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Parametric Effects during Nonconventional Machining of PR-AL-SiC-MMC, s by CNC Wire cut EDM

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Abstract— ***The widespread adoption of particulate metal matrix composites for engineering applications has been hindered by the high cost of producing components. Although several technical challenges exist with casting technology yet it can be used to overcome this problem. Achieving a uniform distribution of reinforcement within the matrix is one such challenge, which affects directly on the properties and quality of composite material. In this study aluminum (Al-6063)/ Silicon carbide (SiC) reinforced particles metal-matrix composites (MMCs) are fabricated by melt-stirring technique. The MMCs bars and circular plates are prepared with varying the reinforced particles of SiC by weight fraction ranging from 5%, 10%, 15% and 20%. The average reinforced particles sizes of SiC are 220 mesh, 300 mesh and 400 mesh respectively. The stirring process is carried out at 200 rev/min rotating speed by graphite impeller for 15 min. The series of machining tests are performed on CNC Wire cut EDM. Prepared specimens of Al/SiC MMCs are used as work piece (anode), brass wire of diameter 0.25 mm is used as wire electrode and water is used as the dielectric fluid. The parameters are investigated Cutting Speed Vc mm/min, Width of cut b mm, Spark Gap Wg mm, Metal Removal Rate MMR mm^3 /min, Surface roughness Ra (µm), Peak Roughness Rz(µm) for each experiment by varying mesh size (220 mesh, 300mesh and 400 mesh) of SiC Particles, and weight fractions wt % (5%, 10%, 15%, and 20%) of SiC particles. The investigation of results are done graphically.***

Index Terms—**Cutting Speed (Vc), Metal Removal Rate (MMR), Particulate Reinforced Al/SiC Metal Matrix Composites (PRALSICMMC), Peak Roughness (Rz), Silicon Carbide (SiC), Surface roughness (Ra).**

I. INTRODUCTION

The correct selection of manufacturing conditions is one of the most important aspects to take into consideration in the majority of manufacturing processes and, particularly, selection of parameters related to CNC Wire cut Electrical Discharge Machining (EDM). Metal Matrix Composites (MMC's) have very light weight, high strength, and stiffness and exhibit greater resistance to corrosion, oxidation and wear. Fatigue resistance is an especially important property of Al-MMC, which is essential for automotive application. These properties are not achievable with lightweight monolithic titanium, magnesium, and aluminum alloys. Particulate metal matrix composites have nearly isotropic properties when compared to long fibre reinforced composite. Metal Matrix Composite (MMC) is engineered combination of metal (Matrix) and hard particles (Reinforcement) to tailored properties. Stir casting is accepted as a particularly promising route, currently can be practiced commercially. Its advantages lie in its simplicity, flexibility and applicability to large quantity production. It is also attractive because, in principle, it allows a conventional metal processing route to be used, and hence minimizes the final cost of the product. This liquid metallurgy technique is the most economical of all the available routes for metal matrix composite production and allows very large sized components to be fabricated [1]. The cost of preparing composites material using a casting method is about one-third to half that of competitive methods, and for high volume production, it is projected that the cost will fall to one-tenth [2]. Among the non-conventional methods, Wire Electrical Discharge Machining (WEDM) is most widely and successfully applied process in machining of hard metals or those that would be very difficult to machine with traditional techniques. Prediction and proper control of WEDM parameters during actual machining is of immense important, which may increase the machining efficiency and as well as can improve the quality of machining product. Variation of geometric inaccuracy due to wire lag against parametric settings was investigated [3]. From the past literature survey [4-6], work has been done on WEDM parameters using Taguchi methodology. Predictions for wire rupture prevention during WEDM operation [6]. Parametric Study [7] of Electrical Discharge Machining of ALSI 304 Stainless steel But no exhaustive work has been carried out to study the effects of various setting parameters. In this study aluminum (Al-6063)/SiC Silicon carbide reinforced particles metal-matrix composites (MMCs) are fabricated by melt-stirring technique. The MMCs bars and circular plates are prepared with varying the reinforced particles of SiC by weight fraction ranging from 5%, 10%, 15% and 20%. The average reinforced particles sizes of SiC are 220 mesh, 300 mesh and 400 mesh respectively. The stirring process is carried out at 200 rev/min rotating speed by graphite impeller for 15 min. The series of machining tests are performed on CNC Wire cut EDM. Prepared specimens of Al/SiC MMCs are used as work piece (anode), brass wire of diameter 0.25 mm is used as wire electrode and water is used as the dielectric fluid. The parameters are investigated Cutting Speed Vc mm/min, Width of cut b mm, Spark Gap Wg mm, Metal Removal Rate MMR mm^3 /min, Surface roughness Ra (µm), Peak Roughness Rz(µm) for each experiment by varying mesh size (220 mesh, 300mesh and 400 mesh) of SiC Particles and weight fractions wt % (5%, 10%, 15%, and 20%) of SiC particles. The investigations of results are done

