MANUFACTURING OF METAL ALLOY & HYBRID COMPOSITES-A STATE OF REVIEW

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Abstract: This paper gives the details of hybrid composites, their fabrication methods and evaluation of mechanical, tribological behavior and machining characteristics. Investigations on the various aspects of Hybrid composites furnish several conclusions regarding the influence of various parameters on the performance of the composites. Mostly micro structures of the hybrid composites fabricated through casting routes have been found to be stable with the distribution of uniformed reinforce particles. Therefore, the hybrid composites can be constructed with various combinations of reinforcements to carry out desirable mechanical properties. The density of Hybrid composites increases with increasing reinforcements such as SiC, TiC, B4C....etc., while incorporation of partial reinforcements like fly ash, mica, rice husk, etc. reduces the density of composites. The study also reports that the hybrid composites can be treated as a replacement for regular composite materials in different advanced applications.

Keywords: Metal alloys, Hybrid Composite, reinforcements,

I. Introduction

Materials required for the present world are stronger, lighter and cost effective. Present researchers are focusing to develop hybrid composites, which has good strength to weight ratio to meet the requirement. The main advantages[56] of Hybrid Composites over monolithic, alloys and composite materials were high strength to weight ratio, good corrosion/wear resistance, strength/stiffness, low thermal conductivity/coefficient of thermal expansion, light weight, Better impact and flexural properties Reduced overall cost of the composite. The example: aircraft as well as Automobile applications, where the fuel economy plays the key role. Hybrid composites consisting of one matrix and two or more reinforcement. These are bonded due to heterogeneous mixing of one or more particles reinforcement, which has been homogeneous phases at macro level and fabricated through various techniques such as powder metallurgy route, stir casting two step stir casting, squeeze casting to aim the mechanical properties and tribological behavior: high specific strength, including stiffness, density, micro hardness, low coefficient of thermal expansion, high thermal resistance, good damping capacities, better wear resistance, and corrosion resistance[1-5].

2. Classification of hybrid composites:

Normally composites are categorized into particle reinforced, fiber reinforced and the structural one. It is also classified based on matrix material such as polymer matrix composites(PMC), metal matrix composites(MMC) and ceramic matrix composites(CMC). Hybrid materials defined as the mixtures of two or more materials with Atomic or molecular level of different materials with chemical-bonds between their different materials. Aluminum metal matrix hybrid composite reinforced with silicon carbide, boron carbide, fly ash, Graphite, Si3N4 and Rice husk. Magnesium metal matrix hybrid composite reinforced with silicon carbide, titanium carbide, boron carbide, molybdenum di-sulfide Copper metal matrix hybrid composite reinforced with silicon carbide, boron carbide, titanium carbide. And other reinforced hybrid composites like fiber reinforcement as well as fiber/metal hybrid laminates, The selection of reinforcement particles plays a major role in composites for incorporating high end properties. There are two important factors to be considered while choosing reinforcement particles for developing a composite. Firstly, the reinforcement particles should be stiffer and stronger than the material matrix to strengthen the composite and secondly, to obtain good crystal structure as well as interface bond between the matrix material and reinforcement particles. [6.7]

