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Effects of process parameters on material removal rate in WEDM

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ABSTRACT

Purpose: In this paper, the effects of various process parameters of WEDM like pulse on time (T_{ON}), pulse off time (T_{OFF}), gap voltage (SV), peak current (IP), wire feed (WF) and wire tension (WT) have been investigated to reveal their impact on material removal rate of hot die steel (H-11) using one variable at a time approach. The optimal set of process parameters has also been predicted to maximize the material removal rate.
Design/methodology/approach: The experimental studies were performed on ELECTRONICA SPRINTCUT WEDM machine.
Findings: The material removal rate (MRR) directly increases with increase in pulse on time (T_{ON}) and peak current (IP) while decreases with increase in pulse off time (T_{OFF}) and servo voltage (SV).
Practical implications: Wire electrical discharge machining (WEDM) is a specialized thermal machining process capable of accurately machining parts which have varying hardness, complex shapes and sharp edges that are very difficult to be machined by the traditional machining processes. The practical technology of the WEDM process is based on the conventional EDM sparking phenomenon utilizing the widely accepted non-contact technique of material removal.
Originality/value: We can say that the wire feed and wire tension are neutral input parameters.
Keywords: WEDM; T_{ON}; T_{OFF}; MRR; WT; WF; SV; IP

1. Introduction

Wire Electrical discharge machining (WEDM) is a nontraditional, thermoelectric process which erodes material from the work piece by a series of discrete sparks between a work and tool electrode immersed in a liquid dielectric medium. These electrical discharges melt and vaporize minute amounts of the work material, which are then ejected and flushed away by the dielectric. The schematic representation of the WEDM cutting process is shown in Figure 1.

Wire electrical discharge machining (WEDM) is a specialized thermal machining process capable of accurately machining parts with varying hardness or complex shapes, which have sharp edges that are very difficult to be machined by the main stream machining processes. At present, WEDM is a widespread technique used in industry for high-precision machining of all types of conductive materials such as metals, metallic alloys, graphite, or even some ceramic materials, of any hardness [1-3].

Many Wire-EDM machines have adopted the pulse-generating circuit using low power for ignition and high power for machining. However, it is not suitable for finishing process since the energy generated by the high-voltage sub-circuit is too high to obtain a desired fine surface, no matter how short the pulse-on time is assigned [4].

As newer and more exotic materials are developed, and more complex shapes are presented, conventional machining operations will continue to reach their limitations and the increased use of wire EDM in manufacturing will continue to grow at an accelerated rate [5].

Experiments proved that the surface roughness can be improved by decreasing both pulse duration and discharge current. When the pulse energy per discharge is constant, short pulses and long pulses will result in the same surface roughness but dissimilar surface morphology and different material removal rates. The removal rate when short pulse duration is used is much higher than when the pulse duration is long [6].

Under the same discharge energy, the comparison of analytical and experimental results shows that a discharge current with a short-duration pulse and a high peak value removes the work piece material mainly by gasifying, while a discharge current with a long-duration pulse and low peak value removes the work piece material mainly by melting. It was also found that surfaces machined by a discharge current with a short- and long-duration pulses would have similar roughness values when the pulse energies were almost the same and were high enough [7].

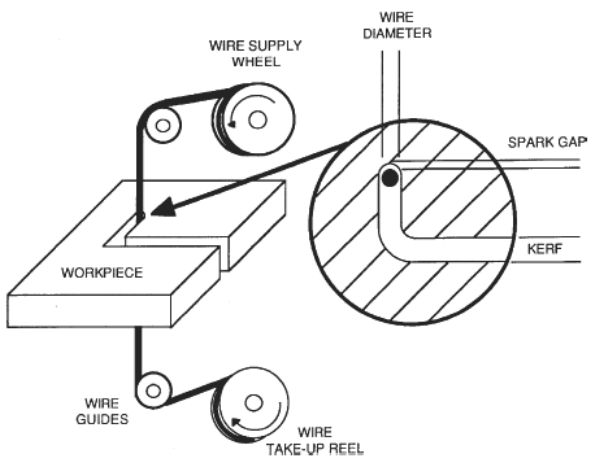

Fig. 1. Schematic representation of Wire EDM cutting process

Nihat Tosun et.al [8] investigated on the effect and optimization of machining parameters on the kerf (cutting width) and material removal rate (MRR) in wire electrical discharge machining (WEDM) operations. The experimental studies were conducted under varying pulse duration, open circuit voltage, wire speed and dielectric flushing pressure. The settings of machining parameters were determined by using Taguchi experimental design method.

