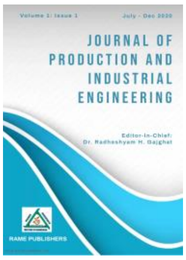

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Analysis and Optimization of EDM Process Parameters using Taguchi Method for AISI 304

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Abstract- **Electrical discharge machining (EDM) is one of the most important Non-conventional machining processes. Voltage (V), Spark on time (Ton), Discharge current (Ip) are important process parameters in this technique. The values of these parameters significantly affect such machining outputs as the material removal rate.**

In this dissertation work three-dimensional thermo-physical model for the electrical discharge machining was developed using ANSYS software and experiment have been conducted on die sinking EDM using AISI 304 as a workpiece to investigate the effect of most significant machining parameters. For that L9 orthogonal array was developed, and material removal rate (MRR) for AISI 304 was measured for every experimental run. For validation purpose, parametric analysis using ANSYS has been conducted to predict the MRR. To find out the regression equation and optimum process parameters mathematical modeling of MRR has been carried out using MINITAB software.

Keyword - Electrical discharge machining (EDM), Spark on time, Current, Voltage, Tensile test, Material Removal Rate (MRR)

I. Introduction

Electro Discharge Machining (EDM) is an electro-thermal non-conventional machining Process, where electrical vitality is utilized to create electrical flash and material expulsion basically happens because of thermal energy of the spark. EDM is primarily used to machine hard to-machine materials and high-quality temperature safe alloys. EDM can be utilized to machine troublesome geometries in little clusters or even on work shop premise. Work material to be machined by EDM must be electrically conductive.

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A. Principle of EDM

Fig. 1 shows schematically the fundamental working rule of EDM process. In EDM, a potential distinction is applied between the tool and workpiece. Both the tool and the work material are to be conduits of power. The tool and the work material are drenched in a dielectric medium. For the most part kerosene or deionized water is utilized as the dielectric medium. A gap is kept up between the tool and the workpiece. Contingent on the applied expected distinction and the gap between the tool and workpiece, an electric field would be built up. For the most part the tool is associated with the negative terminal of the generator and the workpiece is associated with positive terminal. As the electric field is set up between the device and the job, the free electrons on the apparatus are exposed to electrostatic forces. On the off chance that the work or the bonding energy of the electrons is less, electrons would be discharged from the device (accepting it to be associated with the negative terminal). Such outflow of electrons is called or named as cold emission. The "cold emitted" electrons are then quickened towards the activity through the dielectric medium. As they gain speed and energy, and begin moving towards the jon, there would be crashes between the electrons and dielectric atoms. Such impact may bring about ionization of the dielectric particle relying on the work capacity or ionization energy of the dielectric atom and the energy of the electron. Consequently, as the electrons get quickened, more positive particles and electrons would get produced because of crashes. This cyclic procedure would build the convergence of electrons and particles in the dielectric medium between the tool and the job at the spark gap. The focus would be high to such an extent that the issue existing in that channel could be portrayed as "plasma".

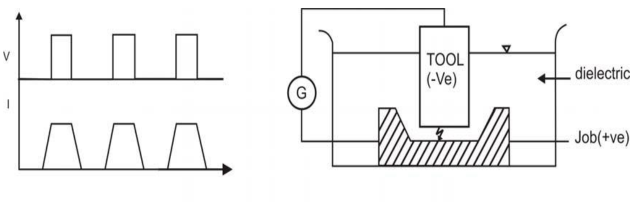

Figure 1. Schematic representation of the basic working principle of EDM process.

The electrical obstruction of such plasma channel would be less. Along these lines out of nowhere, countless electrons will spill out of the tool to the job and particles from the job to the tool. This is called avalanche motion of electrons. Such development of electrons and particles can be outwardly observed as a sparkle. Therefore, the electrical energy is dispersed as the thermal energy of the spark. The fast electrons at that point encroach at work and particles on the device. The dynamic energy of the electrons and particles on sway with the outside of the job and tool separately would be changed over into thermal energy or heat flux. Such serious restricted heat flux prompts outrageous momentary kept ascend in temperature which would be in abundance of 10,000oC. Such limited outrageous ascent in temperature prompts material removal. Material removal happens because of moment vaporization of the material just as because of melting. The liquid metal isn't expelled totally however just mostly. As the potential contrast is pulled back as appeared in Fig. 1, the plasma channel is not, at this point continued. As the plasma channel breakdown, it creates pressure or shock waves, which empties the liquid material shaping a pit of expelled material around the site of the sparkle.

