Effect of Reinforcements on Magnesium Matrix Composites- A Review

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Abstract- *Magnesium one of the third structural element which is used in various applications such as aerospace, defence organisation and automobile industries. Aluminium which is widely used in all over the world which overshadowed magnesium for these past decades. Magnesium which is 1/3rd lighter than aluminium and has the density of ρ=1.738 g/m3 and low weight compared to aluminium. When the magnesium reinforced with reinforcement particles such as B4C, Zro2, SiC, Al2O3, etc. This paper reviews about the magnesium reinforced with Nano and micron level particle and analysing the microstructure, SEM analysis, impact, hardness, tensile and wear properties of magnesium.*

I. INTRODUCTION

Magnesium alloy has high corrosion resistance, ductility, hardness and high impact strength so that it is using in various applications such as fuel tanks, Ladders, Laptops, televisions, cell phones, Luggage, Portable power tools, Chain saws, hedge clippers, weed whackers, wings, housings, transmission cases, engine blocks, Bicycles and other sporting equipment, Equipment for material handling. Although magnesium had many benefits it did not gain any attention in past years but now magnesium is gaining some attention by all the fields such as automotive and automobile industries. Magnesium is the most abundant structural element in the world. All over the world seas has a huge deposit of magnesium and it sources up to 8,50,000 tonnes per year. The magnesium is extracted from magnesite and dolomite. This is 2% of the earth's crust due to its weight and it is the most plentiful structural element in the sea water and it is obtained in other places of sea such as underground brines and salty layers. In land magnesium has been extracted in rocky minerals like magnetite, dolomite, olivine and serpentine. In the world magnesium has been supplied largely by United States of America, supplying 45% of magnesium to the world. Countries like China, Turkey, North Korea, Slovakia, Austria, Greece, Europe are mining 10 million tonnes per year.

Stir casting is one of the ancient techniques and it is classified into manual stir casting and automatic stir casting. Stir casting is the liquid state method where the material is heated beyond the supercritical temperature and make it into a liquid state and the pour the liquid into the die through which the desired shape can be obtained. The simplest and cost effective method in the liquid state fabrication methods. When the Boron Carbide is introducing into the melt it is preheated for 1hr at certain temperature. The Boron Carbide varies from 0% to 7% in each magnesium matrix. The furnace has to be controlled within 750℃ to avoid chemical reactions between the substances and the temperature in the furnace has been calculated using a thermocouple that has been inserted in the furnace. The stirring process is done through a stirrer driven by a electric motor and the stirrer is used to disperse the boron carbide Nano powder equally into the AZ61 magnesium alloy. The reinforcement particle and the magnesium alloy has to be stirred for 10 mins at 650rpm. The stirring should be done until the composite reaches the mushy zone. The microstructure and various mechanical properties can be studied using these samples through various procedures or methods. This can evident the effectiveness of the stir casting technique.

II. LITREATURE REVIEW

Magnesium based metal matrix composites were successfully prepared by stir casting technique. [1] The uniform distribution of B4C reinforcement particles and good interface bonding between Mg/B4C particles was observed in cast composites significant grain refinement was observed with the addition of B4C particles in the composite material The significant improvement in hardness, yield strength, and ultimate tensile strength was obtained with the addition of B4C particles. The unreinforced Mg exhibits ductile type of failure, whereas the fracture surface of composites shows brittle failure.

The magnesium matrix composites reinforced by stainless steel (Fe–18Cr–9Ni), titanium alloy (Ti–6Al–4V), and aluminium alloy (Al–5Mg–3Zn), were Prepared by the pressure infiltration technology distribution [2]. The grain size and distribution in the as-cast magnesium matrix composites have the same characteristics, and their sizes are mainly concentrated at 200–300 µm, and the size distribution is random and does not obey normal distribution. The average grain sizes of magnesium matrix composites with the reinforcements of MISC, MITC, and MIAC are 14, 20, and 24 µm, respectively. Compared with AZ31, the mechanical properties of metal composites interpenetrated by metal reinforcement have a significant improvement.

Swamyhas developed Magnesium powder as matrix mixed with Fly ash (FA) in weight percentages of 0, 0.5, 1, 1.5, and 2%(wt) as reinforcement were produced through powder metallurgy route. The specimens were Sintered and tests were conducted successfully. Specimens were subjected to evaluate the behaviour of mechanical properties of MMC. Hardness of Mg/FA composite is greater than pure Mg and better after sintering. Compressive strength increases with increase in percentage of reinforcement and sintered specimens gives better results than unintered. Yield strength increases remarkably with the increase in Reinforced particulate for sintered specimens.

