation of reinforcing particles which is caused by the floating or settling of the reinforcement particles, because of density difference between matrix and reinforcement, during the melting and casting processes. Microstructural inhomogeneity's can cause notably particle agglomeration and sedimentation (clustering) in the melt and subsequently during solidification. Inhomogeneity in reinforcement distribution in these cast composites could also be a problem as a result of interaction between suspended ceramic particles and moving solid-liquid interface during solidification.

The various methods by which uniform distribution of reinforcing phase can be achieved as follows:

- Injection of particles in the matrix with inert carrier gas.
- Incorporation of reinforcing phase in semi-solid condition.
- Material properties and process parameters
- Geometry of the mechanical stirrer, , placement of the mechanical stirrer in the melt, melting temperature.
- Particle size and the density surface area.
- Design of the mold, proper gating system and temperature of mold before pouring.
- Greater thickness of the melt prevents the ceramic phase to settle down in the bottom of the furnace.

The developments in the stir casting process is to maintain homogeneity or uniform distribution of particles in the matrix is two and three stage mixing process. In this process, first the matrix and reinforcing particles are preheated for certain period, and then the matrix is heated to above its liquidus temperature, so that the metal is totally melted. This melt is then cooled down to a temperature between the liquidus and solidus points and kept in a semi solid state. At this stage, the preheated particles are added in three steps i.e. Total amount of reinforcement was calculated and is being introduced in to the melt 3 times rather than introducing all at once [18], and mixed manually for some time, because it was very difficult to mix using automatic device when the alloy was in a semi solid state. The slurry is again heated to a fully liquid state and then automatic mixing was carried out for certain period. This novel mixing process results in uniform microstructure compared to conventional stirring, and also it breaks the thin gas layer around the particle surface, which impedes wetting between the particles and matrix. The gas layer around the particle surface breaks effectively, because of great abrasive action by the high melt viscosity.

Dr,A.Manna et al study, 6063 Aluminium alloy metal matrix composites reinforced with three different sizes 220, 300 and 400 mesh and weight fractions of silicon carbide particles upto 20% by stir casting. The microstructure and mechanical properties of the prepared specimens are investigated experimentally. From the results it showed that hardness and tensile strength of the composites increased, with decreasing size and increasing weight fraction of the particles[19].

A.R.I. Kheder et al study pure aluminium alloy as a base reinforced with various reinforcements (Al2O3, SiC, MgO) of 50 μm respectively. From the results it shows that addition of these reinforcements increases mechanical properties, and SiC is the most effective strengthening particulates [20].

Compocasting (or) Rheocasting:

Compocasting is a liquid state process in which the reinforcement particles are added to a metallic alloy matrix at a temperature with the solid-liquid range (semi – solid state) of the alloy. This is followed by agitation of the mixture to form a low viscosity slurry. The reinforcing particles are mechanically entrapped and prevented from settling or agglomerating because the alloy is already partially solid [21-22]. The reinforcing particles interact with liquid matrix to effect bonding, and results in better distribution of reinforcement particles, lower porosity, better wettability and as well as lower volume shrinkage. This is one of the most economical methods of fabricating a composite with discontinuous fibres or particulates. However, this process overcomes poor distribution and incorporation of the reinforcement particles in the matrix as in the stir casting process.

B. ABBASIPOUR, et al study A356 aluminum alloys reinforced with carbon nano-tubes (CNTs) were produced by stir casting and compocasting routes and their microstructural characteristics and hardness were examined. In order to alleviate the problems associated with poor wettability, agglomeration and gravity segregation of CNTs in the melt, CNTs were introduced into the melts by injection of CNT deposited aluminum particles instead of raw CNTs. Aluminum particles with mean diameters of less than 100 μm were first deposited by CNTs using Ni-P electroless plating technique and then injected into the melt agitated by a mechanical stirrer. The slurry was subsequently cast at temperatures corresponding to full liquid as well as 0.15 and 0.30 solid fractions. The results show that addition of CNTs to A356 matrix can significantly refine both full liquid and semi-solid cast microstructures. Hardness of the samples is also significantly increased by addition of CNTs and A356-CNT composite cast at 0.3 solid fraction produces the highest hardness [23].

