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SIMULATION OF STIR CASTING PROCESS FOR UNIFORM NANO PARTICLES DISTRIBUTION BY COMPUTATIONAL FLUID DYNAMICS

Boda Surendra[1], Kagithapu Rajendra[2]
Department of Mechanical Engineering,
Aditya Engineering College Autonomous, Surempalem A.P.India.[1]
Assistant Professor, Department of Mechanical Engineering,
Aditya Engineering College Autonomous, Surempalem A.P. India.[2]
Email:suryamech967@gmail.com

Abstract

In thispresent work is to study and simulate the stir casting process to achieve uniform particle distribution at different heights in the tank. In the process, the percentage of volume fraction at five different locations was studied as the stirring speed and blade anglewere changing. Other stir casting process parameter that is viscosity, stirring time is maintainedconstant. In this work a simulation study was conducted to investigate the effect of stirringspeed and blade angle on the volume fraction of the Nano particles at different locations. Theresults of the simulation it is concluded 100 rpm stirrer speed and 30 degrees Blade Angle ismore effective in all locations. The time taken to achieve uniform particle distribution. Bladeangle and speed of stirrer played a significant role in distribution of silicon-carbide particles inaluminium semi solidmetal (SSM).

Keywords: Simulation, Stir Casting.

I. INTRODUCTION

The application of Metal Matrix Composites (MMCs) as structural engineering materials has received increasing attention in recent years. Their high strength and toughness at elevated temperatures coupled with low-density makes them suitable for use in application where conventional engineering materials, such as steel are used MMCs exhibit significantly higher stiffness and mechanical strength compared to matrix alloys, but often suffer from lower ductility and inferior fracture toughness MMCs gain the ability to withstand higher tensile and compressive stresses by the transfer and distribution of an applied load from the ductility matrix to the reinforcement material this load transfer is only possible due to the existence of an interfacial bond between the reinforcement material and its properties coupled with a good fabrication method both of which effect this bond will significant influence the resulting MMC.

Composite material: “A composite material is formed by a close combination of at least two chemically and physically distinct materials which should remain separate and distinct while a good and continuous interface between them is maintained; the reinforcing components in the whole volume of the matrix should be as uniform as possible.” There are different routes by which MMCs may be manufactured, and among all the liquid-state processes, stir casting technology is considered to have the most potential for engineering application in terms of production capacity and cost efficiency casting techniques are economical, easier to apply and more convenient for mass production with regard to other manufacturing techniques there are also various types of the reinforcement material continuous and discontinuous fiber, or particle. The main factors controlling the properties of MMCs fabricated using casting techniques include: reinforcement distribution, wetting of reinforcement by matrix alloy, reactivity at the reinforcement/matrix interface and porosity content in the solidified casting. The effective introduction of a reinforcement element into the liquid matrix is difficult owing to insufficient wetting of the ceramic particles by the liquid alloy. Increasing the liquid temperature, coating or oxidizing the ceramic particles, adding some surface-active elements such as magnesium or lithium into the matrix and stirring the molten matrix alloy for an adequate time during incorporation are some ways of improving the wettability and making the mixing and retention of the ceramic particles easier.

1.1.1 Current Application and Market Opportunities

Current markets for MMCs are primarily in military and aerospace applications. Experimental MMC components have been developed for use in aircraft, satellites, jet engines, missiles, and the National Aeronautics and Space Administration (NASA) space shuttles. The first production application of a missile guidance system. The most important commercial application to date is the MMC diesel engine piston made by Toyota. This composite piston offers better wear resistance and high-temperature strength then the cast iron piston it replaced. It is estimated that 300,000 such pistons are produced and sold in Japan annually. This development is very important because it demonstrates that MMCs are at least not prohibitively expensive for a very cost sensitive application. Other commercial applications include cutting tools and circuit-breaker contacts. Longer Term Application Metal matrix composites with high-speed rotating shafts for ships or land vehicles. Goods wear resistance, along with high specific strength, also favors MMC use in automotive engines and brake parts. Tailorable coefficient of thermal expansion and thermal conductivity make them good candidates for lasers, precision machinery, and electronic packaging. However, the current level of development effort appears to be inadequate to bring about commerciacialization of any of these in the next 5 years, with the possible exception of diesel engine piston. Based on information now in the public domain, the following military applications for MMCs appear attractive: high temperature fighter aircraft engines and structures; high-temperature missile structures; and spacecraft structures. Testing of a National Aerospace Plane(NASP) prototype is scheduled for the early to mid-1990s, which might be too early to include MMCs. However, it may be possible to incorporator MMCs in the structure or engines of the production vehicle.