Along these lines to sum up, the material removal in EDM for the most part happens because of arrangement of shock waves as the plasma channel breakdown inferable from cessation of applied likely distinction. For the most part the work piece is made positive and the tool negative. Subsequently, the electrons strike the job prompting cavity arrangement because of high temperature and dissolving and material removal. So also, the positive particles encroach on the device prompting tool wear. In EDM, the generator is utilized to apply voltage beats between the tool and the job. A constant voltage isn't applied. Just sparking is wanted in EDM instead of arcing. Arcing prompts limited material removal at a specific point though starts get circulated everywhere throughout the tool surface prompting consistently disseminated material removed under the tool.

B. Types of EDM

Electric discharge machining empowers the machining operation in a few different ways. A portion of these tasks are like conventional operations, for example, milling and die sinking others have its own trademark. Various characterizations are conceivable and it ought to be remembered that, current advancements in its technology include various kinds of operations. Be that as it may, a straightforward and general grouping can done by considering famous applications, for example,

- Die Sinking EDM
- Wire EDM
- EDM Milling

C. Tool Material

Device material ought to be to such an extent that it would not experience a lot of tool wear when it is encroached by positive ions. Consequently, the confined temperature rise must be less by fitting or appropriately picking its properties or in any event, when temperature increases, there would be less melting. Further, the tool ought to be effectively functional as mind boggling formed geometric highlights are machined in EDM.

Thus, the basic characteristics of electrode materials are:

- High electrical conductivity – electrons are cold emitted more easily and there is less bulk electrical heating.
- High thermal conductivity – for the same heat load, the local temperature rise would be less due to faster heat conducted to the bulk of the tool and thus less tool wear.
- Higher density – for the same heat load and same tool wear by weight there would be less volume removal or tool wear and thus less dimensional loss or inaccuracy.
- High melting point – high melting point leads to less tool wear due to less tool material melting for the same heat load.

Cylindrical hollow shaped pure copper of outer diameter 6mm and inner diameter 4 mm is used for machining of AISI 304 material.

D. *Work Piece Material*

It is capable of geometrically machining complex or difficult material components such as heat-treating tool steels, composites, super alloys, ceramic, carbides, heat-resistant steel etc. The material is precisely and difficult to machine.

The EDM method is used in several types of tool material. Moreover, the steel tool contains carbon and alloys which are particularly suitable for tools. Their rationality comes from their special hardness, abrasion resistance, their ability to hold a trim and their protection against twisting at elevated temperatures (red-hardness). Tool steel is usually used in a heat-treated state. For applications such as stamping dies, metal cutting tools, and others, higher carbon grades are regularly used.

It is suitable for the processing of hard materials, such as heat treatment of tool steels, composites, super alloys, ceramics, carbides, thermal-resistant steels, etc. For such applications as stampings, metal-cutting tools, and others, the high carbon grades are regularly used.AISI evaluations of tool steel is the most widely recognized scale used to distinguish different evaluations of tool steel. Individual composites inside an evaluation are given a number; for instance: A2, O1, D2, P20 and so on.

Contingent on the literature review, it is realized that almost no work has been finished on AISI 304 material. Subsequently in this test utilizing AISI 304 tool steel material (thickness 8 g/cm3) work piece utilizing a copper (thickness 8.9 g/cm3) The work piece is as a meager portion of measurements 80 mm x 80 mm x 2 mm. Little estimated work pieces are utilized for simplicity of weight measurement on the balance. Tool electrode is as a cylinder with the end goal that high-speed dielectric moves through it.

