Parametric Effects during Nonconventional Machining of PRALSICMMC by EDM

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ABSTRACT

Advance Particulate Reinforced Al/SiC Metal Matrix Composites (PRALSICMMC) is gradually becoming very important materials in manufacturing industries e.g. aerospace, automotive and automobile industries due to their superior properties such as light weight, low density, high strength to weight ratio, high hardness, high temperature and thermal shock resistance, superior wear and corrosive resistance, high specific modulus, high fatigue strength etc. In this study aluminium (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 EDM. Prepared specimens of Al/SiC MMCs are used as work piece (anode), copper electrodes are used as tool (cathode) and kerosene is used as the dielectric fluid. The parameters are investigated Time taken, Tool wear Rate(TWR) and Metal Removal Rate(MRR) for each experiment by varying mesh size (220 mesh, 300mesh and 400 mesh) of SiC Particles, weight fractions wt % (5%, 10%, 15%, and 20%) of SiC particles, Pulse Peak Current I_P (2 Amp, 6 Amp, 10 Amp,14 Amp), Pulse on time T_{on} (30 μ sec, 50 μ sec, 70 μ sec and 90 μ sec), Pulse off time T_{off} (3 μ sec, 5 μ sec, 7 μ sec and 9 μ sec) and gap voltage Vg (25 Volts, 30 Volts, 35 Volts and 40 Volts). The investigations of results are done graphically.

KEYWORDS: Particulate Reinforced Al/SiC Metal Matrix Composites (PRALSICMMC), Silicon Carbide (SiC), Melt Stirring Technique, Tool Wear Rate(TWR) and Metal Removal Rate(MRR).

1. INTRODUCTION

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 aluminium 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, EDM is most widely and successfully applied process in machining of hard metals or those that would be very difficult to machine with traditional techniques. The material is removed from the work piece by the thermal erosion process, i.e., by a series of recurring electrical discharges between a cutting tool acting as

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an electrode and a conductive workpiece in the presence of a dielectric fluid. This discharge occurs in a voltage gap between the electrode and work piece. Heat from the discharge vaporizes minute particles of work piece material, which are then washed from the gap by the continuously flushing dielectric fluid [3]. The effectiveness of the EDM process with tungsten carbide is evaluated in terms of material removal rate, the relative wear ratio and the surface quality. the composite electrodes obtained a higher MRR than Cu metal electrodes; the recast layer was thinner and fewer cracks were present on the machined surface [4]. The regression models [5] and Taguchi methods [6] are used for modeling and analyzing the influence of process Variables computer simulation of EDM machining with the side and face of the electrodes is developed [7]. The test results showed the electric discharge machining of WC-Co confirms the capability of the system of predictive controller model based on neural network with 32.8% efficiency increasing in stock removal rate [8].

In this study aluminium (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 EDM. Prepared specimens of Al/SiC MMCs are used as work piece (anode), copper electrodes are used as tool (cathode) and kerosene is used as the dielectric fluid. The parameters are investigated Time taken in each experiment, Tool wear Rate(TWR) and Metal Removal Rate(MRR) by varying mesh size(Al, 220 mesh, 300mesh and 400 mesh) of Sic Particles, weight fractions wt % (5%, 10%, 15%, and 20%) of Sic particles, Peak current Ip(2 Amp,6 Amp,10 Amp,14 Amp), T_{on} (30, 50, 70 and 90), T_{off} (3, 5, 7 and 9) and gap voltage Vg (25 Volts, 30 Volts, 35 Volts and 40 Volts).

2. EXPERIMENTATION

2.1 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 aluminium (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. Aluminium 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 liquidus temperature, cooled down to just below the liquidus temperature to keep the slurry in asemi-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

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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 .

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

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

Fig.1 (b) shows pouring mixture of molten Al and SiC particles and Fig.1 (c) shows prepared workpiece 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 workpiece was given by lathe machine.

2.2 Fabrication of electrodes

Copper electrodes with diameter of 4.4 mm and length 70 mm were used in this experiment and their physical properties are given in table (ii).

Table (ii) Physical properties of Copper electrodes

Electrical resistivity(μΩ⁄cm)	1.96
Electrical conductivity compared with silver	92%
Thermal conductivity (W/mK)	268-389
Melting point (°C)	1083
Specific heat (cal/g °C)	0.092
Coefficient of thermal expansion($X10^{-6}°C^{-1}$)	6.6
Specific gravity at 20°C(g/cm^3)	8.9

2.3 Experimental techniques

The work piece (Al/SiC –MMC) and the electrode (copper diameter 4.4mm) are mounted on an EDM machine (EMS 5030 + generator of PSR 35).