3. Properties of the material:

The Ultimate properties of the hybrid composites depend on reinforcement of individual Nano particles properties selected and the metal matrix. Mechanical Properties the most common properties considered are ductility, strength, impact resistance, hardness, and fracture toughness. Mechanical properties were improved with ceramic particles such as SiC, TiC, Alumina, B4N...etc and decreased by increases of Bamboo Leaf Ash (BLA), Fly Ash (FA), Rice Husk Ash (RHA), Mica. The strengthening effect of composite material is degrading with increase in the size of reinforcement particles and inter-particle spacing is increasing with increase of reinforcement particle size, supported results shown in below. [9,10]
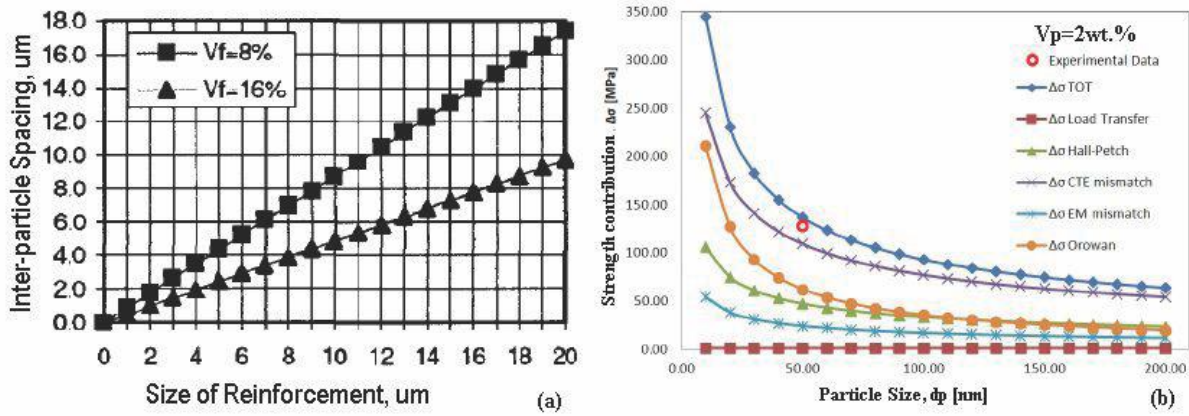
Figure 1. (a) Effect of reinforcement size and volume fraction on inter-particle spacing of reinforcement[7].(b) Effect of strengthening contributions and total resulting strengthening increment for a 2 wt.% Al_2O_3 reinforced Al matrix composite[8]

It is the study of interacting surfaces in relative motion. The tribological interactions of a solid surface are with interfacing materials and environment may result in material loss from the surface, tribological properties such as wear resistance improved by increasing of Gr, Fly ash, Mica, Bamboo leaf ash, Rice husk ash, Fly ash...etc Chemical Properties: Chemical interactions and reactions between the matrix and the reinforcement particles determined by the interface adhesion. With the correct resin selection as well as the construction of composites can withstand exposure. In general, higher chemical concentrations and temperatures result in lower durability and higher corrosion behavior of composites. Corrosion resistance improved by increases of SiC, Mica, e-glass...etc Physical Properties: The density of hybrid composites Increases with increases of ceramic reinforcements, while incorporation of partial reinforcements such as rice husk ash, fly ash, mica, etc. reduces the composites density. [11]

4. Processing of hybrid composites:

Researchers were approached to manufacture the Hybrid Composites (HBCs) through various routes such as powder metallurgy(PM), stir casting, two step stir casting, squeeze casting and other processes were discussed below.

4.1 Powder Metallurgy:

It's the method to prepare materials or composites from metal powers. This process can greatly avoid the yield losses in manufacturing components at lower costs. PM process consists three main steps are powder blending; die compression as well as sintering were showed in a schematic diagram. Research work done through this method to enhance the properties of composites, is presented here.

