Parametric Optimization of Material Removal Rate of EDM (AISI-4147) by using Taguchi Approach

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Abstract-*Electric discharge machine is a non-conventional machining. In which there is no contact between tool and work piece. By EDM process machiningof hard material components that are difficult to machine such as heat treated tool steels, ceramics, composites, carbides, heat resistance steel which are usedin die and mould producing industries, aero space and nuclear industries. EDM is a non-contact type technique of material removal and in this spark is used to remove the material from the work piece. Since the EDM is an attractivemeans of making tool and dies with high accuracy in dimension and surface finish quality of micro scale parts.*

The present experimental research studies the process parameters that are influencing the machining concert and its productivity. A collective approachis used for the optimization in parameters and performance characteristics which are based on Taguchi method. The experiments are based on Taguchi"s L9 orthogonal array. The reaction graph and reaction table of each near of machining constraints are took from Taguchi method to select the optimum levels of machining factors. In the work, the machining parameters for thesis are current, pulse on time and pulse off time, which are optimized for minimum tool wear rate (TWR), maximum material removal rate (MRR) and minimum surface roughness during electro discharge machining of AISI 4147. Analysis of Variance is also used to find out variable affecting the various responses mentioned above.

Keywords: *Electric discharge machine, Taguchi"s L9 orthogonal array, AISI-4147, Material Removal Rate.*

1. INTRODUCTION

EDM or electric discharge machining is completed when a release revenue place betweenterminal and cathode, due to release the powerful heat energy is produced near the zone. That isnecessary to melt and evaporate the provisions in the sparkling region. To improve the effectiveness of the process, a die electric fluid (hydrocarbon or mineral oils) is used in this work bit and the tool is submerged. It has been experiential in the course that if both the conductors are of equal material, the electrode joined to helpful terminal mostly corrodes at a earlier rate than the other. Due to this, the work piece is normally made the anode. A properslit, recognized as flash slit, should be continued between the tool and the slog sides tocomplete the process. Since the flash follows at the place where the device and the effortsurface are the close enough and after each spark the spot changes (due to the materialelimination later each flash), the spark trips all over the shallow. This is the reason of uniform material deletion very above the outward, and to finish work piece adapts to the tool apparent.

This is a very common machining method for exact solid metals. For which it is dreadful todevice by straight machining procedures. It has been widely used in extant commerce, mainly for spiteful of intricate reliefs or delicate holes that are trying to machine by straight machining systems. But that there is only one dangerous control in EDM. That is working with electricallyconductive tackles. Tools that can be machined by using EDM are nickel-based mixtures, exactsolid tool braces, conductive fusions, High speed braces, conductive earthenware, etc.

Basically electrical discharge machining is electro-thermal non-traditional material removal process. That is broadly castoff to produce expires, moulds, punches, final shares for troposphere and motorized commerce, machining of ceramics, nozzles, complexes and exact components. The working process of EDM method (figure) is depend upon the thermo electric energy. This energy is formed among a effort and an electrode, that is inundated in a dielectric liquid with the path of electrical modern. A needed state for making a ejection is ionization of dielectric. Appropriate power is brought and passion of dielectric pitch builds up among them. The electrons pause slack from the apparent of cathode and are pressed near the anode under field powers. The continuous flushing of the dielectric is necessary for efficient removal of debris.

The metal removed due to concentrated heating and then vaporization of material during machining process when the distance between the tool electrode and the work part anode is recalled and electrostatic pitch of plenty strength is customary among them, affecting cold emission of electrons from tool electrode. These liberated electrons accelerate towards the anode. Later reaching ample speed , the electrons strike with the particles of dielectric liquid violation them into electrons and helpful ions. Electrons so twisted also quicken and might in the end dislodge to other electrons from the dielectric fluid grains. In the end a digit of tapered columns of ionized dielectric fluid fragments is proven, relating two cathodes affecting an landslide of electrons since the conductivity of the ionized support is identical large which is ordinarily seen as a trigger. Thus a very high hotness is settled on the anodes. This is the goal of melting and vaporization of the electrode material and the molten metal evacuates by a mechanical blast, resulting in a small crater on both the electrodes.

2. LITERATURE REVIEW

Electrical discharge machining (EDM) is the machining rehearsal in which there is not at all contact midst instrument and work piece. And it has been incessantly embryonic from a mere industrial geometrically composite or hard solid part and die production process to a small computer level submission machining alternate attracting a momentous amount of inquiry comforts. In recent years, EDM researchers have found a number of ways to improve the sparking efficiency that including some unique experimental concept that depart from the EDMoutmoded sparkling occurrence.

