Effects Of Pulse Peak Current And Spark Gap Set Voltage During Machining Of PR-AL-SiC-MMC,s by WEDM

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Abstract

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 aluminium (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 the reinforced particles of SiC by weight fraction 15% and average reinforced particles sizes of SiC are 300 mesh. The stirring process is carried out at 200 rev/min rotating speed by graphite impeller for 15 minutes. 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 Pulse Peak Current I_P (150 Amp, 170 Amp, 190 Amp, and 210 Amp)and Spark gap set voltage S_V (15 volts, 20 volts, 25 volts, 30 volts). The investigations of results are done graphically.

Key words- Particulate Reinforced Al/SiC Metal Matrix Composites (PRALSICMMC), Silicon Carbide (SiC), Spark Gap Wg mm, Cutting Speed (Vc), Metal Removal Rate (MMR) and Surface roughness (Ra)

1. INTRODUCTION

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 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 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. Surappa et al [1997] 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, Skibo et al [1998] it is projected that the cost will fall to one-tenth. Dauw et. al [1994] 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. Ozdemir et.al [2006] Variation of geometric inaccuracy due to wire lag against parametric settings was investigated. George et. al [2004] and Mahdavinejad et. al [2009] from the past literature survey, work has been done on WEDM parameters using Taguchi methodology. Rao et al [2010] predictions for wire rupture prevention during WEDM operation. Parametric Study 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. Rozenek et al. [2001] investigated the effect of machining parameters (discharge current, pulse-on time, pulse- off time, voltage) on the machining feed rate and surface roughness during WEDM of metal matrix composite AlSi7Mg/SiC and AlSi7Mg/Al_2O_3. Generally, the machining characteristics of WEDM metal matrix composites are similar to those which occur in the base material (AlSi7Mg aluminum alloy). The machining feed rate of WEDM cutting composites significantly depends on the kind of reinforcement. The maximum cutting speed of AlSi7Mg/SiC and AlSi7Mg/Al_2O_3 composites are approximately 3 times and 6.5 times lower than the cutting speed of aluminum alloy, respectively". Yan et al. [2005] comprehensively investigated into the locations of the broken wire and the reason of wire breaking in machining Al_2O_3p/6061Al composite using WEDM.

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 the reinforced particles of SiC by weight fraction 15% and average reinforced particles sizes of SiC are 300 mesh. 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 Pulse Peak Current I_p (150 Amp, 170 Amp, 190 Amp, and 210 Amp) and Spark gap set voltage S_v (15 volts, 20 volts, 25 volts, 30 volts). The investigations of results are done graphically.

2. EXPERIMENTATION

2.1 Fabrication of Al/SiC metal matrix composites

Reinforced particles of Silicon Carbide (SiC) weight fraction 15% and mesh size 300 was 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.

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 450⁰C for 2 hr before melting and SiC particulates were preheated at 1100⁰C 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 ± 10⁰C 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 .

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

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

Fig.1 (b) shows pouring mixture of molten Al and SiC particles. The fabrication of composite was done by gravity casting. Fig.1 (c) shows prepared workpiece of Al/SiC-MMCs weight fraction 15% and mesh size 300. The uniform size (dia. 35 mm and thickness is 6mm) of workpiece was given by lathe machine.

2.2 Experimental techniques

The different sets of experiment work performed on an ELECTRONICA SPRINTCUT WEDM machine, Manufactured by Electronica Machine Tools Ltd. Pune, Pulse Generator :EPULSE-40A. Technical Specifications and Features of sprintcut wire cut EDM machine are as follows:-

- 4 axes CNC
- Precision LM guide ways for all axes
- Max. cutting speed : 160 mm^2/min
- 0.25Ø special soft brass wire on 50 mm thick HCHCr (steel) workpiece)
- Best surface finish : 0.8 μ Ra
- Taper : ± 30°/ 50 mm
- E-pulse technology
- Elcam - Powerful part programming software
- Table size - 440 X 650 mm
- Surface finish: 0.8 μ Ra.
- Complex profile cutting
- Auto job setting parameters

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.

Fig.2 Machining Experiment on 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 Sprintcut wire cut EDM machine 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 ELECTRONICA SPRINTCUT CNC wire cut-EDM machines. The spark gap (W_g, μm) is calculated from the relation as follows.

$$W_g = b - d/2 \quad (1)$$

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

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

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 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- Spark gap set voltage S_V (15 volts, 20 volts, 25 volts, 30 volts).