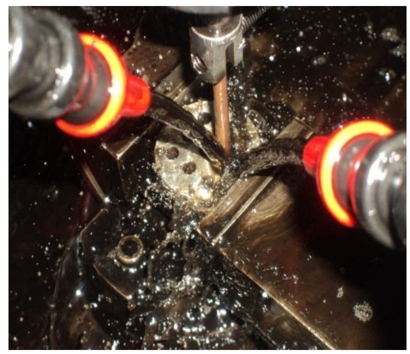

Fig.2(b) Machined number of holes by EDM

A number of holes were machined shown in "fig 2(b)" where the diameter of the holes was the same as the diameter of the electrodes used. Material removal rate of the work piece material and the wear rate of the electrode were obtained based on the calculation of percentage of mass loss per machining time (wt.%/min). The work pieces and electrodes after machining have thoroughly cleaned with acetone to remove the carbon deposition, and the weight measurements were taken on electronic weighing machine, which has a resolution of 0.0001 grams. Each experiment was repeated three times and the averaged for MRR (grams/min), TWR (grams/min) and Time taken.

The MRR and TWR is defined as

$$MRR = \frac{\text{Difference in weight of workpiece before and after machining}}{\text{Time of machining}}$$

$$TWR = \frac{\text{Difference in weight of electrode before and after machining}}{\text{Time of machining}}$$

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The design of experiments technique has been implemented to conduct the experiments. It is a powerful work tool which allows us to model and analyse 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, 300mesh and 400 mesh and Al 6063 alloy) of Sic particles and Constant parameters were Wt. % of Sic= 15%, I_p =10amp, T_{on} =70 μ sec, T_{off}= 7 μ sec, V_g =35 Volts. Machining was done and parameters were Measured Time Taken (min.), Tool Wear Rate (gm/min) and Metal Removal Rate (gm/min). 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, I_p =10amp, T_{on} =70 μ sec, T_{off}= 7 μ sec, V_g =35 Volts. Machining was done and parameters were Measured Time Taken (min.), Tool Wear Rate (gm/min) and Metal Removal Rate (gm/min). The investigations of results are done graphically.

(3) Variant parameter was Pulse Peak Current I_P (2 Amp, 6 Amp, 10 Amp,14 Amp) and Constant parameters were Mesh size of Sic= 300, Wt. % of Sic= 15%, T_{on} =70 μ sec, T_{off}= 7 μ sec, V_g =35 Volts. Machining was done and parameters were Measured Time Taken (min.), Tool Wear Rate (gm/min) and Metal Removal Rate (gm/min). The investigations of results are done graphically.

(4) Variant parameter was Pulse off time T_{off} (3 μ sec, 5 μ sec, 7 μ sec and 9 μ sec) and Constant parameters were Mesh size of Sic= 300, Wt. % of Sic= 15%, I_p =10amp, T_{on} =70 μ sec, V_g =35 Volts. Machining was done and parameters were Measured Time Taken (min.), Tool Wear Rate (gm/min) and Metal Removal Rate(gm/min). The investigations of results are done graphically.

(5) Variant parameter was Pulse on time T_{on} (30 μ sec, 50 μ sec, 70 μ sec and 90 μ sec) and Constant parameters were mesh size of Sic= 300, Wt. % of Sic= 15%, I_p =10amp, T_{off}= 7 μ sec, V_g =35 Volts. Machining was done and parameters were Measured Time Taken (min.), Tool Wear Rate (gm/min) and Metal Removal Rate (gm/min). The investigations of results are done graphically.

(6) Variant parameter was Gap voltage V_g (25 Volts, 30 Volts, 35 Volts and 40 Volts) and Constant parameters were Mesh size of Sic= 300, Wt. % of Sic= 15%, I_p =10amp, T_{on} =70 μ sec, T_{off}= 7 μ sec. Machining was done and parameters were Measured Time Taken (min.), Tool Wear Rate (gm/min) and Metal Removal Rate (gm/min). The investigations of results are done graphically.

