A Review on Fabrication and Characteristics of Metal Matrix Composites Fabricated By Stir Casting

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Abstract: Need of new materials is always important in industries, better mechanical properties and lower in cost are the main parameters which attracts everyone to develop a new material. This need arises in the form of composite materials. This paper reviews about the composites, their existence, fabrication by stir casting and the characterization of metal matrix composites. Different fabrication techniques were mentioned which can be used for the manufacturing of metal matrix composites but specially focused on stir casting. Uses of stir caste in the various researches are shown in this paper and which gives us better idea to understand various parameters for stir caste like stirrer speed, melting temperature, spindle speed and percentage of reinforcement. Characterization of a metal is always important to describe its properties and which is described with different testing. It explains the revised property of metal matrix composites and that shows it is far better than the parent metal.

Keywords: Composites, Metal Matrix Composites, Stir Casting

1. Introduction:
Composites are the results of our requirements for new materials which should be light in weight, lower in cost and higher in strength. It is very important for new age industries and automobile sectors where we need best. For fabrication of composites any method can be used but stir casting is very famous in the researchers due to its simplification and better results. Stir casting process gives the fabrication of composites by using mechanical stirring. In this process mixing of reinforcement materials in the parent material is completed in a crucible which is placed in the furnace. Furnace provides the required temperature for melting the parent material also we use a mechanical stirrer for stirring the melt material, and then we can add the reinforcement in the form of powder or preheated particles. After stirring at required speed and required time which varies according to different materials, we can find out the complete mixing of reinforcement into the molten material. After mixing we can send this melt into the designed mould for casting and after cooling we will find our desired product. Purpose of using stir casting was its simplicity, economical, suitable for net shape component and is applicable for mass production. This process increases the various mechanical properties of base material like tensile strength, hardness and uniform distribution of particles in SEM. C. Kaman and R. Ramanujam [1] found 16% higher ultimate tensile strength and improvement of 81.1 % in Brinell hardness. Mohanavela et al [2] found that flexural strength was increased from 248.20 MPa to 427.43 MPa and reveals the nearly homogenous distribution of reinforced particles. Composite may be defined as a combination of two or more different materials to create a superior and unique materials and the most important benefits of composites are their properties like non-corrosive, non-conductive, flexible, low maintenance, long life and design flexibility.[3] Metal matrix composites are made of a continuous metallic matrix and one or more discontinuous reinforcement phases, they have high strength, high modulus, high toughness and impact properties. Metal Matrix nano composites are the new category of composites in which the reinforcement in the range of nano meter size is being used. Also hybrid metal matrix composites are being used in which we use more than one reinforcement to increase the properties of base materials and due to these increased properties they are widely being used in aircraft and space industries.
2. Fabrication Methods:
The fabrication of metal-matrix composite can involve metals in the solid, liquid, or vapor state. However, a semisolid method that involves the coexistence of solid and liquid forms of the metal is also possible. Following are few methods of fabrication which used by various researchers:

2.1 Stir Casting
In this process, the reinforcing phases that are usually in powder form are distributed into molten aluminum by mechanical stirring. Before doing mechanical stirring, the surfaces of both must be properly cleaned to minimize the reaction between these two. Introducing reinforcement particles to the stirred molten matrix sometimes will entrap not only the particles but also other impurities such as metal oxide and slag, which is formed on the surface of the melt [41]. During pouring, air envelopes may form between particles, which can alter the interface properties between particles and the melt, and also retarding the wettability between them. A major concern that is associated with the stir casting process is the segregation of reinforcing particles which is caused by the settling or surfacing of reinforcement particles during melting and casting process. To prevent settling of particles a motor driven agitator is used.[37-39]

This method suffers from the difference in density between the liquid metal and the reinforcement and the consequent tendency for the reinforcement to sink or float, thus resulting in nonuniform distribution of the reinforcement in the solidified composite. To overcome this problem, compocasting is necessary. Compocasting (rheocasting) involves vigorously agitating a semisolid alloy so that the primary phase is nondendritic, thereby giving a fiber–alloy slurry with thixotropic properties.[5]

![Figure 1. Stir Casting Setup](image)

3. Review on Stir Casting:
C. Kannnan and R. Ramanujam[1] used stir casting setup for their experiment with squeeze casting as per fig 2. They told that it was very useful for even distribution of reinforcement particles. They used 30-50 nm Al₂O₃ and micron sized (5-10 µm) SiC particles for their investigation. Another important parameter was preheating temperature and they used 400°C, 500°C and 600°C for their investigation and also stirred speed was considered and fixed for 600 rpm which was continued for 4 minutes and it was sufficient for their work.
Mohanvel et al. [2] used 60 to 70 microns Al₂O₃/Gr for reinforcement with preheating on 400°C and 300°C at a speed of 400 rpm continued for 1800 sec. their experimental setup is shown in fig 3.