Rameshhas explained Sintering of Al composites is more energy efficient than for most other PM materials due to the relatively low sintering temperatures. The apparent density, tap density and theoretical density increase with the addition reinforcements to the pure Al matrix. The reason for the density increase was the filling with fine powders of reinforcements of the pores formed in the matrix by large irregular Al particles. Coefficient of friction was stabilized with incorporation of solid lubricants in composition of composite at solid state for various sliding speeds and applied loads. Incorporation of graphite particles in the aluminium matrix as a second reinforcement decreases the wear rates of the composite compared to SiC reinforced composite.

The sintered metal–graphite composites out of aluminium alloys and magnesium alloys by spark plasma sintering(5). Some composites outperformed copper for specific heat sink applications. The measured thermal conductivity of up to 390 W m^{-1} K^{-1} in our samples is more than two times the value of the metal matrix and approaches the TC of copper. Due to the low density of aluminium, magnesium and graphite, the achieved specific thermal conductivity is four times higher than that of copper. This makes the sintered materials ideal for heat sinks, in particular for mobile or aerospace applications

AZ31 MMC microstructure, hardness and density were evaluated by Senthilkumar (6). It shows random dispersion of reinforcing particles SiC and Al_2O_3 particle in Mg matrix. Reinforcing Aluminium alloys with ceramics particles has shown an appreciable increase in its mechanical properties. Hardness of Mg is increased by 16.47% with increase in SiC reinforcement. Density of AZ31-Al_2O_3-SiC hybrid composites was found to increase with increase in SiC. SiC serve as a complementing reinforcement for the development of low-cost high-performance magnesium hybrid composite.

Ipek Explain The incorporation of particulates into the matrix material that the hardness of MMCs was higher than that of unreinforced magnesium (7)The compressive test results illustrate a significant effect of 3 wt.% B_4C on the compressive strength of magnesium MMCs manufactured by P/M with magnesium and B_4C powders with a mean size of 69 µm. The difference in compressive strength of the samples was mainly due to the plastic deformation mechanisms, which vary with the bonding strength of interfaces. The optimum reinforcement content (wt.%) was investigated to obtain improved compressive strength and hardness. XRD analysis revealed MgB_2, MgO, and Al_2O_3 phases in Mg/B_4C MMCs. The densities of the samples are between 1.56 and 1.51 g/cm^3.
Karanahas explained DIY materials are created through individual or collective self-production practices, often by techniques and processes of the designer's own invention. They can either be totally new materials developed versions of existing materials. DIY materials offer great opportunities to positively contribute to product design through material experimentation as well as distributed and shared production processes. initially simple two-way classification to consider different types of DIY materials: the first type describes DIY new materials focused on creative material ingredients, whilst the second type describes DIY new identities for conventional materials focused on new production techniques. Of course as DIY material development increases pace, it will be necessary to add and review cases to check that the existing classification still holds true.

Wang has developed Magnesium matrix composites reinforced with TiC particles can be fabricated by adding a TiC–Al master alloy processed via SHS reaction into molten magnesium and using the semi-solid slurry stirring technique.by Wang TiC particles in the master alloy are fine, spherical, and since TiC particles are surrounded by aluminium, the particle surfaces are uncontaminated, which makes the wetting of TiC particles in the magnesium alloy significantly improved.

Feyerabend Magnesium alloy-based metal matrix composites are novel cy to compatible metals with adjustable mechanical and corrosive properties. The distribution and size of the hydroxyapatite particles are of major importance for mechanical and corrosive properties. the addition of hydroxyapatite particles enhanced the corrosion resistance of the magnesium matrix in artificial sea water and cell solutions
Sabariz has explainedSintering can be efficiently used to produce final products of magnesium; however, as the process

parameters have a direct influence on the quality of the final product, these should be carefully studied. The magnesium filings attained good mixing and excellent compatibility, what coupled with the possibility of being produced from industrial wastes, at reduced cost, makes this a preeminent raw material for powder metallurgy. In spite of the losses of mechanical strength caused by the grain growth, it is noticeable that the presence of CeO2 increases the strength of the composite, which archived a difference up to 18% in hardness between pure magnesium and the specimens with 4 wt. % of reinforcement

Jebadurai developed Hybrid AZ91D–B4C–Gr composite has been successfully developed by stir casting technique. The density, porosity, hardness, ultimate tensile strength, optical microstructure and abrasive wear were evaluated. As compared with pure AZ91D magnesium alloy, the density of AZ91D composite and hybrid composite increased. The porosity ofAZ91D hybrid composite is less compared to AZ91D alloy and AZ91D–B4C composite. Hardness value ofAZ91D–B4C composite is high compared to AZ91D alloy and AZ91D–B4C–Gr hybrid composite. Similarly, tensile strength of composite decreased when compared to alloy and hybrid composite. This is due to the presence of graphite in hybrid composites. The incorporation of B4C reinforcement to AZ91D alloy increases the wear resistance of the composite. The developed composite has exhibited higher wear resistance and higher coefficient of friction when compared with matrix and hybrid composite. The addition of Gr reinforcement in AZ91D–B4C composite as a hybrid reinforcement further decreased the wear resistance of the composite. The addition of graphite particles provides solid lubrication to the composites and decreases the metal to metal contact and the coefficient of friction, resulting in the reduction of the wornsurface temperature.