A study conducted was by Subramanian Gopalakannan and Thiagarajan Senthilvelan to observed the effect of beaten current on physical deletion rate, anode wear, surface bumpiness and space overcut in weathering resistant stainless hardens viz., 316 L and 17-4 PH. The supplies used in the effort were machined by changed electrode supplies such as graphite, copper-tungsten & copper. It is practical in the procedure that the productivity constraints such as measurable deduction rate, cathode wear and apparent coarseness of EDM upsurges with similar addition in pulsed current. The last result gained that the high factual exclusion rate have been gotten with copper cathode whereas copper-tungsten generated minimum anode wear, smooth exterior varnish and good dimensional correctness.
The study of Pravin R. Kubade and V. S. Jadhav It is found by dimension that the MRR is mostly unfair by peak modern where as additional the other issues used, have a actual less effect on factual deletion rates. The electrode dress rate is largely partial by peak recentand pulsate on spell, duty round and gap energy have a very less upshot on conductor wear rates. Peak modern has the most power on radial overcut then tailed by duty cycle and thumpon time with almost actual less impact by gap voltage.

A.K. Sarathe conducted trials and found well machining routine was obtained commonly with the anode as the cathode and the work-piece as an anode and it was pragmatic that for high MRR main process strictures are peak recent, pulsation on stint, thump off spell, whereas for anode wear were mainly partial by peak recent and thump on stint. The apparent quality of the work was chiefly partial by peak modern. The tool shape structure concerned besttool shape for upper MRR and lower TWR is globular, followed by tetragonal, trilateral, quadrilateral, and equilateral cross pieces.

In a research, Abhishek Gaikwad, Amit Tiwari, Amit Kumar and Dhananjay Singh studied the upshot of governor factors (i.e., present, pulse on interval, pulse off interval, liquid pressure) for all-out material deduction rate (MRR) and least electrode wear speed (EWR) for EDM of hard sensible Stainless steel 316 with copper as spiteful tool conductor. In this paper together the electrical non electrical matters have been committed which directs MRR and EWR. The paper is based on Project of research and optimization of EDM progression strictures. The practice used is the Taguchi technique which is a statistical conclusion assembly tool helps in lessening the number of investigates and the error connected with it. The enquiry exhibited that the Pulse off time, Current has weighty effect on factual subtraction rate and anode wear rate separately.

C.H. Cheron machined XW42 tool steel and concluded that the material removal ratewith Cu electrode is greater than graphite electrode. He also concluded that Cu is suitable for roughing the surface while graphite is suitable for finishing surface.

A similar study was conducted by Ahmet Hascalık and Ulas¸Caydas using parameters which are pulse current and pulse duration. These concludes that electrode material has an obvious effect on the white layer thickness, the material removal rate, surface roughness and electrode wear are increasing with process parameters.

S. Ben Salem et al Accompanied experiments by untried project approach and start that a few expanse of tests are essential to find best effect and the outward bumpiness impartiality shows that the recent intensity is the main touching factor on granularity.

In a research carried out by V. Chandrasekaran et al on WC/5ni Composites Using Comeback Surface Methodology established that the MRR is all-out for all works. So the MRR growths with the part of nickel. The surface irregularity increases with growth in present and coloring weight regardless of %Ni. The optimum Ra values decreased with increasing electrode rotation. Francesco Modica et al aimed of enquiry to shed a light on the next of kin and need among the material elimination process, notorious in the appraisal of the tool garb ratio (TWR) and material elimination rate (MRR), and some of the most imperative technological constraints (*i.e.*, open voltage, ejection current, pulse width and regularity), in order to experimentally measure the factual waste created and heighten the industrial process in order to diminution it. Kumar Sandeep studied facets related to exterior quality and copper elimination rate which are the most central strictures from the point of sight of decideon the optimal condition of methods as well as economical phases.

3. EXPERIMENTATION

EXPERIMENTATION SETUP

ELECTRONICA S-70 ZNC EDM machine was used for machining the samples. The machine is as shown in the figure below. EDM is a, non-traditional" or „non-conventional" collection of machining systems. Ideally, EDM can be as seen as a strings of interruption and renewal of the liquid dielectric in-between the conductors.

