

## **Wear Study Of Stir Cast Aa7075 Metal Matrix Composites And Optimization Of Wear Using Grey Relational Analysis**

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### **Abstract**

The aim involved in designing metal matrix composite materials is to combine the desirable attributes of metals and Ceramics. Present work is focused on the machining and preparation of AA7075/SiCp composites produced by the stir casting process by taking different Reinforcement % of SiCp by weight (0, 5, 7.5, and 10). Hardness Test and Wear test calculations performed on the samples obtained by the stir casting process. For wear testing a plan of experiment based on L16 Taguchi orthogonal array is used to acquire the wear data. Grey relational analysis approach is used for optimization of aluminium based metal matrix composite to determine metal matrix properties with certain chemical composition and identifies the most significant process parameters which will affect the properties. An analysis of variance is employed to investigate the influence of four controlling parameters, viz, SiCp content, normal load, sliding distance & sliding speed on dry sliding wear of the composites. It is observed that SiCp content, sliding distance, and Sliding Speed significantly affects the dry sliding wear while Normal Load effect on wear is almost negligible. At last the micro-structural study of the wear surface and composites indicates the nature of wear to be mostly adhesive & distribution of the particles in the composites.

### **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 applications where conventional engineering materials, such as steel are used. MMCs exhibit significantly higher stiffness and mechanical strength compared to matrix alloys, but often suffers from lower ductility and inferior fracture toughness. MMC brings the ability to withstand higher tensile and compressive stresses by the transfer and distribution of an applied load from the ductile matrix to the reinforcement material. This load transfer is only possible due to the existence of a interfacial bond between the reinforcement elements and

the matrix material. Therefore, appropriate selection of reinforcement material and its properties coupled with a good fabrication method. 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. There are also various types of the reinforcement material continuous and discontinuous fiber and particle. Although the mechanical properties of the MMC with discontinuous fiber or particles (DRMMC), are not as good as those of continuous fiber reinforced composites, the isotropic properties and low cost of DRMMCs make them potentially useful materials. Silicon carbide and aluminum alloys have been widely used as reinforcement and matrix material respectively, because of the compatibility between these materials, and their potential properties when combined. The main factors controlling the properties of MMC's 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. The selection of high silicon content aluminum alloy was found to delay the chemical reaction whereas the use of inert atmosphere, and the controlled stirring parameters was found.

### **II. MATERIAL SELECTION**

The aim of designing metal matrix composite materials is

to combine the desirable attributes of metal and ceramics. The addition of high strength, high modulus refractory particles to a ductile metal matrix will produce a material whose mechanical properties are intermediate between the matrix alloy and the ceramic reinforcement. Metals have a useful combination of properties such as high strength, ductility, and high temperature resistance, but sometimes some of them have a low stiffness value, whereas ceramics are normally stiff and strong, but brittle. For example, aluminium and silicon carbide have very different mechanical properties with Young's modulus of 70Gpa and 400Gpa, coefficients of thermal expansion of  $24 \times 106/^{\circ}\text{C}$  and  $4 \times 106/^{\circ}\text{C}$ , and yield strength of 350 Mpa and 600 Mpa respectively. By combining these materials e.g. AA7075 (at T6 condition) with 17 volume fraction of SiC particle, a MMC with Young's modulus of 96.6 Gpa, and yield strength of 510 Mpa can be produced by carefully controlling the relative amount and distribution of the ingredients of the composites, as well as the processing conditions these properties can be further improved. There are a number of criteria that need to be considered before a right selection of the material can be made. Some of these criteria are inter-related several criteria for the selection of matrix and reinforcement materials are as follows: i) Compatibility ii) Thermal properties iii) Fabrication method iv) Application v) Cost vi) Properties vii) Recycling.