Squeeze casting:

The earliest reports on squeeze casting originate in the 1878 Russian literature that suggested pressure should be applied to molten metals whilst they solidify in a mold. The commercial development of squeeze casting began to take place in Europe, North America and Japan, only after 1960. The squeeze casting of aluminium alloys is a rapidly developing technical process that offers the potential for widespread utilization and growth. It is the combination of gravity die casting and closed die forging. Squeeze casting is a process in which the molten metal solidifies under the application of pressure which is maintained until the end of solidification. The applied pressure promotes the grain refinement, which in turn increases the mechanical properties of the squeeze cast components.

The high pressure during solidification keeps the molten metal in direct contact with the die surface providing true to die dimensions in the castings. The close contact with the die surface during solidification results in a rapid solidification of castings. The rapid solidification produces fine secondary arm spacing in the castings, so that good strength and ductility can be obtained. Since the process minimizes both gas porosity and shrinkage cavities, excellent properties are obtained [24-26]. The process has the capability of producing near net shape castings that essential for pore free. This permits the solution heat treatment of the castings so that after selective aging, excellent mechanical properties can be obtained.

Two different types of squeeze casting technology have evolved, based on different approaches to metal metering and metal movement during die filling. These have been given the names “direct” and “indirect”. Both the direct squeeze casting and indirect squeeze casting have advantages and disadvantages.

Direct squeeze casting is sometimes called metal forging since the process is close to that of forging. Liquid metal is poured into the lower half of a die, then the upper half of the die is closed. High pressure is applied to the entire cavity until the metal has solidified. The biggest advantage of direct squeeze casting process is that pressure is applied to the entire surface of the liquid metal during freezing, producing castings of full density. This technique, inevitably, gives the most rapid heat transfer, yielding the finest grain structure but does not control the die filling stage. This leads to turbulent flow and the entrapment of brittle surface oxide films. The inherent time delay occurring after the metal is poured and prior to pressurization with the ram often leads to premature solidification. A highly accurate metering system is needed to control the dimensions of the casting. However, with the direct procedure there is a disadvantage in that the volume of the melt must be determined exactly, since no gate is present and thus the quantity of the melt determines the size of the cast construction unit. Another disadvantage is the appearance of oxidation products, formed in the cast part during dosage.

Indirect squeeze casting is performed in a manner closer to conventional die casting method, where the melt is pressed into the form via a gate system with a hydraulic ram, the residues will remain in this gate. The flow rate of the melt through a gate is, due to its larger diameter, substantially less than with die casting, which results in a less turbulent mold filling and gas admission to the melt by turbulences is avoided. The metal flow can be controlled via the injection speed and pressure application begins as soon as the die is filled. The casting forms inside a closed die cavity and the dimensions of the casting are easier to control. The use of a highly accurate metering system is not required. As a result, the indirect squeeze casting process has seen more commercial use than the direct process in die casting industry

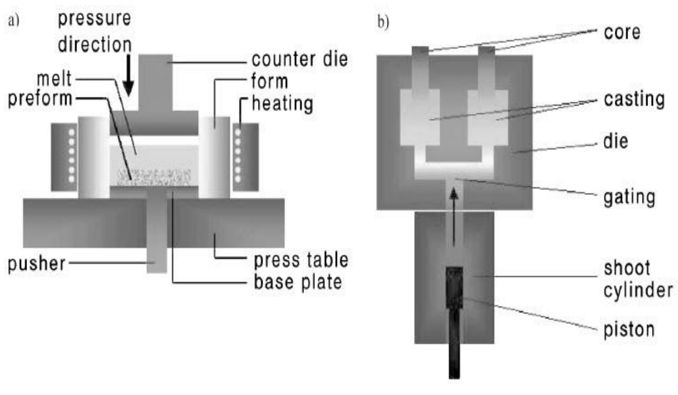

Fig2. Direct and Indirect squeeze casting

The various steps involved in squeeze casting process are as follows: The squeeze casting process makes use of die halves i.e; bottom die and top die. Die is coated by a water based graphite lubricant for easy removal of casting after solidification, and it is preheated around 200-250°c by ceramic band heater. The metal /alloy is melted is melted in a electrical resistance furnace. The molten metal/alloy is poured into the die cavity which already haves preform. Pressure is applied over the molten metal by means of a punch until the solidification ends. Once the solidification is completed, the punch is withdrawn and the component is ejected.