1.1.2 Research and Development Priorities of MMCs

MMCs are just beginning to be used in production applications. In order to make present materials more commercially attractive, and to develop better materials, the following research and development priorities should receive attention:

- Cheaper Processes: To develop low cost, highly reliable manufacturing processes, research should concentrate on optimizing and evaluating process such as plasma spraying, powder metallurgy processes, modified casting techniques, liquid metal infiltration and diffusion bonding.
- Cheaper Materials: Development of lower cost fiber reinforcement is a major need. Continued development work on exiting materials is important to lower costs as well. Coatings Research in the area of reinforcement/matrix interface coatings is necessary. These coatings can prevent deleterious chemical reactions between matrix and reinforcement which weaken the composite, particularly at high temperatures, and optimize the interracial fiber/matrix bond.
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1.2 Stir Casting Process

There are different routes by which MMCs may be manufactured, and among all the liquid-state processes, stir casting technology is considered to have the most potential for engineering applications in terms of production capacity and cost efficiency casting techniques are economical, easier to apply and more convenient for mass production with regard to other manufacturing techniques. Stir casting process is one of the methods to produce MMCs. Stir casting experimental setup consists of furnace, a motorized stirrer, crucible placing beaker, and a temperature controlling unit. The process involves in stir casting process crucible to be placed in a beaker, the furnace should be on. After the furnace heating temperature reached to the melting point temperature of the crucible, the crucible starts get melted. Now by adding reinforcement materials into molten metal external agitation should be done by using motorized stirred. Due to stirring the reinforcement materials added distributed to throughout the molten metal. The distribution of reinforcement materials mainly depends on stirrer geometry, speed of stirrer, viscosity of molten metal and mixing time.

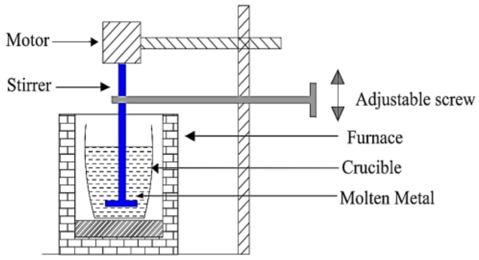


Fig 1. Schematic Diagram of Stir Casting Process.

2. MODELLING, MESHING, SOLUTION

2.1 Geometry

Ansys workbench Design Modeler used to create the geometry of the mixing tank to perform the simulations of the Stir Casting Process. In the design modeler they number of options to create the geometry of any modelling. By using these options and operation we can create the geometry of the fluid mixing in a tank. Now, show that the 2D view of the geometry with dimensions.

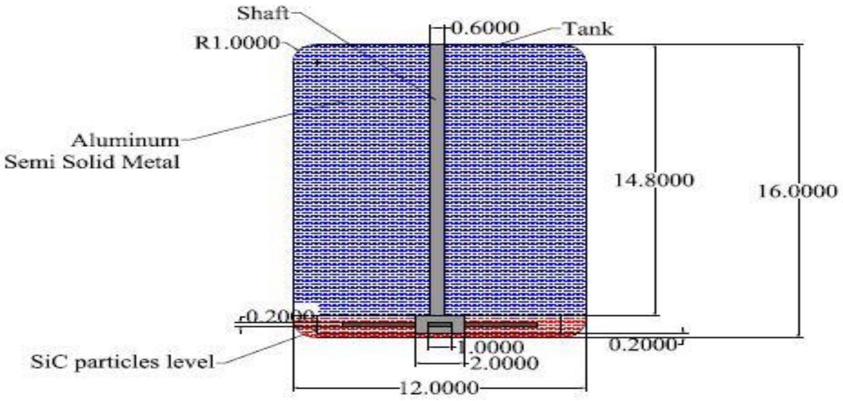


Fig 2. Schematic Diagram of Simulation Set up of Stir Casting Process.

