Review Article

Influence of reinforced particles on the Mechanical properties of Aluminium Based Metal Matrix Composite – A Review

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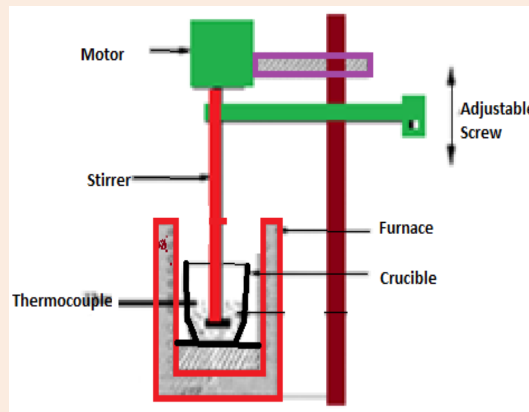
Abstract

Aluminium based metal matrix nanocomposite are being used for a variety of applications such as military, aerospace, electrical industries and automotive purposes owing to their improved properties such as high strength to weight ratio, good ductility, high strength and high modulus, excellent wear and corrosion resistance. There are wide variety of processes for processing the AMMC's, in this context only stir casting processes is considered, as it is found to be economical for manufacturing large components. Stir casting is the method used for large scale production due to its flexibility and simplicity. This paper presents the influence of various reinforced particles and process parameters on the properties of aluminum based metal matrix composite through stir casting process.

Keywords: stir casting, composite, Aluminium metal matrix composite, Nano particles, mechanical properties



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Introduction

Metal matrix composite is refers to a composite consist of metal or alloy, combined with metal or non-metallic reinforcement. Metal matrix composite is reinforced with nano particles refered as a metal matrix nano composite. The various reinforced materials used as nanocomposite are alumina, illmenite, Sic, etc. aluminium is widely used a matrix material due its high wear resistance, corrosion resistance and high strength to weight ratio.

Addition of high modulus and high strength refractory particle to the low ductile matrix produces composite whose properties are in between matrix and reinforcement. In this properties are improved by controlling the processing conditions, distribution of reinforcement and relative amount. Manufacturing of aluminum metal matrix composites can be broadly categorized into two groups one is liquid state process which includes squeeze casting, ultrasonic assisted casting, compo casting and stir casting, the other category is solid state process, which includes friction stir process, vapour deposition technique, powder blending followed by consolidation (PM processing) and diffusion bonding.

Implications of reinforced particles on aluminium metal matrix

S.A. Sajjadi et al [17] investigated the physical and mechanical properties of Aluminium matrix composites (AMCs) reinforced with micro and nano-sized Al_2O_3 particles. Authors also analysed the influence of various processing parameters such as heat treatment of particles, stirring speed, reinforcement particle size, and weight percentage of reinforcement particle size on microstructure and mechanical properties of the AMCs. Al_2O_3 particles with two different sizes of 20 μm and 50 nm were chosen as the reinforcement particles. Al_2O_3 particles are heat treated at

1100^0C for 20 min in an inert atmosphere, injected by inert argon gas and aluminium melt is rotated at different speeds of 200, 300 and 450 rpm. It was observed that the amount of hardness and porosity of composite samples increased with increasing the weight percentage of Al_2O_3 particles and decreasing the particle size and compressive strength increases with increasing Al_2O_3 percentage. Compressive strength is more in nano composites compared to micro composites.

M. Karbalaei Akbari et.al [6] Fabricated nanometric alumina particle – reinforced A356 composites. The nano alumina particles, which was separately milled using planetary ball mill having ball to powder ratio 20:1 for 24 hours, were wrapped in aluminium foils and added into molten aluminium. It was followed by stirring at a constant speed of 450 rpm at durations of 4, 8, 12 and 16 min at a casting temperature of 850^0c. The composite slurry was poured into cast iron mold. The cast specimens were heat treated to the following schedule i.e., 8hours at 495^0c, followed by 2 H at 520^0c, followed by water quenching (40^0c) and artificially aged for 8h at 180^0C. The hardness and tensile properties were improved by addition of Nano-alumina particles. The maximum hardness was achieved at 4 min of stirring time. By means of increasing the stirring time, there will be a reduction in the tensile performance of composite.

Hossein Abdizadeh et.al [1] fabricated and investigated the mechanical properties of nanoMgo reinforced Al composites by stir casting and powder metallurgy methods. Mgo nano particles of 1.5, 2.5 and 5 vol% have been taken. Processing temperature of 800, 850 and 950^0c for stir casting and 575, 600 and 625 ^{0}c for powder metallurgy have been considered. Al-Mgo nano composite exhibited high hardness values for 5 vol % of Mgo. Better mechanical properties were observed at 625 and 850^0c for powder metallurgy and stir casting respectively. Better Homogeneous distribution and mechanical properties were observed for stir casting compared to powder metallurgy.