Advantages of squeeze casting over conventional die casting: Internal soundness, thereby increasing the suitability potential for critical applications, High degree of refinement in the structure of the alloy, No porosity, Excellent surface finish, Low operating costs, High degree of surface finish and dimensional accuracy, Net shape can be obtained, Improved mechanical properties, Elimination of metal wastage due to the absence of feeders or risers, Increases density

Abdulkabir Raji Study was carried out to compare cast microstructures and mechanical properties of aluminium silicon alloy components cast by various means. For this purpose, sand casting, chill casting and squeeze casting methods were used to produce similar articles of the same shape and size from an Al-8%Si alloy. It was observed that the grain size of the microstructures of the cast products increased from those of squeeze casting through chill casting to sand casting. Conversely, the mechanical properties of the cast products improved from those of sand casting through chill casting to squeeze casting. Therefore, squeeze cast products could be used in as cast condition in engineering applications requiring high quality parts while chill castings and sand castings may be used in as cast condition for non-engineering applications or engineering applications requiring less quality parts[27].

Dr B.Mohan et al study "Effect of Process Parameters on squeeze casting of AA6061 for Mechanical Properties". Squeeze casting of AA6061 is done by varying squeeze pressure (35 MPa, 70 MPa, 105 MPa) at three levels and keeping the die preheat temperature (200 °C), pressure applied duration (15 s) and three components are produced. The specimens are made from the components and they are tested for tensile strength and hardness. From the results, it is observed that, the component which is produced by applying the maximum pressure exhibits improved mechanical properties when compared with the other components[28].

Powder metallurgy:

Powder metallurgy techniques have emerged as promising routes for the fabrication of particulate reinforced metal matrix composites. It is the process of blending fine powdered materials, compacting (pressing) into a desired shape and then heating the material (sintering)to a desired shape .it is usually used for high melting point matrices and avoids segregation effects and brittle reaction product formation prone to occur in liquid state processes

Steps involved in the powder metallurgy process are as follows: The matrix and the reinforcement powders are blended (mixed) to produce a homogeneous distribution. While blending some lubricants are also added so that during the next operation of compacting, the die wear and the friction between the metal particles may be reduced. Usual lubricants used are powdered graphite or lithium stearate. Blending is usually done dry—no water is added. Good blending produces no agglomeration of both the metallic and ceramic particle powders. To achieve this, several parameters such as particle size, blending speed and duration have taken into consideration to ensure the reinforced particles distributing homogeneously in the matrix powders [29]. After blending, the mixed powders are placed in a die and compacted by pushing a punch in under pressure, it produces a part called green body. The density of ‘‘green body’’ is almost as high as the density of solid metal. Ejection of green body from the die becomes easier with the use of lubricants. Compacting requires high pressures of the order of 700 MPa to cause mechanical interlocking in particles. Before sintering, however, the lubricant must be driven out by a low temperature heating cycle.

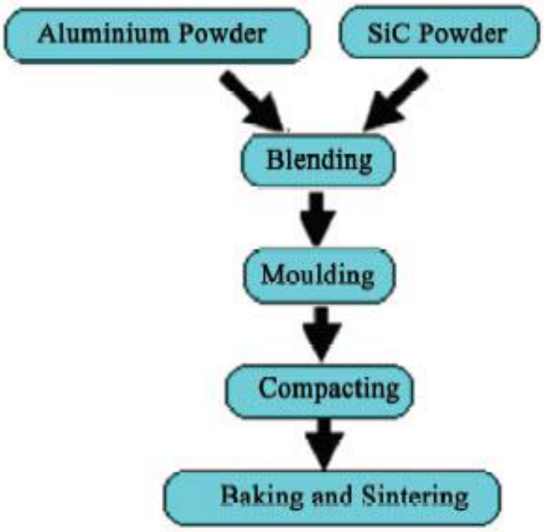

Fig 3. Powder metallurgy process

And then, green compacts are heated in a muffle type furnace in a controlled atmosphere. Temperatures are maintained between 60–80% of the melting point of metal or alloy concerned. Sintering time may range from 20 minutes to 60 minutes. During processing, the matrix powders have exposed to atmosphere, which contains oxygen and moisture also, and it would oxidize at high temperature. Moreover, the moisture would react chemically with the oxide, and such reaction would reduce the bonding force of matrix and reinforced particles and further deteriorate the mechanical properties of the composites. Thus, the degassing should carry out in an environment of elevated temperatures and high vacuum, where the dew point and the oxygen partial pressure are low. The adsorbed compounds will evacuate and further oxidation can suppressed effectively.

