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Research Article

Manufacturing of Particulate Reinforced Aluminum Metal Matrix Composites using Stir Casting Process

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Abstract

Composite material is a combination of two or more materials having compositional variations and depicting properties distinctively different from those of the individual materials of the composite. Aluminum hybrid reinforcement technology is a response to the dynamic ever increasing service requirements of such industries as transportation, aerospace, automobile, marine, etc. Manufacturing of aluminum alloy based casting composite by stir casting is one of the most economical methods of processing MMC. In present work we aim to manufacture composite material by reinforcing Al alloy with Al_2O_3 and fly ash particles. The wettability between all these materials is assured by stir casting process. Aluminium alloy A356 is uses as matrix material and hybrid reinforcement of Al_2O_3 and fly ash which is industrial waste. Reinforcement added in different percentage by weight of matrix material. Casting was made in rectangular permanent metallic mould having dimension 220x220x20mm^3.These rectangular plate castings were used for further mechanical studies.

Keywords: *Aluminium Matrix Composites (AMCs), Stir casting, Particulate Reinforcement, Hybrid Composite.*

1. Introduction

A composite is a material that consists of constituents produced via a physical combination of pre-existing ingredient materials to obtain a new material with unique properties when compared to the monolithic material properties. A composite is a material made with several different constituents intimately bonded. The reinforcement may be in the form of whiskers, particles, plates, rods, etc. The matrix may be metallic, resinous, ceramic or organic. The constituents of a composite do not dissolve or merge completely into each other but act in concert. This yields endless possibilities with infinite combinations, hence making it an 'evergreen' field of study.

Composites are most successful materials used for recent works in the industry. Metal composites possess significantly improved properties including high tensile strength, toughness, hardness, low density and good wear resistance compared to alloys or any other metal. There has been an increasing interest in composites containing low density and low cost reinforcements.

Fabrication techniques affect the microstructure, the distribution of the reinforcing materials and interfacial bond condition between reinforcing phase and matrix. These techniques has to ensure uniform distribution of the reinforcing material in the matrix and formation of good bond between matrix and reinforcing material, to obtain MMCs with optimum properties.

The widespread adoption of particulate metal matrix composites (MMCs) for engineering applications has been hindered by the high cost of producing components of complex shape. Casting technology may be the key to overcoming this problem with stir casting. But the problem arises with stir casting is wettability and porosity. To overcome the problem of porosity a hybrid casting process is needed (Abhishek Kamboj *et al*., 2012).

The addition of Fly ash and Alumina reinforcement particles to the Aluminium matrix improves the tensile strength, compressive strength and hardness behaviour. The reinforcement material is having more factor of safety compare to unreinforced alloy material because of more yield strength due to presence of the reinforcements in the matrix alloy (Prakash Gadade *et al*., 2013). The extent of enhancement of properties of hybrid composites is strongly dependent on the nature of the reinforcement, its hardness, particle size, volume fraction, and uniformity of dispersion within the matrix and the method of hybrid production (S. O. Adeosun *et al*., 2014).

The ultimate tensile strength (UTS), compressive strength and hardness increase up to 27%, 17% and 4% respectively with reinforcement percentage up to 12% by weight of matrix material and then decreases gradually(Amol Mali *et al*., 2015).

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Table 1 comparative analysis of different techniques of fabrication of DRMMC

Method	Range of shape & size	Metal Yield	Range of volume fraction	Damage to Reinforcement	Cost
Stir Casting	Not limited by size	Medium	0.4 to 0.7	Little damage	Least Expensive
Squeeze casting	Limited By preform shape Up to 2cm height	Low	Up to 0.45	Severe damage	Moderately Expensive
Powder metallurgy	Wide range, restricted size	High	-	Reinforcement fracture	Expensive
Spray casting	Limited shape, large size	Medium	0.3 to 0.7	-	Expensive

2. Manufacturing of Aluminium Matrix Composites (AMC)

Manufacturing techniques affect the microstructure, the distribution of the reinforcing materials and interfacial bond condition between reinforcing phase and matrix. These techniques has to ensure uniform distribution of the reinforcing material in the matrix and formation of good bond between matrix and reinforcing material, to obtain MMCs with optimum properties (J. Hashim *et al*., 1999).

There are several fabrication techniques available to manufacture different MMC. Depending on the choice of matrix and reinforcement material, the fabrication techniques can vary considerably. Fabrication methods can be divided into three types. These are solid phase process, liquid phase process and semi-solid fabrication process. Among the variety of manufacturing processes available for discontinuous metal matrix composite, stir casting is generally accepted as a particularly promising route, because of low cost. Its advantages lie in its simplicity, flexibility and applicability to the large quantity production. This semi solid metallurgy technique is the most economical of all available routes for MMC production. It allows very large sized components to be fabricated, and is able to sustain high productivity rates. The cost of preparing composite materials using a casting method is about one third to one half that of competing methods (Naher *et al*., 2004). A comparative study of different techniques for discontinuously reinforced metal matrix composites (DRMMC) production is given in Table 1 (Pardeep Sharma *et al*., 2008).

