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Fabrication of Nano Hybrid Metal Matrix Composites through Stir Casting Route: A Review

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Abstract. Nanocomposite are the most promising advance multi-phase material, having nano particles in its composition within its structure (size being less than 100 nm) and contain at least one phase with constituents in the Nano-meter size range .The properties of nanocomposites are controlled by the type/size of the reinforcement/ nature of bonding and type of processing method. Among the various processes of manufacturing prevalent for discontinuous nano hybrid metal matrix composites, particularly stir casting is accepted as a favorable method, which is also commercially viable. Stir casting is advantageous for mass production of composites for being simple and flexible in nature along with cost effectiveness. As it is low-cost comparably and also offers wide selection of materials. Further, it produces better bonding of reinforcements with the matrix, due to the uniform stirring action.

Keyword: MMNC, Nano Hybrid Metal Matrix Composites, Stir Casting

1. Introduction

Futuristic Materials viz. nano-metallic hybrid composites are widely applicable in various areas viz. aerospace, defense, automobiles and nano-electro mechanical systems (NMES). Metal matrix nano composites (MMNC) are those materials comprising of a ductile metal/ alloy matrix in which few nano sized reinforcement material is embedded. The enhanced mechanical properties of MMNCs such as hardness, corrosion, density, porosity and tensile strength are analyzed by different standardized procedures, so as to align the MMNCs with different applications. MMNCs is a combination of metal and ceramic properties, i.e., ductility and toughness along with high strength to weight ratio and modulus. Thus, metal matrix nano composites are viable for producing materials having high strength both in shear and compression processes, along with cryogenic and high service temperature proficiencies. [1]



Solid phase process such as powder metallurgy, diffusion bonding, are expensive because it needs expensive starting materials such as powder or foil matrix etc. Liquid phase process (casting process) is generally less expensive than solid phase process. In the casting process, high temperature melt is used. Metal matrix nano composites (MMNCs) are synthesized using various techniques. These techniques are classified as (a) liquid-state processes: stir casting, (b) solid state processes: powder metallurgy (PM) techniques and Friction Stir Processing and (c) liquid-solid processing: Compo casting and spray forming.[2]

1.1 Powder Metallurgy:

The primitive process of powder metallurgy comprises of three major stages. Firstly, the primary material is grinded into many miniature individual particles. Then, the different powders of metals and /or ceramics are blended in required proportions [3].

1.2 Friction Stir Processing:

In Friction Stir Process, a barrel shaped rotating tool with a concentric pin and shoulder is sunk into the material surface [3].

1.3 Squeeze/Compo Casting:

For attaining desired shape of a product along with the advantages of casting and forging squeeze casting is employed. Squeeze casting employs two dies out of which one is stagnant and other moves for applying pressure [3].

1.4 Spray Forming:

In spray forming process the melt of an alloy is passed forcefully through a small orifice along with a current of inert gas the jet so formed is infused with reinforcement and thus breaking the liquid metal into small semi solid droplets [3].

1.5 Stir Casting:

Stir casting is a primary process of composite production whereby the reinforcement ingredient material is incorporated into the molten metal by stirring. [2] .As shown in figure.1 the schematic of stir casting set-up along with stirrer and mould is depicted.

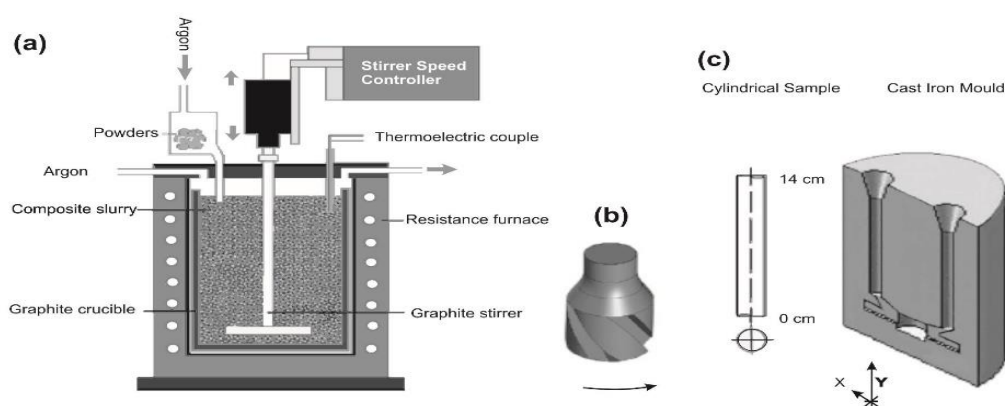


Figure. 1 The schematic of (a) crucible and facilities, (b) graphite stirrer and (c) cast iron mould.[15]

