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# Stir Casting Technology for Magnesium-based Metal Matrix Composites- A Review

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*Abstract:* **Generally Metal Matrix Composites (MMCs) is produced in industry by Stir casting method. Stir casting technology is also used for mass production system. In this method of production, process parameter is simple and running production cost is less as compared to other method. This method is simply and the process used during the manufacturing is established. In this paper, we have to consider all the aspect from section of material, design of furnace, process parameter, Quality aspect and total cost regarding to stir casting method. During the manufacturing of Metal Matrix Composites of magnesium, some problem has been happed, which is removed by selecting the proper Composite characteristics. For minimize the short coming during the process and improving the mechanical properties of product, we have to select the proper process parameter, reinforcement material and furnace. The different method of magnesium based MMC manufacturing is discussed in this paper, which will be beneficial for researcher. A stir casting furnace with bottom tapping is perfectly equipped with an electromagnetic stirrer, ultrasonic stirrer and squeeze attachment, was chosen based on a literature review for MMC manufacturing.**

***Keywords* — Magnesium alloy; Metal matrix composites (MMC): Stir casting technology**

## I. INTRODUCTION

Stir casting is one of the important methods for manufacturing of metal matrix composites of magnesium in industry. Mechanical stirring process is implementing during the manufacturing of MMC reinforcement. of magnesium metal During the manufacturing of metal matrix composite and reinforcement, a number of flexible aspect is consider for design and material selection. In the case of traditional material like magnesium, the hybrid characteristics have been obtained for given metal. In modern time for the structural design, Magnesium-based matrices are implemented. In general, the pure form of magnesium is not used in the case of structural application due to less strength. Aluminum, zinc and copper is added with magnesium to increase the casting ability and mechanical strength. For improving the ductility, Manganese is added. These alloys have low as well as high temperature strength. Such type of alloy has high corrosion resistance and more stiffness. The reinforcement is much more strength than matrix form for MMC of magnesium alloy. Due to some obstacles, MMC of magnesium is limited as compared to MMC of aluminum.

**Figure 1 (a) : Electric Furnace** **Figure 1 (b) : Stirrer Blades**

## II. LITERATURE REVIEW

Rao et al. (2015) calculated the mechanical & physical characteristics of AZ91D/SiC created using the stir casting procedure. In this process the stirrer speed was maintained constant i.e. 580 rpm for 20 min at 660°C. The reinforcing particles in the composite were distributed uniformly samples as confirmed from the SEM photographs. The effects of adding SiC particles on matrix hardness were investigated. The hardness and UTS of Mg-based composite manufactured samples as represented in Figure2.[1] a) b)

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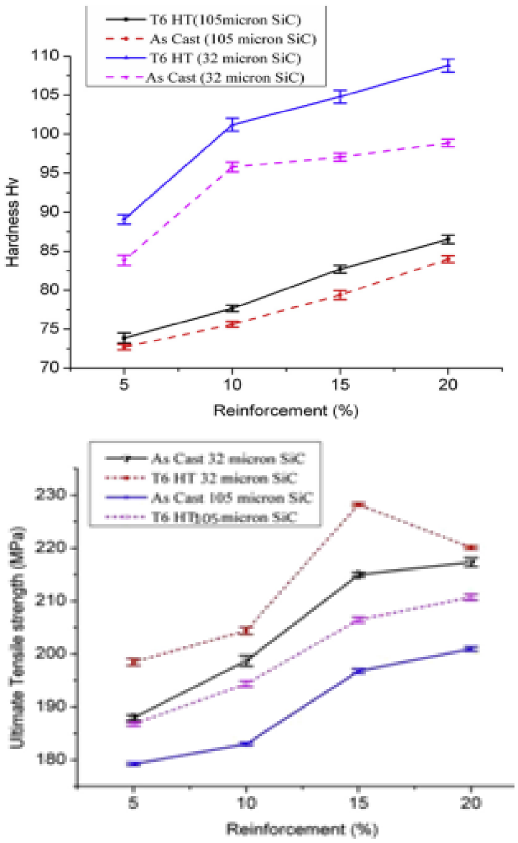