Hewidy et al [9] developed mathematical models correlating the various WEDM machining parameters (peak current, duty factor, wire tension and water pressure) with metal removal rate, wear ratio and surface roughness based on the response surface methodology.

Mahapatra [10] studied the relationships between various control factors and responses like MRR, SF and kerf by means of nonlinear regression analysis, resulting in a valid mathematical model. Finally, genetic algorithm, a popular evolutionary approach, is employed to optimize the wire electrical discharge machining process with multiple objectives. The study demonstrates that the WEDM process parameters can be adjusted to achieve better metal removal rate, surface finish and cutting width simultaneously.

2. Experimental methodology

The experimental studies were performed on ELECTRONICA SPRINTCUT WEDM machine (Figure 2). Various input parameters varied during the experimentation are pulse on time (T_{ON}), pulse off time (T_{OFF}), servo voltage (SV), peak current (IP), wire feed (WF) and wire tension (WT). The effects of these input parameters are studied on material removal rate using one factor at a time approach. The units of some input parameters such as wire tension, pulse on time, pulse off time, servo feed etc. are taken as per the machine setting [11].

Fig. 2. WEDM machine tool

Different settings of pulse duration, open circuit voltage, wire speed and dielectric flushing pressure were used in the experiments. During all experiments, two input variables flushing pressure (WP) and peak voltage (VP) were kept constant. The value of WP is fixed to1 unit (15 kg/cm^2) and value of VP is fixed to 2 units. In each experiment one input variable was varied while keeping all other input variables at some mean fixed value and the effect of change of the input variable on the output characteristic i.e. material removal rate is studied and reported in this paper.

CuZn37 Master Brass wire with 0.25 mm diameter (900 N/mm^2 tensile strength) was used in the experiments. The work piece material, H-11 hot die steel with 125 mm × 100 mm × 24 mm size was used. During the experiments 5 mm × 5 mm square was cut to obtain a rectangular punch of 5 mm × 5 mm × 24 mm.

To evaluate the effects of machining parameters on performance characteristic (MRR), and to identify the performance characteristic under the optimal machining parameters, a specially designed experimental procedure is required.

3. Observations

Various experiments were performed to find how the output parameter varies with the variation in the input parameters. The experiments were performed in constant voltage mode of the WEDM. In the first set of experiments pulse on time (T_{ON}) is varied from 105 units to 129 units in the steps of 3 units. All other input parameters such as wire feed, wire tension, servo voltage, peak current, pulse off time were kept constant. The change in material removal rate due to change in pulse on time is shown in Table 1.

Fixed input variables in first set of experiments are: T_{OFF} =51 units; IP = 230 A; WF = 8 m/min; WT = 8 units (1140 gms); SV = 20 Volts; S_F = 2050 units.

Table 1.
MRR and T_{ON} values

SR. No.	T_{ON} (units)	Material removal rate (mm^2/min)
1	105	08.16
2	108	15.60
3	111	22.56
4	114	30.34
5	117	37.68
6	120	47.04
7	123	54.00
8	126	63.12
9	129	69.60

In the second set of experiments pulse off time (T_{OFF}) is varied from 63 units to 39 units with regular decrement of 3 units. All other input parameters such as wire feed, wire tension, servo voltage, peak current, pulse on time are fixed to some constant value. The change in material removal rate due to change in pulse on time is shown in Table 2.

Fixed input variables in second set of experiments are: T_{ON} = 114 units; IP = 230 A; WF = 8 m/min; WT = 8 units (1140 gms); SV = 20 Volts; S_F = 2050 units.

Table 2.
MRR and T_{OFF} values

SR. No.	T_{OFF} (units)	Material removal rate (mm^2/min)
1	63	16.56
2	60	18.72
3	57	21.12
4	54	25.44
5	51	29.52
6	48	36.00
7	45	44.88
8	42	51.12
9	39	55.44

In the third set of experiments wire tension (WT) is varied from 2 units (420 gm) to 12 units (1620 gm) in the steps of 2 units. All other input parameters such as pulse on time, pulse off time wire feed, servo voltage, peak current time are fixed to some value. The change in material removal rate due to change in pulse on time is shown in Table 3.

Fixed input variables in third set of experiments are: T_{ON} = 114 units; T_{OFF} = 51 units; WF = 8 m/min; IP = 230 Amp; SV = 20 Volts; S_F = 2050 units.

Table 3.
MRR and WT values

SR. No.	WT (units) (gms)	Material removal rate (mm^2/min)
1	2 (420)	29.52
2	4 (660)	29.52
3	6 (900)	29.52
4	8 (140)	29.28
5	10 (1380)	29.76
6	12 (1620)	29.52

In the next set of experiments wire feed (WF) is varied from 2 m/min to 12 m/min in the steps of 2. All other input parameters such as pulse on time, pulse off time wire tension, servo voltage, peak current time are fixed to some value. The change in material removal rate due to the change in pulse on time is shown in Table 4.

