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# Aluminum-6061 Reinforced with Zirconium Dioxide Metal Matrix Composite by Stir Casting Method: A Review

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**ABSTRACT:** Among all the composites manufacturing's, stir casting is the best and predominant method in a simple way of processing. Because of their merits like its simplicity, flexibility and applicability to batch production with less cost compared to other techniques. Generally these composites are being used in various fields like as aerospace, automobiles, and in defence services. Due to their most needed properties like mechanical properties, low density, and corrosion resistance as compared to raw materials and conventional metals or alloys. In These present review which deals the process of stir casting such as, the melting process of base metal, temperature maintenance on the process, conditions of adding the reinforcement into a molten metal and the affect of stirrer speed and stirring time on casting process. The effect of the stirrer and feeding mechanism has also been discussed in the paper. And in these we discussed additional about the work who already done on metal matrix composites by stir casting techniques and little observation on their results what they gained from their experience.

**KEYWORDS:** Metal matrix composites, Stir casting, Base material, Reinforcement, Mechanical properties.

### I. INTRODUCTION

Now a days the engineering applications needed a materials that are stronger, lighter in weight and less cost to effort. Mostly this kind of materials is we try to use in automobiles, aerospace and in some defence equipments. A single metal or materials does not exhibit the required properties, so we try to combine two or more materials to produce a new material with required properties. From this moto the metal matrix material composites are introduced. From these mmc's we get the properties like high specific strength, low co-efficient thermal expansion and high thermal resistance, superior wear resistance, high stiffness and less corrosion ability. After getting success these mmc's are used in high range instead of conventional materials or alloys.

The common metallic alloys used in mmc's are alloys of light metals (Al, Mg and Ti) and other metallic alloys like Zinc (Zn), Copper (Cu) and Stainless steels have been used. Aluminum is mostly used metallic alloy in the preparation of mmc's. Because of its properties and easy to available. Generally most of mmc's are developing from the aluminum; these metallic alloys are acts as a base material. For increasing the properties of selected base metal we must add some reinforcement.

A key challenge in the processing of composites is to homogeneously distribute the reinforcement phases to achieve a defect free-microstructure. Based on the shape the reinforcement phases can be either particles or fibers. Because of the low material cost it is suitable for automatic processing, these composites are preferable. The fiber reinforced composites for automotive applications and other applications. There are two primary processing classifications made for the manufacturing of metal matrix composites.

1. Liquid state processes
  - a. Stir casting

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- b. Compo casting
- c. Squeeze casting
- d. Spray casting
- e. In-situ (reactive) processing
- f. Ultrasonic assisted casting
- 2. Solid state processes
  - a. Powder blending followed by consolidation
  - b. High energy ball milling
  - c. Friction stir process
  - d. Diffusion bonding
  - e. Vapours deposition technique

The selection of the processing way depends on some factors like

- a. Type and level of reinforcement.
- b. Loading and the degree of micro structural integrity desired.

The nature of simplicity, flexibility and applicability to large quantity production stir casting is generally accepted as a promising route in the manufacturing of mmc's on among the processing routes. It is also attractive and simple processing way because in principle, it allows a conventional processing way to be used and these can be minimizes the final cost of the output product. It allows very large size component to be fabricated.

In a stir casting process, the reinforcement materials are distributed into molten base material (matrix) by mechanical stirring. Stir casting of metal matrix composites was initiated in 1968, when S. Ray, alumina particles into an aluminum melt by stirring. Molten aluminum contains the ceramic powders. Mechanical stirrer in furnaces is a heart to the casting. So before adding the reinforcement materials the melt should be subjected to degassing by suitable medium, because the molten metal reacts with atmospheric oxides and undergoes oxidation. In the stir casting with bottom pouring techniques, the moulds kept just below or near to the furnace opening. This type of arrangement reduces the incorporation of particulates and reduces the time of pouring. Due to the reduction in time of pouring and due to a better particulate mixing of materials the composite properties are improved.

The matrix material melted in a crucible by heating it in a furnace. The stirring is activated by means of a motor at the top of the stirrer. The stirrer can be moved up and down by means of a rack and pinion arrangement. Reinforcement is added to the matrix after stirring the matrix material for a certain amount time. Preheating of crucible is also carried out to avoid thermal distortion of the composite material.