The fabrication of hybrid composite done through powder metallurgy route used the factorial method to analyze the tribological performance of Cu hybrid composite and reported the addition of Graphite-decreases hardness as well as adding of TiC increases hardness. While performing the wear test the weight loss of hybrid composite decreases up to some limit as the volume percentage of graphite increases. fabricated Al2219/15SiC and Al2219/15SiC3Gr hybrid composite using Liquid Metallurgy route, reported inclusion of Graphite to Al/SiC particles reduces thrust force. Observed the feed rate significantly influencing on surface finish, thrust force as well as burr height. Drilling of Al2219/15SiC3Gr hybrid composite had poor surface finish when it compared to Al2219/15SiC composite due to pullout of graphite particles. Also identified that the surface roughness value decreases with increasing in cutting speed, increasing with increasing in feed rate And burr height reduced when hybrid composite drilled with carbide drill bit then coated carbide as shown in figure 3.
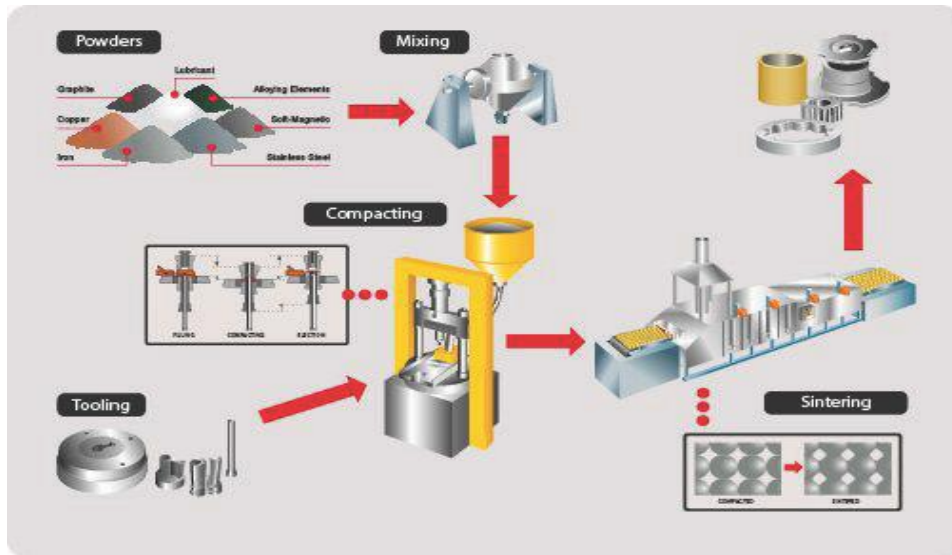
Figure 2. Schematic Diagram of Powder Metallurgy Technique
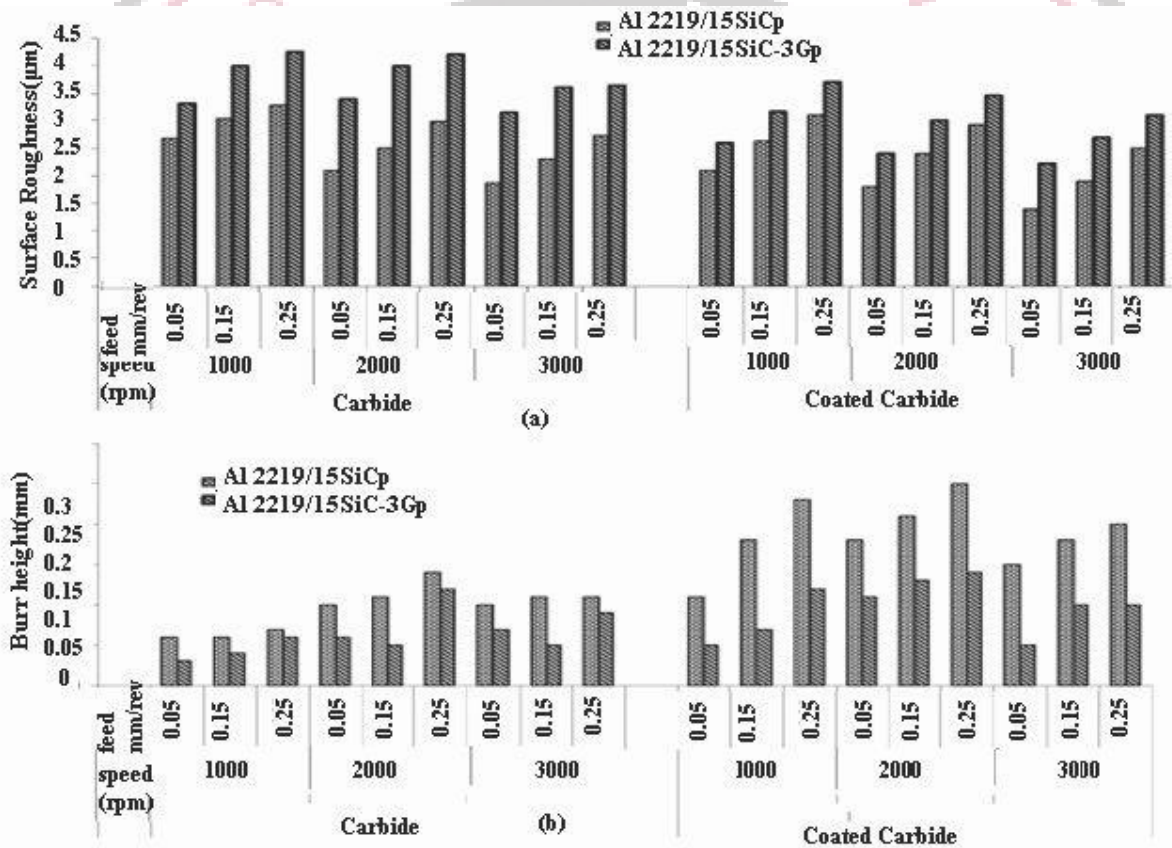