Fixed input variables in forth set of experiments are: T_{ON} = 114 units; T_{OFF} = 51 units; WT = 8 units (1140 gms); IP = 230 Amp; SV = 20 Volts; S_F = 2050 units.

Table 4.
MRR and WF values

SR. No.	WF (m/min)	Material removal rate (mm^2/min)
1	2	30.00
2	4	29.76
3	6	30.48
4	8	30.24
5	10	30.48
6	12	29.76

In the next set of experiments peak current (IP) is varied from 230 amp to 50 amp in the decrements of 20 amp. All other input parameters such as wire feed, wire tension, servo voltage, pulse on time, and pulse off time are fixed to some value. The change in material removal rate due to change in pulse on time is shown in Table 5.

Fixed input variables in fifth set of experiments are: T_{ON} = 114 units; T_{OFF} = 51 units; WF = 8 m/min; WT = 8 units (1140 gms); SV = 20 Volts; S_F = 2050 units.

Table 5.
MRR and IP values

SR. No.	IP (A)	Material removal rate (mm^2/min)
1	230	30.24
2	210	28.32
3	190	27.36
4	170	24.72
5	140	25.92
6	110	22.80
7	80	19.20
8	50	12.48

In the last set of experiments servo voltage (SV) is varied from 5 volts to 80 volts in the increments of 15 volts. All other input parameters such as wire feed, wire tension, servo voltage, pulse on time, and pulse off time are fixed to some value. The change in material removal rate due to change in pulse on time is shown in Table 6.

Fixed input variables in fifth set of experiments are: T_{ON} = 114 units; T_{OFF} = 51 units; WF = 8 m/min; WT = 8 units (1140 gms); IP = 230 Amp; S_F = 2050 units.

Table 6.
MRR and SV values

SR. No.	SV (Volts)	Material removal rate (mm^2/min)
1	5	35.04
2	20	29.76
3	35	24.24
4	50	18.00
5	65	13.44
6	80	08.64

4. Result and analysis

The experiments are based on one factor experiment strategy. In this only one input parameter was varied while keeping all others input parameters at constant values. During this experimental procedure, six sets of experiments were performed. After analyzing the results of the experiments performed, various facts came into light. The effect of pulse on time (T_{ON}) on the output parameter is shown in Figure 3.

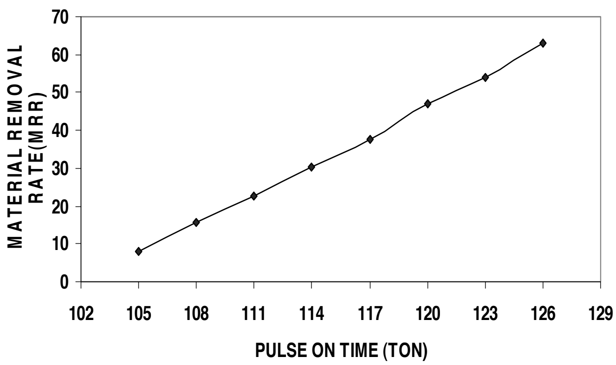

Fig. 3. Pulse on time vs. material removal rate

The graph shows that material removal rate increases with the increase in the pulse on time. So the pulse on time can be adjusted to get the desired material removal rate.

For the second set of experiments the effect of pulse off time (T_{OFF}) on the output parameter is shown in the Figure 4.

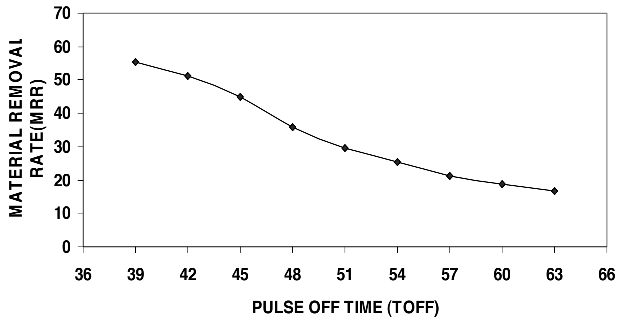

Fig. 4. Pulse off time vs. material removal rate

The graph reveals that the material removal rate decreases with increase in the pulse off time. So the value of pulse off time can be selected in such a way that we get the desired material removal rate.

For the third set of experiments the effect of wire tension (WT) on the output parameter is shown in the Figure 5.