The matrix material utilized in experimental studies in these papers is Aluminum 6061 as a base material and Zirconium Dioxide as a reinforced material. Whose chemical compositions are shown in below:

Table 1: Chemical composition of aluminium alloy 6061

Constituent	Al	Mg	Si	Fe	Cu	Zn	Mn	Cr	Other
Wt.%	96.50	0.956	0.562	0.532	0.236	0.202	0.102	0.046	0.864

The mechanical properties of Al 6061 based on the temper or heat treatment of the material. It offers relatively high strength, good workability, high machinability, high resistance to corrosion and largely available in nature.

Table 2: Chemical composition of zirconium dioxide powder

Constituent	ZrO <sub>2</sub>	SiO <sub>2</sub>	TiO <sub>2</sub>	Fe <sub>2</sub> O <sub>3</sub>	Other
Wt.%	99.5	0.10	0.007	0.002	0.39

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Zirconium Dioxide is a white crystalline oxide of zirconium. The density of these material is  $5.85 \text{ g/cm}^3$  and melting point greater than  $2600^\circ\text{C}$ . It exhibit high strength, high structure toughness, excellent wear resistance and high hardness etc....

## II. RELATED WORK

To study the properties of base material aluminum 6061 is reinforced with Zirconium Dioxide by varying different weight percentages with the help of stir casting technique, For these we read some of the research articles on stir casting and summarized their results and gathering bit of knowledge from their observations. And also studied some of other researcher articles which are different from the 6061 and the reinforcement. Following observations are gained from some other papers.

Sandeep Kumar Ravesh et al., in their research they use aluminium 6061 as a matrix material and SiC and fly ash as a reinforcement in the fractions of 2.5%, 5%, 7.5% and 10% and 5% of fly ash are mixed with the help of stir casting technique. After completion of casting they, done tensile, hardness and impact tests on these composite specimen. From this tests they got increased values of tensile, hardness, and impact for increasing the weight percentage of reinforcement. At the 10% of SiC and 5% of Fly ash they get  $115 \text{ N/mm}^2$  of tensile strength, 93 RHN of hardness and 7.8 toughness were obtained.

J.Jenix Rino, et al., they investigated the mechanical properties of Al 6063 alloy reinforced with zircon sand and alumina particles with an overall in 8% weight ration by stir casting method. They did a microstructure analysis on that material and the got homogeneous distribution of reinforcement in overall base material. And the tensile and hardness of the composite is increased by adding of 4% zircon sand and 4% alumina particles.

## III. REVIEW

**Dharmesh M.Patoliya, et al.**, in their investigation they take approximately 2Kg of Al 6061 in solid form and melted that in furnace and add fixed quantity of Zirconium Dioxide, it was taken in powder form in suitable crucibles. They preheat the  $\text{ZrO}_2$  for 30min to remove moisture and gasses from surface of the particles. They maintain the stirrer speed at 500rpm and then added preheated  $\text{ZrO}_2$  to molten metal and stirred continuously for 15min for proper mixing of reinforcement and base metal. Then they poured in the sand mould and get desired shape of different testing specimens. They tested the mmc's micro structural characterization by inverted optical microscope. For these they grind the specimen surface by grinding through 220 to 1500 mesh size abrasive papers and polishing with velvet cloth. Then they use Keller's reagent for etched the specimen. They used an image analyser to observes the distribution of  $\text{ZrO}_2$  within the Al matrix. From this observations and obtained micrographs they observed the uniform distribution of  $\text{ZrO}_2$  and they posses good interfacial bonding in between Al 6061 and  $\text{ZrO}_2$  particle. And then they test tensile strength and hardness test, from these tests they observe increased strength due to increasing the weight fractions of  $\text{ZrO}_2$  in Al 6061. The presence of such hard surface area of particles offers more resistance to plastic deformation which leads to increase in the hardness of mmc's. Impact strength also increased from 8Nm to 19Nm by increasing weight fraction of  $\text{ZrO}_2$ .