In general, the solidification synthesis of metal matrix composites involves producing a melt of the selected matrix material followed by the introduction of a reinforcement material into the melt, obtaining a suitable dispersion. The next step is the solidification of the melt containing suspended dispersoids under selected conditions to obtain the desired distribution of the dispersed phase in the cast matrix (Pardeep Sharma *et al*., 2008).

3. Experimental Work on Stir Casting

3.1 Stir Casting

In preparing metal matrix composites by the stir casting method, there are several factors that need considerable attention, including

1. The difficulty of achieving a uniform distribution of the reinforcement material;
2. Wettability between the two main substances;
3. Porosity in the cast metal matrix composites; and
4. Chemical reactions between the reinforcement material and the matrix alloy (J. Hashim *et al*., 1999).

In a stir casting process, the reinforcing phases (usually in powder form) are distributed into molten Aluminum by mechanical stirring. Mechanical stirring in the furnace is a key element of this process. The resultant molten alloy, with ceramic particles, can then be used for die casting, permanent mold casting, or sand casting.

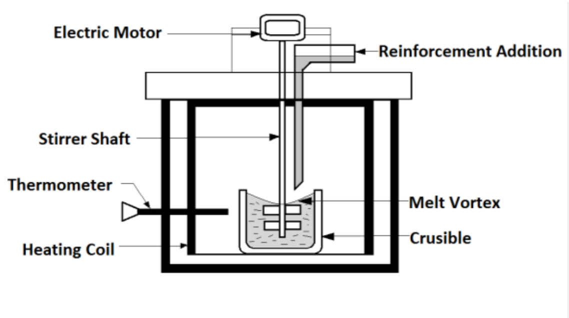

Fig.1 Stir Casting Setup (Schematic)

3.2 Process Parameters

For manufacturing of composite material by stir casting knowledge of its operating parameter are very essential. As there is various process parameters if they properly controlled can lead to the improved characteristic in composite material. The important process parameters are,

- Stirring speed
- Stirring temperature
- Reinforcement preheat temperature
- Stirring time (Holding time)
- Preheated Temperature of Mould
- Powder Feed Rate
- Addition of Mg
- Blade design of Stirrer

Stirring speed is the important process parameter as stirring is necessary to help in promoting wettability i.e. bonding between matrix & reinforcement. Stirring speed will directly control the flow pattern of the molten metal. Parallel flow will not promote good reinforcement mixing with the matrix. Hence flow pattern should be controlled turbulence flow. Pattern of flow from inward to outward direction is best. In our project we kept speed of stirrer at 300 rpm. As solidifying rate is faster it will increase the percentage of wettability.

Holding time is an important process parameter. It is related to the melting temperature of matrix i.e. Aluminium alloy. Aluminium alloys generally melts at 650◦C. The processing temperature is mainly influence the viscosity of Al356 matrix. The change of viscosity influences the particle distribution in the matrix. It also helps to create perfect interface bond between reinforcement and matrix. In our project, in order to promote good wettability, we kept operating temperature at 600-800°C which keeps Al356 in semisolid to liquid state. (G. G. Sozhamannan *et al*., 2012).

Reinforcement was preheated at 300-400◦C temperature for about an hour in order to remove moisture or any other gases present within reinforcement. The preheating of also promotes the wettability of reinforcement with matrix

Stirring promotes uniform distribution of the particles in the liquid and to create perfect interface bond between reinforcement and matrix. The stirring time between matrix and reinforcement is considered as important factor in the processing of composite. Stirring was done for 7-10 minutes.

In casting porosity is the prime defect. In order to avoid these preheating the permanent mould is good solution. It will help in removing the entrapped gases from the slurry in mould It will also enhance the mechanical properties of the cast AMC. While pouring molten metal keep the pouring rate constant to avoid bubble formation.

To have a good quality of casting the feed rate of powder particles must be uniform. If it is non-uniform it promotes clustering of particles at some places which in turn enhances the porosity defect and inclusion defect, so the feed rate of particles must be uniform.(Mandar Valsange *et al*., 2014)

Addition of Magnesium enhances the wettability. However increase the content above 1 wt. % increases viscosity of slurry and hence uniform particle distribution will be difficult.

The blade angle and number of blades are prominent factor which decides the flow pattern of the liquid metal at the time of stirring. The blade with angle 45° & 60° will give the uniform distribution. The number of blade should be 3-4. Blade should be 20mm above the bottom of the crucible. Blade pattern drastically affect the flow pattern. Stirrer blades play an important role in creating vortex of the molten matrix. This vortex formation ensures boding characteristic of matrix and reinforcement.