Bhaskar Chandra et al. [3] focused on various process parameters for stir casting like stirring speed, stirring time, holding time, pouring temperature and the size and position of impeller. They told that by controlling these parameters we can improve porosity and wettability in cast metal matrix composites. Reddy et al. [5] described the stir casting as a liquid state process of composite
materials fabrication, in which the reinforcement particles mixed with a molten metal matrix using mechanical stirring. S Rajesh et al. [6] used stirring for about 4 minutes at 200 rpm by a two stage stirrer after addition of reinforcement using planetary mill at 300 rpm for 2 hours. S Tahamtan et al. [7] used a graphite impeller to stir the molten metal, while prepared powders were added to the uniformly formed cortex. They added particles uniformly over a time period of 15-30 min. after completion of particle feeding, mixing was continued for extra 5 min. after completion of addition the mixture was reheated to 750°C and molten composite was poured into the pre-heated mould. Dinesh kumar koli et al. [8] used stir casting setup with ultrasonic vibrator. They used stirring for 10-15 minutes with mechanical stirrer for homogenous addition of reinforcement, after that again a stirring of melt was conducted for 2-3 minutes with the help of an ultrasonic vibrator. S. A. Sajjadi et al. [10] used different stirring speed of 200, 300 and 450 rpm. Also they used stirring for 10 minutes before addition of reinforcement and 10 minutes after addition of reinforcement. Also they used an inert atmosphere for heat treatment of reinforcement at 1100°C for 20 min. H. R. Ezatpour et al. [11] perform their experiment using stir casting for mixing of reinforcement, they used injection temperature as 750°C and the injection was 7-15 min, pouring temperature was 650°C and the impeller speed was selected as 200, 300 and 500 rpm. J. Jebeen et al. [12] worked on the tensile strength of AA6061/TiC based on process parameters like stirring speed, stirring time, blade angle and casting temperature. X. J. Wang et al. [13] used ultrasonic assisted stir casting for their work, they used semi-solid mixture for stirring and at the same time they inserted the preheated SiC particles into the melt. After stirring melt was heated up to 700°C and then ultrasonic probe was imposed to the melt. After ultrasonic treatment, again the melt was stirred in the liquid condition. Cesar A. Isaza Merino et al. [14] designed and applied two step process for synthesis of MMCs. First Multi wall carbon nanotubes were dispersed in polyvinyl alcohol and the polymeric composite was dispersed by magnetic stirring for 1 hr at an average speed of 900 rpm, followed by a Sonication in a vibra cell series, which was set to a power of 100 W and amplitude of the probe of 20%. Raza Rahmany-Gorji et al. [15] carried out the melting and alloying in a steel crucible under a protective atmosphere of argon gas at 800°C using an electrical resistance furnace. After adding Al₂O₃, the melt was stirred mechanically for 5 minutes using a graphite impeller at 400 rpm to achieve complete mixing. A. Dehghan Hamedan and H. Shahmiri [16] discussed about the modified stir casting and the parameters selected were stirring temperature and stirring rate. To obtain optimum stirring temperature the allo melt was stirred at 650°C, 700°C, 750°C and 800°C. for optimum stirring rate, the melt was stirred at 450 rpm, 700 rpm and 950 rpm. L.Poovazhagan et al. [17] used an ultrasonic assisted cavitation assisted casting setup for manufacturing of composite. They used mechanical stirred at 600 rpm for 2 minutes for a preheated melt at 700°C to obtain a homogeneous mixture of alloy and then reinforcement particle added into the molten metal. After adding reinforcement particle stirring was continued for 15 minutes, when it completed the stirrer was removed and ultrasonic probe was dipped in the molten material at 30mm depth and ultrasonic waves generated which was carried out about 30 minutes. J Hashim et al. [26] found stir casting a very cost effective and possible to obtain a composite with a broad range of mechanical properties. Ulhas K and G. B. Veereesh[30] reviewed about stir casting of aluminum metal matrix composites and found that method of melting base metal, at what temperature and state it to be maintained, conditions in which particulates added and the effect of stirring time and stirring speed on final composite material.