(1) Variant parameter was Pulse Peak Current I_P (150 Amp, 170 Amp, 190 Amp, and 210 Amp) and Constant parameters were Mesh size of SiC =300, Wt. % of Sic= 15%, , pulse peak voltage V_P=100 volts, pulse on time T_{on} = 120 μ sec, pulse off time T_{off} = 48 μ sec, , 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, Spark Gap Wg mm, Width of cut b mm, Metal Removal Rate(MRR) mm³ /min, Peak Surface roughness Rz (μm) and Surface roughness Ra (μm). The investigations of results are done graphically.

(2) Variant parameter was Spark Gap Set Voltage S_V (15 volts, 20 volts, 25 volts, 30 volts) and Constant parameters were Mesh size of SiC =300, Wt. % of Sic= 15%, , pulse peak voltage V_P =100 volts, pulse on time T_{on} = 120 μ sec, pulse off time T_{off} = 48 μ sec, , 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, Spark Gap Wg mm, Width of cut b mm, Metal Removal Rate (MRR) mm³ /min, Peak Surface roughness Rz (μm) and Surface roughness Ra (μm). 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 14"] as shown hereunder. In these graphs all measured parameters Cutting Speed Vc mm/min, Spark Gap Wg mm, Width of cut b mm, Metal Removal Rate(MRR) mm³ /min, Peak Surface Roughness Rz (μm) and Surface Roughness Ra (μm) are taken on vertical axes, Variant parameters Pulse Peak Current I_P (150 Amp, 170 Amp, 190 Amp, and 210 Amp) and Spark gap set voltage S_V (15 volts, 20 volts, 25 volts, 30 volts) are on horizontal axes and constant parameters are shown in box. The investigations of results are done graphically.

