International Journal of Scientific & Engineering Research, Volume 6, Issue 4, April-2015 186
ISSN 2229-5518

Optimization of EDM Process by new Carbon Black Layer Technology and Comparison with Traditional Regression Analysis Method

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Abstract- it is method in which the metals like has talloy, nitralloy, nimonics etc. are such that they can't be machined by conventional methods but require some special techniques. In this paper there is a optimization of characteristics of EDM like Material removal rate, tool wear ratio and surface roughness by using different input parameters like ram speed, current intensity, pulse duration and duty factor. To optimize the EDM process, the fractional factorial method developed by Taguchi, which is a traditional technique that allows a process to be optimized using relatively few experiments when there are large No. of input variables, are used. By traditional method, as result we find out the highest MRR value obtained is (1) 98 mm^3/min; the TWR at these setting 0.5% and the surface roughness (Ra) is 9.4 µm. (2) The lowest TWR obtained is 0.16%, the values of MRR is 17 mm^3/min and Ra is 5.8 µm. (3) The lowest Ra is 4.6 µm, the MRR and TWR values for these settings are 28 mm^3/min & 3.5%. So these results confirms that there is no single set of input parameter settings which optimize all three output parameters. If it is essential to have as smooth a surface finish as possible, then a very low MRR and a very high TWR would be obtained. In new method, there is an improvement in TWR. The mean value in the improvement is (60±16%) to 95% significant. The MRR appears to increase slightly for a preprocessing depth of 0.025 mm but decreases there after so the results confirm the theory that the TWR in improved by the preprocessing method. It can been seen that there is an improvement in all cases. The mean value of the ratio is 1.39 ± 0.9 (95% confidence limit). There is, however, no significant correlation between pulse duration and TWR improvement. The MRR was largely unchanged for the 1 mm preprocessing depth, but was reduced for the 4 mm depth. So we can conclude that the improvement in TWR was due to influence of migrated carbon in new method.

Key words- EDM, CLA method, MRR, Surface roughness, TWR, preprocessing depth, carbon black layer.

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1 Introduction

It is an unconventional method in which the metals like has talloy, nitralloy, nimonics etc. are such that they can't be machined by conventional methods but require some special techniques. EDM is a method of producing hole and slots or other shapes by using an electric discharge (spark) to remove unwanted material, which is difficult to produce by conventional machining process.

1.1 Principle and overview to EDM [8]

(a) Charge up an electrodes
(b) Bring the electrode (cathode) near a metal work piece (Anode)
(c) As the two conductors get close enough, a spark will produce (across a dielectric fluid) and this spark produces enough heat to meet and vaporize a tiny volume of work piece material, leaving a small crater on its surface.
(d) Continue Step 1-3 until a hole (the shape of the electrode) is formed.

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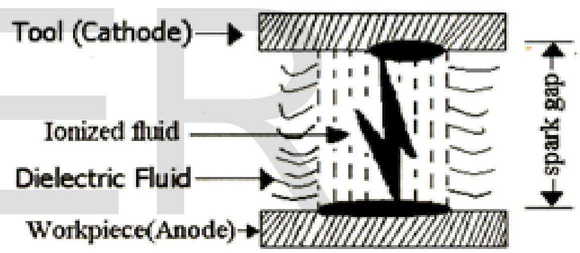

Fig. 1. Principle of EDM [14]

A strong electric field is set up in the spark gap under the application of a breakdown voltage across the tool and the work piece. As the capacitor is charged up to the gap break down voltage, thermionic emission occurs at the hot cathode and streams of electrons are ejected into a highly localized anode region. At the same time, the breakdown of the dielectric take place and a discharge channel is initiated. Electrons then flow from the cathode, impinging on the anode surface, while positively charged ions resulting from ionization of the dielectric move in the opposite direction causing wear of cathode. Owing to the intense and highly localized activity of the electrons and ions, a large amount of heat energy is liberated, sufficient to melt a discrete region of vapor bubbles is ejected and transported away by the flow of dielectric Fluid.