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graphically.

II. EXPERIMENTATION

A. Fabrication of Al/SiC metal matrix composites

Silicon Carbide (SiC) reinforced particles of average particle size 220 mesh, 300 mesh, 400 mesh respectively are used for casting of Al-MMC,s by melt-stir technique. Table (i) represents the chemical composition of commercially available Al-matrix used for manufacturing of MMC. Different dimensions of round bars with 5 vol%, 10 vol%,15 vol% and 20% of reinforced particles of sizes 220 mesh, 300 mesh, 400 mesh respectively.

Table I Chemical composition of matrix Al 6063 alloy.

Elements of Al 6063	Si	Mn	Mg	Cu	Fe	Ti	Al
%	0.44	0.07	0.6	0.018	0.2	0.008	98.664

Experiments are carried out on commercially available aluminum (Al6063) as matrix and reinforced with Silicon Carbide (SiC) particulates. The melting was carried out in a clay-graphite crucible placed inside the resistance furnace. An induction resistance furnace with temperature regulator cum indicator is utilized for melting of Al/SiC-MMCs “Fig. 1(a)” shows designed and developed stirring setup of

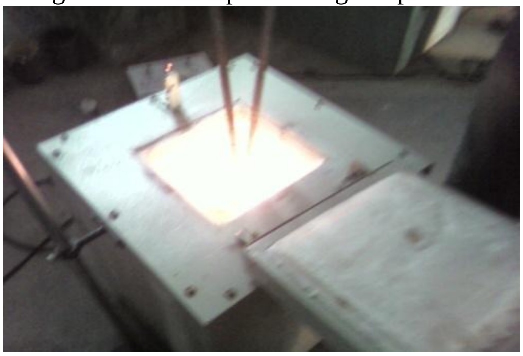

Fig. 1(a) Designed and developed stirring setup

Induction resistance furnace along with temperature regulator cum indicator. Aluminum alloy (Al 6063) was first preheated at 450^{0}C for 2 hr before melting and SiC particulates were preheated at 1100^{0}C for 1 hr 30 min to improve the wetting properties by removing the absorbed hydroxide and other gases. The furnace temperature was first raised above the liquid state temperature, cooled down to just below the liquid state temperature to keep the slurry in a semi-solid state. At this stage the preheated SiC particles were added and mixed mechanically. The composite slurry was then reheated to a fully liquid state and mechanical mixing was carried out for 20 min at 200 rpm average stirring speed. In the final stage of mixing, the furnace temperature was controlled within 760 ± 10^{0}C and the temperature was controlled at 740^{0}C. Moulds (size 40mm diameter ×170 mm long) made of IS-1079/3.15mm thick steel sheet were preheated to 350^{0}C for 2 h before pouring the molten Al/SiC -MMC. the permanent mould was prepared of steel sheet utilized for casting of 40mm diameter ×170mm long bar

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Fig.1 (b) Pouring mixture of molten Al and SiC particles

Fig.1 (c) Prepared work pieces of Al/SiC-MMCs

Fig.1 (b) shows pouring mixture of molten Al and SiC particles and Fig.1 (c) shows prepared work piece of Al/SiC-MMCs of 300 mesh. Then fabrication of composite was followed by gravity casting. Similar process was adapted for preparing the specimens of varying mesh sizes and weight fractions. The uniform size (dia. 35 mm and thickness is 6mm) of work piece was given by lathe machine.