E. *Objective of Present Work*

Research papers show that EDM work on Al-Sic, EN-19, SKH 57, AISI H13, D2 tool steel and various composite materials is very extensive. To validate experimental results, an EDM study of different materials and the various mathematical models can be used.

In this paper, AISI 304 material and tubular copper electrode have selected. Also, few researchers have been taken the process as discharge current, Ton, Voltage. So, here the levels of this parameter are varied in order to find out their optimal values finding the highest for MRR. For this also consulted some industries namely Indo German Tool Room Aurangabad & Track Technical Service, Bhosari, Pune. They suggested that En19, En 24, AISI D3, OHNS, AISI 304 are widely used for production of plastic mold and die making. Parametric analysis has to be done on set of experiment and also, FEA modeling of EDM process has also been carried out to predict the MRR for single discharge. Multi-discharge MRR modeling has also been carried out for the EDM process for which consulted some industries namely MCP technology, Pune and results are verified with the experimental investigation. Effects of different process parameters have also been studied. The aim of this project was to prove or study that FEA will be used in place of experimental study to find MMR.

Literature review carried out in the area of analysis and optimization of EDM process parameters in context to the present work is presented.

P. Narender Singh et al. [1] have directed experimental study on machining of cast Al-MMC with 10% SiCP to examine the impact of current (C), Pulse ON-time (P) and flushing pressure (F) on metal removal rate (MRR), tool wear rate (TWR), taper (T), radial overcut (ROC), and surface roughness (SR) in electric discharge machining and utilization of metal matrix composites. ELEKTRAPULS sparkle erosion machine was utilized for the reason and jet flushing of the dielectric fluid, kerosene, was utilized. Metal device of distance across 2.7mm was picked to drill the specimen. A L27 OA, for the three machining parameters at three levels each, was picked to lead the examinations. ANOVA was performed and the ideal levels for augmenting the reactions were set up. Scanning electron microscope (SEM) examination was done to contemplate the surface attributes.

The impacts of the machining parameters (MRR, TWR and SR) in EDM on the machining qualities of SKH 57 high-speed steel. Experimental structure was utilized to decrease the all-out number of examinations. Portions of the examination were led with the L18 orthogonal array dependent on the Taguchi method. In addition, the sign to-commotion proportions related with the watched qualities in the investigations were dictated by ANOVA and F - test. The relationship of MRR and SR with pulse duration graph in various peak current. During the examination MRR increments with top current MRR at first expanded to a top at around 100 µs, and afterward fell [2].

B.Mohan and Satyanarayana was introduced an advancement of impact of the EDM Current, electrode marital polarity, pulse duration and rotation of electrode on metal removal rate, TWR, and SR, and the EDM of Al-Sic with 20-25 vol. % SiC, Polarity of the electrode and volume present of SiC, The MRR is expanded with increase in discharge current and explicit current it diminished with expanding in pulse duration. Speeding up the rotation electrode brought about a constructive outcome with MRR, TWR and preferred SR over fixed. The electric motor can be utilized to turn the electrode (tool) AV belt was utilized to send the power from motor to the electrode. Optimization parameters for EDM drilling were likewise evolved to sum up the impact of machining characteristics, for example, MRR, TWR and SR [3].

Dhar and Purohit were assesses the impact of current (c), pulse-on time (p) and air gap voltage (v) on MRR, TWR, ROC of EDM with Al–4Cu–6Si alloy–10 wt. % SiCP composites. This trial can be utilizing the PS LEADER ZNC EDM machine and a tube shaped metal anode of 30 mm width. What's more, three elements, three levels full factorial structure was utilizing and breaking down the outcomes. A subsequent request, non-straight scientific model has been produced for setting up the relationship among machining parameters. The model critics were examined using the ANOVA method and found an enormous increase in the MRR, TWR and ROC in a non-direct structure with an increase in current levels [4].

Study of parameter in EDM by utilizing the RSM, the parameter like MRR, TWR, gap size and SR and pertinent test information were gotten through experimentation. They are utilizing Al/Sic composites material and indicated the relationships between the cutting rates, the surface finish and the physical material parameters of this procedure made it hard to utilize. An ideal mix of these parameters was achieved to achieve controlled EDMs and MRR increases, where pulse expansion was achieved in time, maximum current and gap voltage, and MRR decreased, with Sic percent expansion. [5].