Table 3.1 Technical Specifications of EDM

Sr. No.	Specification	Value
1	Model	S-70 ZNC
2	Dielectric Fluid	EDM Oil
3	Input Power Supply	Three phase AC 415 V, 4 wire system, 50 Hz
4	Electrode used	Copper

5	H X W X D machine size	1750 X 1060 X 525 mm
6	Maximum Load Lift	750 kg
7	Pulse on time	0.5 to 4000
8	Pulse frequency	0.1 to 500
9	Main Table Traverse (X,Y)	1100 X 650 mm

Figure 3.1: EDM Machine

Figure 3.2: Machining the workpiece on EDM

WORK PIECE MATERIAL

The solid cast-off for this grind is AISI 4147 description of 5 mm thickness and 10 mmdiameter.

Table 3.2 Properties of AISI 4147

Density (g/cm^3)	Melting point (°C)	Yeild strength (MPa)	Elastic modulus (GPa)	Possion's Ratio	Brinell Hardness
7.85	1427	470	196	0.3	217

Table 3.3 Chemical composition of the workpiece material (AISI 4147) by weight

Material	Fe	C	Si	S	P	Mn	Cr	Mo
% Composition	96. 73 – 97.70	0.45 – 0.50	0.15 – 0.30	<=0.040	<=0.035	0.75 – 1.0	0.80 – 1.1	0.15 – 0.30

TOOL MATERIAL

The tool material used for this work is 100% Copper (Cu). The tool was prepared of dimensions as 2 inches length and 3 mm diameter.

Figure 3.3: Copper Tools

4. RESULTS AND DISCUSSION

CALCULATION FOR MRR

The material elimination rate is the degree at which the substantial is uninvolved during machining. The bulk loss is considered by assessing the sample before and next machining. Machining time is celebrated while machining each example. The factual removal speed is calculated by subsequent method:

$$MRR = \frac{\text{(Work piece weight loss (gm)) X 1000}}{\text{Density (gm/cc) X Machining Time}}$$

Table 4.1: L9 Orthogonal Array

Exp. No	Current (A)	Pulse-on-time (μsec)	Gap Voltage (V)	MRR(mm³/min)
1	1	10	100	0.0849
2	1	15	125	0.1411
3	1	20	150	0.2682
4	5	10	125	0.2548
5	5	15	150	0.3475
6	5	20	100	0.5662
7	9	10	150	0.7280
8	9	15	100	1.911
9	9	20	125	1.2740

Calculation of S/N ratio for MRR

The S/N ratio, which shortens the numerous data facts within a provisional, depends on the type of faces being appraised. For intention of S/N ratio for material elimination rate LARGER IS BETTER situation is opted. The calculation for the scheming of S/N ratio for material elimination rate is:

$$S/NLB = -10 \log (\Sigma (1/yi^2))$$

Table 4.2 Calculation of S/N ratio for MRR

S.No	MRR(mm³/min)	Signal to noise ratio (db)
1	0.0849	-21.4218
2	0.1411	-17.0095
3	0.2682	-11.4308

4	0.2548	-11.8760
5	0.3475	-9.1809
6	0.5662	-4.9406
7	0.7280	-2.7574
8	1.911	5.6252
9	1.2740	2.1034

Calculation of Mean S/N ratio for MRR
Mean S/N ratio is calculated by using following formula

$$nf_i = (nf_1 + nf_2 + nf_3)/3$$

Where nf is mean S/N ratio for factor f at the level value i of the selectedfactor. nf_1, nf_2, nf_3 are S/N ratio for factor f at level.
The factors which affect the machining parameters show in the table as their respective ranks. Rank of the strictures depends on the value of estuary. Complex value of S/N ratio of both factor displays the optimum level of the factor. Peak current displays the foremost outcome in the above retort table and pulse on stretch is less actual as related to peak existing.