3 RESULTS AND DISCUSION

3.1 Results Graph

All the experimental results are presented on graphs [from "fig.3 to 20"] as shown hereunder. In these graphs all measured parameters Time Taken (min.), Tool Wear Rate (gm/min) and Metal Removal Rate (gm/min) 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, Pulse Peak Current I_P (2 Amp, 6 Amp, 10 Amp,14 Amp), Pulse on time T_{on} (30 μ sec, 50 μ sec, 70 μ sec and 90 μ sec), Pulse off time T_{off} (3 μ sec, 5 μ sec, 7 μ sec and 9 μ sec) and gap voltage Vg (25 Volts, 30 Volts, 35 Volts and 40 Volts) are on horizontal axes and constant parameters are shown in box.

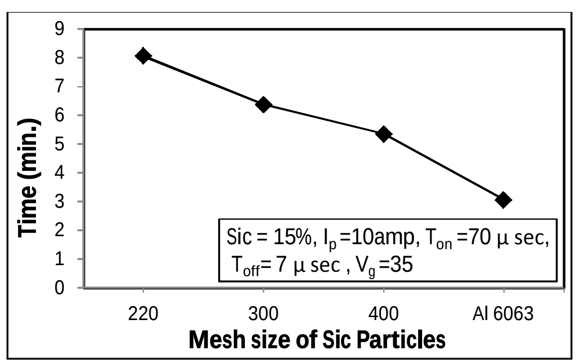

Fig. 3 Time Vs Mesh size of Sic Particles

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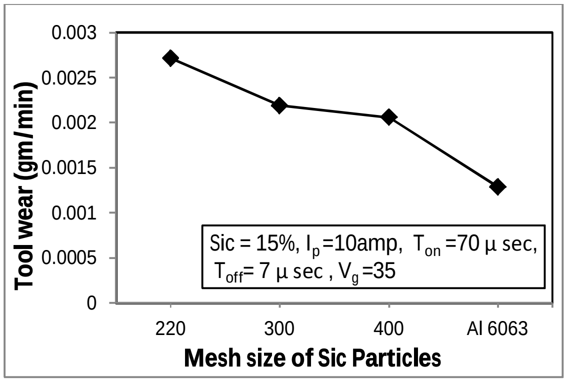

