The Effect of Process Parameters on Mechanical Stir Casting Process

Shashi Prakash Dwivedi[1], Bhavya Gupta[2] and Devesh Chaudhary[3]
[1,2,3]*Noida Institute of Engineering Technology, Greater Noida*
Gautam Buddha Nagar, U.P. 201310, India
[1]shashi.mechanics@gmail.com

***Abstract*— In this study, composites-casting with an aluminium alloy C355 and 5(wt.%) of SiC reinforcement were made. Side by side investigations of tensile strength of the composite was done, 17 samples were fabricated for this study and these samples were machined as per dimension by which tensile test samples were obtained. Aluminium has low weight since its mechanical properties are not so good as compared to iron (Fe). So by reinforcing a material like SiC, mechanical properties can be improved of Al and it can be used in military and aerospace industry because of its low weight and good mechanical properties which is the primary requirement for aerospace industry. The mechanical properties of the fabricated composite are improved in relation to the base alloy, which have an enhanced wear resistance, favourable mechanical properties at room temperature.**

***Keywords*— MMC; RSM; Box Behnken Design; ANOVA; Tensile strength**

I. Introduction

Metal matrix composite have potential application in many fields because of their good physical and mechanical properties, such as high specific strength and stiffness, SiC particles. Reinforced Aluminium matrix composite can be fabricated with the stir casting process, which is one of the chief developments in fabricating Al-355/SiC composite.

The 355 type alloy, especially C-355, is one of a small group of select alloys used to make military and aerospace parts that meet the MIL-A-21180 specification for "Premium strength/Quality" casting (the 206 alloys are also in this group, as are Al-356 and Al-357).They are used in aircraft crank cases, gearboxes, housings and supports, as well as in impellers for superchargers. This alloy has already been used for semi solid processing and to a limited extent for squeeze casting as well. Silicon carbide (SiC), also known as carborundum, is a compound of Silicon and Carbon with chemical formula SiC. It occurs in nature as the extremely rare mineral moissa-nite. Grains of SiC can be bonded together by sintering to form very hard ceramics which are widely used in application requiring for endurance, such as car brakes, car clutches and ceramics plate in bullet proof vests.Stir casting is a method of casting process in which materials are mixed by stirring rotation to form vortex and then prepared molten material poured into the mould for solidification [1-2].

II. Literature Review

Han Jian-min et al described that a stir casting method is one of the most competitive methods for fabricating SiC particle reinforced Aluminium matrix composites because of its low cost with cost with competitive quality [1]. Z.MISKOVIC et al explained composites-casting with Aluminium A356 alloy base and additions of 1, 2 and 3 % (wt.) of Al2O3 reinforcements of 12 micrometer size were made [2]. Shuewian H.Juang et al preformed A356 alloy with thixotropic structure (designed SSM-A356) was systematically studied on mechanical properties in order to establish the database for further investigations in forming and heat treatment [3]. METIN KOK studied the machinability 2024Al/Al203 particle composite was investigated in terms of tool wear, tool life and surface roughness by turning specimens withTiN(K10) coated and HX uncoated carbide tools in different cutting conditions [4]. Jashmi Hasim described that in a normal practice of stir casting technique, cast metal matrix composites (MMC) is produced by melting the matrix material in a vessel, and then the molten metal is stirred thoroughly to form a vortex and the reinforcement particles are introduced through the side of the vortex formed. From some point of view this approach has dis-advantages, mainly arising from the particle addition there is undoubtedly local solidification of the melt induced by the particles, and this increase the viscosity of the slurry [4]. Amir Parkel et al found out the effect of extrusion ratio on the microstructure, mechanical properties, and fracture behavior of metal-matrix composite (MMCs) of AA6061 alloy reinforced with 10 volume percent particulate SiC with an average size of 46 micrometer was studied. Graham Withers described that Aluminium composites with excellent mechanical and physical properties can be produced at low cost by reinforcing the Aluminium matrix with spherical ceramic particles derived from fly ash. Chennakesava Reddy et al describes that the material selection criteria involve the requirement of high strength and good corrosion resistance Aluminium alloys for the matrix materials [5].

III. METHODOLOGY

Response surface methodology (RSM) is a collection of mathematical and statistical techniques for empirical model building. By careful design of experiments, the objective is to optimize a response (output variable) which is influenced by several independent variables (input variables). An experiment is a series of tests, called runs, in which changes are made in the input variables in order to identify the reasons for changes in the output response. Originally, RSM was developed to model experimental responses (Box and Draper, 1987), and then migrated into the modeling of numerical experiments.