Figure 3. (a) Variation of surface roughness value for various speeds and feeds when machining of Al2219/15SiCp and Al2219/15SiCp-3Gr using carbide and carbide coated drills. (b) Variation of burr height with cutting parameter for Al2219/15SiCp and Al2219/15SiCp-3Gr composite when drilling with carbide and carbide coated drills [5]

Shanta Mohapatra, et al. developed a Al hybrid composite with micro Ti particles as micro Al_2O_3 or nano Al_2O_3, investigation done on micro-structural characterization and evaluated micro hardness, corrosion and wear behavior. And also compared with the basic composition for Al hybrid composites of Al+Ti+micro Al_2O_3 and Al+Ti+Nano Al_2O_3, found the better hardness, inferior to corrosion and higher wear resistance. The test results were indicated that, when the composite reinforced with Al+Ti+ Nano Al_2O_3 particles given higher hardness and better wear resistance then other reinforced particles, supported results as shown in figure 4.
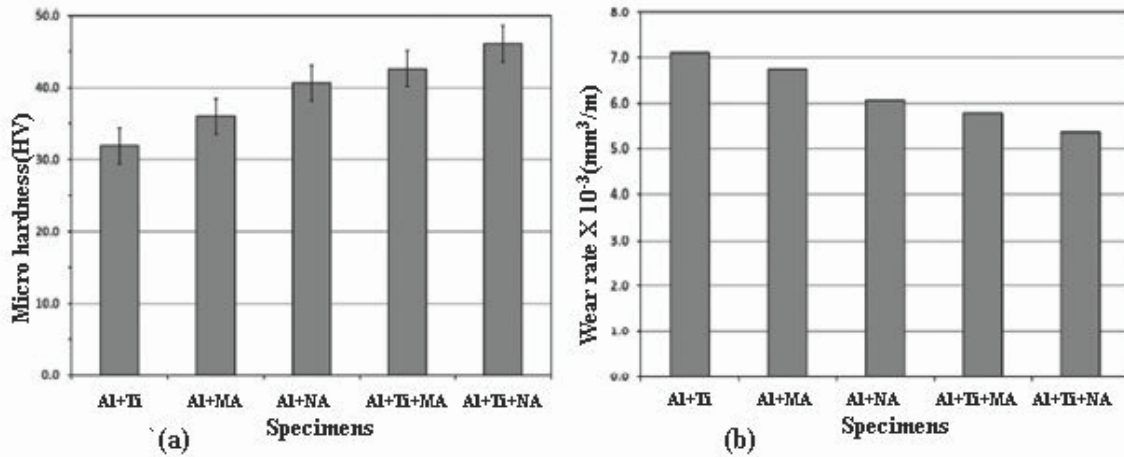
Figure 4.(a) Variation of Avg micro-hardness, (b) Variation of volumetric wear rate for all the Al based composites [6].