**III. EXPERIMENTAL DESIGN AND OBSERVATION**

**Stir casting apparatus**

It consists of a conical shaped graphite crucible used for fabrication of AMCs, as it withstands high temperature which is much more than required temperature [680°C]. Along that graphite will not react with aluminum at these temperatures. This crucible is placed in a muffle which is made up of high ceramic alumina. Around which heating element is wound. The coil which acts as heating element is Kanthal-A1. This type of furnace is known as resistance heating furnace. It can work up to 900°C reach within 45 min. Aluminium, at liquid stage is very reactive with atmospheric oxygen. Oxide formation occurs when it comes in contact with the open air. Thus all the process of stirring is carried out in a closed chamber with nitrogen gas as inert gas in order to avoid oxidation. Closed chamber is formed with help of steel sheet. This reduces heat loss and gas transfer as compared to an open chamber. A K type thermocouple whose working range is -200°C to 1250°C is used to record the current temperature of the liquid. Due to corrosion resistance to atmosphere SS is selected as stirrer shaft material. One end of shaft is connected to

0.5 hp PMDC motor with flange coupling. While at the other end blades are welded. 3 blades are welded to the shaft at 45°C. A constant feeding rate of reinforcement particles is required to avoid coagulation and segregation of the particles. This can be achieved by using a hopper. Aluminium alloy matrix will be formed in the crucible by heating aluminum alloy ingots in a furnace. A stirring action is started at a slow rate of 30 rpm and increases slowly in between 300 to 600 rpm with a speed controller. A mixture of reinforcements (SiC) is to be incorporated in the metal matrix at a semisolid level near 640°C. Dispersion time is to be taken as 5 minutes. After that slurry is reheated to a temperature above melting point to make sure slurry is fully liquid and then it is poured into a mould.



**Figure :Casting after solidification Cast work piece**

**Specimen Size:**

In this project for conducting wear test on pin-on-disc tribometer, Al 7075 MMC samples are used. The specifications of raw material and required specimen are mentioned in the below table.

	Raw material size	Required specimen size
Length	150mm	15mm
Diameter	50mm	6mm

**IV. DESIGN OF EXPERIMENTS:**

In the present experimental study, four parameters such as Sliding distance, Cutting velocity, Load and Sliding Speed have been considered as process variables with 4,4,4,4 levels respectively. The levels have been so selected based on the effects of these parameters on the outputs and trial and error tests were conducted for deciding the values for the input variables. Experiments have been carried out using partial factorial experimental design, which consists of 16 combinations of Sliding distance, Load and Sliding Speed.

**V. MACHINING OF COMPOSITE BY EDM**

After completing the casting process the composite metal casting is machined by the Electric Discharge Machining (EDM) sometimes colloquially also referred to as spark machining, spark eroding, burning, die sinking or wire erosion, is a manufacturing process whereby a desired shape is obtained using electrical discharges (sparks). Electric discharge machining provides an effective manufacturing technique that enables the production of parts made of special materials with complicated geometry which is difficult to produce by conventional machining processes. Controlling the process parameters to achieve the required dimensional accuracy and finish placed this machining operation in a prominent position. For that reason, electric discharge machining has found broad applications in industry.

The input parameters of the electrical discharge machine are current, pulse on time and pulse off time are obtained for each experiments from the design expert software. After the completion of the machining process two machining characteristics material removal rate and surface roughness are calculated and analyzed. After calculating the values they are entered in the software and the mathematical model for MRR and surface roughness are generated. The optimum values for the machining are obtained with the help of mathematical model. The input parameters and the machining characteristics were plotted to obtain the clear view about the influence of the parameters on the characteristics.

**VI. RESPONSE VARIABLES AND MACHINING PARAMETERS**

Pulse on time is defined as the time during which the machine is performed. The machining process become faster after increasing the pulse on time the metal removal rate increase and poor surface finish on the material surface also given in the pulse on time process.

Pulse off Time Pulse off time process is the time during which re-ionization of the dielectric takes place. An insufficient off time can leads to erratic cycling and retraction of the advancing servo thereby slowing down the operation cycle. The main reason for choosing the

above pulse on/off time is to fixing the time for the time interval of time period. This is the main reason for choosing the pulse ON/OFF time. Current This is the amount of power used in discharge machining, measured in units of amperage, and is the most important machining parameter in EDM. In each on-time probe the current increase until it reaches a present level, which is expressed as the peak current. Higher value of current leads to rough surface finish operations and wider creators on work material. Its higher value improves MRR, but at the cost of surface finish and tool wear. Hence it is more important EDM because the machined cavity is a replica of tool electrode and excessive wear will hamper the accuracy of materials.