Why EDM? It can be seen by given tables 1-3.

TABLE 1
COMPARISON OF EDM AND OTHER UNCONVENTIONAL MACHINING PROCESS

ISSN 2229-5518

Feature	EDM	ECM
Speed of metal removal	Very slow	Very fast
Types of job	Same	same
cost	less	more
Power consumption	less	more
Floor space	less	more
Nature of surface produced	Little rough (finish depends on metal of electrode	No burrs at all (finish depends on metal machined)
Economical when requiring lot of metal removal	A few parts are to be made	A large no of parts
Electrode requirement	Some times 2 or 3	1

Table 2
PROCESS CAPABILITY

Process	MRR (mm³/min)	Tolerance (μ)	Surface finish (CLA μ)
USM	300	7.5	0.2-0.5
AJM	0.8	50	0.5-1.2
ECM	1500	50	0.1-2.5
CHM	15	50	0.4-2.5
EDM	800	15	0.2-12.5
EBM	1.6	25	0.4-2.5

Table 3
EFFECT ON EQUIPMENT AND TOOLING

Process	Capital Investment	Tooling & fixtures	Power Requirement	Efficiency	Tool Consumption
USM	B	B	B	D	C
AJM	A	B	B	D	B
ECM	E	C	C	B	A
CHM	C	B	D	C	A
EDM	C	D	B	D	D
EBM	D	B	B	E	A
Conventional machining	B	B	B	A	B

Note: - A=Very low, B=low, C=medium, D=High, E=Very High
Note: - USM=Ultra sonic machine, AJM=Abrasive Jet machine, ECM=Electro chemical machine, CHM=Chemical machine, EDM=electric discharge machine, EBM=Electro beam machine

Fig 2 Experimental setup of EDM

1.2 Description [8]

Every EDM machine has the following basic elements as shown in Figure 3
(i) Spark generator (ii) Servo system
(iii) Dielectric liquid (iv) Mechanical structure

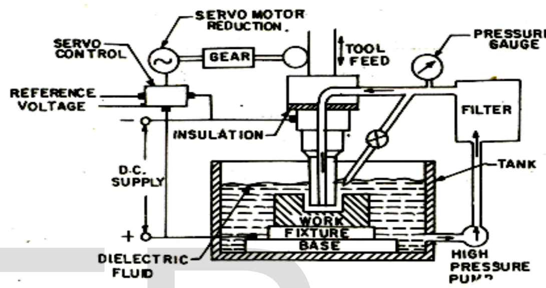

Fig. 3. Description of EDM[14]

Fig. 4 Processing of EDM

2 INPUT PARAMETERS AND OUTPUT PARAMETERS

2.1 Input Parameters [1]

RAM SPEED = Speed at which the tools moves with respect to the work piece.
CURRENT INTENSITY = Peak electric current.
PULSE DURATION = Time during which the discharge takes place.
DUTY FACTER = Ratio of pulse duration to the total pulse time.

2.2 Characteristics (Output Parameters) [1]

MATERIAL REMOVAL RATE = Volume of material removed in unit time.
MRR=1000 * [weight loss (gm)] /
[Density (gm/cc)] * [machining time (min)]
“MRR is proportional to working current value.”

TOOL WEAR RATIO = Ratio of volume of work metal removed from electrode to the actual volume of electrode consumed.

TWR = E_b - E_a (gm) / t (min) * density (gm/mm^3)

E_b & E_a are the weight of electrode material before & after machining

SURFACE ROUGHNESS = Electric spark discharge produces a spherical crater in the work piece, the depth of this crater is defining the surface roughness. It is find by

(i) CLA method (ii) Average line method and also measured by using a stylus surface finish measuring instruments.