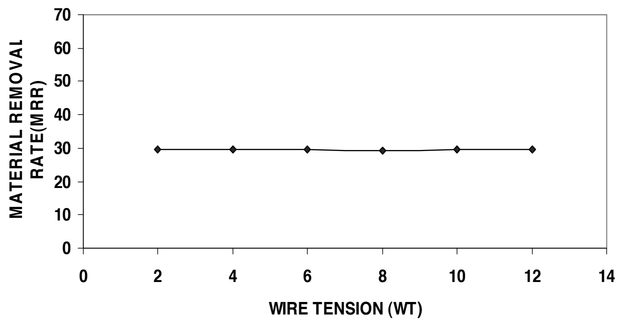

Fig. 5. Material removal rate vs. wire tension

The graph shows that the material removal rate remains nearly constant with variation in the wire tension. So the value of wire tension needs to be selected in such a way to avoid wire breakage due to high tension in the wire.

For the next set of experiments the effect of wire feed (WF) on the output parameter is shown in the Figure 6.

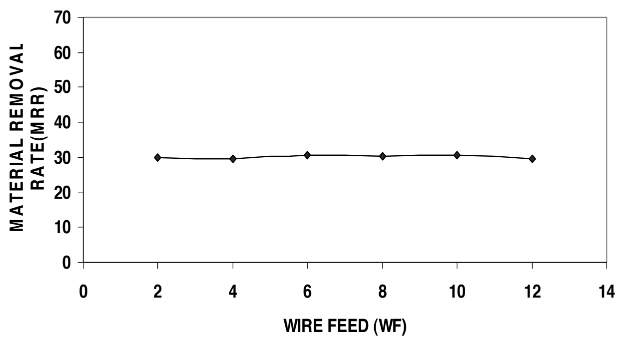

Fig. 6. Material removal rate and wire feed

This graph also shows that the material removal rate remains nearly constant with variation in the wire feed. So the wire feed should be selected in a way that there is no wastage of the wire.

For the next set of experiments the effect of peak current (IP) on the output parameter is shown in the Figure 7.

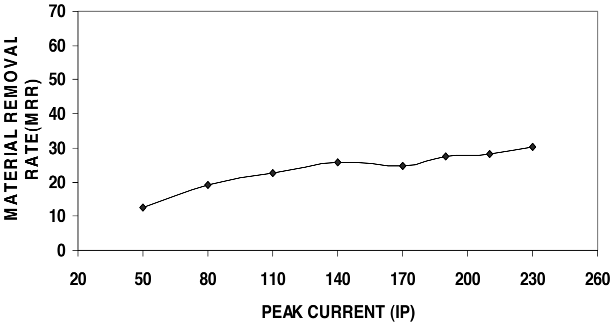

Fig. 7. Material removal rate vs. peak current

This graph shows that material removal rate increases with the increase in the peak current. So value of peak current should be high to obtain higher MRR.

For the next set of experiments the effect of servo voltage (SV) on the output parameter is shown in the Figure 8.

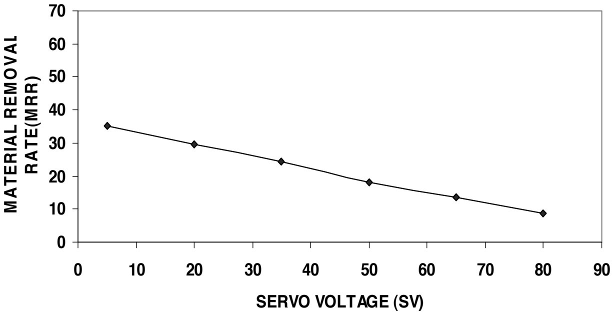

Fig. 8. Material removal rate vs. servo voltage

The graph shows that the material removal rate decreases regularly with increase in the servo voltage. The material removal rate is maximum at the low servo voltage and minimum at high voltage. The decrement of material removal rate is regular.

5. Conclusions

The following conclusions are drawn from the experimental study:

1. The parameters wire feed (WF) and wire tension (WT) have no effect on the material removal rate.
2. The pulse on time parameter has direct effect on the material removal rate, as we increase the pulse on time the material removal rate also increases.
3. When the pulse off time is increased the material removal rate decreases.
4. When peak current is increased the material removal rate increases.
5. Material removal rate decreases with increase in the servo voltage.

In the nutshell we can say that the wire feed and wire tension are neutral input parameters. The material removal rate (MRR) directly increases with increase in pulse on time (T_{ON}) and peak current (IP) while decreases with increase in pulse off time (T_{OFF}) and servo voltage (SV).

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