Advantages of powder metallurgy process: Production of intricate shapes to very close dimensional tolerances, with minimum scrap loss and fewer secondary machining operations. P/M parts are also relatively free from defects. The main advantage of this process is that it incorporates high volume fraction of reinforcement that which is immiscible in liquid casting.

Manjunatha L. H.P.Dinesh study “Fabrication and Properties of dispersed carbon nanotube Al6061 composites” In this present work has been made to investigate the mechanical properties of the fabricated Composites. Al6061 alloys as matrix and Multiwall Carbon Nanotube (MWCNT) as reinforcement (0, 0.5, 1.0, 1.5, 2 ,2.5 & 3 weight percentage) have been fabricated by powder metallurgy process, and the samples were investigated for microstructure, and strength. From the results it shows that Hardness of Al6061-MWCNT composite is greater than Al6061, Micrograph shows good bonding between matrix and reinforcement, Al6061-MWCNT composite showed ductile property where as Al6061 were brittle, Young‘s Modulus increases remarkably with the increase in Reinforced particulate (MWCNT), Tensile strength increases with the addition of MWCNT but compressive strength decreases with the addition of MWCNT [30].

In-situ synthesis:

The composites prepared by ex-situ method suffers thermodynamic instability between matrix and reinforcements, thus limiting their ambient and high temperature mechanical properties [31]. Ex-situ process possesses drawbacks like agglomeration, poor wetting and heterogeneity in microstructure [32]. Ex-situ composite fabrication method consists of many stages, like sorting, alignment, infiltration and sintering, and also it requires complex equipment and procedures.

In recent years, a new route is developed for cost effective fabrication of metal matrix composites is in-situ synthesis. In-situ synthesis is a process where in the reinforcements are formed in the matrix by controlled metallurgical reactions (exothermic reaction), which exhibits a clean matrix / reinforcement interface, which leads to better improvement in mechanical properties of the composites. In situ composites are multiphase materials where the reinforcing phase is synthesized within the matrix during the composite fabrication.

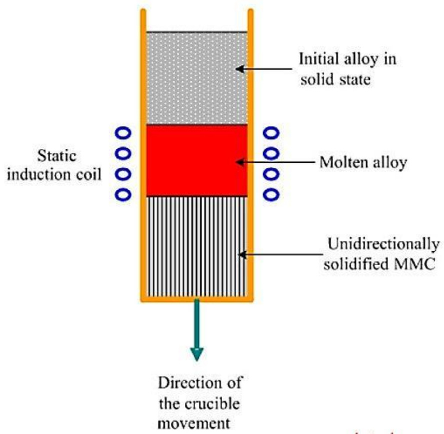

Fig 4. In – situ synthesis

In In-situ process the ceramic reinforcement is incorporated into the matrix by the chemical reaction of the halide salt with molten metal matrix [33]. The in-situ formation of a ceramic second phase provides greater control of size and level of reinforcements, as well as the matrix reinforcement interface, yielding better tailorability of the composites.

These in-situ routes provide advantages such as uniform distribution of reinforcement, finer particle size, clean interface, thermodynamically stable , strong interfacial bonding between the reinforcements and the matrices and process economy in comparison with the conventional ex situ processes. These advantages will lead to better and improved mechanical and triboloigical properties of the in situ composites when compared with the matrix alloy.

Dr. K. Prahlada Rao et al study in-situ Al-Tic with 5% TiC composite was produced by the reaction with the halide salt K2TiF6, and the specimens were investigated for microstructure and hardness From the results it shows that TiC reinforcement is properly distributed over that matrix and size of the reinforcement was less than 1μm, and it reveals that by the addition of TiC reinforcement to the Al6061 matrix the hardness value was increased [34].