The impact of tool rotation on MRR, device wear and surface finish has been tentatively concentrated in oil-die sinking EDM. Tests were directed with a pivoting copper-tungsten device electrode for oil-die sinking EDM of titanium workpiece. Structured examinations were led to contrast rotating EDM and stationary tool EDM. It was discovered that pivot of the tool prompts a higher sparking proficiency and a superior flushing of debris from the release gap thus prompting a higher MRR. In any case, a less fortunate surface finish was acquired with a rotating tool. It was likewise seen that a factually huge impact of tool turns on instrument wear didn't exist [6].

In the current examination, an endeavor has been made to assess the exhibition of electric release machining during machining of AA6061-wt.10% B4Cp metal framework composite. The displaying and streamlining of electric release machining have been made through reaction surface philosophy (RSM) joined with Box-Behnken structure (BBD) of analyses. The impact of machining parameters viz current, pulse ontime and pulse offtime were considered for machining of composite. The reaction factors viz-material evacuation rate, instrument wear rate and surface unpleasantness were researched by applying ANOVA and through factor connection charts in RSM. The exploratory information focuses were seen to be best fitted by non-straight quadratic models. All the elements were seen as factually noteworthy in deciding surface roughness while current and pulse on time were the prevailing variables influencing material removal rate [7].

Experimental investigation of machine parameters is carried out for EDM using U-molded cathode of EN-19 instrument steel. In this paper, an endeavor has been made to machining the En-19 apparatus steel by utilizing U-formed copper terminal perform on electrical discharge machine. Where Diameter of U-formed cathode, Current and Pulse on time are taken as procedure input boundaries and material evacuation rate, device wear rate, overcut on surface of work piece are taken as yield parameters. A lot of eighteen experiments (Taguchi configuration) were performed on electronica make savvy ZNC electric release machine and connections were created among info and yield boundaries. The examination shows that, MRR expanded with the release current (Ip). As the beat term expanded, the MRR diminishes monotonically. On account of Tool wear rate, the most significant factor is release current at that point beat on schedule and after that breadth of hardware. On account of over cut the most significant factor of release current then breadth of the tool and no impact on pulse on time [8].

EDM studies was done on aluminum alloy-silicon carbide composites developed by vortex technique and pressure die casting. In the current work, aluminum compound silicon carbide composites were created utilizing another mix of vortex strategy and weight pass on throwing method. Electrical Discharge Machining (EDM) examines were led on the aluminum combination silicon carbide composite work piece utilizing a copper anode in an Electrical Discharge Machine. The Material Removal Rate (MRR) and surface harshness of the work piece increments with an expansion in the current. The MRR diminishes with increment in the percent weight of silicon carbide. The surface completion of the machined work piece improves with percent weight of silicon carbide [9-10].

II. Experimental Procedure

This explains about the experimental work which is consisting of L9 orthogonal array based on Taguchi design. The orthogonal array reduces the total number of experiments. In this experimental work total numbers of runs are 9. Experimental setup, selection of work piece and tool, experimental procedure and taking all the value and calculation of MRR are explained below.

A. *Experimental Set Up*

For this experiment the whole work can be down by Electric Discharge Machine, model ELECTRONICA-ELECTRA EMS 5535 ZNC (die-sinking type) with servo-head (constant gap) and positive polarity for electrode was used to conduct the experiments. Commercial grade EDM oil (specific gravity= 0.763 kg/m3, freezing point= 94°C) was used as dielectric fluid. Experiments were conducted with positive polarity of electrode. The pulsed discharge current was applied in various steps in positive mode.

The EDM consists of following major part.

- Dielectric reservoir, pump and circulation system.
- Power generator and control unit.
- Working tank with work holding device.
- X-Y table accommodating the working table.
- The tool holder.
- The servo system to feed the tool.

Figure 2. Electric Discharge Machine; model ELECTRONICA-ELECTRA EMS 5535 ZNC (die-sinking type).