The specimens prepared by uni-axial cold pressing and later green compact. Mechanical properties such as density and micro hardness were investigated, conformed that the addition in wt% of multi- wall carbon Nano tubes, bonding and mechanical properties were improved. Micro structure of hybrid studied through SEM, XRD, EDAX, AFM and TEM**.**

4.2 Stir Casting route:
Rotor and ceramic crucible reservoir used to distribute the reinforcement particles into molten Matrix materials by mechanical stirring. Figure 5 shows the schematic diagram of experimental setup contain heating furnace with resistance to melt the base metal, feeding mechanism with ceramic nano particles and mechanical stirrer connected with electrical motor to mix the pre- heated nano particles in matrix liquid
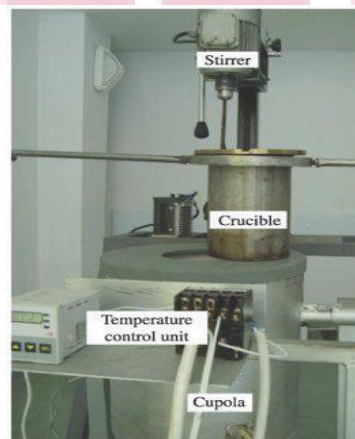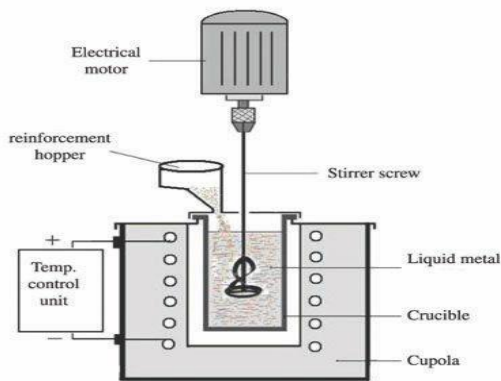

Figure 5. Schematic Diagram of Stir Casting Technique [10]

Few researchers have fabricated hybrid composites through Stir casting method [, conducted experiments to analyze it in various aspects, in such attempts, N Radhika et al., studied hybrid composite of AlSi10Mg reinforced with alumina+Graphite and Un-reinforced alloy specimens, Investigated micro-structural analysis as well as mechanical properties such as tensile strength, double shear strength and hardness of Hybrid composite with that of Un-reinforced alloy. They found that the Hybrid MMCs were higher values than that of un-reinforced alloy. The tribological behavior of hybrid studied using Pin-On-Disc test machine, concluded that the hybrid composites had higher wear resistance compared to the un-reinforced alloy and the wear debris, and worn out surfaces analyses were done by SEM, XRD as shown in figure 6.