2.2. Computational Domain

To perform simulations, a stirred tank domain was made using Design Modeler of Ansys workbench. First designed a stirrer of 4cm length, 1cm width and 0.2 cm thickness of Four flat bladed with 30 ° blade angle. Then create a tank with 6cm radius and 16cm height using sketching and modelling. To specify rotation motion in simulation a separate inner zone created surrounding the rotating blades. At last, parameterization additionally done to change the blade angle and radius of blade.

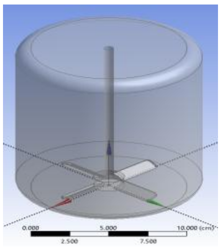


Fig 3. Creation of Tank and Fluid Domain

2.3. Generating a Mesh

Mesh After completing the geometry, go to mesh, Ansys meshing is one of the critical aspects of engineering simulations. Too many cells result in longer solver runs, and too few may lead to inaccurate results. ANSYS meshing technology gives a way to balance these requirements and obtain the right mesh for each simulation in the most automated way that could be available. Present simulation the mesh was tetrahedral mesh generated the automatic method applied.

Non- uniform distribution of reinforcement particles, wettability, porosity and chemical affinity between melt and reinforcement are the important challenges faced in the stir casting practice. Nonuniform distribution of particles is due to the density differences between reinforcement particles and matrix alloy melt. Type and geometry of stirrer, melt temperature and nature of particles effects the distribution of the particles. It can be solved by proper design of the stirrer, control of stirring speed and bottom pouring of the melt. Proper dispersion of the particles in a matrix is also affected by pouring rate, pouring temperature and gating systems. Wettability is the ability of liquid melt to spread on a solid surface.

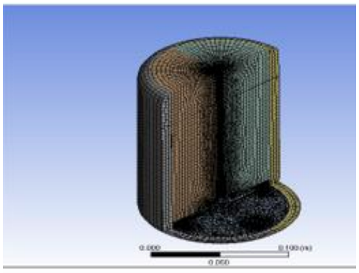


Fig 4. Final Mesh

2.4. Cell Zone and Boundary conditions

In this, Mesh motion were performed with respect to speed, rotation in Y-axis direction to the fluid inner. Out of the total volume of the tank, 5% volume of the tank filled with Silicon-carbide particles at the bottom of the tank, remaining volume filled with Aluminium Semi Solid Metal.

2.5. Solution

In the fluent solutions method, a simple pressure velocity coupling was selected the least square cell based gradient option is used. PRESTO pressure and second order upwind momentum for first order upwind volume of fraction and turbulent kinetic energy of spatial Discretization is used. An unsteady state solver used to solve all flow variables.

Before going to run calculations the solution to be initialization. In the initialization the patch work is there in that mixture is in volume of fraction and adaptation region value is one for Five Percentage of Silicon-Carbide is applied after solution get initialized then go to run for calculation.

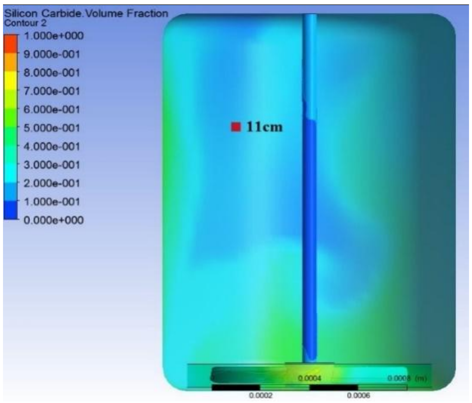
II. RESULT AND DISCUSSION

Based on the two conditions we can found the uniform distributions of reinforcement particles at each and every height.

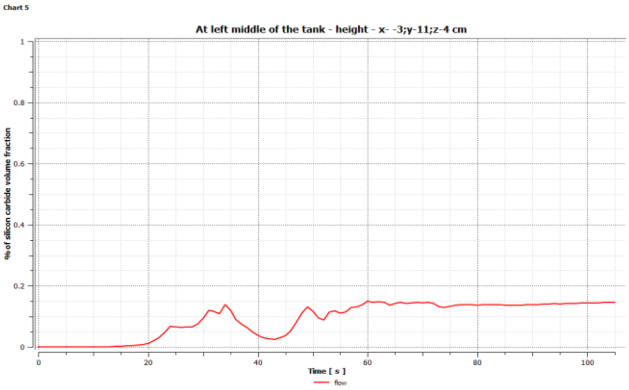
3.1 CONDITION: - 1

Blade Angle = 30 Degrees and Speed of stirrer = 100 rpm.

