Stir Casting Process Simulation by Computational Fluid Dynamics for uniform Nano particles distribution in Al Semi Solid Metal

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Abstract. In this present 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 angle were changing. Other stir casting process parameter that is viscosity, stirring time is maintained constant. In this work a simulation study was conducted to investigate the effect of stirring speed and blade angle on the volume fraction of the Nano particles at different locations. The results of the simulation it is concluded 300 rpm stirrer speed and 30 degrees Blade Angle is more effective in all locations. The time taken to achieve uniform particle distribution. Blade angle and speed of stirrer played a significant role in distribution of silicon-carbide particles in aluminum semi solid metal (SSM).

Key words: MMCs, Simulation, Stir Casting.

1. Introduction
Metal Matrix Composite (MMCs) is a range of advanced materials providing properties which are not achieved by conventional materials. These properties incorporate expanded quality, higher elastic modulus, higher service temperature, improved wear resistance, decreased part weight, low thermal shock, high electrical thermal conductivity, and low coefficient of thermal expansion compared to conventional metals and alloys. The great mechanical properties of these materials and the moderately low creation cost make them very attractive for a variety of application in automotive and aerospace industries. Stir casting involve the addition of particles reinforcement into semi solid metal (SSM) by means of agitation. Effectiveness with which mechanical mixing can incorporate and disperse the particle throughout the melt depends on the constituent materials. Trials were directed by changing stirring speed from 200 to 500 rpm and stirring time. It was seen in the microstructure that the uniform distribution of reinforcement in the aluminum matrix reliant on stirring speeds, time, rate of cooling and volume fraction of reinforcement. Naher, Brabazon. Unfortunately, in normal practice the impact of the stirring activity on the flow pattern can't be seen as they happen in a nontransparent liquid metal inside a furnace. By taking this into consideration we can approximate the flow characteristics as such high temperature using simulation software. Now a day’s Computational Fluid Dynamics (CFD) is utilized for simulation because of low research cost, short research period and detailed description to fluid dynamic behavior, computational fluid dynamic have received rapid development in recent decades. In this study, commercial CFD software was used to simulate stir casting process.

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. Coatings: Research in the area of reinforcement/matrix interface coatings is necessary.

2. Methods
2.1. 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.

![Figure 2.1. Geometry of stirred tank](image)

2.2. Modelling and Numerical Simulation
2.2.1. Mesh
After completing the geometry, go to mesh, Ansys meshing is one of the critical aspects of engineering simulations.

![Figure 2.2. Full view of sweep mesh](image)

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. Non- uniform 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.

2.3. Simulation set up
In this simulation was performed using Multiphase volume of fluid model. The continuity, momentum equations are solved for phases and coupling between phases is pressure and interface exchange coefficients in solver. In this study Nano sized silicon-carbide particles and aluminum semi solid metal(SSM) materials are taken. In the models a volume of fluid of two phases and a viscous laminar were used to perform simulations. The standard k-ω turbulence model was used to resolve the turbulent solid-liquid flow field.

2.3.1. 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 Aluminum Semi Solid Metal.

2.4. Solution Methods
In this the pressure-velocity coupling simple scheme method and least squares cell based gradient and PRESTO pressure were used for calculation of cell interfaces and second order upwind discretization scheme was used for momentum, first order upwind used for volume fraction and first order upwind for turbulence kinetic energy, first order upwind used for transient formulation. The unsteady state solver was utilized to solve for all flow variables. Hybrid initialization was used in the solution initialization and patched the two regions.

2.5. Calculation
Here we are varying two parameters i.e., speed and Blade Angle and other one parameter are kept constant i.e., Viscosity of Semi Solid Metal with time.

![Figure 2.5](image)

Figure 2.5. Initial Volume Fraction of Silicon-carbide at '0' seconds

It shows the Volume Fraction of silicon-carbide over aluminum Semi Solid Metal at Zero seconds. After completion of run for calculation the results were obtained in two conditions.

3. Results
In this Nano sized silicon-carbide particle are uniformly distribute in aluminum semi solid metal(SSM).
In this condition, simulate the stir casting process to achieve uniform particle distribution at different heights in the tank. In this a small unit cell will be considered at five different locations the changes in percentage of volume fraction silicon-carbide over a period of time.

**Figure 3.1.** Contours of Volume Fraction of Silicon-Carbide for 300 rpm and 30 degrees’ blade angle at 60 seconds

### 3.1 Condition: - 1

Blade Angle = 30 Degrees and Speed of Stirrer = 300 rpm. At Height = 8cm

Graph: 3.1. Percentage of Silicon-Carbide Volume Fraction vs Time for 8cm Height.

### 3.2 Condition: - 2

Blade Angle = 30 Degrees and Speed of Stirrer = 100 rpm. At Height = 8cm

Graph: 3.2. Percentage of Silicon-Carbide Volume Fraction vs Time for 8cm 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. By comparing above graphs results, we can draw a tabular form of each Height in this we can found how much of time taken to achieve uniform distribution of reinforcement particles.

At Height = 8cm

| Table 3.1. Input condition and output conditions for different Heights. |
|-----------------------------|-----------------------------|-----------------------------|
| Stirrer speed (RPM)         | Blade Angle              | Time (sec)      |
| 300                         | 30                        | 65             |
| 100                         | 30                        | 90             |

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.

Table 3.2. Time taken to achieve uniform particle distribution

| Stirrer Speed (RPM) | Blade Angle | Height (cm) |
|---------------------|-------------|-------------|
|                     |             | 1           | 8          | 11         | 12          | 15          |
| 300                 | 30          | 57          | 65         | 69         | 65          | 68          |
| 100                 | 30          | 75          | 90         | 80         | 80          | 75          |

Graph 3.3  Time (sec) vs Height (cm)
We observed all the condition with the heights blue colored condition i.e., blade angle 30 degrees and stirrer speed 300 rpm is the best result shown because of all the heights are approximately same and less time to achieve uniform distribution of Nano sized Silicon-carbide particles as shown in table 3.2

4. Conclusion

Current markets for MMCs are primarily in military and aerospace applications. MMC components have been developed for use in aircraft, satellites, jet engines, missiles, and the National Aeronautics and Space Administration (NASA) space shuttles. Uniform mixing was observed at viscosity at 3.2 m Pa-sec. In this results of the simulation is conclude at 300 rpm stirrer speed and 30 degrees is more effective in all locations. At time of 57 seconds the reinforcement particles are starting to stabilize as shown in the graphs. In the bar graphs the time taken to achieve uniform particles distribution from the two conditions, the condition of 300 rpm stirrer speed and 30° blade angle are compared in all locations are approximately sametime were found i.e., 57, 65, 69, 65, and 68 (sec) are better uniformed distribution of SiC particles. It is also observed in the blue colored indication. 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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