PARTICLE DISTRIBUTION IN Al-SiC METAL MATRIX COMPOSITES – A REVIEW

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ABSTRACT

In recent years, composite materials have been used for structural and non-structural application in aeronautical, marine and transport industries, due to their enhanced mechanical and thermo physical properties. Casting technology is the key for producing Metal Matrix Composite (MMC) components of even minimally complex shapes. In Stir casting technique metal matrix composites are produced by melting the matrix material in a crucible, then the molten metal is stirred thoroughly to form a vortex and then reinforcement particles are introduced from the top of the crucible. Achieving a uniform distribution of reinforcement within the matrix is one of the challenge which impacts directly on the properties and quality of the composite materials. This paper attempts to analyze some of the parameters like Heat Treatment of Particles, Solidification Time, Impeller Parameter (type, diameter and width), and Inert gas atmosphere for the uniform distribution of the reinforcement in the matrix.

Keywords: Stir Particle distribution, Metal Matrix Composites and Casting

INTRODUCTION:

Considerable research from all over the world has been devoted to Metal Matrix Composite (MMCs) research over the past few decades involving a broad area of MMC fabrication. Composite materials are continuously displacing traditional Engineering materials because of their advantages of high stiffness and strength over homogeneous materials formulations. Composite material is a mixture of two or more different materials with distinguished interface separating them. Composites may have metal, ceramic or polymer matrices and be reinforced with particles or fibers. The present work considered only Metal Matrix Composites (MMCs) reinforced with discrete particles. The development of MMCs has been one of the major innovations in materials in the past two decades.

In any type of the fabrication method used, Wettability, distribution of the reinforcement material and porosity in the composites are among the main problems. Wettability can be defined as the ability of liquid particles to make the intimate contact with solid particles. Many methods have been proposed to overcome this situation. However ideas normally suitable for the preparation of materials and their use may not be suitable for different approaches.

The fabrication of MMCs using a stir casting technique represents a potential means of producing complex shaped components. In Stir casting technique MMCs are produced by melting the matrix material in a crucible, then the molten metal is stirred thoroughly to form a vortex and then reinforcement particles are introduced from the top of the crucible. In the present research, aluminium based, SiC particle reinforced MMC is being made using a stir casting technique. In this method the aluminum matrix is placed in a crucible which is placed in an electric furnace. A stirrer is then applied after the matrix material is completely melted. Wetting agent (Mg Powder) is added and stirred continuously and then the heat treated SiC particles are added in the inert atmosphere and stirred for uniform dispersion. The importance and difficulty of achieving a uniform distribution of particles in the matrix were also studied.

It is known that effective stirring action is necessary to control distribution from immediately after the addition of the particles into the melt, until pouring into a mould. However, in normal practice, the efficiency of the stirring action in the closed crucible cannot be seen, and the result of the stirring can only be deduced from the solidified MMC, using optical examination, and may not be clear due to contributing solidification effects. Actual measurement of fluid flow characteristics is expensive, time consuming, and in the case of molten metal may be dangerous.

In these situations computational fluid dynamics (CFD) can provide a means for understanding the details of flow. The emphasis is on investigating optimum stirring conditions in order to achieve effective flow patterns to disperse the solid particles in the melt.