A. AnsaryYar et.al [19] fabricated Aluminium alloy matrix composite reinforced with nano-particle Mgo through stir casting method. Aluminium alloy (A356.1) matrix composites reinforced with 1.5, 2.5, and 5 vol% nano particles of Mgo. Composite was fabricated at 800, 850 and 950^0C. Mechanical properties like hardness and compressive strength increased at 1.5 vol% Mgo fabricated at 850^0C.

L. Rasidhar et.al [5] fabricated ilmenite ($FeTio_3$) based Aluminium based nano composite. Illmenite nanoparticles having 1 to 5 weight percentage were added to Al (99.7) Matrix. Stirring speed of melt is 650 to 700 rpm for 10-15 min. The temperature was maintained at 850^0c throughout stirring. In order to minimize the oxidation to the molten aluminium, argon gas is supplied to the crucible. Tensile and hardness values increased with increase in reinforcement. Tensile and hardness values were maximum at 5 wt % of illmenite reinforcement.

Karbalaei Akbari et.al [4] have evaluated hardness,wear resistance and compressive strength of nano-sized Al_2O_3 reinforced A356 alloy matrix. Milling of nano Al_2O_3 and Al and Cu powders is performed and they are incorporated into A356 alloy via vortex method. The change in hardness, wear resistance and compressive strength is observed. Powders of nano Al_2O_3 and Al and Cu are mixed in appropriate ratios of Al/Al_2O_3=1 and Cu/Al_2O_3=1. Milling of these mixed powders was performed in a planetary mill for 4h in, wet situation. The mixed powders were then wrapped in aluminium foils and added into molten A356 alloy which is kept in a resistance furnace and stirring is performed. Stirring process is done at a constant rate of 450 r.p.m for 4,8,12 and 16 min at 850^oC. The composite slurry obtained was then poured into Cast iron mold to obtain A356/1.5 vol.% nano Al_2O_3 composites. Agglomerated particles were observed in its microstructure. Porosity level increased with an addition of nano Al_2O_3 particles and increase in stirring time. Addition of nanoparticles also increased hardness, compressive strength and wear resistance.

Hamid Reza Ezatpour et.al [2] have investigated the microstructure and mechanical properties of Al6061-nanocomposite fabricated by stir casting. Nano sized Al_2O_3 particles are used as the reinforcement material. After fabrication by stir casting, the nanocomposites were extruded at 550^oC. Extrusion is used as secondary processing so as to eliminate agglomeration of particles and reduction or elimination of porosity and improves bonding. Using a planetary ball milling machine having a ball to powder weight ratio as 8:1 and steel balls of 8-10mm diameter, milling was performed. Milled nano Al_2O_3/Al composite powder was injected into the Al6061 melt by argon gas and stirred to produce homogeneous mixture. Bar extrusion was performed using a hydraulic press. Prior to extrusion, solution heat treatment was performed at the bars at 550°C for 2h followed by quenching in water. Then age hardening heat treatment was carried out with solution time and age hardening times of 2h and 3h respectively. A fine grain microstructure with high porosity was observed and porosity volume percent increased with increasing alumina weight fraction. A decrease in porosity and homogeneous dispersion of nano-alumina particles was observed after extrusion which in turn increased strength and ductility.

Rajesh Kumar Bhushan et.al [7] fabricated and investigated the behavior of 7075 Al alloy which is reinforced with Sic particles of 10 and 15 weight % and of size 20-40 μm by stir casting process. Microstructure of 7075 Al alloy, AA7075–10 wt. % SiC particles (20–40 μm) and AA7075–15 wt. % Sic particles (20–40 μm) composites are found. There are no unfavorable chemical reactions; hence, these composites are suitable for automobile, aircraft, and space applications

H. Abdizadeh et.al [8] investigated the influence of ZrO_2 content and casting temperature on the mechanical properties and fracture behavior of A356 Al/ZrO_2 composites. A356 aluminium alloy composite reinforced with 5,10and 15 vol % ZrO_2 were fabricated at 750, 850 and 950^{0}C temperature through the stir casting method. Reinforcing the ZrO_2 in aluminium matrix alloy increases the hardness and ultimate tensile strength. The best mechanical properties were achieved for the specimen prepared at 750^{0}C with 15 vol.% of ZrO_2.