2. Past Work (Review of Research)

Siddhesh.et.al (2017) employed stir casting technique to produce the metal matrix mono composites and nano hybrid composites. Resistance furnace was used for melting Al2219 at 750 0C in graphite crucible. Reinforcements of n-B4C, n- B4C /MoS2 particles were added to the vortex formed in the melt after preheating. [4]

Samuel.et.al (2017) used stir casting apparatus for producing the composite of aluminum alloy AA5083 and MWCNT through compo-casting. Nitrogen was used for degassing of liquid melt which aided the reduction of oxide formation. [5]

AathiSugan.et.al (2017) fabricated the composite with Magnesium AZ91D alloy as matrix and B₄ C and graphite particulates as reinforcements. Pure magnesium solids and other metals of Mg AZ91D were added to the furnace when the temperature reached at 800° C. After proper mixing the melt was poured into preheated dies. [6]. Fatiel.et.al (2017) used ZA-27 alloy and ZnO particles as a reinforcement for the composites.ZA-27 alloy was heated at 600° C and 5 g of magnesium was added to improve wettability of the composite. The matrix was cooled at semi solid state and then nano particles was added by constant stirring. C₂ Cl₆ was used for degassing as it reduces porosity and removes entrapped air. [7]

Moses.et.al (2016) investigated the optimum range of criterion involved namely speed of stirrer, duration of stirring, angle of tilt of blade and casting parameters giving highest UTS for the composite of AA6061 as matrix and TiC as reinforcements in stir casting method. [8]. Riteshraj.et.al (2016) used the modified stir casting equipment which incorporated automatic bottom pouring arrangement which drastically reduced the difficulties associated with melt pouring and avoided the oxide inclusions in the final casting formed at the melt surface, thereby reducing the percentage of porosity in the cast sample. [9].Sameer.et.al (2016) prepared the composite in a mild steel crucible kept in a resistance furnace. The preheated Al₂ O₃ particulates wrapped in an aluminum foil was submerged beneath the melt. Afterwards the mixture was stirred with a rotation speed of 450 rpm. [10].Ezatopour.et.al (2016) developed nano composites with A7075 alloy as matrix and nano- Al₂ O₃ particles. Aluminum matrix nano composites were produced by combinational stir-casting process, aluminum (mm) and alumina (nm) powders was mixed and injected into the molten aluminum by argon gas during mechanical stirring as shown in figure. 2. [11]. Rashad.et.al (2016) fabricated the composite by stir-casting method. GNPs were added as reinforcements and AZ31 magnesium alloy as matrix metal. AZ31-GNPs composites was subjected to tensile testing to assess high temperature formability of composite. It was evolved that like CNTs, GNPs also have the capability to sustain tensile strength at elevated temperatures. [12]. Mouzavian.et.al (2016) exercised hot extrusion process for producing stir cast aluminum matrix–SiC composites with a view to enhance their microstructure and reduce cast part defects. [13]

Tiruvnkadam.et.al (2015) aimed to replace the conventional cast iron cylinder liner (CL) in diesel engine by introducing lightweight aluminum Al 6061 nano hybrid composite cylinder liner (NL)[14]. Karbalei.et.al (2015) investigated the tensile performance and fracture behavior of aluminum matrix composites reinforced with TiB₂ nano and micro particles. The composite was prepared with stir casting technique. Significant improvements in tensile strength (43%) and elongation (27%) were attained in the Ti B₂ nanocomposite. [15]

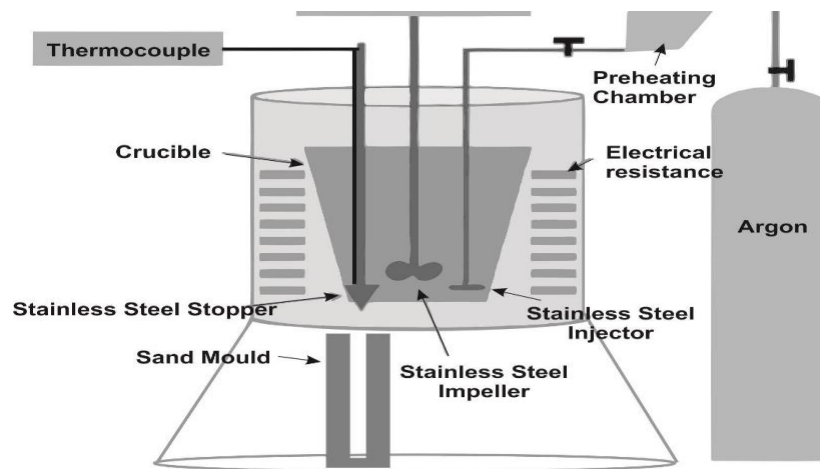


Fig.2 Schematic line Diagram of Stir Casting [11]