**Figure 2(a) & (b): Hardness and UTS of magnesium alloy (AZ91D) composite [1]**

Dziubinska, et al. (2015) was performed the test on AZ31 based aluminum reinforced composite by new forging technology. At 410 °C a prototype of semi open die forging pressed the equipment with three moving tools for obtained a desired shape of brackets, ribs used in aircraft applications. The application of magnesium is most popular in aircraft manufacturing industry as a result of their light weight, outstanding mechanical properties and better design characteristic regarding to specific gravity. The observations of hardness (64 HB), tensile strength (290 MPa), elongation (11%), yield strength (171 MPa) were determined [2].

Suwas et al. (2015) examined Mg/SiCp and AZ91/SiCp and machined it both specimen as well as die were warmed for 2 hours, and the specimen was lubricated with MoS2. By altering the die opening size, The composite was extruded at extrusion ratios of (R=15:1) and (R=50:1) (15mm & 9 mm), and texture development indicates the creation of 〈101¯0〉 ‖ED texture fiber for all substances after deployment [3].

Haghshenas et al. (2017) studied the mechanical properties of matrix composites like magnesium–hydroxyapatite (Mg/HAP), magnesium–calcium polyphosphate (Mg/CPP) , magnesium/fluorapatite (Mg/FA) , magnesium-tricalcium phosphate composites (Mg/TCP), and hybrid Mg/HAP + -TCP. Different Author emphasis on composite manufacturing methods .In comparison to the AZ91 magnesium alloy, the Mg metal matrix composite enhanced with FA nanoparticles showed a higher overall hardness and elastic modulus, 103HV and 42.3GPa, respectively [4].

Kumar et al. (2017) studied the stir casting technique was used to create and metal matrix composite of magnesium alloy is characterize by reinforced with SiC. In this method, 20 micron size particle of SiC are used during the reinforcement. At 700°C, the AZ91 were melted by the help of electric resistive furnace in a crucible. The melted AZ91 was stirred for 12 minutes and kept for 15 minutes at this temperature. The optical microscope and scanning electron microscopy (SEM) were used to examine the microstructure of the composite made just using stir casting method. Based on the investigation it was found that yield strength was increased upto 105.44MPa and UTS was increased upto 193.96MPa for AZ91/SiC composites [5].

Chelliah, et al. (2017) performed the experiment on during dry sliding condition wear, a die-cast microstructure and its homogenized Mg-alloys AZ91 evolved. Tribological testing were carried out at load of 50 N and sliding speed of 2.5 m/s for a disc setup by using pin. Because of the brittle character at the grain boundaries with intermetallic phase of the beta-Mg17AL12, AZ91 Mg –alloy was unsuitable for tribological applications. Their tribological performance was enhanced by increasing ductility by mixing with beta-Mg17AL12 matrix by heat treatment. The specimens were sectioned from the die-cast AZ91 Mg –alloy ingot and machined to cylindrical pins with diameters of 6 mm and lengths of 30 mm in order to undertake tribological tests, and heat treatment was performed for 48 hours at 425°C in an argon atmosphere. When compared to as-cast AZ91, the coefficient of friction of homogenized AZ91 was enhanced by 120 percent and the wear rate was reduced by 6.21 times [6].

Arokiasamy, et al. (2018) investigated the effect of process parameters in the case of friction stir casting on the hardness, ductility, crystal structure of AZ91D/Al2O3/SiC hybrid composites. Higher hardness of composites produced by pinning effect on reinforcement particles and reduction of grain size was observed due to increase in rotational speed of stirrer. Hardness of a composite was measured to be 69.3Hv at the speed of 600 rpm [7].

Jinxia, et al. (2018) was find out the tensile strength and yield strength after adding the cast AZ91D alloy in microstructure. Author's was also determined the tensile strength and yield strength of microstructure by increasing the frequency of a mechanical vibration. Author observed that initially strength of microstructure will increase and then decrease when frequency of vibration increases. Author calculated the tensile and yield strength of microstructure at 100 Hz frequency are 143.4 MPa and 121.6 MPa respectively [8].