B. Experimental Techniques

The different sets of experiment work performed on an Elektra opticut - 434 CNC wire cut-EDM machines, Manufactured by Electronic Machine Tools Ltd. Pune. Model G-30, Pulse Generator Model : EPULSE- 20 C(Opticut). The work material, electrode and the other machining condition are as follows.

(i) Work- piece : Al/SiC- MMC [anode]
(ii) Electrode (tool): 250µm Φ brass wire (cathode)
(iii) Work piece size : height 6 mm, diameter 35 mm
(iv) Cutting length, : 20 mm
(v) Specific resistance of die-electric fluid, mA : 1-3
(vi) Die – electric temperature, °C : 22 – 25
(vii) Flushing pressure of die- electric fluid, kg/cm^2 : 15.

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Fig.2 Machined number of Cubes by WEDM

A number of *Cubes (size 5mmX5mmX6mm)* were cut as shown in "fig. 2" The mean cutting speed data (Vc, mm/min) is calculated from the available direct data displayed in the computer monitor of the machine Elektra opticut - 434 CNC wire cut-EDM and the data recorded from the actual length of cutting during various settings of experimental machining operation. Surface roughness (R_a and R_z) µm is measured using a Surfcom 120A-TSK, a roughness measuring instrument and the width of cuts (b, mm) are measured using a Digimatic Caliper Mitutoyo. Gap current (Ig, amp) is directly recorded from the ammeter of the Elektra Opticut - 434 CNC wire cut-EDM machines. The spark gap (W_g, µm) is calculated from the relation as follows.

$$2\,W_g + d = b \qquad (1)$$

Where, W_g is the spark gap or gap width, µm; d, diameter of electrode wire (250 µm Φ, brass wire); and b is the width of cut, µm. The metal removed rate (MRR) is calculated as followed

$$Y_{MRR} = V_c\, b\, h \;\; mm^3/min \qquad (2)$$

Where, V_c is the cutting speed, mm/min; b, width of cut, mm; and h is the height of the work piece, mm. The design of experiments technique has been implemented to conduct the experiments. It is a powerful work tool which allows us to model and analyze the influence of designed variant parameters and designed constant parameters over the measured parameters. These measured parameters were unknown functions of the former designed parameters. The following designed experimental settings were done-

(1) Variant parameter was mesh size (220 mesh, 300 mesh and 400 mesh and Al 6063 alloy) of Sic particles and Constant parameters were Wt. % of Sic= 15%, pulse peak current I_p =4 amp, pulse on time T_{on} =6 µ sec, pulse off time T_{off}= 6 µ sec, pulse peak voltage V_p =50 volts, Spark gap set voltage S_V = 25 volts, Wire Feed Rate W_F = 6 and Wire Tension W_T = 1020, Machining was done and parameters were measured Cutting Speed Vc mm/min, Width of cut b mm, Spark Gap Wg mm, Metal Removal Rate mm^3 /min, Surface Roughness Ra(µm) and Peak Surface Roughness Rz(µm). The investigations of results are done graphically.

(2) Variant parameter was Wt. % (5%, 10%, 15% and 20%) of Sic particles and Constant parameters were Mesh size of Sic= 300, pulse peak current I_p =4 amp, pulse on time T_{on} =6 µ sec, pulse off time T_{off}= 6 µ sec, pulse peak voltage V_p =50 Volts, Spark gap set voltage S_V = 25 volts, Wire Feed Rate W_F = 6 and Wire Tension W_T = 1020, Machining was done and parameters were measured Cutting Speed Vc mm/min, Width of cut b mm, Spark Gap Wg mm, Metal Removal Rate mm^3 /min, Surface roughness Ra (µm)and Peak Surface roughness Rz (µm)The investigations of results are done graphically.