Input Parameters	Current (Amps)	Pulse On Time (µS)	Pulse Off Time (µS)
RANGE	10-20	40-60	7-9

**Optical Microscopy Test:**

The microstructures at different magnifications in figures are clearly shows grain boundaries. The grains are observed to be of a varied size range. The shape of the grains is found to be in the form irregular polygons. The microstructure consists of equiaxed grain with grain size No: 6 to 7 in the matrix. Precipitates can be observed along the grain boundary in the microstructure. These dots are carbide inclusions. The inclusions observed are of a fairly narrow size range and are randomly distributed. The precipitates differ a lot in the size; some of them are very large when compared to others, which are very small.

**Density Test:**

Density is the physical property that reflects the characteristics of the composites. In a composite, the production of the matrix and the reinforcement have been expressed either as the weight fraction(w), which is relevant to fabrication, or the volume fraction V, which is commonly used in property calculations. by relating weight and volume fractions via density, the following expression has been obtained and its general form has been known as rule of mixture. Rule of Mixtures is a method of approach to approximate estimation of composite material properties, based on an assumption that a composite property is the volume weighted average of the phases (matrix and dispersed phase) properties.

**Process Parameter and Their Levels: -**

Process	1	2	3	4
Reinforce	0	5	7.5	10
Load (N)	5	10	15	20
Sliding	500	1000	1500	2000
Sliding	179	239	298	358
Cutting velocity	0.75	1	1.25	1.7

**Confirmatory Test**

A confirmatory test was carried out for the above optimum input parameters such as current, pulse on time and pulse off time. The output values, MRR and SR are shown in the following table (4) using copper electrode in EDM.

Current (Amps)	Pulse on time (µs)	Pulse off time (µs)	MRR (g/min)	SR (µm)
13	50	8	0.0821	10.3

Table Confirmation test values

We can find out the effect of factors on response by analysis of variance. From the table 5.10 it is clear that sliding distance have maximum effect on wear. Speed and load also have some effect on wear followed by reinforcement but distance has a very less effect on wear.

**CONCLUSIONS**

The present work has successfully demonstrated the production of aluminum 7075 based metal matrix composites with % of SiCp by weight as reinforcement through stir casting process. Physical and mechanical characteristics of produced composites and the application of Taguchi based Grey relational analysis for multi-objective optimization of process parameters in mechanical and physical characterization study of Aluminum 7075-based metal matrix composites has been studied and analyzed. The conclusions drawn from the present work are as follows:-

An attempt has been made to fabricate samples of AA7075-based metal matrix composites by varying % of SiCp by weight through stir casting process.

- 1) Hardness of the cast sample is studied and found to be increasing with increasing % of SiCp by

weight.

- 2) The highest Grey relational grade of 1 is observed for the experimental run 6, shown in response table (Table No. 14) of the average Grey relational grade, which indicates that the optimal combination of control factors and their levels are 10% SiC, 10N load, 500m Sliding distance and 358rpm Sliding speed.
- 3) The order of importance for the controllable factors to the minimum wear, density and maximum hardness in sequence, is the Reinforcement %, Sliding Speed, Load and Sliding distance; order to the minimum wear, in sequence is the Reinforcement %, Sliding Speed, and Load. As Sliding distance is almost affecting the wear.
- 4) From the Taguchi based Grey Relational analysis the optimal combination of process parameters for minimum wear, density & maximum hardness is found to be A2B1C4D4, i.e., higher reinforcement (% of SiC by weight), along with lowest level of applied load, sliding speed and sliding distance. With this combination we found that the wear is less than other all experimental value in the DOE.
- 5) From the microstructure study of wear surface and distribution of Reinforcement particles it is observed that mostly wear due to adhesive wear mechanism which has occurred on the wear track and also some traces of abrasive wear mechanism .
- 6) Reinforcement particles are uniformly distributed up to 10% and after that higher density particles are segregated somewhere in the metal matrix composites.

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