Stir Casting used in manufacturing of Aluminium Matrix Composite

Mandar Valsange[1] S.G.Kulkarni[2] S.A. Sonawane[3]
[1]PG Student [2, 3]Asst.Professor
[1, 2, 3]S.K.N Sinhgad College of Engineering, Pandharpur.

Abstract—*Aluminum alloys are widely used in aerospace and automobile industries due to their low density and good mechanical properties &tribological properties like better corrosion resistance and wear, low thermal coefficient of expansion as compared to conventional metals and alloys. Various processing techniques for the production liquid state fabrication of Aluminium Matrix Composites like squeeze casting, powder metallurgy, Spray casting, Lanxide technique. Manufacturing of aluminum alloy based casting composite materials via stir casting is one of the prominent and economical route for development and processing of metal matrix composites materials. This paper presents an overview of stir casting process & preparation of AMC material by using aluminium as matrix form and SiC, Al2O3, graphite, fly-ash as reinforcement by varying proportion.*

Keywords:- Aluminium alloy, Reinforcement, Matrix, Stir-casting.

I. INTRODUCTION

Now days in Industry development of advanced engineering materials for various engineering applications goes on increasing. To achieve this material Composite is the better option for the Conventional monolithic materials .The composite materials have achieving good combination of strength, stiffness, toughness and density etc. A composite material is defined as a material which is composed of two or more materials at a microscopic scale and has chemically distinct phases [1].Now a days the particulate reinforced aluminium matrix composite are gaining importance because of their low cost with advantages like isotropic properties and the possibility of secondary processing facilitating fabrication of secondary components. Cast aluminium matrix particle reinforced composites have higher specific strength, specific modulus and good wear resistance as compared to unreinforced alloys. Number of materials such as SiC, Al_2O_3, B4C, TiB2, ZrO2, SiO2 and Fly Ash are being used as reinforcements to improve the properties of Al alloy.

These advantages can be used to achieve better properties. For example, elastic modulus of pure aluminium can be enhanced from 70GPa to 240GPa by reinforcing with 60 vol.% continuous aluminum fiber. On the other hand incorporation of 60 vol% alumina fiber in pure aluminium leads to decrease in the coefficient of expansion from 24 ppm/°C to 7 ppm/°C. Similarly it is possible to process Al-9% Si-20 vol% SiCp composites having wear resistance equivalent or better than that of grey cast iron. The commonly used reinforcement is silicon carbide particulates (SiCp) in cast alloy matrix (modified compositions of 356 and 357 Al alloys) and alumina particulates in wrought alloy matrix (6061/2024). Even though the possibilities of using different kinds of reinforcement in Al alloys as reinforcements, except SiCp and A1203 others have not shown any commercial potential. But Now days fly ash is used as reinforcement due to the (SiO2, Al2O3, Fe2O3 as major constituents and oxides of Mg, Ca, Na, K etc. as minor constituents) is one of the most inexpensive and low density material which is abundantly available as solid waste by product during combustion of coal in thermal power plants.

II. MANUFACTURING OF AMC

A major challenge in the processing of composites is to homogeneously distribute the reinforcement phases to achieve a defect-free microstructure. Based on the shape, the reinforcing phases in the composite can be either particles or fibers. The relatively low material cost and suitability for automatic processing has made the particulate-reinforced composite preferable to the fiber-reinforced composite for automotive applications.

Primary processes for manufacturing of AMCs at industrial scale can be classified into two main groups.

A. *Liquid state processes:*

Composites involve incorporation of dispersed phase into a molten matrix metal, followed by its Solidification. In order to provide high level of mechanical properties of the composite, good interfacial bonding (wetting) between the dispersed phase and the liquid matrix should be obtained. Wetting improvement may be achieved by coating the dispersed phase particles (fibers). Proper coating not only reduces interfacial energy, but also prevents chemical interaction between the dispersed phase and the matrix.

The methods of liquid state fabrication of Metal Matrix Composites:

- Stir Casting
- Infiltration
- Gas Pressure Infiltration
- Squeeze Casting Infiltration
- Pressure Die Infiltration

B. *Solid state processes:*

Solid state process include Powder blending followed by consolidation (PM processing), high energy ball milling, friction Stir Process, diffusion bonding and vapors deposition techniques. The selection of the processing route depends on many factors including type and level of reinforcement loading and the degree of microstructural integrity desired. Among the variety of manufacturing processes available for discontinuous metal matrix composites, stir casting is generally accepted, and currently practiced commercially Its advantages he in its simplicity, flexibility and applicability to large scale production and, because in principle it allows a conventional metal processing route to be used, and its low cost This liquid metallurgy technique is the most economical of all the available routes for metal matrix composite production allows very large sized components to be fabricated, and is able to sustain high productivity rates