III. RESULTS AND DISCUSION

A. Results Graph

All the experimental results are presented on graphs from figure 3 to 14 as shown hereunder. In these graphs all measured parameters Cutting Speed Vc mm/min, Width of cut b mm, Spark Gap Wg mm, Metal Removal Rate mm^3 /min, Surface Roughness Ra (µm) and Peak Surface Roughness Rz (µm) are taken on vertical axes, variant parameters mesh size (220 mesh, 300mesh and 400 mesh) of SiC Particles, weight fractions wt % (5%, 10%, 15%, and 20%) of SiC particles are on horizontal axes and constant parameters are shown in box.

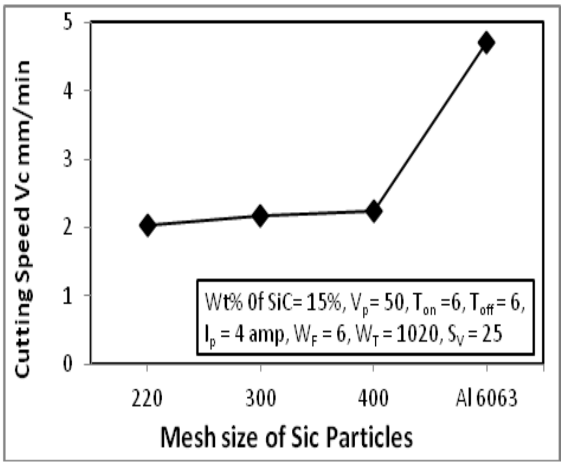

Fig. 3 Cutting Speed Vc mm/min Vs Mesh size of Sic Particles

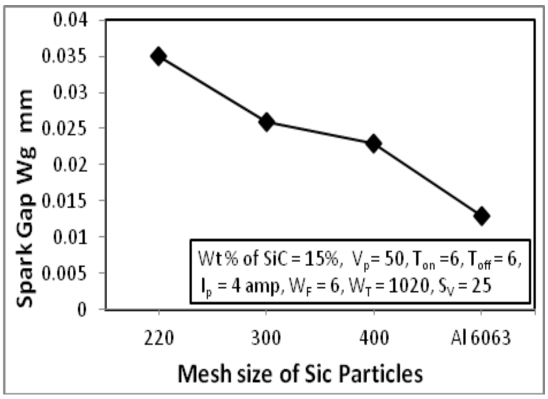

Fig. 4 Spark Gap Wg mm Vs Mesh size of Sic Particles

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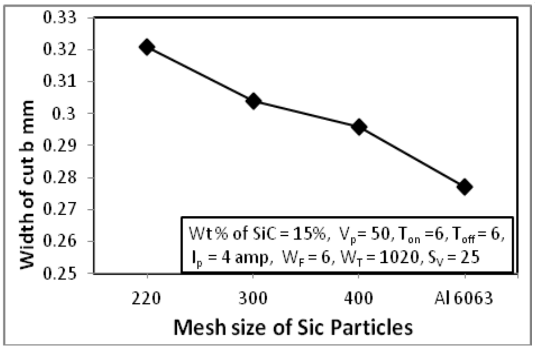