Table 4
CHARACTERISTICS OF EDM PROCESS

(a) Mechanism of process	controlled erosion (melting and evaporation) through a series of electric sparks
(b) Spark gap	0.010-0.125
(c) Spark frequency	200-500 KHz
d) Peak voltage across the gap	30-250 V
(e) Material removal rate	5000 mm^3/Min
(f) Specific power consumption	2-10 W/mm^3/Min
(g) Dielectric fluid	Kerosene, Liquid paraffin, silicon oil
(h) Tool material	Brass, cu, w, graphite, cu-tn alloys
(i) Material that can be machined	All conducting metals & alloys
(j) Limitations	High specific energy consumption, non-conducting material can't be machined
(k) Max tool Dia	10 mm

2.3 Selection of Electrode material [3]

There are three types of electrode materials
(i) Metallic: Cu, (Cu + Tn), Brass, Al etc.
(ii) Nonmetallic: Graphite
(iii) Combination of above two types: (Cu + Graphite)

2.4 Advantages of (Cu + Tn) Electrode are as follows

(i) Tool wear ratio is very low
(ii) Thermal conductivity is very high
(iii) Surface finish better
(iv) It is best for machining of carbide materials and micro machining

3 OPTIMIZATION OF EDM PROCESS [1]

To optimize the process, the fractional factorial method developed by Taguchi, which is a technique that allows a process to be optimized using relatively few experiments when there are large No. of input variables, are used. The output parameters to be optimized here were MRR (Material Removal Rate) TWR (Tool Wear Ratio) and Ra (surface roughness). The tool electrodes were made of 75/25 tungsten-copper and MRR and TWR were measured by weighing both tool and work piece before and after processing. Surface finish was measured by using a stylus surface finish measuring instrument. The tools were subjected to energy dispersive x-rays (EDX) to investigate how their structure might be altered during the EDM process.

3.1 Graphical Representation (Traditional method)

3.1.1 Regression using two variables

From the Taguchi analysis the most input critical parameters were found to be current intensity and pulse duration. Taguchi done a detailed investigation to show how the performance of the EDM process varies with these parameter. For this purpose he used the specific value 18.3A, 24.3A & 37.1A. Ampere of current intensity and pulse duration was varied between 18 µs - 560 µs in steps of varying sizes. [14]

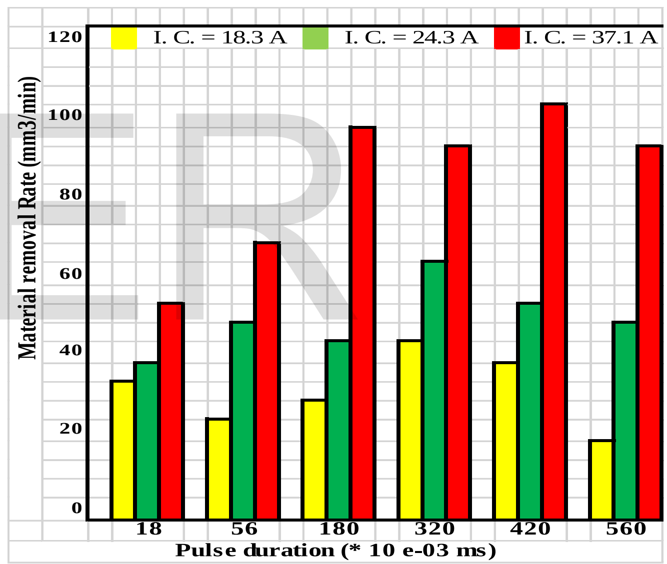

Fig.5. Variation in MRR for different current intensity and Pulse duration

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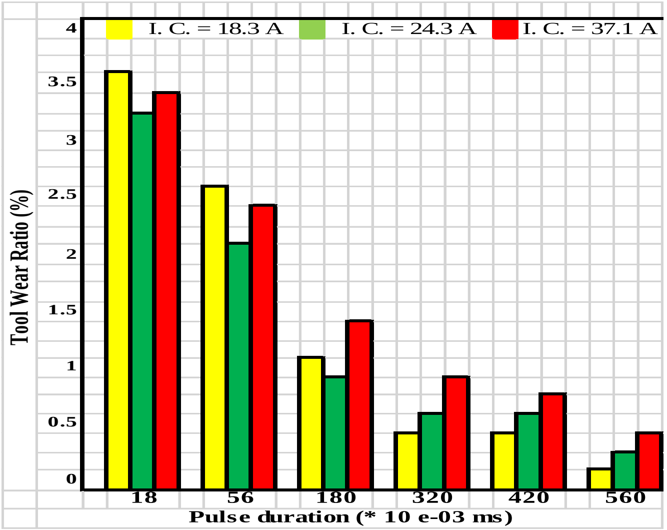