T.V. Christy et al manufactured the Aluminum-TiB2 metal matrix composite containing 12% by weightTiB2p through in-situ process and made the comparison of the mechanical properties and the microstructure of Al 6061 alloy with Al–TiB2 metal matrix composite Results showed that the composite Al-6061/TiB2/12p was successfully produced by the in-situ reaction procedure. Strings as well as particulate agglomerates were present as distinct microstructural features of the composite. The manufactured Al-TiB2 composite exhibited higher values of hardness, tensile strength and Young’s modulus than the base alloy. The ductility of the composite was found to be slightly lower than that of the aluminium 6061alloy [35].

Advanced shear technology:

The above conventional methods produce agglomerated structures exhibiting lower strength and ductility due to non-wettability of reinforcement by matrix alloys and density differences between the two materials and lack of efficient mixing technology to achieve a uniform distribution of fine-size reinforcement within the matrix. As a result, the introduction and retention of reinforcing particles in matrix is extremely difficult.

To overcome this, a new rheo-processing method, the melt-conditioning advanced shear technology (MCAST) process, has been developed for manufacturing near-net-shape MMCs with homogeneous distribution reinforcement in the matrix. The key idea is to apply sufficient shear stress (τ) on particle clusters embedded in the liquid metal to overcome the average cohesive force or the tensile strength of the cluster. Molecular dynamics studies suggest that the intensive shearing can displace the position of atoms that are held together with high strength bonds. Under a high shear and high intensity of turbulence, liquid can penetrate into the clusters and displace the individual particles within the cluster.

The novel process for synthesizing MMC consists of two steps: Distributive mixing & Dispersive mixing under intensive shearing. The first part of the fabrication process was conventional mechanical stirring for the distributive mixing of the reinforcement in the matrix. For the second and novel part of the processing, a twin-screw machine was used for the dispersive mixing of the reinforcement particles in the liquid.

Distributive Mixing

Distributive mixing employs conventional mechanical stirring to pre-mix the Al alloy with reinforcing particles. The mixing equipment is same as conventional stir cast setup. A controlled argon atmosphere was maintained inside the furnace throughout the whole experiment to prevent melt oxidation. The reinforcement particles were transferred slowly and continuously into the melt which was mechanically stirred at 600-800 rpm. After all the reinforcement was introduced successfully into the liquid metal, the composite mixture was allowed to solidify in the crucible and subsequently reheated to the preset melting temperature, and then stirred, but it produces agglomerated stuctures in the melt.

Dispersive mixing

Agglomerated structures formed in stagnant zones (e.g., near crucible walls) due to lack of sufficient shear force in distributive mixing. In order to break up the agglomerates, it is important to apply an adequate shear stress which overcomes the average cohesive force or tensile strength of the clusters The process of dispersive mixing under intensive shearing innovatively adopts a high-shear dispersive mixing action of the twin-screw mechanism to the task of overcoming the cohesive force of agglomerates. The twin-screw mechanism used for the MCAST process consists of a pair of co-rotating, fully intermeshing, and self-wiping screws. The screws have specially designed profiles as shown in (Fig.5).

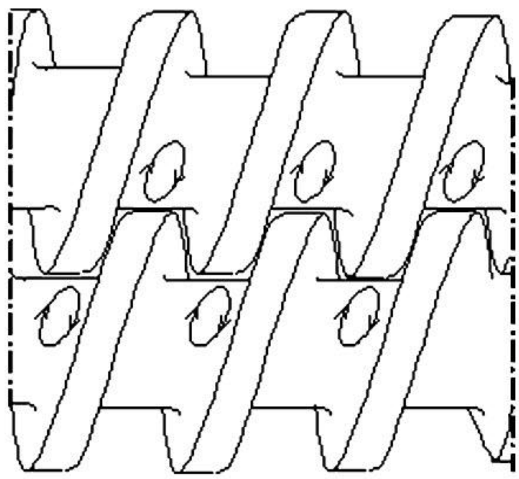

Fig 5. Twin Screw mechanism

which result in high-shear rate and high intensity of turbulence.. The basic function of the twin screws is to break up the agglomerates and clusters embedded in the liquid melt under a high-shear stress and disperse the particles uniformly under the high intensity of turbulence.