Fig.2 Stirrer Blades

3.3 Materials

Aluminium alloy Al356 is to be selected as matrix material and Alumina (Al_2O_3) along with fly ash particles as reinforcement material.

Fig.3 Ingots of aluminum alloy Al 356

Al 356 alloy possesses excellent castability, good weldability and good corrosion resistance. Also it has better machinability and mechanical properties. It is used in Aircraft pump parts, automotive transmission cases, Aircraft fittings, Control parts, Water-cooled cylinder blocks, Aircraft structures and engine controls. (S.G. Kulkarni *et al*., 2014).

Table 2 Composition of Al356 (S.G. Kulkarni *et al*., 2014)

Constituent	Percentage
Cu max	0.25
Mg	0.2-0.45
Mn max	0.35
Si	6.5-7.5
Fe max	0.6
Zn max	0.35
Ti max	0.25
Other	0.05
Al	Rem

The reinforcement material used is hybrid reinforcement of alumina (Al_2O_3) and fly ash. Fly ash is an industrial by-product generated during combustion of coal. Deposition of fly ash is concerning environmental problem due to its polluting characteristics. Therefore, considerable research has been undertaken worldwide to place this by-product into the applied technologies.

Table 3 Composition of fly ash (Sharanabasappa R Patil *et al*., 2013)

Constituent	Percentage
Al_2O_3	28.44
SiO_2	59.96
Fe_2O_3	8.85
TiO_2	2.75
Loss of ignition	1.43

3.4 Manufacturing Procedure

An electric induction furnace was used for the stir casting process. After cleaning Al356 ingots, they were cut to proper sizes, weighed in requisite quantities and were charged into a cast iron crucible placed in the furnace, at 400°C. The alloy started melting with elevated temperature. One percent by weight pure Magnesium is added into the charge at 600°C after confirming the semisolid state to improve wettability between matrix and reinforcement. Then material was hold for about an hour until its temperature gain reached 800°C. The scum powder was added into the melt which resulted into accumulation of impurities at the surface of liquid melt. The scum was removed. Degasification tables of Hexachloroethane were added for removal of gases from the molten alloy.

The amount of scum powder and degasification agent used was 0.05 percent by weight of Al356. Fly ash and Alumina were weighed separately in 2, 4 and 6 percent each. The combination of reinforcement was preheated to 300°C - 400°C for 1 hour before pouring in to the melt of Aluminium Alloy. This was done to facilitate removal of any residual moisture as well as to improve wettability and to avoid chemical reaction.

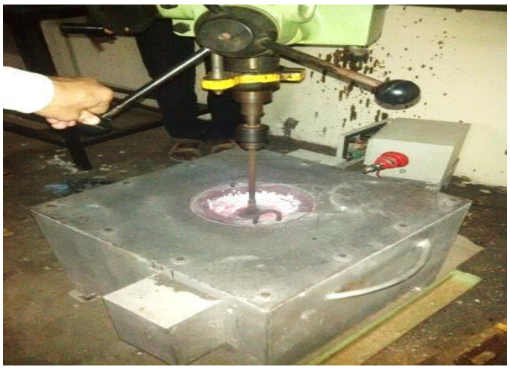

Fig.4 Stirring process

The molten metal was stirred with a stirrer at speed of 300 rpm for 7-10 minutes. A vortex was created in the melt because of stirring where preheated fly ash and Alumina were poured centrally into the vortex at 0.5 gram per second feed rate. The stirrer was moved down slowly, from top to bottom by maintaining a sufficient clearance from the bottom. The stirrer was then pushed back slowly to its initial position. The pouring temperature of the liquid was kept around 800°C. Liquid Composite was poured in the MS permanent mould with uniform pouring rate, keeping pouring distance constant, to maintain the fluidity of melt. Mould also was preheated at 300°C - 400°C for 1 hour. Casting was made in rectangular metal mould of dimension 220x220x20mm^3.

Fig.5 Plate Casting

Conclusions

From the process of stir casting and the overall work carried out, we can set the following conclusions:

1) Aluminum matrix composites have been successfully fabricated by stir casting technique with fairly uniform distribution of fly ash and Al_2O_3 particles.
2) Stir casting is very efficient, simple and cost effective method of manufacturing of Aluminium matrix composites and also it is most suitable for mass production.
3) Processing variables such as holding temperature, stirring speed and time, blade design of the stirrer and preheating process are among the important factors to be considered in the production of cast metal matrix composites as these have an impact on quality and properties of casting.
4) It has been observed that preheating the mould improves the soundness of the casting, shown by a decrease in the porosity level. The pouring distance from the crucible and the mould should be as short as possible.
5) The wettability between matrix and reinforcement will be improved by addition of magnesium in melt.
6) The fabricated Aluminium metal matrix composite is isotropic in nature due to fairly uniform distribution of reinforcement.