Fig.6. Variation in TWR for different current intensity and Pulse duration

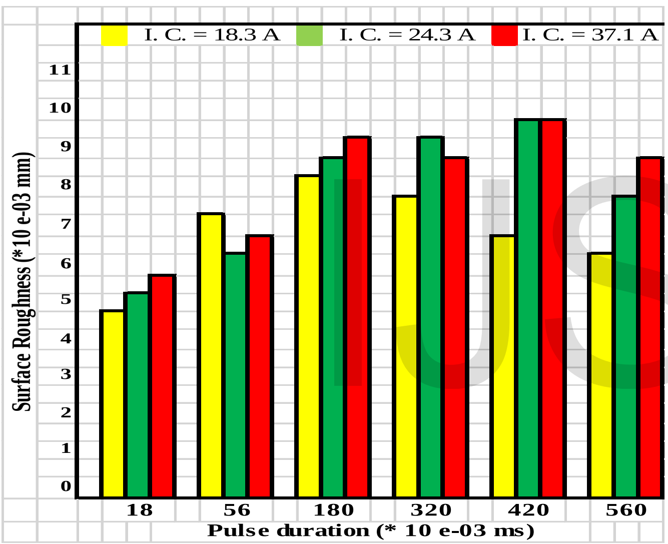

Fig. 7. Variation in Ra for different current intensity and Pulse duration

Fig.5-7 Show how MRR, TWR and R, varied as these parameters were changed. Fig.5, in this fig, the yellow blocks, the green block and the red blocks shows how, the material removal rate (mm^{3}min) varies with pules duration at current intensity of values 18.3 amp, 24.3 Amp and 37.1 Amp respectively. It is clear from fig. That the best value of MRR are obtained. With the highest current intensity values, but appear to peak at intermediate values of pulse duration. Fig.6, Shows the variation in tool wear ratio (TWR) with different current intensities and pulse durations. From this figure it is clear that the TWR decreases with increasing pulse duration; the relationship of TWR with current intensity is more complex, but at higher pulse duration, increases with increasing current intensity.

The fig.7, Shows the variations in surface roughness (Ra) for different current intensities and pulse durations. From this figure it is clear that the surface finish is optimum (i.e. lowest) at low current intensities and low pulse- duration, though the relationships for other values are more complicated. It appears to decrease also at higher pulse duration values.

3.1.2 SEM and EDX analysis -To, investigate how their structure and composition might be altered during the EDM process.

3.1.3 Taguchi Array Analysis - Used an orthogonal array in which taguchi takes into account the no. of variables and level at which variables can be set.

3.2 Results of traditional method

Regression using two variables: - From fig. 5 to 7, we find out the highest MRR value obtained is (1) 98 mm^3/min; the TWR at these setting 0.5% and the surface roughness (R_a) is 9.4 μm. (2) the lowest TWR obtained is 0.16%, the values of MRR is 17 mm^3/min and R_a is 5.8 μm (3) The lowest R_a is 4.6 μm, the MRR and TWR values for these settings are 28 mm^3/min & 3.5%. So these results confirms that there is no single set of input parameter settings which optimize all three output parameters.

If it is essential to have as smooth a surface finish as possible, then a very low MRR and a very high TWR would be obtained. If MRR is the most critical parameter, a reasonably low TWR ratio could be obtained but the surface roughness would be near its maximum value. So in practice, a compromise between the various output parameters must be used to determine the input settings.