Titus revealed SiC-GO Nano sheet reinforced Mg MMC is effectively facticated through adopted solvent based powder metallurgy route. Influence of reinforcement over basic and functional properties are studied. A mathematic model is developed using ANN to study the influence of control factor. Worn out surface morphology during constant wear condition is investigated by SEM and further the following conclusion are made. Addition of SiCp-GO Nano sheet shows drastic improvement in micro hardness (89 HV) while compared to its base matrix material (45 HV). Incremental in reinforcement wt.% shows decremented order in its density. Addition of reinforcements decreases the wear rate and increases the coefficient of friction. Occurrence of plastic deformations and delamination wear was notified over the worn out surface. ANOVA results depicts that r-GO wt.% and applied load are the significant influential factor for specific wear rate. Developed back propagation feed word ANN model have better predictability to study the effect of control factors with R value of 99.8%. The developed MMC could use in sliding applications where higher wear resistance was need.

Praveen kumarhas developed Magnesium AZ31B alloys filled with micron sized tungsten carbide composites were remarkably prepared through low cost stir casting process. SEM photographs display the almost homogeneous distribution of WCpin the Mg matrix. The macro-hardness and UTS of AZ31B/WC MMCs enhances with augment in wt% of WC. The mechanical properties of the developed composites are improved with the augment in filler content when compared to the plain Mg matrix alloy. The manufactured composites are widely suitable for various renewable energy applications like wind mill blades and solar panels based components.

Huang has explain Friction stir processing successfully fabricated bulk Mg-AZ31 based composites with 10 20vol% of nanoZrO2 particles and 10vol% of nano-SiO2 particles. The distribution of the 20nm Nano-particles after four FSP passes resulted in satisfactorily uniform distribution. The average grain size of the AZ31 matrix of the 4P FSP composites could be effectively refined to 2{4mm, as compared with the 6mm in the FSP AZ31 alloy (without particles) processed under the same FSP condition. The crystalline ZrO2 phase is very stable, no reaction between ZrO2 and Mg phases occurred during the FSP mixing. The hardness and tensile properties at room temperature Friction stir processing successfully fabricated bulk Mg-AZ31 based composites with 10{20vol% of nanoZrO2 particles and 5{10vol% of nano-SiO2 particles. The distribution of the 20nm Nano-particles after four FSP passes resulted in satisfactorily uniform distribution The average grain size of the AZ31 matrix of the 4P FSP composites could be effectively refined to 2{4mm, as compared with the 6mm in the FSP AZ31 alloy (without particles) processed under the same FSP condition. The crystalline ZrO2 phase is very stable, no reaction between ZrO2 and Mg phases occurred during the FSP mixing. The hardness and tensile properties at room temperature of the AZ31 composites with Nano-fillers were improved (up to Hv 105), as compared with the AZ31 cast billet (Iv 50). The hardened bulk section or surface layer would greatly improve the wear resistance that is vital for practical applications. The effective hardness of the present particle reinforced composites can be approximately predicted by the iso stress model when the hardness of the hard particle is much higher than that of the soft matrix and the volume fraction of the particles is much lower than that of the matrix.

Gupta has effect Blend-press-sinter powder metallurgy technique coupled with hot extrusion can be used to synthesize Mgbased composites containing nano-size oxide particulates reinforcement e.g., Al2O3, Y 2O3 and ZrO2. Microstructural characterization shows reasonably uniform distribution of reinforcements with good matrix reinforcement interfacial integrity. The presence of reinforcing particulates, irrespective of type, assisted in the significant grain refinement of magnesium matrix. (he results of mechanical characterization revealed that the presence of the Nano-size oxide particulates in magnesium matrix lead to significant improvement in hardness, 0.2%YS, UTS, ductility and work of fracture. Almost the particulates type investigated, Al2O3 particulates were found to be most effective in increasing strengthpropertieswhiletheZrO2 particulates were most effective in increasing ductility and work of fracture. Fractography revealed that fracture behaviour of the plastically deforming magnesium metal matrix was changed from complete cleavage mode of ductile and intergranular, dominated by formation, growth and coalescence of the microscopic voids with the activation of non-basal slip system in the presence of Nano-size oxide particulates.