References

Abhishek Kamboj, (2012), Design and Development of Hybrid Stir Casting Process, *International Journal of Applied Industrial Engineering*, 1(2), 1-6.

Prakash Gadade, Arun L.R, (2013) Characterization of Aluminium fly ash-Alumina Composite for Piston Analysis by CAE Tools, *International Journal of Innovative Research in Science, Engineering and Technology*, Vol. 2, Issue 12,8047-8060.

S. O. Adeosun, L.O. Osoba, O. O. Taiwo, (2014), Characteristics of Aluminum Hybrid Composites, *International Journal of Chemical, Nuclear, Metallurgical and Materials Engineering*, Vol:8 No:7, 692-699.

Amol Mali, S. A. Sonawane, Sachin Dombale (2015) Effect of Hybrid Reinforcement on Mechanical Behavior of Aluminium Matrix Composite, *International Journal of Engineering Research & Technology (IJERT)*, Vol. 4 Issue 01, 130-133.

J. Hashim, L. Looney, M.S.J. Hashmi, (1999), Metal matrix composites: production by the stir casting method*, Journal of Materials Processing Technology*, 92-93, pp.1-7.

Sumsun Naher, (2004), Examination of the Stir – Casting Method to Produce Al - SiC Composites, *A Thesis in School of Mechanical and Manufacturing Engineering Faculty of Engineering and Computing, Dublin City University,* pp. 1-141.

Pardeep Sharma, Gulshan Chauhan, Neeraj Sharma, (2008), Production of AMC by stir casting – An Overview, *International Journal of Contemporary Practices*, Vol.2, Issue1 pp.23-46.

S. G. Kulkarni, J. V. Meghnani, Achchhe Lal, (2014), Effect of Fly Ash Hybrid Reinforcement on Mechanical Property and Density of Aluminium 356 Alloy, *International Conference on Advances in Manufacturing and Materials Engineering AMME, Procedia Materials Science 5,* pp. 746-754.

Ajay Singh, Love Kumar, Mohit Chaudhary, Om Narayan, Pallav Sharma, Piyush Singh, Bhaskar Chandra Kandpal, Som Ashutosh, (2013), Manufacturing of AMMCs using Stir Casting Process and Testing its Mechanical Properties*, International Journal of Advanced Engineering Technology,* Volume IV, Issue III , pp. 26-29.

Mandar Valsange, S.G.Kulkarni, S.A. Sonawane, (2014), Stir Casting used in manufacturing of Aluminium Matrix Composite*, International Journal for Research in Technological Studies*, Vol. 1, Issue 9, pp. 35-38.

Mr.Sharanabasappa R Patil, Prof B.S Motgi, (2013), A Study on Mechanical Properties of Fly Ash and Alumina Reinforced Aluminium Alloy (LM25) Composites, *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*, Volume 7, Issue 6, pp. 41 - 46.

Ajit Kumar Senapati, Abhijit Bhatta, Satyajeet Mohanty, P.C.Mishra, B.C.Routra, (2014), An Extensive Literature Review on the Usage of Fly Ash as a Reinforcing Agent for Different Matrices, *International Journal of Innovative Science and Modern Engineering (IJISME),* Volume-2, Issue-3, pp. 4-9.

Ajit Kumar Senapati, Purna Chandra Mishra, Bharat Chandra Routara, (2014), Use of Waste Fly ash in Fabrication of Aluminium Alloy Matrix Composite, *International Journal of Engineering and Technology,* Vol. 6 No. 2, pp. 905-912.

G. G. Sozhamannan, S. Balasivanandha Prabu, V. S. K. Venkatagalapathy, (2012), Effect of Processing Parameters on Metal Matrix Composites: Stir Casting Process, *Journal of Surface Engineered Materials and Advanced Technology,* Vol. 2, pp. 11-15.

Rajeshkumar Gangaram Bhandare, Parshuram M. Sonawane, (2014), Preparation of Aluminium Matrix Composite by using Stir Casting Method and it's Characterization, *International Journal of Current Engineering and Technology,* Special Issue-3, pp. 148-155.

Amol D. Sable, S. D. Deshmukh, (2012), Preparation of Metal-Matrix Composites by Stir Casting Method, *International Journal Of Mechanical Engineering And Technology,* Volume 3, Issue 3, pp. 404-411.

R. Kumar, J. Jegan, L .Initha, (2014), Processing of Aluminium Metal Matrix Composites (AMMC) through Stir Casting Route, *IPASJ International Journal of Mechanical Engineering,* Volume 2, Issue 12, pp. 17-25.