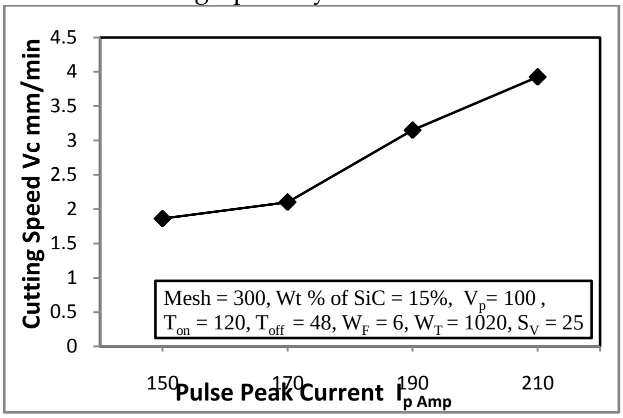

Fig.3. Cutting Speed Vc mm/min Vs Pulse Peak Current I_p

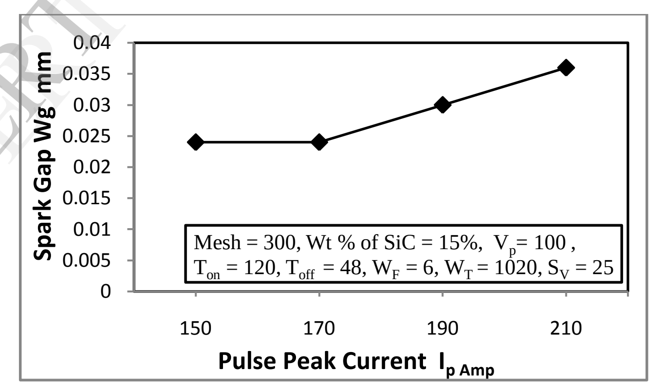

Fig. 4. Spark Gap Wg mm Vs Pulse Peak Current $I_{p\ Amp}$

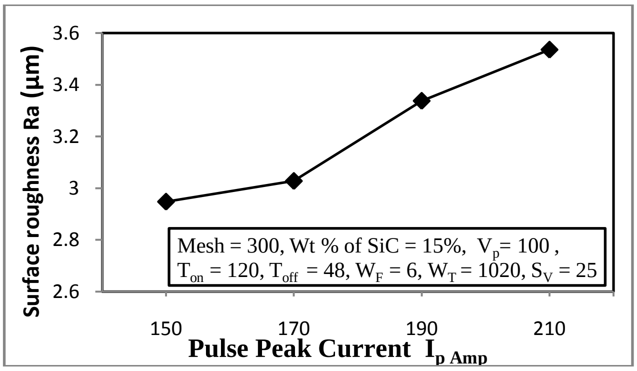

Fig. 5. Surface roughness Ra (μm) Vs Pulse Peak Current $I_{p\ Amp}$

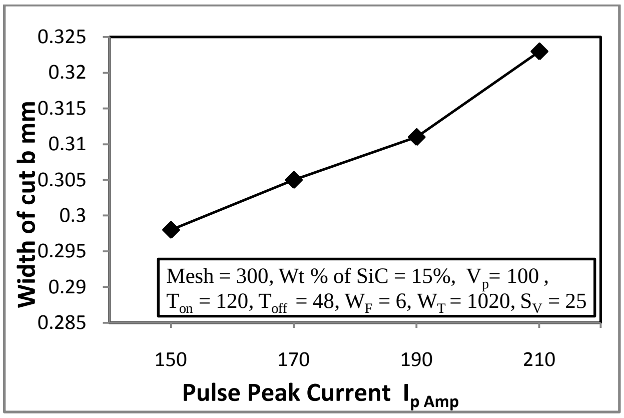

Fig.6. Width of cut b mm Vs Pulse Peak Current $I_{p\ Amp}$

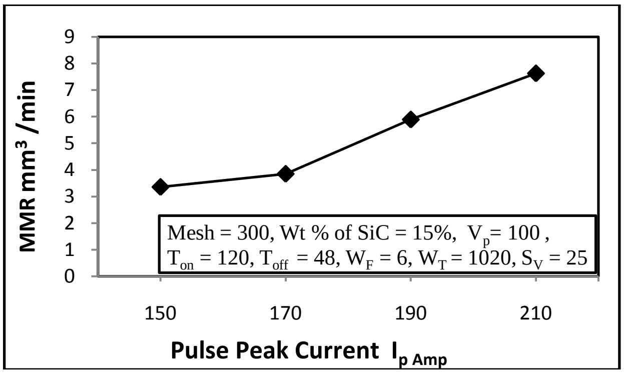

Fig. 7. MMR mm^3 /min Vs Pulse Peak Current $I_{p\ Amp}$

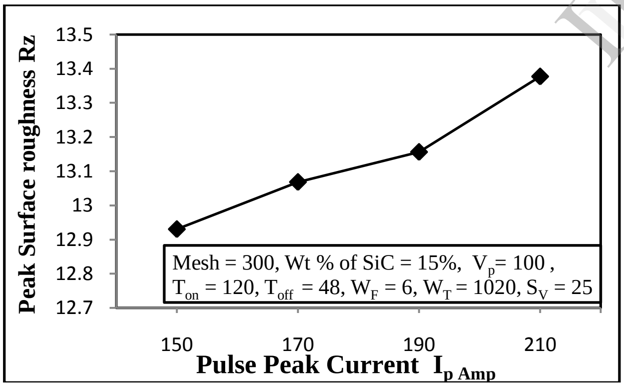

Fig.8. Peak Roughness Rz(μm) Vs Pulse Peak Current $I_{p\ Amp}$

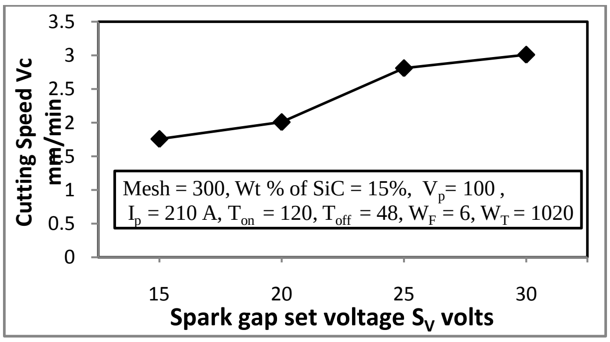

Fig.9. Cutting Speed Vc mm/min Vs Spark gap set voltage S_V volts

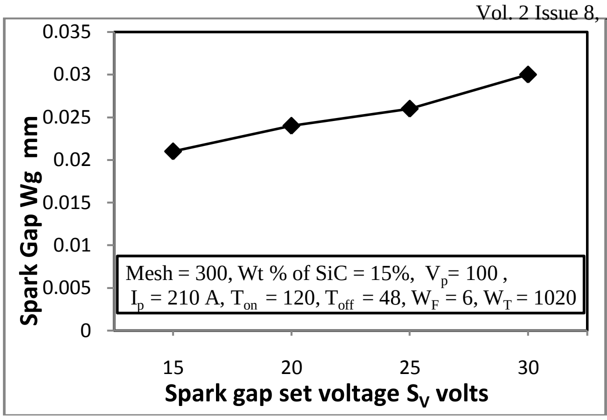

Fig.10. Spark Gap Wg mm Vs Spark gap set voltage S_V volts

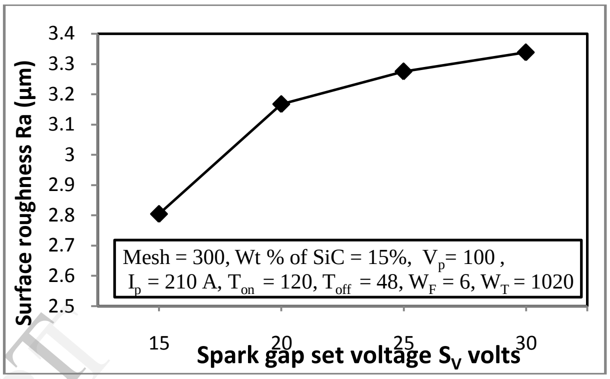

Fig.11. Surface roughness Ra (μm) Vs Spark gap set voltage S_V

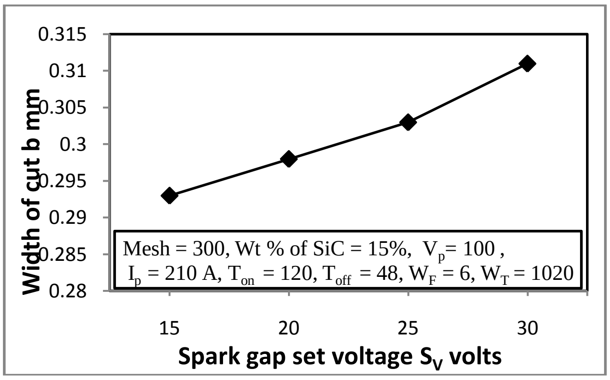

Fig.12. Width of cut b mm Vs Spark gap set voltage S_V volts

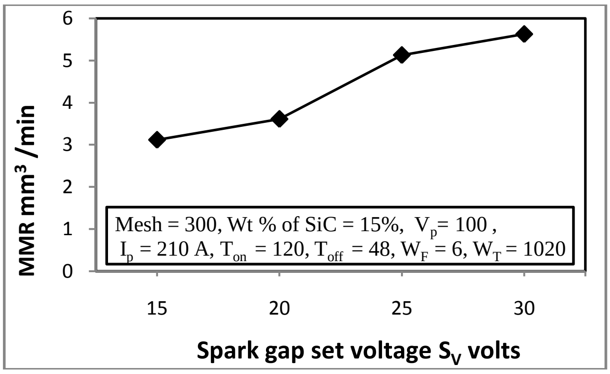

Fig. 13. MMR mm^3 /min Vs Spark gap set voltage S_V volts

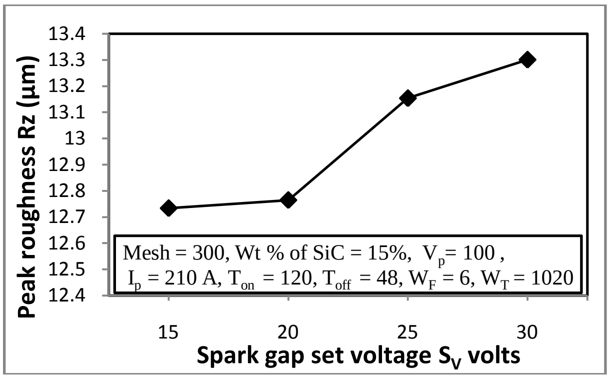

Fig.14. Peak Roughness Rz(µm) Vs Spark gap set voltage S_V volts

3.2 DISCUSSION

1. **Effect of Pulse Peak Current I_P (Amp)**