**K. Aruna, et al.**, for their research work they choose stir casting among the diffusion bonding, ospray method, liquid infiltration, powder metallurgy, in-situ technique etc... in this stir casting method they use ceramic coated stirrer, in order to maintain a uniform distribution of reinforcement. They add different weight fractions of  $\text{ZrO}_2$  in range of 0 wt% to 10 wt% in Al 6061. For degassing and increasing the wettability of molten metal they externally added Hexa Chloro Ethane ( $\text{C}_2\text{Cl}_6$ ). They did metallurgical tests for observing the microstructure of composite and mechanicals tests for the study of properties like tensile and hardness of the composite. From these tests results they concluded that the tensile strength and hardness of the composite is gradually increased with increasing of weight fraction. And the reinforcement and base material is uniformly bonded with each other. Due to increasing of weight percentage of zirconium dioxide the elongation is also decreased.

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**K. B. Girisha, et al.**, they do this research is to find the effect of varying weight fraction of zirconium oxide nanoparticles i.e 0.5%, 1%, 1.5% and 2% reinforced Al 356.1 composite by stir casting. Due to high content of zirconium oxide, they observe the particle agglomeration in composite. And finally they concluded that the hardness and wear properties also increased with increasing if zirconium oxide nanoparticle weight percentages.

**Udayashankar. S, et al.**, they said zirconia is one of the most inexpensive, easily available reinforcement and has high strength at elevated temperature and have best mechanical and wear properties. Zirconium Dioxide is one of the most studied ceramic material. They fabricate a composite with the help of stir casting technique. In this the stirrer assembly consisted of graphite stirrer, which was connected to a variable speed motor vertically at the top of the furnace by means of steel shaft. The speed range of the motor used in this method is 50 – 800rpm motor. The stirrer consists of four blades at an angle of  $120^{\circ}$  apart. Clay graphite crucible is placed at bottom of the furnace for collecting the molten metal which is coming out from the furnace after stirring. The capacity of furnace is 4 Kg. Initially the base material that means Al 6061 is melted at  $750^{\circ}$ . At the time of melting of base material, on other side the reinforcement is preheated at  $400^{\circ}$  for one hour. Then the preheated zirconium dioxide is added in weight fractions of 0, 3, 6, 9, 12% into a melted base material. Additionally they added small amount of degassing agent hexa chloro ethane ( $C_2Cl_6$ ) For reducing the porosity. They maintain stirrer speed in range between 500 – 700 rpm, and did a stirring continuously for another 5 minutes. Then the molten metal is poured into a mold which was also preheated to  $500^{\circ}$  for 30 mins to obtain uniform solidification. They test the specimens for knowing the properties like tensile and hardness of composite and microstructure of the composite. From this they find the uniform distribution of zirconium dioxide in Al 6061 was at 9% of zirconia. The tensile strength values of the Al 6061 -  $ZrO_2$  was found to be more than base metal Al alloy. Hardness is also increased with increasing of reinforcement fraction.

**M. Ramachandra, et al.**, the main aim of this research is to study the corrosion property of aluminum matrix nano-composite of an aluminum alloy (Al 6061) reinforced with nano  $ZrO_2$  particles. Metal matrix nano-composites with the addition of nano – sized ceramic particles can be significant for automobile, aerospace and numerous other applications. They made an attempt to investigate the inexpensive fabrication of light weight MMNC's with reproducible microstructure and superior properties by use of ultrasonic nonlinear effects namely transient cavitation and acoustic streaming to achieve uniform dispersion of nano-sized  $B_4C$  particles in molten aluminum alloy and found that mechanical properties of the cast MMNC's have been improved significantly even with a low weight fraction of nano-sized  $B_4C$ . The mechanical and physical properties due to their extremely grain size and high boundary volume fractions we called them as Nano-Structure materials (1-100nm). In this present work they used 50nm sized zirconium dioxide as a reinforcement and Al 6061 as a base material. For synthesis of n-  $ZrO_2$  here they use solution combustion method. Through mixture of 5gms of zirconyl nitrate along with the calculated amount of the fuel urea and 25ml of distilled water is prepared in a petri dish, for through this mixing a magnetic stirrer is used for about 15mins and at the end we get homogeneous solution. The fuel urea preheated with the help of muffle furnace about  $500^{\circ}C$ . In muffle furnace placed the prepared homogeneous solution for boiling which yields a viscous liquid, due to high exothermic process these catches fire and homogenous solution gets converted into a flaky type powder. That flaky  $ZrO_2$  powder taken out and allowed to cool further in atmosphere. Then that flaky powder dropped into grinder and is ground into a final powder to get nano-sized  $ZrO_2$ . To get an adequate amount of n-  $ZrO_2$ , we need to repeat the solution combustion process for number of times.