Dash et al. (2018) consider the vertical induction furnace. During operation Mg alloy is heated at 500 to $550^0$C.Mg alloy is heated up to melting point under the atmosphere of inert gas argon in a graphite crucible. During the die

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moulding process, in a muffle furnace the material matrix of AZ91D, and TiCp is solidified. The molted form of AZ91D, and TiCp is pouring in mould cavity at high temperature 1390$^{o}$C at 660rpm for time duration of 2 Hours. By the help of stir casting technique, TiCp MMC is manufactured On the basis of different weigh percentage of AZ91D/ (0, 10, and 20 weight percent). In stir casting process, without agglomeration, the metal matrix is disseminated [9].

Bommala, et al. (2019) was describing the application of magnesium alloys. Magnesium alloys composites are also used in biomedical field. Mg-based composites like Mg-Ca, Mg-Al, Mg-Zn, Mg-REE are used in the application of medical science. Some of the reinforcement which used in Mg-based composites are hydroxypatite (HAP), Calcium Polyphosphate (CPP), and -tricalciumphosphate (CPP) Due to high strength as compared to weight, some of the specific Mg- based composites are used for orthopedic application. Due to biocompatibility and biodegradability ability of composite material, it is used in medical fields. The outcome of the result is as shown in Figure3 [10].

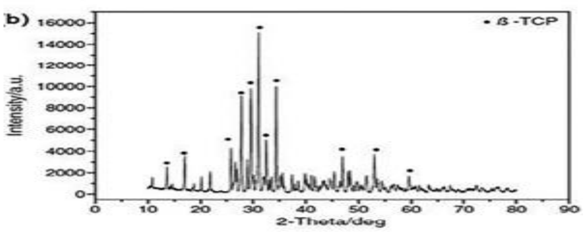


**Figure 3.: XRD Pattern of β-TCP[10]**

Gui, et al. (2020) described the effect of alloy element in manufacturing of composite in stir casting process. Author considers the Mg-Al91Zn alloy and MgZn5Zr alloy for manufacturing of composite material. In this process, the mixture was heated up to melting point temperature (Approximately 740$^{0}$C), running speed (600rpm) and stirring time (6 to 8 minutes).Distribution of different proportion of element is investigate by SEM Method and different element is determined by EDS Method, which is as shown in fig 4.It is observed that composite material has high tensile strength and more elongation due to application of load. Experimentally the author calculated the tensile strength of given composite is 178MPa and elongation due to load is increased by 1.8 % [11].

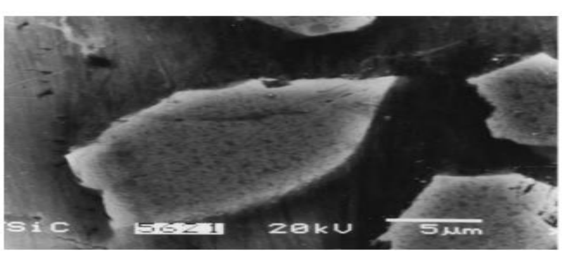


**Figure 4.: Magnesium matrix/SiCinterface shown by SEM Photograph[11]**

Nie, et al. (2020) worked on MMC(magnesium matrix composite ) by using nano particle. During the manufacturing of nano composite by using magnesium alloy, some problem has been take place. When the nano composite has been manufacture, than nanoparticle is dispersed in molten form due to vander waals force is acting between magnesium matrix and nano particles. And also due to low wettability, it is challenge to manufacturing the nano composite of magnesium. Such type of difficulty can be overcome by using Ultrasonic vibrations, which is shown in fig5. During the vibration of ultrasonic machine, the pressure and temperature has been reached up to 100 atm and 5000$^{0}$C and micro hot spots has been visualized. Ultrasonic machine has broken the nano particle cluster due to vibration and achieve the high temperature. After the experiment on magnesium matrix nano composites, the yield strength and ultimate tensile strength are measured as 422 MPa and 435MPa respectively [12].