Bharath.et.al (2014) synthesized metal matrix composite using 6061Al as matrix material reinforced with ceramic Al_2O_3 particulates using stir casting technique [16]. Ramnath.et.al (2014) fabricated metal matrix composite with aluminium alloy, alumina (Al_2O_3) and boron carbide by stir casting which involved the mixing of the required quantities of additives into stirred molten aluminium [17]. Hossein.et.al (2014) manufactured Al–nano MgO composites using A356 aluminum alloy and MgO nanoparticles via stir casting. Introduction of MgO nanoparticles to the Al matrix caused increasing of the hardness values. [18]. Padmavati.et.al (2014) investigated the friction behavior of Al6061 with various percentage volumes of Multiwall carbon nanotube and Silicon Carbide reinforcement through stir casting method. Under mild wear conditions, the composite exhibited lower wear rate and friction coefficient in contrast to Aluminium. [19]. Rajeshkumar.et.al (2014) manufactured composite material by reinforcement of SiC, Al_2O_3 , and graphite particles into the matrix of Al alloy. Addition of reinforcement enhanced the mechanical, metallurgical and tribological properties of composite produced as compared to the original alloy of aluminum. [20]. Hariprasad.et.al (2014) explored the wear behavior of Al 5083 composites manufactured by stirring technique reinforced with Al_2O_3 and B_4C . The exploration of wear resistance inferred that with the increase of weight percentage of reinforcements wear resistance increased along with light adhesive wear of the samples. [21]. Shashiprakash.et.al (2014) investigated A356/SiC metal matrix composite made-up by electromagnetic stir casting. It was inferred that type of fabrication process and percentage of reinforcement are the effectual factor influencing the mechanical properties. [22]. Suresh.et.al (2014) reinforced Al6061 with various percentages of TiB_2 particles by using high energy stir casting method. The tensile and ultimate strength of the Al6061 increased with increase in the amount of TiB_2 . Wear resistance and coefficient of friction of Al6061 alloy by the addition of TiB_2 decreased with increased TiB_2 . [23]

Mazahery.et.al (2013) investigated, the effect of the volume fraction of the nano-SiC particles on the mechanical properties of the Al–Si matrix composites fabricated by stir casting technique. The yield strength and tensile strength increased, but the elongation decreased with the increase in the volume fraction of the SiC particles. [24]. Karabaei.et.al (2013) used a novel approach to fabricate Al_2O_3 nanoparticle reinforced aluminum composites. To avoid agglomeration of nanoparticles in matrix. Al_2O_3 nanoparticles were separately milled and were incorporated into A356 alloy via stir casting method [25]. Tahamtan.et.al (2013) fabricated $\text{Al}_{20}\text{O}_6 / \text{Al}_2\text{O}_3$ p cast composites by the injection of reinforcing particles into molten Al alloy in two different forms i.e. as Al_2O_3 particles and milled particulates of alumina in the process of stir casting [26]. Umanath.et.al (2013) investigated the wear behavior of Al6061-T6 discontinuously reinforced with silicon carbide (SiC) and aluminium oxide (Al_2O_3)

composite. The results revealed that the wear resistance of the 15% hybrid composite is superior than that of the 5% composite. [27]

3. Conclusion

The stir casting method generally involves the heating of the matrix material to a melting temperature in a crucible which is chemically inert to the materials that are going to be charged into it. The particulates are preheated in order to improve its mixing with the matrix material also to avoid thermal mismatch. The melt may or may not be stirred prior to mixing the particulates. The mixing of the particulates can be two-step or three-step which is a variation depending on the weight percentages of the reinforcement. The mixing can be in semi-solid state or above liquidus state. An inert atmosphere may be maintained during stirring and pouring the melt into the mold in order to avoid defects in the cast product.

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