Method	Range of shape and size	Range of volume fraction	Damage to reinforcement	Cost
Stir casting	wide range of shapes; Larger size; up to 500 kg	Up to 0.3	No damage	Least expansive
Squeeze casting	limited by preform shape Up to 2cm height	Up to 0.5	severe damage	Moderately expansive
Spray casting	limited shape; large size	0.3-0.7	-------------	Expansive
Lanxide technique	Limited by pre-form shape. Restricted size	-------------	-------------	Expansive

Table.1: A comparative analysis of different technique used for manufacturing of AMC [3]

III. Stir-Casting:

Stir Casting is a liquid state method of composite materials fabrication, in which a dispersed phase (ceramic particles, short fibers) is mixed with a molten matrix metal by means of mechanical stirring. Stir Casting is the simplest and the most cost effective method of liquid state fabrication. The liquid composite material is then cast by conventional casting methods and may also be processed by conventional Metal forming technologies. In this process particles are often tend to form agglomerates, which can be only dissolved by intense stirring .However, here gas access into the melt must be absolutely avoided, since this could lead to unwanted porosities or reactions. Careful attention must be paid to the dispersion of the reinforcement components, so that the reactivity of the components used is coordinated with the temperature of the melt and the duration of stirring, since reactions with the melt can lead to the dissolution of the reinforcement components. Because of the lower surface to volume ratio of spherical particles, reactivity is usually less critical with stirred particle reinforcement than with fibers.

Stir Casting is characterized by the following features:

1. Content of dispersed phase is limited (usually not more than 30% by volume).
2. Distribution of dispersed phase throughout the matrix is not perfectly homogeneous:There are local clouds (clusters) of the dispersed particles (fibers) 2. There may be gravity segregation of the dispersed phase due to a difference in the densities of the dispersed and matrix phase.
3. The technology is relatively simple and low cost.

Distribution of dispersed phase may be improved if the matrix is in semi-solid condition. The method using stirring metal composite materials in semi-solid state is called Rheocasting. High viscosity of the semi-solid matrix material enables better mixing of the dispersed phase [3].

IV. Process Parameter

A. *Stirring Speed*

In stir casting process Stirring Speed is very important parameter for consideration due to wettability. Stirring speed is decided by fluidity of metal speed, dispersion of particulates are not proper because of ineffective vortex.

B. *Particle Preheating Temperature*

Preheating of particulate is necessary to avoid moisture from the particulate otherwise there is chance of agglomeration of particulate due moisture and gases. Along this SiC particles are heated at 1000ºC to form a oxide layer on the SiC particles which make it chemically more stable and by the oxide layer formation wettability will increase so particles will effectively embedded in aluminium matrix and less number of porosities in casting. After oxide layer formation preheating of particulate is done on temperature of 400° C.

C. *Stirrer Design*

It is very important parameter for stir casting process. It is essentially requires for vortex formation for the uniformly dispersion of particles. There is different type of stirrer some 90º form the shaft and some are bent at 45º. There is a no uniform dispersion of particles in case of no vortex formation.

D. *Stirring temperature*

It is related to the melting temperature of matrix i.e. aluminium. Aluminium generally melts at 750-800◦C.At low melt temperature the wettability is more in Matrix & reinforcement hence the bonding is poor. The processing temperature is mainly influence the viscosity of Al matrix. The change of viscosity influences the particle distribution in the matrix. The viscosity of liquid decreased when increasing processing temperature with increasing holding time stirring time. It also accelerates the chemical reaction between matrix and reinforcement

E. *Addition of Mg*

The composites produced by liquid metallurgy techniques generally show excellent bonding between ceramic and molten matrix when reactive elements are added to reduce wettability. The addition of magnesium to the melt may promote wetting by reducing the surface tension of the melt, decreasing the solid-liquid interfacial energy of the melt, or reducing wettability by chemical reaction

F. Holding time

Effect of the holding time helps in the Al-SiCp composites mainly two ways: to distribute the particles in the liquid, and to create perfect interface bond between reinforcement and matrix. The holding time between matrix and reinforcement is considered as important factor in the processing of composites .When the holding time is less the particles are distributed uniformly in the matrix the liquid matrix has sufficient viscosity in the temperature range and velocity of particle flow is small. In case of large holding time the liquid has sufficient viscosity at lower Temperature but the contact time b/w the matrix and reinforcement too large during this period the particles are distributed uniformly in the liquid even though some of particles form clusters which could be also located in the matrix region.

G. Preheated Temperature of Mould

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.

H. Powder Feed Rate

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.

V. Experimental Setup And Procedure

Initially calculated amount Al alloy was charged into Graphite crucible and superheated to a temperature of 750 to 800 C for one hour in an electrical resistance furnace. The furnace temperature was controlled to an accuracy of ±500C using a digital temperature controller. A novel three stage mixing combined with preheating of the reinforcing particles is followed. Reinforcement particulates were preheated to a temperature of 600ºC in an oven to remove the adsorbed gases from the particle surface and to avoid high drop of temperature after addition of particulates. Preheated Reinforcement particles were introduced into the vortex of the molten alloy after effective degassing using solid hexachloroethane ($C2Cl6$). Vortex is generated with the help of a graphite impeller. The extent of incorporation of Reinforcement particles in the matrix alloy was achieved in steps of 3. i.e. Total amount of reinforcement required was calculated and is being introduced into the melt 3 times rather than introducing all at once. At every stage before and after introduction of reinforcement, mechanical stirring is carried out for a period of 7 min. The stirrer was preheated before immersing into the melt, and is located approximately to a depth of 2/3 height of the molten metal from the bottom and run at a speed of 700 rpm. Composite mixture was poured into permanent cast iron moulds having diameter 21mm and length of 200mm at a pouring temperature of 750 C.