Sourav Kayal et.al [18] has observed the solidification behavior of stir cast Al alloy metal matrix composite. Authors have fabricated Aluminium alloy (LM-6)- SiCp composite. Experiments were carried out over a range of particle weight percentages of 2.5%, 5% 7.5%, 10%, 12.5%, 15%, and it was observed that cooling rate decreases with increase in the SiC content. Hardness increases with increase of the fraction of SiCp. SEM images show that uniform distribution of SiC particles in the composite casting.

Himanshu Kala et.al [3] reviewed on the tribological and mechanical behavior of stir cast aluminium matrix composites. With the addition alumina to the aluminium there was an increase in its mechanical and tribological behavior. Organic reinforcement like fly ash, coconut ash improved tensile and yield strength.

Abhishek Kumar et.al [9] fabricated A359/Al_2O_3 metal matrix composite and investigated the influence of Al_2O_3 as cast MMCs. Authors proposed a new method called electromagnetic stir casting which is modified stir casting method. Aluminum alloy A359 has been reinforced with 2 wt. %, 4 wt.%, 6wt.%, 8 wt.% of Al_2O_3 having an of average 30μm size. Hardness of Cast composite increases linearly with an increase in weight fraction of Al_2O_3. A microstructure observation shows that electromagnetic stirring action produces cast MMCs with smaller grain size.
Madeva Nagaral et.al [10] investigated the mechanical behavior of Al6061, reinforced with 6 wt% of Al_2O_3 and graphite is added from 2, 4 and 6 wt % into the base matrix. Mechanical properties like hardness and tensile strength of MMC were found to increase with the addition of Al_2O_3 particles but Micro-Vickers hardness of the Al6061-6wt% Al_2O_3 were found to be decreasing with the increase of graphite content and the influence of graphite content on tensile strength is very less.

Lakhvir Singh et.al [11] prepared a composite containing 3, 6, 9 wt % of Al_2O_3 reinforced in pure aluminium and observed the influence of particle size, weight percentage and stirring time on mechanical properties. All the mechanical properties increased with an increase in weight percentage, stirring time and decrease in particle size of the reinforcement.

Manoj Singla et.al [20] developed aluminium based silicon carbide particulate metal matrix composite. Aluminium (98.41% C.P) and SiC (320-grit) chosen for the study. Reinforcement of SiC weight fraction was 5%, 10%, 15%, 20%, 25%, and 30%, by keeping all other parameters constant. Authors observed that uniform dispersion of SiC particles in the aluminium matrix through the two step stir casting method, maximum hardness and maximum impact strength obtained at 25% weight fraction of 320 grit size SiC particles.

G. G. Sozhamannan et.al [15] observed the influence of processing temperature and stirring time on Al-11Si-Mg alloy reinforced with 10% of SiCp of size 40 μm. Specimens were prepared at 700^0c, 750^0c, 800^0c, 850^0c and 900^0C. The specimens prepared at 850°C and 900°C having pores and particles clustering were observed and it was found that viscosity of Al matrix decreases with increasing processing temperatures. Tension test revealed that ultimate strength increased gradually up to 800°C and then decreased gradually.

Ajay Singh et.al [12] focused on the behavior of aluminium cast alloy (6063) with alumina. They conducted various tests like impact, hardness and tensile test and it was observed that with the increase of alumina weight percentage increases brittleness and the ultimate tensile strength, yield strength increased with the addition of alumina weight percentage in the matrix.

Haisu et.al [16] fabricated nano sized ceramic particle reinforced aluminium matrix composites. In Al 2024 – Alumina nanocomposites prepared by solid-liquid mixed casting combined with ultrasonic treatment, first the matrix was superheated at 750^oc and held for 15 min and the powdered Al/Alumina particles were added to the melt and stirred. Then an ultrasonic probe was dipped in the melt and sonicated for 5 min. Solid-Liquid casting method decreased the agglomeration of alumina nano particles whereas ultrasonic treatment improved the distribution of alumina nano particles and refined the grain structure. There was an increase in the ultimate tensile strength and yield strength of the nanocomposite.

Manjunath C. Melgi and Dr. G. K. Purohit et.al [13] studied the microstructure and mechanical behaviuor of aluminium silicon carbide metal matrix composite. Authors observed that tensile property increases with increase in SiC, the toughness of composite decreases as silicon carbide percentage increases. Microstructure showed that silicon carbide particles are uniformly distributed throughout the MMC casting.