Table 4.3 Calculation of mean S/N ratio for MRR

Level	Peak Current	Pulse on Time	Voltage
1	-16.621	-12.018	-6.912
2	-8.666	-6.855	-8.927
3	1.657	-4.756	-7.790
Delta	18.278	7.262	2.015
Rank	1	2	3

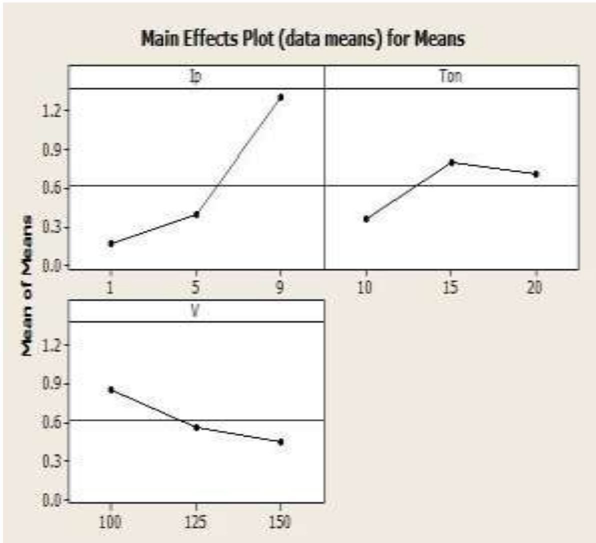
Analysis of Variance for MRR
The following table shows ANOVA of MRR showed on MINITAB 16.0. The resultshows that the impact of current is maximum and is 73.95%.

Table 4.4 ANOVA of MRR

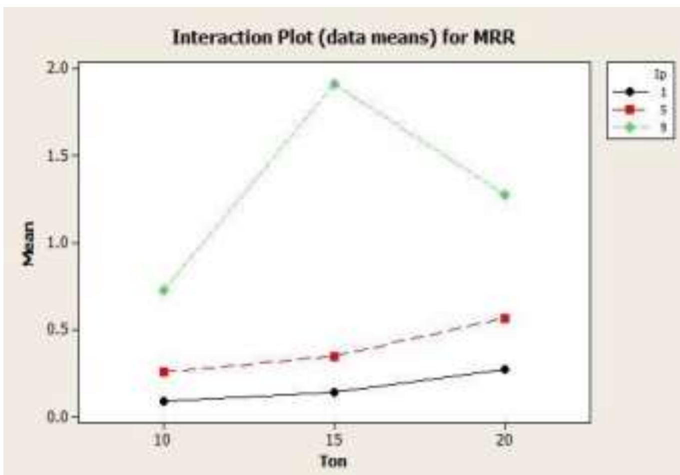
Source	DOF	SS	Adj MS	F value	% Contribution
Peak Current	2	2.186	1.093	12.29	73.95%
Pulse on Time	2	0.327	0.163	1.84	11.06%
Voltage	2	0.265	0.133	1.49	8.96%
Error	2	0.178	0.089		6.03%

Total	8	2.956			100%

At least 95% confidence



The above graph offerings the main conclusion plot for revenues. It displays that with growth in current, the MRR initially surges at gentler rate but with growing in the level of current, MRR progresses at a complex rate. The discharge energy is higher at higher levels of pulse on time thus we get higher material removal rate. For lesser pulse on time, the acquittal energy is deficient thus the material exclusion rate is low. In the case of current, the MRR tends to reduction with surge in voltage. Voltage is the least persuading limitation for energy and has a influence of only 8.96%.



The above plot elucidates that at lower levels of peak current (i.e. 1A and 5A) the pulse on time has low influence on MRR. This is due to the datum, as at high present the power of spark is further and hereafter the material uninvolved from the work piece will need some time to get flushed from the gap. As this removed material is present between the spark gap, hence the intensity of spark reaching the surface of the work piece is reduced.

Optimal Levels of Parameters for MRRPeak

- Current : 9A
- Pulse on Time : 15 μ sec
- Voltage : 100 V

5. CONCLUSIONS

This uncertain search for optimization of input machining parameters in Electrical discharge Machining of AISI 4147 using L9 orthogonal array of Taguchi method. Features like Modern, Pulse on Time and Voltage and their relations have been create. The product shows the recital of factors at different points to optimize the MRR, TWR and Outward Unevenness.

Following decisions are made thru the exploration:

- MRR initially rises at deliberate rate with modern but complex levels of up-to-date, MRR increases at a upper rate. Higher the present, amount of spark is improved and thus brass removal rate growths. Furthermore, current is the most weighty aspect for MRR.
- In situation of pulse on spell, the MRR rise with growth in its near but it has a short effort of 11.06%. The ejection energy is complex at higher stages of pulse on time hence we get higher material elimination rate. For lesser pulse on time, the release energy is insufficient thus the material elimination rate is low.
- MRR tends to reduction with rise in voltage. Voltage is the least impelling parameter forvoltage and has a impact of only 8.96%.

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