Fig. 4 Tool Wear (gm/min) Vs Mesh size of Sic Particles

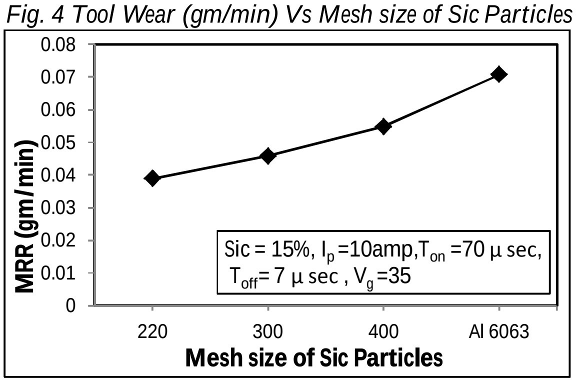

Fig. 5 MRR (gm/min) Vs Mesh size of Sic Particles

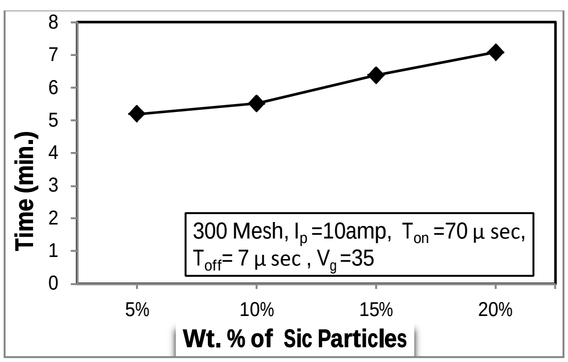

Fig. 6 Time Vs Wt.% of Sic Particles

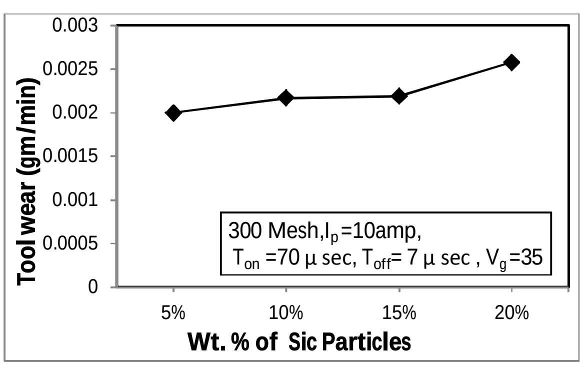

Fig. 7 *Tool Wear (gm/min) Vs Wt.% of Sic Particles*

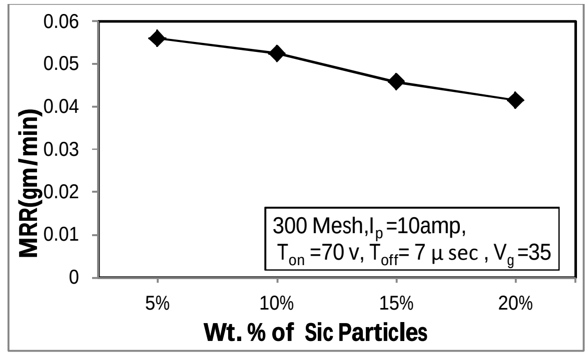

Fig. *8 MRR (gm/min) Vs Wt.% of Sic Particles*

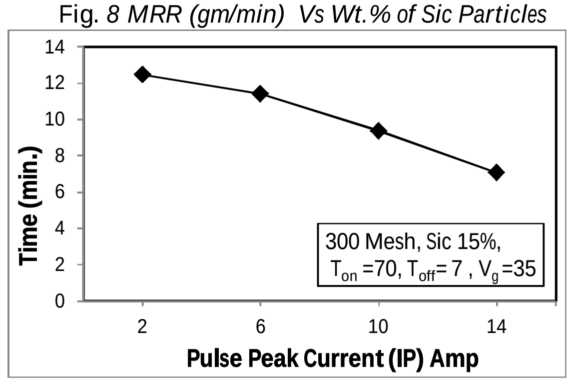

Fig. 9 Time Vs Pulse Peak Current (IP) Amp

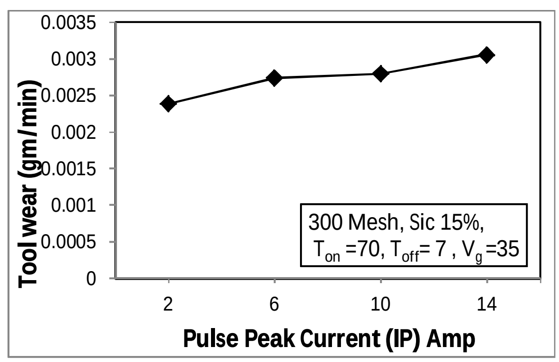

Fig. 10 Tool Wear (gm/min) Vs Pulse Peak Current (IP) Amp

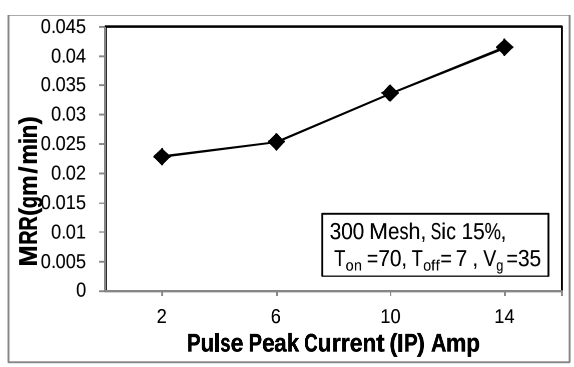

Fig. 11 MRR (gm/min) Vs Pulse Peak Current (IP) Amp

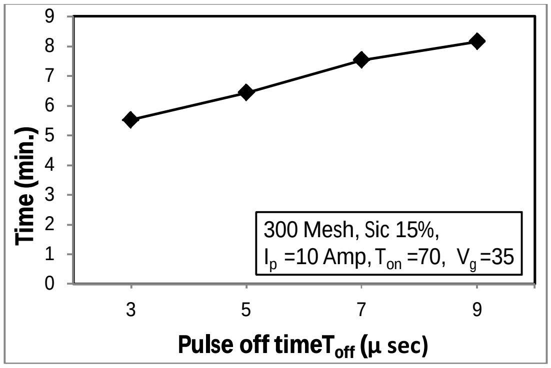

Fig. 12 Time Vs Pulse off time T_{off} (μ sec)