TABLE 5
TAGUCHI EXPERIMENTS

	Ram speed (mm^3/ min	Current Intensity (A)	Pulse Duration (*10^{-03} ms)	Duty Factor
Minimum TWR	700	18.3	560	80
Maximum MRR	700	37.1	420	80
Minimum SR	400	18.3	18	18

So for this process we can use 700 mm/min Ram speed and 18.3 A current intensity for optimizing process and pulse duration can take as per as output requirement and duty factor is fixed for all.

4 Latest Technology using Carbon Black Layer

When the carbon comes from the dielectric and other migrated elements, the amount of layer present is varies with current intensity and pulse duration. This layer has been called the "Black Layer".

The result outlined in previous section suggested a new method for improving EDM performance as follows. A first cut is done using a lower current intensity and a long pulse duration, which is normally associated with low MRR and

ISSN 2229-5518

TWR as shown in figure 5 & 6, but which will cause carbon to migrate to the tool thus inhibited tool wear. The current intensity and pulse duration are then altered to setting which normally give high MRR with a much lower TWR than is normally obtained. [5]

Fig. 8 Carbon black layer using in EDM Process

The purposed new method can be summarized as follow:

(a) A lower current intensity and long pulse duration are used for the first part of the erosion to create a wear inhibitor carbon layer on the surface of copper tungsten tool electrode.

(b) A higher current intensity and long pulse duration are used in the remaining part of the erosion cycle because of the added carbon, to improve the material removal rate and maintain a lower tool wear ratio due to the inhibitor carbon layer. [14]

4.1 Results of new method and comparison with traditional method

Several set of experiments have been conducted to test whether or not the new method improve EDM performance.

In the first of these, the preprocessing depth was varied from 0.025 to 4 mm and a total depth of 18 mm was eroded. In traditional method when whole process were carried out in one stage, a current intensity of 37.1 Amp, with pulse duration of 560 µs was used. In the new method, current intensity of 18 Amp and pulse duration of 420 µs is used for the preprocessing stage with 37.1 Amp, with pulse duration of 560 µs (i.e. the same value as in the traditional experiments) for the second stage. The comparison between the value of MRR and TWR obtained in the traditional method and new method are shown in the table. The actual values obtained and their ratios are shown. It can been seen that in all cases, there is an improvement in TWR. The mean value in the improvement is (60±16%) to 95% significant. The MRR appears to increase slightly for a preprocessing depth of 0.025 mm but decreases there after so the results confirm the theory that the TWR in improved by the preprocessing method. The decrease in MRR at higher preprocessing depth is probably due to the fact, that the current intensity use in the preprocessing stage (18.3 Amp) give a very low MRR. It is also shown in table 6 & 7.

TABLE 6
COMPARISON BETWEEN LATEST TECHNOLOGY AND TRADITIONAL METHOD

Methods	Pre processing Depth (mm)	MRR mm^3/min	Ratio of MRR value	TWR (%)	Ratio of TWR value
Traditional Method					
I=37.1A, t_p=560µs	0	89	1	0.38	1
New Technology					
(a)I=18.3A,	0.025	94	1.06	0.28	1.36
t_p=420µs	0.5	82	0.92	0.22	1.74
(b)I=37.1A,	1	83	0.93	0.21	1.77
t_p=560µs	4	73	0.82	0.17	2.23

TABLE 7
COMPARISON OF TWR FOR TRADITIONAL & LATEST TECHNOLOGY FOR VARIOUS PULSE DURATIONS

Pulse duration (µs)	TWR (Traditional) I = 37.1 A, t_p = 560 µs	TWR (New Tech) I = 18.3 A, t_p = 420 µs I = 37.1 A, t_p = 560 µs	Ratio	TWR (Traditional) I = 24.3 A, t_p = 560 µs	TWR (New Tech) I = 14.8 A, t_p = 320 µs I = 24.3 A, t_p = 560 µs	Ratio
18	3.35	2.67	1.25	3.34	2.74	1
56	2.17	1.66	1.31	1.89	1.53	1.24
180	1.09	0.74	1.47	0.86	0.62	1.39
320	0.65	0.41	1.59	0.39	0.27	1.44
420	0.47	0.39	1.21	0.25	0.17	1.47
560	0.38	0.26	1.37	0.17	0.10	1.70

To access whether the improvement in tool wear ratio depends on pulse duration, a series of experiments was done. This dependence was studied because when small pulse durations are used in the traditional method, there is a high TWR which means that the layer is easily removed. In experiments a range of pulse duration with two sets of traditional and new setting and preprocessing depth of 1 mm (24.8 Amp) and 4 mm (37.1 Amp) was used. The ratio of TWR for new method and traditional method is given in the table 7.