In this paper they prepared composite by using vortex technique. The base metal Al 6061 are melted at a temperature of  $800^{\circ}$  in graphite crucible using 3-phase electrical resistance furnace. And the molten metal degassed at  $780^{\circ}$ . The reinforcement particles i.e n-  $ZrO_2$  preheated at  $650^{\circ}$  and then it is added to molten metal and stirred continuously. They maintain stirring time in between 5-8 mins and the impeller speed range is 600rpm. To increase the wettability they added magnesium in small quantities additionally. Poured these molten metal into a cylindrical permanent metallic molds of size 50mm diameter and 175mm height. They maintained pouring temperature is  $700^{\circ}$ . In these the reinforcement fractions varies from 0wt% to 7.5wt% in steps of 2.5wt%. for testing microstructure they used scanning electron micrograph. With the help of this the particulate size is found to be 50nm. The distribution of  $ZrO_2$  is uniform and form good interfacial bonding between  $ZrO_2$  and Al 6061. In addition they clearly confirmed that the nano particles

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successfully embedded in the Al matrix. And finally they concluded that the production of bulk nanocomposites using conventional stir casting is effective, and they did some corrosion test on that specimen and they observed that the corrosion rate of Al 6061 is higher than the nano composites produced. By observing the total plots, we can conclude that on increasing the percentage of  $ZrO_2$  nano particles in the nano composite the corrosion rate decreased simultaneously.

**M S Raviraj, et al.**, a circular furnace is filled with Al 6061 and it is heated up to a temperature range  $900^{\circ}$ - $950^{\circ}$  C. The crucible is made of steel and the reinforcement was blended with a proper quantity of flux to intimate dispersion prior to adding it up to matrix melt. To avoid the defects in the cast, degas agent HexaChloro Ethane was added to melt. It stirred at a speed of 700rpm and then poured into a preheated mould. The observed, the adding of flux prompted the contact clean wetting surface since all of the slag removed from the furnace.

**Pradeep Sharma, et al.**, used a 1000grams of aluminium alloy in graphite crucible and it is melted in electric furnace at the temperature  $900^{\circ}$ . To form fine vortex a mechanical stirrer is used. The  $Si_3N_4$  particulates were preheated to oxidize the surface of reinforcement and fed into melt aluminium alloy matrix. Argon gas is used to maintain the inert atmosphere and the mixture was stirred. The molten metal is poured into the preheated mould. The authors concluded that, the density of composite is increased from 2.69 to 2.75  $g/cm^3$ , and also they using SEM images and XRD analysis to find out the presence of  $Si_3N_4$ .

**Sachin Malhotra, et al.**, find the influence of different weight percentages of zirconia and constant percentage fly ash reinforced to Al 6061 MMC's by stir casting. The tensile strength and hardness of the composite are increased with increasing of reinforcement weight percentage. At 10% of zirconia and 10% fly ash the get better hardness 94 HV and tensile strength 278 MPa. The elongation of base material Al 6061 is significantly reduced to a range of 85% to 90% due to the reinforcement addition.

### IV. CONCLUSION

All the researchers who did their research on MMC's are mostly used processes is stir casting. This process involves the heating of base material to its melting temperature in a electric furnace. It melts on crucible which is chemically non react to the melted material. At present there are some kind of crucibles are used in our surroundings. On these crucibles we basically mostly used type is coke fired type. The reinforcements are preheated for the purpose of avoiding the thermal mis-match. Various weight percentages of reinforcements are mixed in base material in two or three steps. Stirring can be carried in above the liquids state. To avoid defects in the fabricated cast specimen, an inert atmosphere must be maintained during the mixing of base material and reinforcement, and in the process of pouring of melt into a mold. Due to vortex creation some gasses are generated, to avoid these extra gasses and porosity we must add the heat flux agent. Due to this heat flux there is an increasing of wettability of reinforcement on matrix material. The microstructure of the composite has a uniform distribution of reinforcement in the base material.

From the literature, it may be concluded that the method, procedure which is adopted to produce the MMC's, reinforcement temperature, degassing, the stirrer speed and the stirrer time and mold preheated temperature and poring temperature off the molten material, and finally the distribution of reinforcement and base material etc...all have an important role on the properties of the metal matrix composites.

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