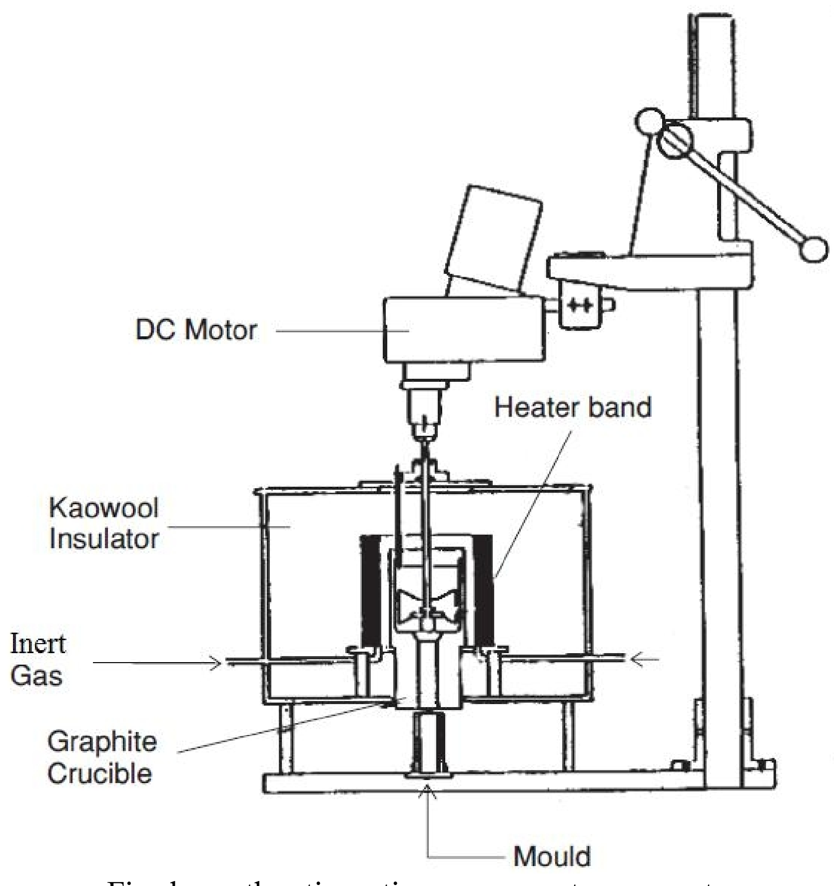


Fig shows the stir casting process setup apparatus

EXPERIMENTAL DETAILS FOR Al-SiC:

A commercial casting grade A384 aluminium alloy has been used for this work. A weighted quantity of the A384 Al alloy was melted in a graphite crucible and the melt was superheated by about 100 ◦C to get the fluidity. This molten metal was stirred using a mild steel impeller at a speed 500–700 rpm to create the vortex. The impeller blades were designed such that it creates vortex to achieve the particle mixing. The impeller blades were coated with a zirconium-based coating to minimize blade dissolution in molten metal. During the process, the molten metal was well agitated by a mechanical stirrer to create turbulence motion. The depth of the immersed impeller was approximately 2/3 of the height of the molten metal from the bottom of the crucible and the speed of the stirrer was maintained at 500/600/700 rpm. Silicon carbide powder of average size 60 µm is taken for this study and the calculated quantity of SiC was heated in atmospheric air at 800 ◦C for 2 hours, was then fed at a constant rate into the root of the vortex. The heat treatment on SiC particles was done in order to form a layer of SiO_2 on the SiC, which improves the incorporation of the SiC in to the molten melt. The molten metal–SiC slurry was stirred continuously for the different combination of processing conditions. The molten metal poured into the mild steel die, which is preheated to about 300 ◦C.

HEAT TREATMENT OF PARTICLE:

Particle treatment refers to the heating of SiC. The reason for heat treating the particles is

