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Simulation of stirring in stir casting

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Abstract

Now-a-days, Aluminum Matrix Composites (AMCs) are extensively used in industrial applications. For AMCs, stir casting is the cheapest and most flexible productiontechnique. Homogeneity of the reinforcement particle in the final cast determines the intended properties of composite material. However, the effect of the stirring parameters on the homogeneity of the particle distribution in the composite is not well studied. In this paper, the stirring action is simulated to correlate with the experimental results. For this a computational model of stir casting is developed. Effect of important stirring parameters such as speed and number of blades in the stirrer are studied. The effectiveness of stirring is quantified based on the shear rate developed in the flow field. The results obtained using the model was found to be in good correlation with the published experimental results.

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Keywords:

1. Introduction

The term composite refers to a combination of base matrix material and reinforcing particle. Depending upon the proportion of composite added, the final composite properties may be controlled. Composites made using aluminum as base metal is known as Aluminum Matrix Composites (AMCs). Various advantages in AMCs over base metal include greater strength, improved stiffness, reduced density, improved high temperature properties, controlled

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thermal expansion coefficient, thermal/heat management, enhanced and tailored electrical performance, improved abrasion and wear resistance, control of mass, improved damping capabilities etc. [1].

Nomenclature

AMC	Aluminium Matrix Composite
MMC	Metal Matrix Composite
SiC	Silicon Carbide
CFD	Computational Fluid Dynamics
UDF	User Defined Function

The AMC applications vary widely from industry to industry. Considerable interest for AMCs has been shown by Aerospace, Defense and Automobile industries. Particular applications of AMCs include Fan Exit Guide Vanes (FEGV) of gas turbine engines, ventral fins and fuel access cover doors for military aircrafts. Manufacture of hydraulic manifold for flight control is also carried out using Aluminum Matrix Composites. AMC Brake pads for cars and trains largely contribute to its demand in industries. Electronic industries also have huge demand for AMCs for packaging applications.

Production methods for manufacturing AMCs aim to achieve a uniform mix between base metal matrix and the reinforcing particles. Of various AMC manufacturing techniques, stir casting has the advantage of being the simplest, most flexible and cheapest process of all. Stir casting is highly favored in industries as it follows a conventional process path [2]. Stir casting uses mechanical stirring to vigorously stir the aluminum melt with simultaneous addition of reinforcement [3]. A mechanical stirrer is used for this purpose.

In general the mixing of powders in a liquid media includes three stages [4]. This is the same case with mixing of SiC particles in molten aluminum. The three stages are:

- Incorporation of the powder in the liquid media.
- Wetting of the powder particles.
- Breaking down of the particle agglomerates and aggregates.

Here, the first two stages of dispersion, i.e., the incorporation of particles in liquid medium and wetting of particles added, are dependent upon the physical and chemical nature of the particles as well as base metal. Hence minimal amount of control can be enforced in these two stages. Therefore, the dispersion can only be controlled in the final stage i.e. stirring of the melt. The force acting upon a particle doublet under stirring is given by the equation

$$F = 6\pi\eta a^2\gamma \tag{1}$$

Where, η is the kinematic viscosity of the fluid, a is the mean characteristic length of the particle and γ is the shear rate in the fluid.

The stir casting machine essentially consists of a furnace crucible with a stirrer provided from the top. A control panel having buttons for varying speed of stirrer, heat input rate of the furnace, height of the stirrer blades is also present. AMC stir casting process starts by filling the crucible with aluminum metal billets. The furnace heats the billets till they turn liquid. . Afterwards the stirrer is lowered into the crucible and vortex motion is imparted to the aluminum melt by rotation. Stirring action causes dispersion of SiC particles into molten aluminum. After sufficient mixing, the melt is transferred to casting mold using a bottom tap hole.

Various studies have been conducted to understand the stirring action in stir casting. A research work that examines the SiC distribution in stirred liquids was carried out by Rohatgi et al [5]. The work investigates the distribution of SiC in a SiC-water mixture during stirring. By selectively sampling and examining the mixture, effect of baffles in stirring process was found out. It has been reported that a SiC-water model can provide satisfactorily the results that are obtained by the actual casting experiment.