Liua has significant amount of time and effort has been devoted to the research and development of magnesium matrix composites in recent years. Various techniques have been developed and applied to the processing of magnesium matrix composites, such as stir casting, pressure and pressure less infiltration, powder metallurgy, gas injection and in-situ formation of reinforcement in the matrix. Key factors affecting the performance of the magnesium composites are the matrix composition; the chemistry; the shape, size, and distribution of the reinforcements; and the bonding strength at the reinforcement/matrix interface. High strength in the composites is normally achieved at the cost of compromised ductility. Never the less, grain refinement is an effective way of improving ductility and strength at ambient temperatures. However, caution has to be taken in using fine-grained materials elevated temperatures because creep resistance can be adversely affected by the fine grain size. The acceptance of the magnesium matrix composites as engineering materials depends not only on the performance advantages of the materials, but also on the development of cost-effective processing technologies for these materials.

Lim he evaluates dry sliding wear tests of Mg9Al alloy and its 8vol.% SiC-reinforced composite pins against a steel counter face were carried out under loads of 10 and 30N, and over a range of sliding speeds from 0.2–5m/s. Five different wear mechanisms were found to operate under these conditions. They are: abrasion, oxidation, delamination, adhesion, thermal softening and melting. 2. The dominant wear mechanism under the lower load of 10N is oxidation. The composite generally exhibits better wear resistance (15–30% improvement) due to its superior load-bearing capacity and its ability to maintain a stable oxide film, which protects against metal-to-metal contact with the steel counter face during sliding. 3. A transition from oxidation to delamination and abrasion occurs with an increase in applied load to 30N. The wear resistance of the composite deteriorates as the presence of a second phase promotes delamination wear. 4. A gradual transition from delamination and abrasion to adhesion takes place with a rise in sliding speed under the higher load. The composite once again shows slightly improved wear resistance due to its higher load-bearing capacity. 5. At even higher speeds, increased frictional heating leads softening and melting. The massive plastic deformation experienced by the pin under 30N and 5m/s limits the use of the Mg AL alloy and its composite to milder sliding conditions. The presence of SiCp does not appear to be beneficial in reducing wear rates or delaying such thermally activated processes.

A uniform and continuous Si coating was obtained, and the effective fabrication of CNT-reinforced metals depends on the homogenous dispersion of CNTs in the metal matrix and the interfacial adhesion between them.(19) In this study, it is investigating magnesium matrix composites reinforced with multi-wall carbon nanotubes that have been coated with Si in order to improve the wettability. This research has shown that silicon powders can be coated onto carbon nanotubes by a directly heating method. Silicon powder has been effectively coated on the surface of MWNTs and well covered and continuous. The solid reaction method for the Si-coat MWNT Nano composite has made very simple, inexpensive and high mass. The results obtained pave the way for the formation of coated carbon nanotubes for the development of composites with a homogenous microstructure and improved performance. TEM observations show that the interface between MWNTs and matrix is wettability and in good adhesion. The analysis results of Raman spectroscopy and structure properties of MWNT, SEM images of MWNTs suggest that after solid reaction, the smooth MWNTs surface become rough, and the surface defects of Si-coat MWNTs are enhanced, but the integrity of the MWNTs patterns is not damaged. We believe that the present technique method for preparing SiMWNT is suitable for fabrication of other CNT reinforced metal composites with high strength properties.

Rashad has explain the disintegrated meld deposition technique is a suitable method to incorporate carbonaceous reinforcement, GNPs during liquid state processing to fabricate AZ61-GNP composite with uniform dispersion of reinforcement particulates.(20) Room temperature mechanical characterization of materials revealed a significant increase in micro hardness, tensile and compression yield strengths with addition of GNP. Thus, GNP has high potential to improve mechanical properties of magnesium alloys. The increased mechanical properties of composite are attributed due to grain refinement, uniform dispersion of GNP, changes in basal texture intensity, and efficient load transfer from soft matrix to hard two dimensional GNPs. This may be attributed due to complete recrystallization of composite matrix during high temperature testing. Furthermore, fracture mode of composite changes to ductile mode with increase in testing temperatures.

III. CONCLUSIONS

It is concluded that the magnesium alloy when reinforced with nano particles shows good result. When magnesium reinforced with boron carbide shows improvement in tensile and hardness properties. Sometimes pores may occur in the magnesium alloy but it is low. The thermal properties of the magnesium alloy shows some improvement by adding boron carbide. The ductility slightly decreased but adding submicron results in improvement in ductility. The wear volume decreased by reducing SiO2 particles.

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