(1) Remove the moisture

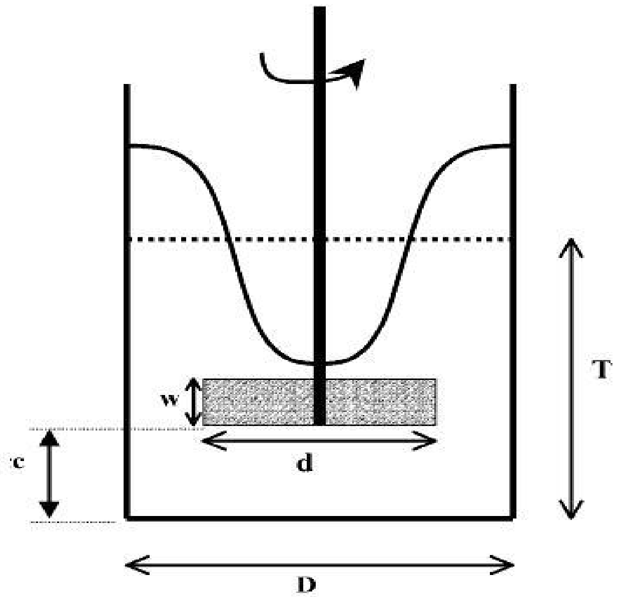
(2) Form SiO_2 layer on the particle

When the particles are not heat treated, they may not wet with aluminium matrix because no formation of SiO_2 layer on the particles. Aluminium alloy is heated to 750^0 (approx) in a crucible using an electrical furnace. Now the SiC is added to the aluminium which is in the molten state. The mixture should be continuously stirred for the proper mixing of the matrix and reinforcements. The density of Aluminium ($2.7g/cm^3$) is lesser than SiC ($3.2g/cm^3$), if the stirring is not done then SiC gets deposited either at the bottom or at the sides.

SOLIDIFICATION TIME:

The solidification time should be kept minimum in order to avoid the formation of the Al oxides. Once the composite is poured into the mould it takes some time to come to the equilibrium state, so always the mould should be preheated in order to minimize the temperature difference. If the mould is not preheated then the equilibrium state is not attained quickly. Solidification begins when the temperature of the molten matrix drops below the liquidus temperature.

IMPELLER PARAMETER:



Dimensions of vessel and impeller. D: diameter of vessel; d: diameter of impeller; T: liquid depth in the vessel; w: width of impeller; c: clearance between the bottom of the tank and impeller bottom.

Type of impellers:

Impellers are nothing but pumps. Depending upon the pumping action, impellers are classified into axial flow and radial flow impellers. Axial flow impellers include all with a blade that makes an angle less than 90 degrees with the plane of impeller rotation. Axial flow impellers pump fluid vertically up or down away from the blades parallel to the shaft. Radial flow impellers have blades, which are parallel to the shaft. Radial impellers pump/discharge fluid horizontally away from the impeller blades.

Diameter of the impeller:

The effect of impeller diameter (d) can be assessed only with respect to the vessel diameter (D) in which the liquid with particles is being stirred. For solid suspension applications, the practical maximum d/D ratio is 0.6 while the minimum will vary according to process viscosity, increasing as the viscosity increases. A large number of impellers have a d/D of approximately 0.3 which is applicable to fluid viscosity of 10 poise. In the synthesis of Al MMCs by liquid metallurgy route, the processing temperature varies from 680 to 750 ^{0} C. The viscosity of an aluminum alloy melt at this range of temperatures falls within 10 poise. Investigators have used d/D values ranging from 0.3 to 0.75. Porosity content of the composite has been found to increase drastically with an increase in d/D ratio of the impeller from 0.56 to 0.63.