N.S. BAREKAR, et. al study Aluminum-graphite particulate metal matrix composites by advanced shear technology. In this work, production of advanced Al/graphite composites with high-quality microstructures characterized by a uniform distribution of the reinforcement throughout the whole sample and good mechanical properties of the final product. The key idea is to apply sufficient shear stress (s) on particle clusters embedded in the liquid metal by the twin screw mechanism, to overcome the average cohesive force or the tensile strength of the cluster, and the specimens were investigated experimentally. From the results it shows that a good combination of improved ultimate tensile strength (UTS) and tensile elongation (e) is obtained compared with composites produced by conventional processes [36].

Ultrasonic assisted casting:

In recent years, metal matrix nanocomposistes (MMNC) research is going on, in a greater extent. MMNCs overcomes many limitations compared with conventional metal matrix composites (micro inclusions) such as poor ductility, low fracture toughness and machinability.

Casting, as a liquid phase process, is well known for its capability to produce as cast light weight components of Metal Matrix Nanocomposites (MMNCs) with good reinforcement distribution and structural integrity. However, nanosized ceramic particles present difficult problems: it is extremely difficult to disperse them uniformly in liquid metals because of their poor wettability in metal matrix and their large surface-to volume ratio, which easily induces agglomeration and clustering.

In order to achieve a uniform dispersion and distribution of nanoparticles in aluminum matrix nanocomposites, G.I.Eskin et al., Yong Yang et al., Yong Yang, Xiaochun Li et al developed an innovative technique that combined solidification processes with ultrasonic cavitation based dispersion of nanoparticles in metal melts. It was reported that ultrasonic cavitation can produce transient (in the order of nanoseconds) micro "hot spots" that can have temperatures of about 5000^0C, pressures above 1000 atm, and heating and cooling rates above 10^{10} K/s. Transient cavitations could produce an implosive impact strong enough to break up the clustered fine particles and disperse them more uniformly in liquids. It is envisioned that strong microscale transient cavitations, along with macroscopic streaming, might effectively disperse & distribute nanoparticles into melts and also enhance wettability, thus making the production of as-cast high performance light weight MMNCs feasible.

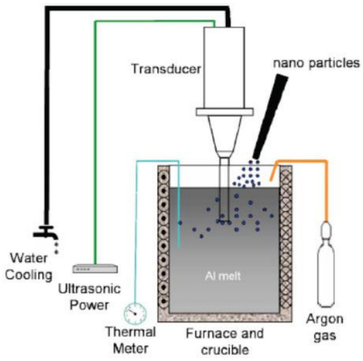

Fig 6. Ultrasonic assisted cavitation setup.

Suneel Donthamsetty et al studied the Mechanical properties of A356- SiC nanocompositstes fabricated by ultrasonic assisted cavitation by varying the weight percentages ranging from 0.1 to 0.5, and compared with the micro particulate reinforced alloy. With the increase in reinforcement ratio, tensile strength, hardness of nano SiC reinforced composites were increased with no significant change in ductility. Whereas for microcomposite, slight increase in strength, hardness and decrease in ductility were observed [37].

Donthamsetty et al prepared the composites by ultrasonic cavitation assisted fabrication and investigate the effect of selected nanomaterials (SiC, B4C, CNTs) on the microstructure and mechanical properties of composite. Then, tensile specimens with different weight fractions of nanomaterials are cast and tested. From the results, it shows a nearly uniform distribution and good dispersion of the nano-particles within the Al matrix, although some of small agglomeration found. Both hardness and tensile strength are increased with nano reinforcement [38].

Friction stir processing:

The above existing methods are not suitable for producing surface composites with particulate reinforcement, because of formation of detrimental phases and also it forms interfacial reaction between reinforcement and metal matrix. The above problems can be avoided by preparing the composite below the melting point of substrate.

In recent, Friction stir processing (FSP) is one of the new and promising thermo mechanical processing techniques that alters the microstructural and mechanical properties of the material in single pass to achieve maximum performance with low production cost in less time using a simple and inexpensive tool. Its principle is same as Friction stir welding, in which a non-consumable rotating tool with a specially designed pin and shoulder is plunged into the interface between two plates to be joined and traversed along the line of the joint. The friction caused by the rotating tool heats up the materials around the pin to a temperature below the melting point and deforms plastically. The rotation of the tool "stirs" the material and reinforcement together and results in a mixture of the two materials.