.Deals with fabrication of AA6351+SiC+B$_4$C hybrid composite and prepared samples were experimented by turning test with the help of poly crystalline diamond (PCD) tool to steady the effect of B$_4$C, concluded that the poor surface finish observed at lower cutting speed but increases with increased depth of cut and feed rate. The quality of surface found to be low with increasing of B$_4$C particles, MRR increased by increasing of input parameters such as depth of cut, feed rate, cutting speed and analysis part done with Analysis of Variation(ANOVA), found the combinations for optimal output. The developed the hybrid composite of AA6082+(Si3N4+Gr). Investigated mechanical properties and micro structure, analysis part were done with SEM, XRD, both micro as well as macro hardness and tensile strength of hybrid composites. Results were enhanced with the reduction in % elongation with increases in wt% of ball mill. The supported results as shown in figure 7.
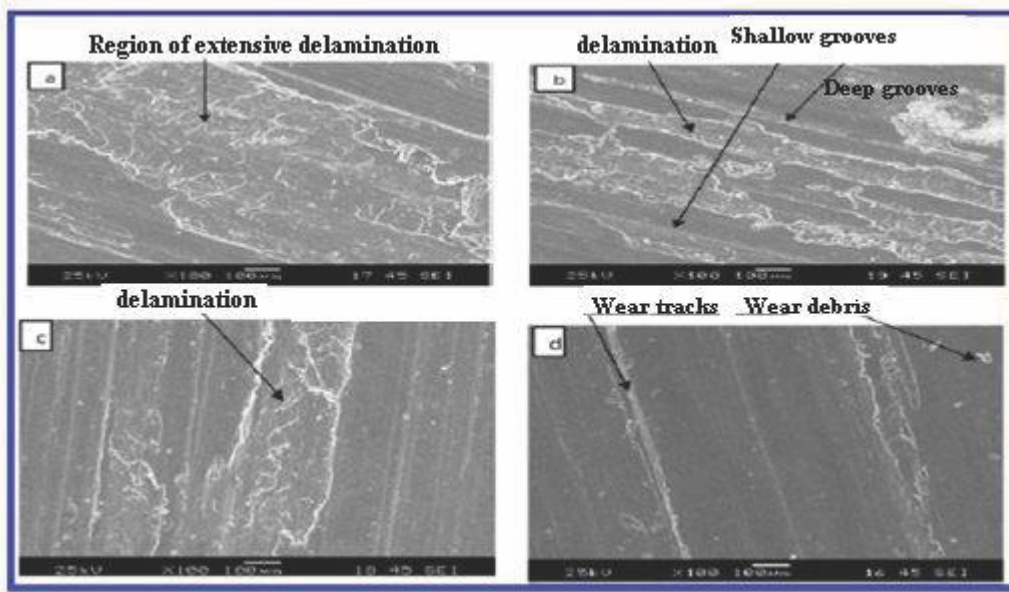
Figure 6. Scanning Electron Microscopy of worn surfaces indicating various surface morphologies: (a) Al alloy; (b) Al-3Al2O3-3Gr; (c) Al-6Al2O3-3Gr; (d) Al-9Al2O3-3Gr. [14]
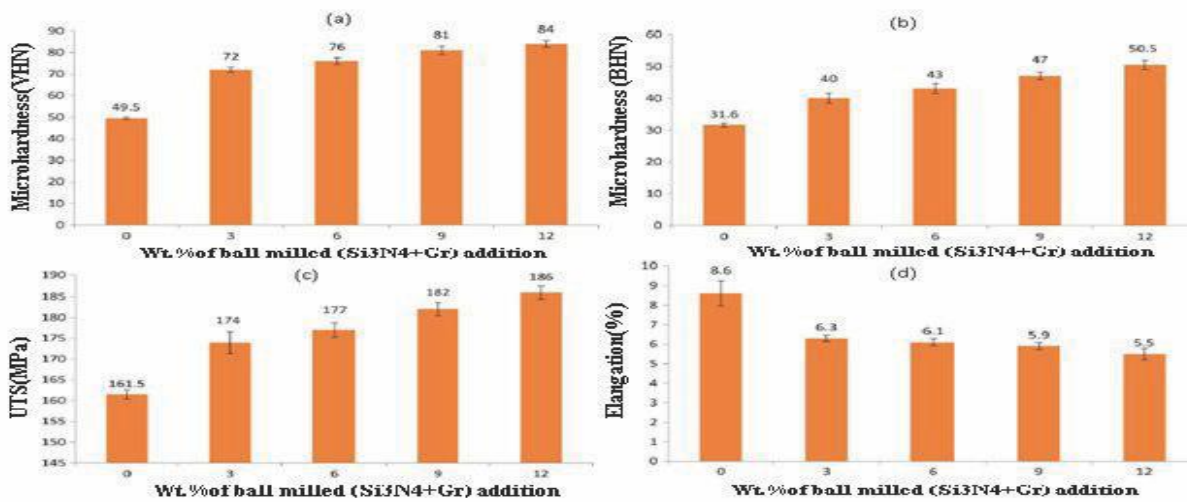