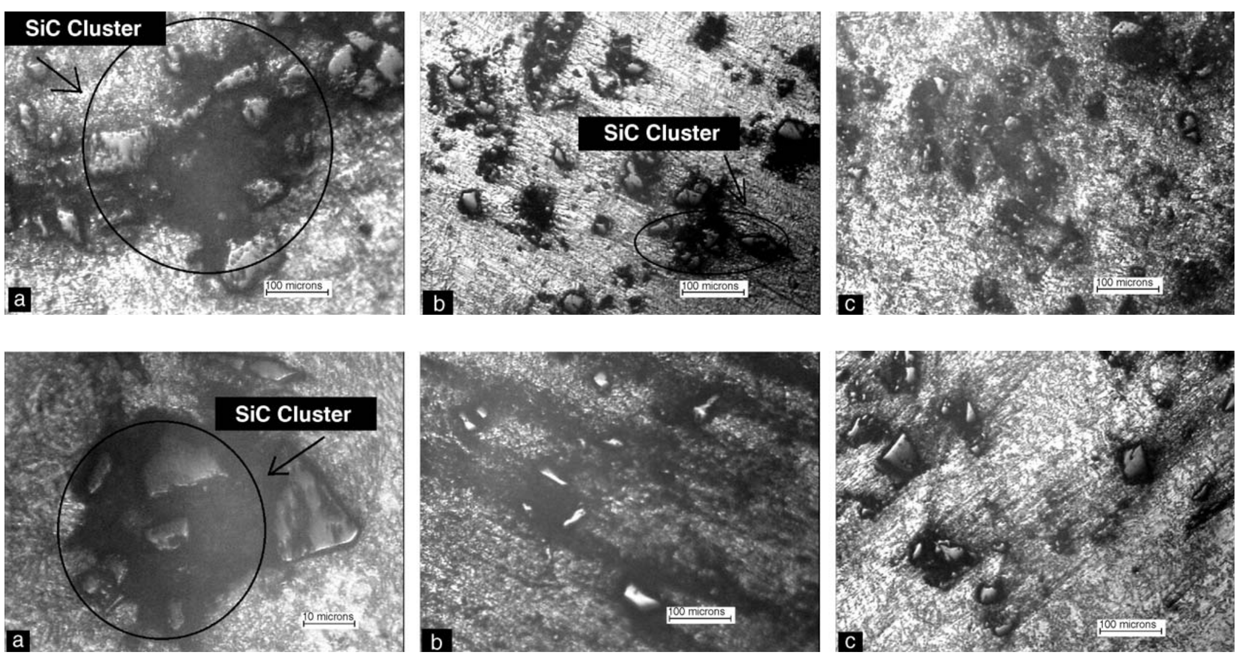
Width of the impeller:

The impeller width is usually expressed in terms of impeller diameter. This ratio is significant only when the speed with which the impeller is rotated comes into picture. As the blade width increases, both the radial and axial flow of the impeller increases. The increase in the axial component favors the suspension, whereas the increase in the radial component hampers the suspension because it counters the axial flow rising along the tank wall. Moreover, it appears that with an increase in blade width, the extent of increase in the radial flow is relatively more compared to that in the axial flow. In fact, the extent of reduction in critical speed (the minimum speed required by the impeller so that no particle remains at rest on the bottom of the vessel) decreases with an increase in w up to w/d of 0.35.Above this value, radial component dominates the flow pattern and critical speed starts increasing with the blade width. It is clear from the above that the axial flow component is more predominantly required than radial flow component for the solid suspension applications. Again, for the synthesis of MMCs, it is always better to stir at a minimum speed for minimum air entrapment. Hence, it is advisable to have a stirrer width falling within the optimum w/d ratio of 0.35.

INERT GAS ATMOSPHERE:

The Aluminium can easily oxidize when it gets heated up, this forms a thin oxide layer over the molten Aluminium. When this is formed then the SiC does not combine with the molten Aluminium. To prevent this, inert gases like argon is supplied continuously into the furnace at the rate of 3 cm^3/min, which will reduce the formation of oxides. This inert gas atmosphere should also be maintained during the transfer of molten composite in to the die to prevent the formation of blow holes.

Microstructure of Solidified Composites:



The above optical image shows the SiC particle distribution in aluminium matrix. As in the above fig a) and fig b) where the SiC particles are found in cluster then brittle property is obtained in that region. So SiC particles are not allowed to form cluster which leads to the failure of the material by brittleness. Whereas in fig c) where the particles are uniformly distributed enhances the strength of the metal matrix composite.

CONCLUSION:

This paper reviewed the various process parameters which promote particle distribution in the molten Al alloy. Previous results show that mechanical stirring is necessary to promote wetting and uniform particle distribution. Decreasing the solidifying time improves the wetting. Use of heat treated particles also improves the wetting and particle distribution. The presence of oxide layer on the melt surface creates a resistance to reinforcement particle penetration. The various impeller parameters were also reviewed for the better distribution of particles. The use of inert gas during the stirring prevents the formation of melt oxide layers. The optical images show that the particles are uniformly distributed and some of the particles are clustered.

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