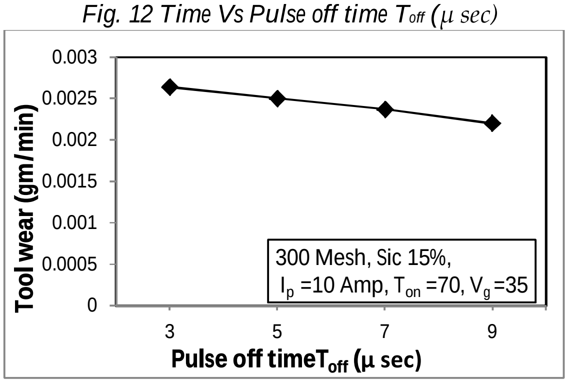

Fig. 13 Tool Wear (gm/min) Vs Pulse off time T_{off} (μ sec)

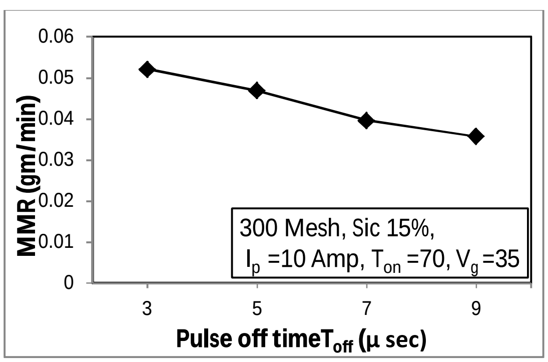

Fig. 14 MRR (gm/min) Vs Pulse off time T_{off} (μ sec)

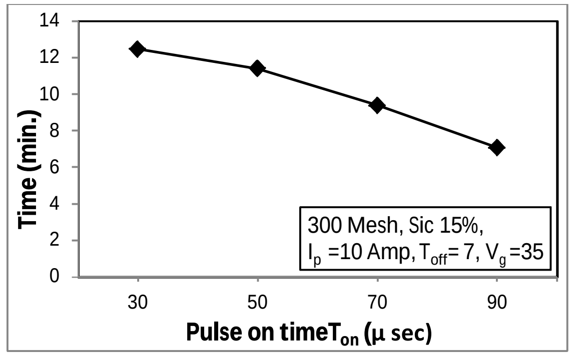

Fig. 15 Time Vs Pulse on time T_{on} (μ sec)

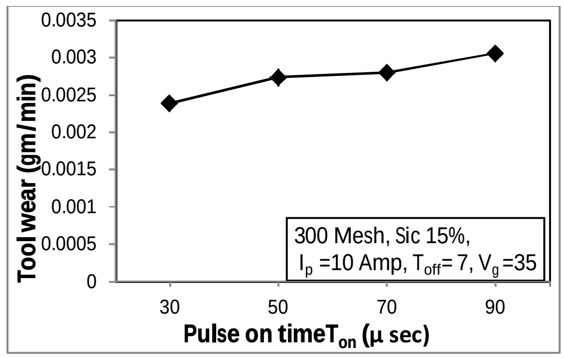

Fig. 16 Tool Wear (gm/min) Vs Pulse on time T_{on} (μ sec)

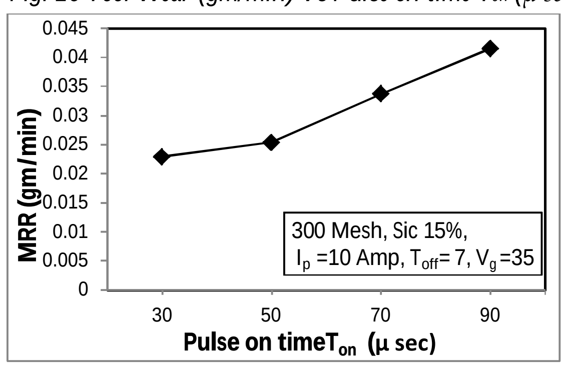

Fig. 17 MRR (gm/min) Vs Pulse on time T_{on} (μ sec)