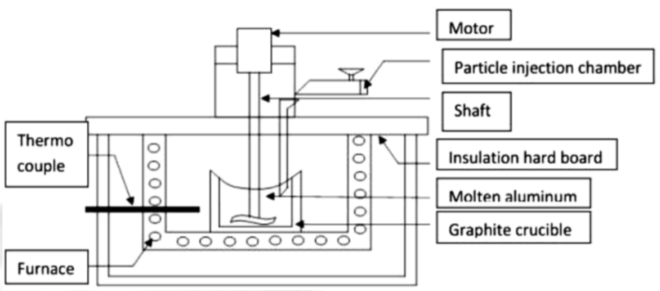

Fig. 1: Stir Cast apparatus [3]

VI. Conclusion

In present study the aim is study the various manufacturing of AMC by stir casting process & it's operating parameters.In this Composite Aluminium Alloy is selected as matrix phase while Ceramic (SiC, Alumina and Graphite) act as reinforcement. With the help of stir casting process we had successfully manufactured AMC at less cost. While manufacturing AMC we come to know that operating parameter are partly major roles for uniform distribution of reinforcement.

From above study we have some conclusion for the operating parameters.

1. For uniform dispersion of material blade angle should be 45° or 90 °.It should avoid avoids the agitation of the melt surface, and the formation of vortex must be avoided or minimized.
2. Preheating of mould&reinforcements helps in reducing porosity as well as increases mechanical properties.
3. Addition of Mg is reduced the wettability

Acknowledgment

It is privilege for me to have been associated with Mr. S. G. Kulkarni, Mr. S. A. Sonawane, Asst. Prof. Mechanical Engineering Department, SKNCOE, Korti, pandharpur during this paper work. I have been great pleasure that I express my deep scene of gratitude to him for his valuable guidance and constant encouragement throughout this work.

References

[1] D. Verma, P.C. Gope, M.K. Maheshwari, R.K. Sharma"Bagasse Fiber Composites-A Review" J. Mater. Environ. Sci. 3 (6) 2012, 1079-1092.
[2] Sukhwinder,Singh Jolly "Advancements in Composite Materials and Their Applications in Engineering and Technology" International Global Research Analysis Volume 1,Issue 5,Nov 2012.
[3] Pardeep Sharma, Gulshan Chauhan, Neeraj Sharma " Production of AMC by stir casting – An Overview" International Journal of Contemporary Practices Vol.2.
[4] R. S. Rana,RajeshPurohit and S Das "Review on the Influence of Alloying elements on the Microstructure

&Mechanical properties of Aluminium Alloys & Aluminium Alloys composites" International Journal of Scientific and Research Publications, Volume 2, Issue 6, June 2012.

[5] Bharath V, MahadevNagaral& V Auradi:"Preparation Of 6061al-Al2O3 Metal Matrix Composite By Stir Casting And Evaluation Of Mechanical Properties" International Journal of Metallurgical & Materials Science and Engineering,Vol.2 Issue 3,Sep 2012,pp 22-31.

[6] VivekKumar,Pradeep Kumar, Puneet Kumar: "Development of AA2218-Al2O3 MMC's And Characterisation for Mechanical properties" International Journal of Innovative Research in Science, Engineering and Technology ,Vol. 2 Issue 5,May 2013.

[7] S. M. Suresh, Debadutta Mishra, A. Srinivasan, R. M. Arunachalam and R. Sasikumar: "Production and characterization of micro and Nano Al2O3 particle-reinforced LM25 Aluminium Alloy composites" ARPN Journal of Engineering and Applied Sciences VOL. 6 NO. 6, JUNE 2011.

[8] S.A. Sajjadi, H.R. Ezatpour, H. Beygi: "Microstructure and mechanical properties of Al–Al2O3 micro and nano composites fabricated by stir casting" Materials Science and Engineering A 528 ,2011,pp 8765– 8771.

[9] M. N. Wahab, A. R. Daud and M. J. Ghazal: "Preparation And Characterization Of Stir Cast-Aluminum Nitride Reinforced Aluminum Metal Matrix Composites" International Journal of Mechanical and Materials Engineering (IJMME), Vol. 4 No. 2, 2009,pp115-117.

[10] G. B. Veeresh Kumar, C. S. P. Rao2, N. Selvaraj,M. S. Bhagyashekar: "Studies on Al6061-SiC and Al7075-Al2O3 Metal Matrix Composites" Journal of Minerals & Materials