At Height = 11cm



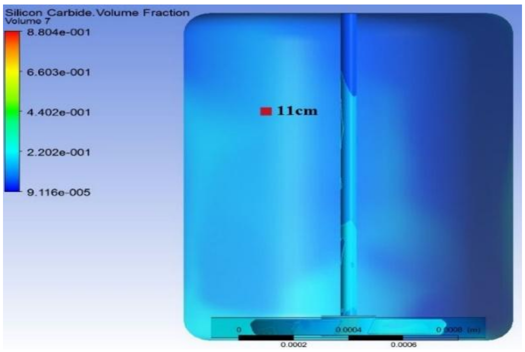
a) Contours of Volume Fraction (Silicon-Carbide)



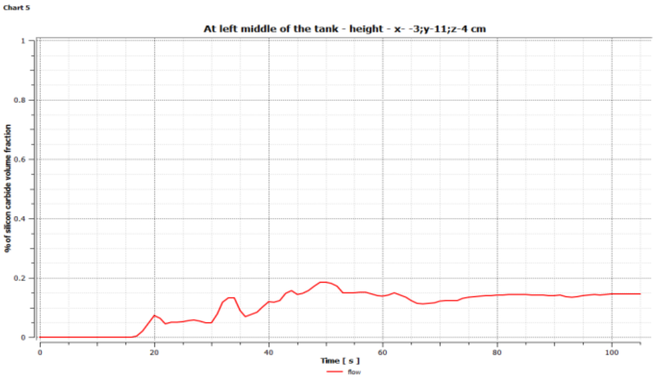
Graph 1. Percentage of Silicon-Carbide Volume Fraction vs Time for 11cm Height

3.2 CONDITION: - 2

Blade Angle = 60 Degrees and Speed of stirrer = 100 rpm.



a) Contours of Volume Fraction (Silicon-Carbide)



Graph:2 Percentage of Silicon-Carbide Volume Fraction vs Time for 11cm Height

From beginning of the stirrer starts from 0 seconds to 105 seconds up to 60 seconds the particles are moving randomly after that the reinforcement particles are stabilize it is shown in graphs. Bycomparing above graphs results, we can draw a tabular form of each Height in this we can found howmuch of time taken to achieve uniform distribution of reinforcement particles.

Table 1. Input condition and output condition for Height = 11cm

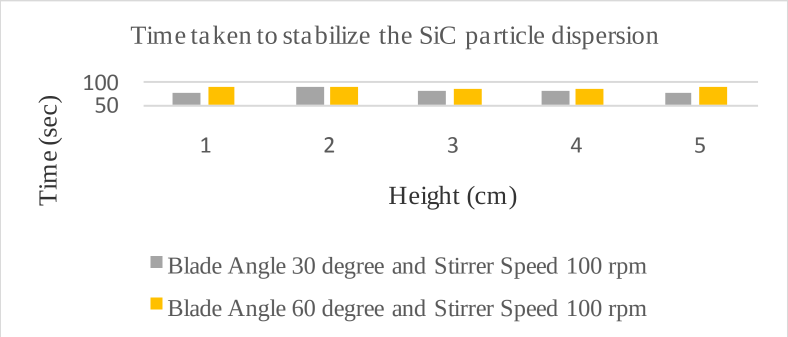
Height = 11cm				
Stirrer Speed (RPM)	Blade Angle	Time (sec)	% of Sic	Max. % of Sic
100	30	80	14	15
100	60	85	14	19

By comparing above two input conditions we can get the output results. In this above three terms are imported into excel software and found the results. In these all heights are compressed into one tabular form with respect to above three terms. These results shown in below.