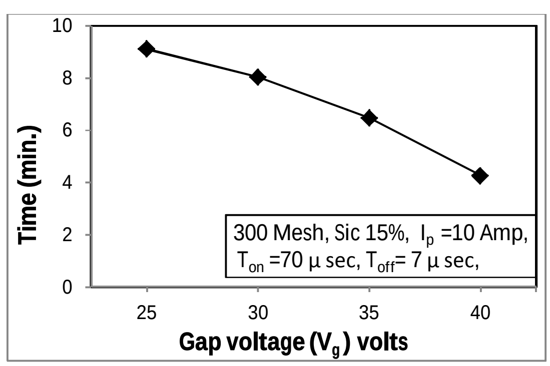

Fig. 18 Time Vs Gap voltage (V_g) volts

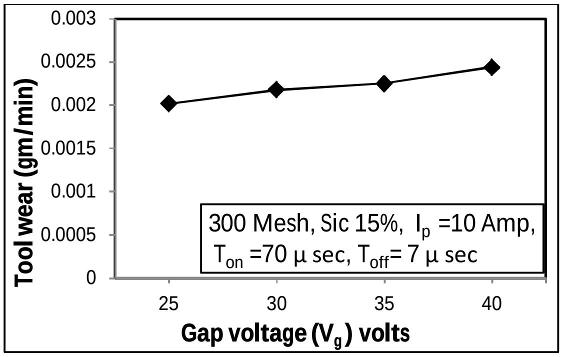

Fig. 19 Tool Wear (gm/min) Vs Gap voltage (V_g) volts

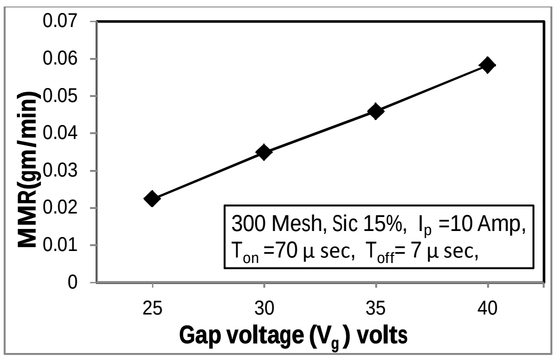

Fig. 20 MRR (gm/min) Vs Gap voltage (V_g) volts

3.2 DISCUSSION

1. **Effect of Mesh size of Sic Particles**
   "Fig. 3,4 and 5" shows the effect of Mesh size on Time (min.) ,Tool wear Rate (gm/min) and Metal Removal Rate (gm/min). With increase of Mesh Size (220 mesh, 300 mesh, and 400 mesh) of SiC particles time taken and Tool Wear rate decreases and metal remove rate increases.
2. **Effect of Wt.% of Sic Particles**
   "Fig. 6,7 and 8" shows the effect of Wt.% of Sic Particles on Time (min.) ,Tool wear Rate (gm/min) and Metal Removal Rate (gm/min). With increase of Wt.% (5% <10%<15%< 20%) **of Sic** particles time taken and Tool Wear rate increases and metal remove rate decreases.
3. **Effect of Pulse Peak Current (IP)**
   "Fig. 9,10 and 11" shows the effect of Pulse Peak Current (IP) Amp on Time (min.), Tool wear Rate (gm/min) and Metal Removal Rate (gm/min). With increase of Pulse Peak Current (IP) (2 Amp, 6 Amp, 10 Amp,14 Amp) metal remove rate and Tool Wear rate increases and time taken decreases.
4. **Effect of Pulse off time T_{off} (μ sec)**
   "Fig. 12,13 and 14" shows the effect of Pulse off time T_{off} (μ sec) on Time (min.), Tool wear Rate (gm/min) and Metal Removal Rate (gm/min). With increase of Pulse off time T_{off} (3 μ sec, 5 μ sec, 7 μ sec and 9 μ sec) metal remove rate and Tool Wear rate decreases and time taken increases.
5. **Effect of Pulse on time T_{on} (μ sec)**
   "Fig. 15,16 and 17" shows the effect of Pulse on time T_{on} (μ sec)on Time (min.), Tool wear Rate (gm/min) and Metal Removal Rate (gm/min). With increase of Pulse on time T_{on} (30 μ sec, 50 μ sec, 70 μ sec and 90 μ sec) metal remove rate and Tool Wear rate increases and time taken decreases.
6. **Effect of Gap voltage (V_g) volts**
   "Fig. 18, 19 and 20" shows the effect of Gap voltage (V_g) volts on Time (min.), Tool wear Rate (gm/min) and Metal Removal Rate (gm/min). With increase of Gap voltage V_g (25 Volts, 30 Volts, 35 Volts and 40 Volts) metal remove rate and Tool Wear rate increases and time taken decreases.

4. CONCLUSION

Maximum MRR can be achieved at high value of I_p, T_{on}, V_g and low value of T_{off} , Mesh size of Sic Particles, Wt. % of Sic Particles. Minimum TWR can be achieved at low value of I_p, T_{on}, V_g , Mesh size of Sic Particles and Wt.% of Sic Particles. Minimum Time is consumed at high value of I_p, T_{on}, V_g and low value of T_{off}, Mesh size of Sic Particles, Wt. % of Sic Particles.

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