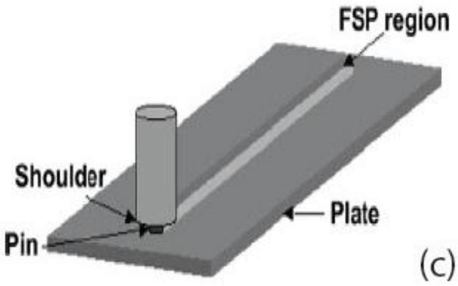

Fig 7. Friction stir processing

SiC particle reinforced aluminum alloys have been studied the most For example, the feasibility of making bulk SiCp reinforced aluminum metal matrix composites (MMCs) with the dimension of 150 mm in length, 60 mm in width and 6 mm in depth via friction stir processing (FSP) was demonstrated by Wang et al. [39]. Good interface bonding between particles and the base metal can be obtained. The volume percentage of SiCp is about 1.5% in the reinforced region. The microhardness of the reinforced MMCs is 10% higher than that of the base metal, Al-6Mg-Mn [40-42].

Shafiei-Zarghani et al.used friction stir processing (FSP) to incorporate nano-sized Al2O3 into AA6082 aluminum alloy to form particulate composite surface layer as shown in Figure 8(a). The Al2O3 particles have an average size of about 50 nm. Perfect bonding between the surface composite and the aluminum alloy substrate was achieved as shown by the defect-free interface in Figure 8(b). Mechanical properties include microhardness and wear resistance were tested. The results show that the increasing in number of FSP passes causes more uniform distribution of nano-sized alumina particles. The microhardness of the surface improves by three times as compared to that of the as-received Al alloy. A significant improvement in wear resistance in the nano-composite surfaced Al was observed as compared to the as-received Al alloy. The wear rate is reduced to one third of that of the as-received Al alloy when friction stir processed composite layer was incorporated as shown by the curves in Figure 8(c) [43].

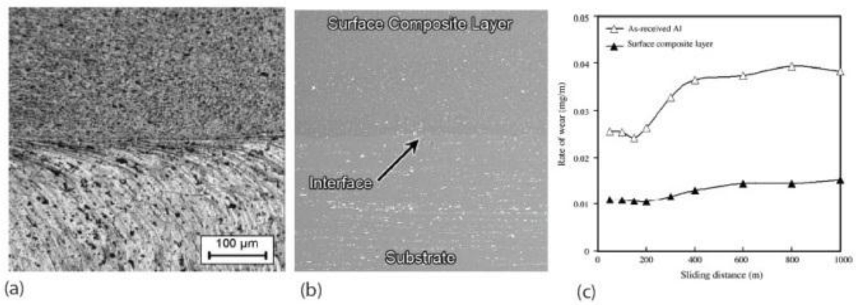

Fig 8. Friction stir processed composite surface

FSP technology is very effective in microstructure modification of reinforced metal matrix. composite materials. Compared with other manufacturing processes, friction stir processing has the advantage of reducing distortion and defects in materials.

Conclusions:

This review paper presents the views, techniques, innovations to process particulate composites, experimental and theoretical results obtained and conclusions made over the years by various researchers in the field of particulate aluminium MMCs.

- It is observed that, increase in weight percentage of reinforcement increase mechanical properties and decreases ductility.
- Wettability can be improved by
- incorporating wetting agents and process parameters.
- The reinforcement should not be more
- than 30 % in liquid state processing, leads to inhomogeneity.
- To maintain homogeneity, the reinforcement is added in three steps into molten matrix rather than once.
- Stir casting is a low cost process and it is economical for mass production.
- Compocasting overcomes poor distribution of reinforcement compared to stir casting.
- Low or Nil porosity and shrinkage cavities, dimensional accuracy can be obtained by squeeze casting.
- Composites with high weight percentages can be achieved by powder metallurgy technique, with minimum scrap loss.
- Clean matrix/reinforcement interface can be achieved by in-situ synthesis.
- To achieve uniform distribution of nano reinforcements in the matrix, twin screw mechanism is adapted.
- Uniform distribution of nano reinforcements and increase in wettability in the matrix can also be achieved by ultrasonic cavitation.
- Surface composites effectively can be processed by friction stir processing.

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