   From "fig.3 to 8" shows the effect of Pulse Peak Current I_P (150 Amp, 170 Amp, 190 Amp, and 210 Amp) on Cutting Speed Vc mm/min, Spark Gap Wg mm, Width of cut b mm, Metal Removal Rate MRR mm³/min, Peak Surface Roughness Rz(µm) and Surface Roughness Ra(µm). With increase of Pulse Peak Current I_P (150 Amp, 170 Amp, 190 Amp, and 210 Amp) Cutting Speed Vc mm/min, Metal Removal Rate mm³/min, Spark Gap Wg mm, Width of cut b mm, Peak Surface Roughness Rz (µm) and Surface Roughness Ra (µm) increases.

2. **Effect of Spark gap set voltage S_V (volts)**
   From "fig.9 to 14" shows the effect of Spark gap set voltage S_V on Cutting Speed Vc mm/min, Spark Gap Wg mm, Width of cut b mm, Metal Removal Rate mm³/min, Peak Surface Roughness Rz(µm) and Surface Roughness Ra(µm). With increase of Spark gap set voltage S_V (15 volts, 20 volts, 25 volts, 30 volts) Cutting Speed Vc mm/min, Metal Removal Rate mm³/min, Spark Gap Wg mm, Width of cut b mm, Peak Surface Roughness Rz (µm) and Surface Roughness Ra(µm) increases

4. CONCLUSION

Maximum cutting speed and MRR can be achieved at high value of Pulse Peak Current I_P (210 Amp.) and Spark gap set voltage (30 volts). Smooth machining can be achieved at low value Pulse Peak Current I_P (150 Amp.) and Spark gap set voltage (15 volts).

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