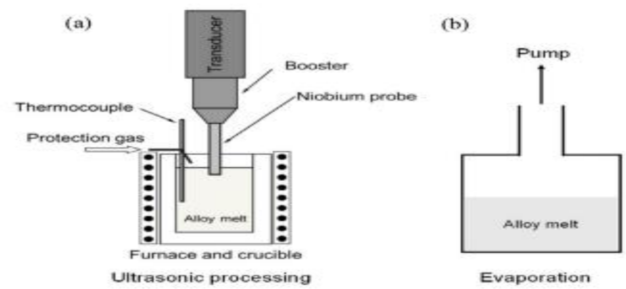


**Figure 5.(a) : Ultrasonic processing machine and 5(b): evaporation process of alloy[12]**

Gui et al. (2020) described that in the electric furnace at 720°C, 1.5kg Magnesium alloy was charged in a steel crucible prepared at 400°C. Mg-A191Zn alloy and the MgZn5Zr alloy melt at 740°C was refined for 6-8 minutes by swirling it at 1500 rpm for around 25 minutes at 600°C. The yield strength and elastic modulus of the Mg-Al9Zn/15SiCp composite increase 112 and 33%, respectively, over the unreinforced alloy, and rise 24 and 21%, respectively, for the Mg-Zn5Zr/15SiCp composite [13].

Lee, Kim (2020) was examined the various effect of Extrusion and high ratio differential speed rolling were used to create AZ31 alloy-based matrix composites with carbon black reinforcement (HRDSR). Magnesium chips coated with carbon black bulk composite material were created by extrusion at 623 K and hot pressing at 693 K. After HRDSR extrusion and subsequent annealing, the material had a comparable grain size of 16.3-17.9 m and the greatest mechanical qualities when compared to carbon black with a lower percentage of 0.03 percent (0.01 percent). The inclusion of carbon black boosted the strain hardening rate at all phases of a composite in both extruded and annealed HRDSR, according to the authors. HRDSR was also used on extruded materials to increase carbon black dispersion in

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the matrix by applying significant shear stress and shear strain [14].

Li et al (2021) explored CNT-Mg2Si/AZ91D composites utilized the SPS technique. CNT were treated for 30 minutes at room temperature in a strong acidic mixture with ultrasonic stirring, and then the mixture was condensed and refluxed for 4 hours at 75°C before being filtered. The Si and AZ91D powder was ball milled for 4 hours for 2 hours before being combined. The composite powder was solidified by SPS at 400 °C for 5 minutes under 35MPa. When compared to the AZ91D alloy, the 0.3CNTs-2.7Mg2Si/AZ91D composite has the highest hardness (92.7 HV), compressive ultimate strength (408.2 MPa), compressive yield strength (238.3 MPa), and elongation (24.5%) [15].

## III. CONCLUSION

Stirred casting process is influence by different process parameter like porosity, wettability, mixing rate of reinforcement, stirred blade angle and distribution of reinforcement particle. It is observed that SiC matrix is better than $Al_2O_3$ reinforced Magnesium matrix due to less wearing and creep resistance. But $Al_2O_3$ matrix is better than CNTs reinforced MMC due to less wear rate. Wettability has been increased by adding carbon nano tubes in magnesium alloy and its matrix. When the literature review is done, then it is concluded that Magnesium alloys has less wear rate as compared to MMC of Magnesium. When quantity of reinforcing in MMC is gradually increased than wear resistance will improved. Among the different Magnesium alloy and its MMC, Wear resistance of AZ91-6.5-UST is highest. Boron carbide will increase the bond strength of alloy and matrix. So B4C is added to magnesium MMC to increase the bond strength as well as flexural strength. Mechanical properties of magnesium alloy can be changed by adding fibres material. For decreasing the ductility and increasing the tensile strength, artificial and natural fibres are added to magnesium metal matrix composite.

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