Fig. 5 Width of cut b mm Vs Mesh size of Sic Particles

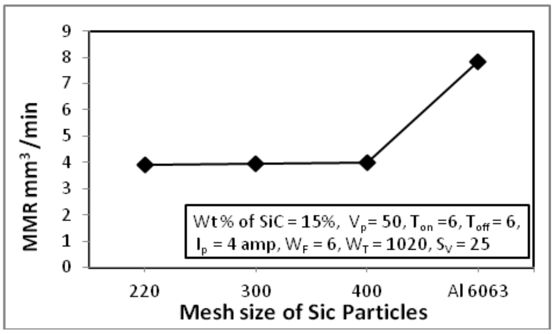

Fig. 6 MMR mm^3 /min Vs Mesh size of Sic Particles

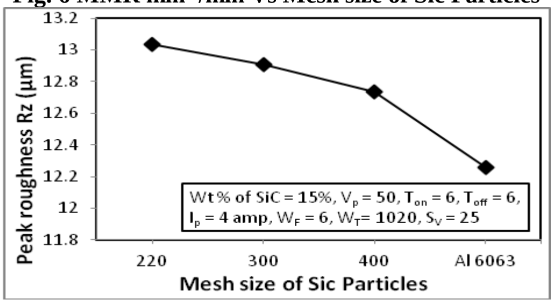

Fig. 7 Peak Roughness Rz(µm) Vs Mesh size of Sic Particles

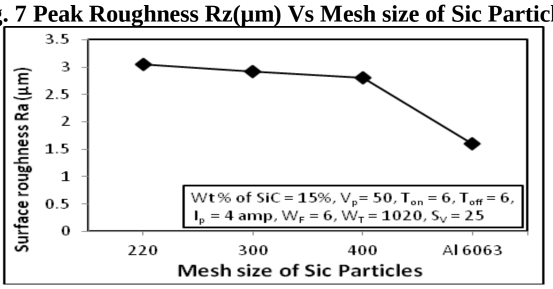

Fig. 8 Surface roughness Ra (µm) Vs Mesh size of Sic Particles

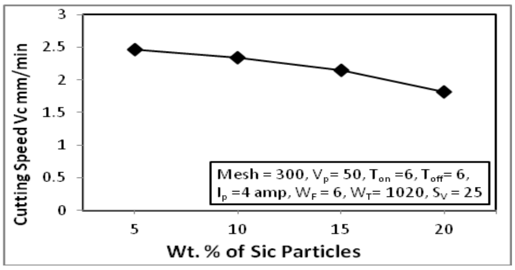

Fig. 9 Cutting Speed Vc mm/min Vs Wt. % of Sic Particles

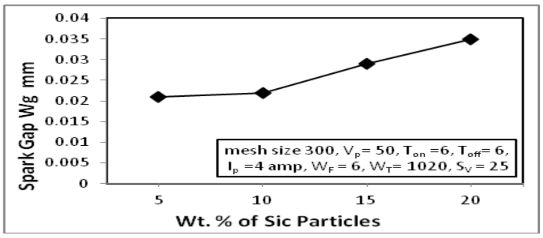

Fig. 10 Spark Gap Wg mm Vs Mesh size of Sic Particles

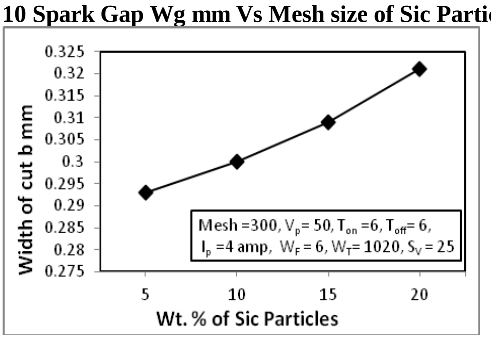

Fig. 11 Width of cut b mm Vs Wt. % of Sic Particles

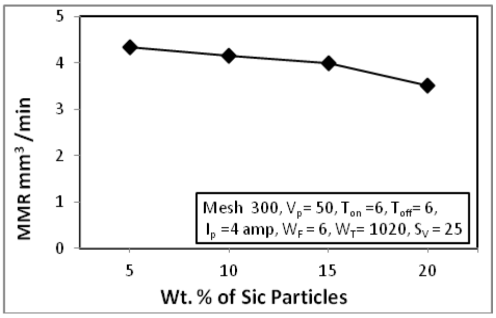

Fig. 12 MMR mm^3 /min Vs Wt. % of Sic Particles

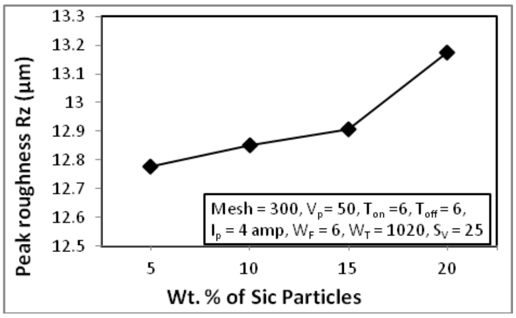

Fig.13 Peak Roughness Rz(µm) Vs Wt. % of Sic Particles

IV. CONCLUSION

Maximum cutting speed and MRR can be achieved at high value of Mesh size and at low value Wt. % of Sic Particles. Smooth machining can be achieved at high value of Mesh size and at low value Wt. % of Sic Particles.

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