Shubham Mathur et al [14] studied the effect of process parameters on aluminum based silicon carbide particulate metal matrix composite through stir casting process. Authors found that there is an improvement in harndess, tensile and impact strength of the composite with increase in the grit size of SiC.

Factors affecting the composite fabrication by stir casting

Factors affecting the preparation of Aluminium based metal matrix composite are Uniform distribution of reinforcement materials, Wettability between the two main substances, Porosity in the cast metal matrix nanocomposite and Chemical reactions between the cast metal matrix alloy and reinforcement particles.

Uniform distribution of reinforcement materials

This problem arises due to the density differences between reinforcement particles and matrix alloy melt. Factors such as type of stirrerused, melt temperature, type amount and nature of particles etc. It can be solved by proper design of the stirrer, control of stirring speed and bottom pouring of the mold.

Wettability between matrix metal and reinforcement alloy

It can be defined as the ability of a liquid to spread on a solid surface. Some of the reasons that contribute to low wettability are increase in surface area as the size of particles decreases, increasing tendency for agglomeration of particles, surface energy etc. Methods to improve Wettability are coating of particles, addition of alloying elements to the molten matrix alloy, treatment of particles and ultrasonic irradiation of the melt.

Porosity in cast metal matrix nanocomposites

Porosity levels should be kept to minimum as this kind of a composite defect can be detrimental to the corrosion resistance of the casting and it can control mechanical properties of the cast metal. it arises due to Gas entrapment during mixing, Hydrogen evolution and Shrinkage. Strategies to minimize porosity are Compocasting in vacuum, Extensive inert gas bubbling through the melt, Casting under pressure, Compressing and extruding and Rolling of materials after casting to close the pores

Chemical reactions between the cast metal matrix alloy and reinforcement particles

It contributes to the poor quality of cast AMC. Preheating of both matrix and reinforcement before mechanical stirring can solve the problem. The surface of both must be properly cleaned in order to minimize the reaction between the two.

Process Parameters

Stirring speed

It is an important parameter because it improves wet ability and Stirring while slurry is solidifying improves incorporation of particles into matrix alloy.

Stirring temperature

It influences change in viscosity of Al matrix and also accelerates chemical reaction b/w matrix and reinforcement material. The viscosity of liquid decreased with increasing processing temperature with increasing holding time.

Reinforcement preheat temperature

Preheating of reinforcement particles assisted in removing surface impurities, desorption of gases and altering the surface composition.

Stirring time (holding time)

It distributes particles in the matrix and creates perfect interface bond between matrix and reinforcement. Particles are distributed uniformly when holding time is less. During stirring vortex created, it can suck air bubbles into liquid metal. at higher temperature with the more stirring time it is possible form particles clusters in the composite.

Preheated temperature of the mould

In order to improve the mechanical properties of cast composite, it is better to have preheated permanent mould for pouring the slurry which in turn helps to remove the entrapped gases from the mould.

Powder feed rate

Feed rate of powder particles must be uniform otherwise it promotes clustering of particles which in turn causes the porosity and inclusion defect.

Discussions

1. The homogeneity and decreased porosity is achieved in Al6061/Alumina composite at 550^0C. If graphite is added to this composite it results in decreased hardness. The hardness, ultimate strength and yield strength of Al6063/alumina is increased with increase in weight percentage of alumina, also compared to solid – liquid casting, the ultrasonic treatment has given good grain structure strength and yield strength.
2. The casting of AlA356/ alumina followed by stir casting at the rate of 450 rpm has given good hardness, tensile properties, aompressive strength and waer resistance. But there is reduction in tesnsile properties when stirring time exceeds 4 min, AlA356/ZrO_2 of 15 % percentage volume results in good mechanical properties at 750^0C. 15 % vol of nano MgO, AlA356 composite fabricated at 850 ^{0}C is good in hardness and

compressive strength, the homogeneity of nano MgO is more in stir casting compared to powder metallurgy. The smaller grain size of AlA359/ Al_2O_3 casting can be achieved by Electromagnetic stir casting.

3. The hardness of Al/ Al_2O_3 increases with increase in weight percentage of reinforced heated Al_2O_3. The fine size of particles has given improved mechanical properties. The organic reinforcement like coconut ash and fly ash has given good yield and tensile strength.
4. The hardness Aluminium alloy (LM-6) is increased with increase in Silicon carbide. The two step stir casting has given maximum hardness and impact strength of aluminium 90.41/25 % weight of SiC. The visocity of Al-11 Si-Mg reinforced with silicon carbide is incrased upto specimen preparation temperature of 800^0C and then gradually decreased. The Al 7075/SiC composites are suitable for automobile, aircraft and space applications

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