The difference is in the type of error generated by the response. In physical experiments, inaccuracy can be due, for example, to measurement errors while, in computer experiments, numerical noise is a result of incomplete convergence of iterative processes, round-off errors or the discrete representation of continuous physical phenomena. The application of RSM to design optimization is aimed at reducing the cost of expensive analysis methods (e.g. finite element method or CFD analysis) and their associated numerical noise. The problem can be approximated as described in with smooth functions that improve the convergence of the optimization process because they reduce the effects of noise and they allow for the use of derivative-based algorithms. Venter et al. (1996) have discussed the advantages of using RSM for design optimization applications.

An easy way to estimate a first-degree polynomial model is to use a factorial experiment or a fractional factorial design. This is sufficient to determine which explanatory variables have an impact on the response variable (s) of interest. Once it is suspected that only significant explanatory variables are left, and then a more complicated design, such as a central composite design can be implemented to estimate a second-degree polynomial model, which is still only an approximation at best. However, the second-degree model can be used to optimize (maximize, minimize, or attain a specific target for) a response.

For example, in the case of the optimization of the calcinations of roman cement, the engineer wants to find the levels of temperature($x1$) and time ($x2$) that maximize the early age strength (y) of the cement. The early age strength is a function of the levels of temperature and time, as follows:

$$y = f(x1, x2) + e \quad (1)$$

Where 'e' represents the noise or error observed in the response y. The surface represented by $f(x1, x2)$ is called a response surface.

The Box-Behnken design is an independent quadratic design in that it does not contain an embedded factorial or fractional factorial design. In this design the treatment combinations are at the midpoints of edges of the process space and at the center. These designs are rotatable (or near rotatable) and require 3 levels of each factor. The designs have limited capability for orthogonal blocking compared to the central composite designs [6].

IV. EXPERIMENTATION

A. Material selection

1) Matrix Alloy: In this study, the alloy C-355 is used, which is widely used Aluminium casting alloy. It has a very good mechanical strength, ductility, hardness, fatigue strength, pressure tightness, fluidity and machinability. This alloy is used in many industrial applications such as airframe casting, machine parts, truck chassis parts, aircrafts and missile components and structural parts requiring high strength.

2) Reinforcement Material: Silicon carbide is used as the reinforcement phase. To select a suitable reinforcement material for Aluminium, important facts such as density, wettability and thermal stability were considered. Silicon carbide is a widely used reinforcement material because of its good wettability with the Aluminium matrix. However, SiC reacts with molten Aluminium at temperatures above 1000 K to form $Al2O3$, releasing Silicon into the matrix. Nevertheless, this reaction can be suppressed by high Si content.

B. Experimental Procedure

Aluminium alloy C355 heated to above its liquid temperature in muffle furnace. The temperature was recorded using chromel-alumel thermocouple which was 700°C to 790°C. The C355 Aluminium alloy was firstly melted in furnace, refined and the temperature was maintained as per required temperature. SiC particle with

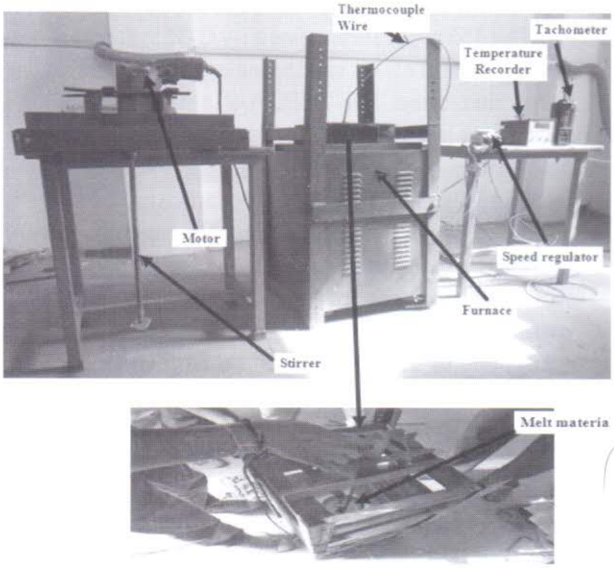

Fig. 1 Experimental setup of mechanical stir casting