4. Testing

Two categories of tests are significant for this research project, among them one is the properties testing such as mechanical properties, physical properties and thermal properties. Next is the metallographic analysis with the aid of a metallurgical microscope to study the particulate distribution uniformity and hence to characterize the phases present in the processed composites.

4.1 Tensile Test
B. Ravi et al. [21] observed that tensile strength is increased by increasing the percentage of reinforcement particles in the composite and it happens due to better interfacial bonding between the matrix and reinforcement. They found enhanced tensile strength of Al metal matrix from 117 MPa to 145 MPa. Aluminium matrix reinforcement with titanium carbide has good potential. S. Gopalakrishnan and N. Murugan[24] find out the increased specific strength with higher % of titanium carbide. H. R. Ezatpour et al. [11] found that in the extruded composite the yield and ultimate tensile strength of the composite increases with Al$_2$O$_3$ content increasing because of increase in load stress. S. K. Pradhan et al. [28] conclude that developed composite by stir casting contains higher hardness and greater tensile strength without much loss of ductility.

4.2 Hardness Test

B. Ravi et al. [21] find out that the hardness value is increased by increasing the wt% of reinforcement particle in the composite and they found the increased microhardness from 62 HV to 68 HV with incremental weight percentages. S. B. Prabhu et al. [25] found from hardness test that the speed and time influence the hardness of the composite. Higher stirring speed and higher stirring time gives better hardness composite and they found it for 600 rpm and 10 min stirring time. H. R. Ezatpour et al. [11] explains that hardness of the composite increases with increasing the particle mass fraction. They also find out that stirring speed at 300 rpm was beneficial for higher harness and also defined that increase in hardness with extrusion can be explained by improving microstructural densification.

4.3 Impact Test

Impact strength of particulate composites can be determined for every type of particulate reinforcement by conducting the impact testing on the standard impact samples, at least three numbers.

4.4 Metallography (optical metallurgical microscopy)

Metallurgical microscope is employed to study the microstructures of the test samples at different magnifications made from the processed composites lab castings. It explains the microstructure of alloy and the composite by which we can easily understand the difference between particles and then it becomes easy to find out about the mechanical properties like density and porosity.

4.5 Scanning Electron Microscopy

Scanning Electron Microscopy (SEM) is an important tool to characterize a wide range of materials from pure metals to advanced materials like composites, nanostructured materials, and superalloys and soon.[29] The unique advantage of this technique is that the interior details of the processed materials like the crystallographic structures, dislocation of the planes, intermetallic phases and precipitates, microstructures and defective locations can be identified very easily at higher magnifications and resolution. H. R. Ezatpour [23] shows SEM micrograph in fig. 4 after extrusion, it shows presence of iron-rich phase at the grain boundaries while hot deformation causes to change morphology of these phases of dendrite to non-dendrite form.
Figure 4. The optical and SEM images in extruded condition of: (a) 6061 alloy with recrystallized grains and nanocomposites with (b) 0.5, (c) 1 and (d) 1.5 wt.% Al₂O₃, (e and f) showing Fe₃SiAl₁₂ phases (non-dendrite interstices) and porosity at grain boundaries.[23]

4.6 Density Measurement
The density of a material is defined as its mass per unit volume. H. R. Ezatpour et al.[23] measured the experimental density of the composite by Archimedean method of weighing small pieces cut from the composite cylinder first in the air and then in the water.

4.7 Thermal Properties
Thermal diffusivity of composite materials is measured using photo flash method. The photo flash detection system consists of a light source, sample holder, thermocouple, low noise preamplifier, oscilloscope, photodiode and a personal computer. The temperature rise at the back surface of the sample is detected by the thermocouple.[29] In the photo flash system, the excitation source consists of a high intensity camera flash. The thermal diffusivity values can be obtained for different thicknesses of the test samples. The thermal diffusivity, $\alpha$ determines the speed of propagation of heat waves by conduction during changes of temperature with time.

5. Conclusion:
After the study about the composites we conclude that various fabrication methods can be used for the manufacturing of composites and they vary form metal to metal and physical state of alloy. Stir casting method was found very economical and beneficial for the manufacturing of composites as various researchers used this method for their work and it can be also modified with
ultrasonic assisted that gives us better mixing of reinforcement in the melt. Stirring speed and stirring time were important parameters which affect the composition of composite. On these parameters the mechanical properties of composite depends and by using them at an optimum rate we can improve various mechanical properties like tensile strength, hardness, density and microstructure of the composite.

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