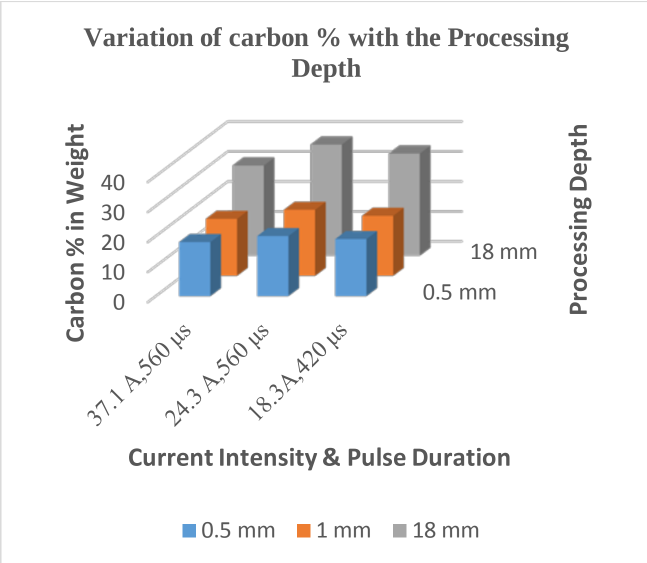

Fig. 9 Variation of Carbon % with the Preprocessing Depth

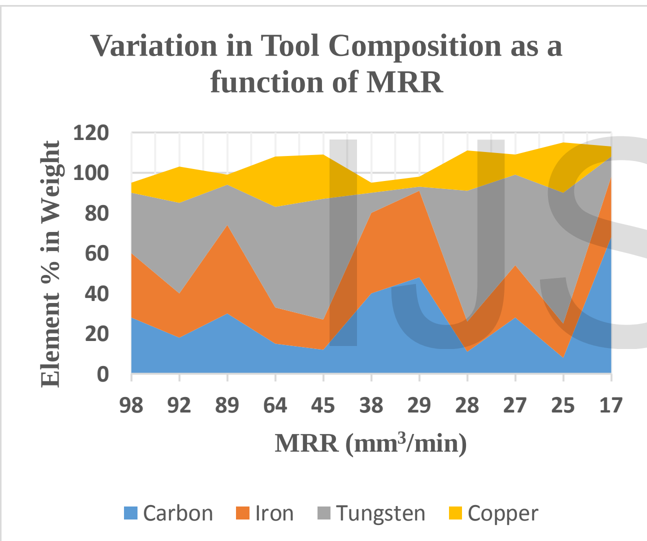

Fig. 10. Variation in Tool Composition as a function of MRR

It can been seen that a series of experiments was done with a range of preprocessing depths using pair of setting with similar percentage of migrated carbon as shown in figure 9.

5 Conclusion

So we can conclude that there is an improvement in all cases by new method. The mean value of the ratio is 1.39 ± 0.9 (95% confidence limit). There is, however, no significant correlation between pulse duration and TWR improvement. The MRR was largely unchanged for the 1 mm preprocessing depth, but was reduced for the 4 mm depth.

To further confirm that the improvement in TWR was due to influence of migrated carbon in new method.

Acknowledgment

We wish to thank Dr. hae-geon lee (Vice President), Dr. Wasihun Yimer (Dean), Mr. Deresse Firew (HOD), Mebratu Yisahak (Coordinator), Alemayehu wakjira ME Deptt, ASOMCME (ASTU), Ethiopia & Dr. A K Raghav, Director, ASET (Amity University Haryana), India. Without their cooperation and support this work was not possible.

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