Figure 7. (a) Variation of micro-hardness(VHN), (b) variation of micro-hardness(BHN), (c) Variation of UTM, (d) Variation of percentage elongation for all with wt.% of ball milled Si3N4+Graddition[16]

Studied milling of hybrid (Al6061/Al_2O_3/Gr) metal matrix composites. The author observed machining parameter such as feed, depth of cut and catting speed, found the optimal machining parameters for surface roughness, tool wear and cutting force by using Response surface methodology (RSM). Analysis part is done by the analysis of variation (ANOVA) to determine the optimal parameters and desirability function approach was used for multiple response optimizations.

4.3 Two-Step Stir casting method:

It is the resent interesting development contains Matrix material heating above its melting temperature and then cool down to a certain temperature between liquid-solidus points. At this stage, preheated nano reinforcement particles are added and mixed. The slurry heated again to fully liquid state and stirred thoroughly. It was used to prepare hybrid composites for (Al+bamboo leaf ash + Al_2O_3) hybrid composite and Al–Mg–Si alloys a base material with different nano reinforcement particles to prepare HBCs, in such connections through two-step stir casting was used to enhance various properties.

Investigated the wear and corrosion behavior of Al–Mg–Si alloy material (reinforced with rice husk and SiC particles) which was fabricated through double stir casting technique. Potential dynamic polarization measurements and open circuit corrosion potential (OCP) were used to steady the corrosion behavior. The corrosion resistance was improved by reinforcement of SiC and Rice husk ash, SiC had great corrosion as well as wear resistance.

To investigate the wear and corrosion behavior of Al–Mg–Si alloy material (reinforced with rice husk ash and Alumina particles) which was fabricated through double stir casting technique? The results indicated that the Al-Mg-Si/10wt% Al_2O_3 single reinforced composites were superior than Hybrid MMCs in NaCl 3.5 percentage solution. Corrosion rate increased with increasing of Wt% risk husk ash in the hybrid composites and wear rate also increases with the addition of Wt% risk husk ash.

4.4 Squeeze casting:

*S*queeze casting is the combination of gravity as well as forging uses an accurately measured quantity of molten metal which is poured into a heated mold. Pressure is applied continuously to the molten metal until it solidifies and forms a desired shape component.
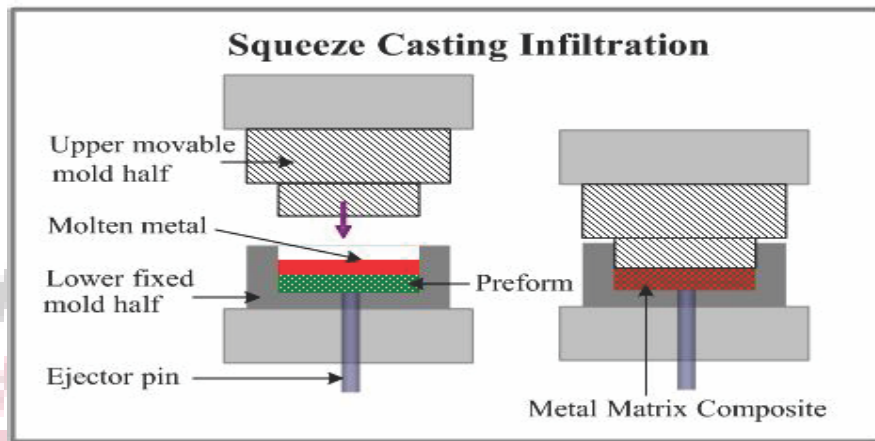

Figure 8. Schematic Diagram of Squeeze Casting Technique

It is used squeeze casting technique to prepare SiC+ Carbon Nano Tubes/6061Al Hybrid composite, investigated the effect of heat treatment and hot extrusion and their bond strength. Experimental results were concluded that the reaction occurred in CNTs-Al at 580^0C to enhance the strength of bond, activation energy between carbon Nano tubes(CNTs) and 6061Al is found to be higher then between carbon Nano tubes and 2024Al. As well as the bond strength between carbon Nano tubes/SiC and Aluminum improved in Heat Treatment of hot extrusion at 580^0C. To prepared Magnesium alloy metal matrix hybrid composite with the reinforcement of SiCp, carbon fiber and in-situ Mg_2Si, in order to analyze the micro structure of Hybrid composites in the cast condition, author had used optical microscope as well as SEM.