(a) Time taken to achieve uniform particle distribution from two conditions:

Table 2. Time taken to achieve uniform particle distribution

Time taken to stabilize the particle dispersion						
Stirrer Speed (RPM)	Blade Angle	Height (cm)				
		1	8	11	12	15
100	30	75	90	80	80	75
100	60	90	90	85	88	90

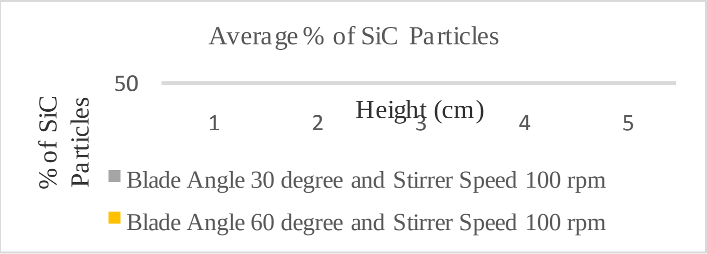


Graph: 3 Time (sec) vs Height (cm)

(b) Settling the percentage of SiC particles from the four conditions:

Table 3 Settling the percentage of SiC particle

% of SiC Particles						
Stirrer Speed (RPM)	Blade Angle	Height (cm)				
		1	8	11	12	15
100	30	25	15	14	15	13
100	60	15	14	14	15	13

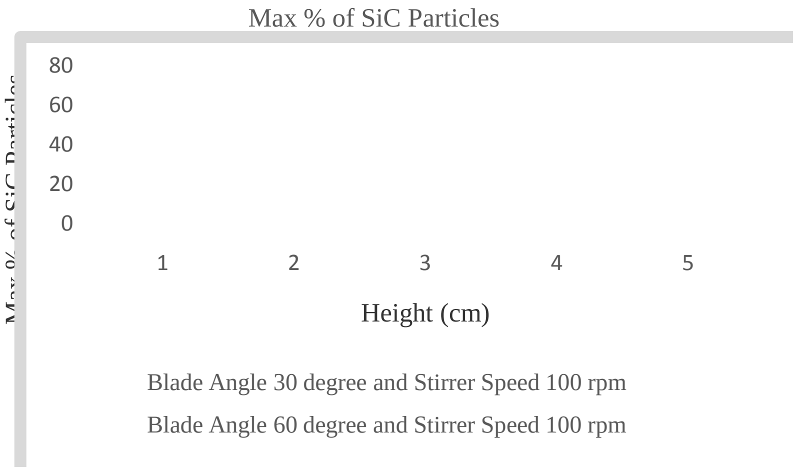


Graph:4 Percentage of Silicon-Carbide particles vs Height (cm).

(c) Maximum percentage of SiC particles:

Table 4 Maximum percentage of SiC particles

Max % of SiC Particles						
Stirrer Speed (RPM)	Blade Angle	Height (cm)				
		1	8	11	12	15
100	30	38	20	15	17	15
100	60	62	34	19	19	19



Graph:5 Maximum percentage of silicon-carbide particles vs Height (cm)

We observed all the condition with the heights blue colored condition i.e., blade angle 30 degrees and stirrer speed 100 rpm are the best result shown.

III. CONCLUSION

The computational fluid dynamics Ansys 15.0 commercial Software is successfully carried out the simulation of stir casting process.Speeds of 100 rpm with 30 and 60 degrees' blade angle at constant viscosity were determined as best in order to produce a uniform distribution of SiC. Uniform mixing was observed at viscosity at 3.2 m Pa-sec, Blade Angle = 30° and Speed of stirrer = 100 rpm.In this results of the simulation it is conclude 100 rpm stirrer speed and 30 degrees is more effective in all locations. In the bar graphs the time taken to achieve uniform particles distribution from the four conditions, the condition of 100 rpm stirrer speed and 30° blade angle are compared in all locations are approximately same seconds were found i.e., 57, 65, 69, 65, 68, are better uniformed distribution of SiC particles. And in average percentage of silicon-carbide particles are compared in all locations are same i.e., 25%, 15%, 14%, 15%, 13% percentage of SiC particles distribution. It is also observed in condition of 100 rpm stirrer speed and 30° blade angle blue colored indication. In the maximum percentage of SiC particles distribution are compared in all locations are approximately same. By this simulation results it was concluded that the two parameters that is stirrer speed and blade angle plays a major role in the distribution of Silicon-Carbide particles over an aluminum semi-solid metal (SSM).

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