Other methodologies were followed many researchers and some are as follows & to prepared a hybrid composite of Banana/Glass fiber reinforced polypropylene through melt- blending technique. Studied and reported an increase in flexural, tensile and impact strengths with an increase of fiber content, absorption rate of hybrid composite decreasing due the presence of coupling agent and glass fiber. In this paper the nature of fiber matrix was tested through SEM analysis of tensile fractured specimen and thermal measurements were also carried out by Differential scanning calorimetric. It is used Friction stir process to prepare the hybrid surfaces by using various nano reinforcement. Due to this process, the mechanical and tribological properties were increased. It is successfully fabricated HBC(Al+SiC+B4C) by using ultrasonic cavitation based solidification process and concluded the addition of nano particle increase in tensile strength and it obtained at 0.5 Vol% B4C and 1.0 of Sic Vol%. It is [prepared] hybrid composites (Cu+TiC+Gr) and successfully sintered using Microwave hybrid sintering technique for Electrical sliding contact applications. An investigation did for the effect of TiC, Graphite reinforcements on mechanical as well as physical properties of hybrid composites, found to be hybrid composites shown higher sintered density, relative density and hardness when is it compared to conventionally sintered composites.

It has done the preparation and characterization of poly ether ketone (PEEK)/fly ash/mica hybrid composites having filler combinations of fly ash to mica ratios at 5:15,10:10,15:5, investigated the performance of the hybrid composites, results found that the hybrid composites of 20 wt% fly ash and mica with other combinations given that the high mechanical properties and Dielectric strength. It is investigated the effect of hybridization of jute fiber on the mechanical properties and water absorption property. Results were concluded that the pure coir composite had the highest water absorption and thickness swelling when it compares with another type of composites. Pure jute composite showed as the lowest thickness swelling and water absorption and highest density as compared with other composite materials.

It Is fabricated magnesium metal matrix composite reinforced with TiC and molybdenum di-sulfide through powder metallurgy route, reported the effect of both TiC and MoS_2 on tribological properties, Wear test performed individually(TiC and MoS_2) reinforced composite and together reinforced hybrid with different combinations by Pin On Disc at dry sliding condition. The experimentation designed by Taguchi technique with L_{27} for 5 factors, 3leval system. they concluded with the

results that the wear resistance of magnesium metal matrix hybrid composite was improved significantly by adding of were used a full factorial method to analyze the tribological behavior of hybrid composites (A356/10SiC/1Gr and A356/10SiC/3Gr). A number of tests were conducted using a block on disc tribometer without lubricant. They studied the effect of load, sliding speed, sliding distance and wt% of Gr, concluded increases the load, sliding speed, sliding distance - increases wear rate of hybrid. And at 1wt% Gr, the specific wear rate decreases. Further increases of 3wt% Gr, causes an increase in specific wear rate. And the factorial design technique found to be a simple, systematic and efficient method for optimizing of wear test parameters.

5. Conclusion:

The major contribution of the Researchers on Aluminum, Copper, magnesium alloys to boost the mechanical and tribological properties of Hybrid composites with tremendous strength, lightweight as well as cost effective less was well received and followed. This paper presented the performance of recommended, the hybrid composites as they are better then Nano composites and other current conventional composites when it is fabricated through stir casting route because a uniform and fine dispersion of Nano sized ceramic particles provided good stability between reinforced particles and inter particle spacing effects to maximize the mechanical and tribological properties

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