B. Important Parameters of EDM

a. Spark On-time (pulse time or Ton)

Machining only takes place during the pulse (Ton). The current is allowed to flow per cycle for the duration (μs). The removal of material is directly proportional to the energy measurement of time applied. The maximum current and the length of time really restrict this energy.

b. Spark Off-time (pause time or Toff)

The time span (μs) between the sparks (in other words, on-time). This time, the molten material is solidified and the Arc gap is wasted time. This parameter affects the speed of the cuts and their stability. In this way, the sparks will become unstable when the off-time is excessively short.

c. Arc gap (or gap)

During EDM procedure, the Arc hole divides the electrode and workpiece. It could be called a spark gap. Spark gap by servo system can be maintained.

d. Discharge current (current Ip)

A share of the power provided to this discharge gap is the discharge current (Ip). Higher current causes higher pulse energy and more deep discharge craters to be developed. This creates the removal rate of material (MRR) and the surface roughness value (Ra). When the gap voltage (Vg) is expanded, comparative effects on MRR and Ra are achieved. Current in amp Allowed to be estimated per cycle. Discharge current proportionate directly to the removal rate of the material.

e. Voltage (V)

It can further impact on the material removal rate and can be measured by volt per cycle. It can be used by volt. In this test the voltage is 50 V.

f. Diameter of electrode (D)

There are two different sizes of 4mm and 6mm width of the Cu-tube electrode in this analysis. This tool is used both as an electrode and for inner flushing.

C. Design Variable

Design parameter, process parameter and constant parameter are following ones,

Design parameters –

- Material removal rate.
- Tool wear rate

Machining parameter –

- Discharge current (Ip)
- Voltage
- Pulse on time (Ton)

Constant parameter-

- Duty cycle
- Flushing pressure
- Polarity.

D. Selection of Process Parameter

Depending upon the literature survey, I have selected the following input parameter which significantly affect on MRR.

- Voltage (V)
- Spark on time or pulse duration (Ton)
- Discharge current (Ip)

The levels of experiment parameters voltage, spark on time, and discharge current are shown in Table. I have consulted to Sam Tolling; they told the range of levels of the process parameters which is favorable to the selected work piece material and dimensions.

TABLE 1
LEVELS OF PROCESS PARAMETERS

Machining Parameter	Symbol	Unit	Level		
			Level 1	Level 2	Level 3
Voltage	V	V	50	100	150
Spark on time	Ton	Ms	40	80	120
Discharge Current	Ip	A	8	12	16

E. Design of Experiment

DOE refers to the planning, design and analysis of an experiment in order to draw valid and objective conclusions efficiently and effectively. In performing a designed experiment, charge is to the input variable and corresponding charges in the output variables are called resource and the output variable called response. Resource may be either qualitative or quantitative. Quantitative factor is discrete in nature (such as type of material, color of sample). Each factor can take several values during experiment. Each such value of factor called is level. A trial or run is a certain combination of factor levels whose effect on output is interest. It is convenient to represent the high-level value of a factor as +1 and the low-level value as -1, and transforming all the factor in to same [-1 1] coded range. It is essential to incorporate statistical data analysis method in experimental design in order to draw statistically sound conclusion from the experiment. Some of the advantages of DOE over One-Variable-At-A-Time approach (OVAT) are that a DOE approach enables to separate the important factor from the unimportant ones by comparing the factor effect. Also, interaction effect among different factor can be studied thought design experiments.

Before starting experiments several things needed to be done in order to run the experiments smoothly and accurately. Bet basically, their Five general steps have been taken to ensure efficient use of DOE tools..

The five general steps are

- Plan the experiment
- Design the experiment
- ‘conducting the experiment
- Analyze the data from the experiment
- Confirmation of the experiment

F. Conducting Experiments: Standardization

AISI 304 Tool steel material particulate was using Copper tube tool with 4mm and 6mm diameter. And the PS 50ZNC (die-sinking type) of EDM machine are used. Commercial grade EDM oil (specific gravity= 0.763, freezing point= 94°C) was used as dielectric fluid. In this experiment three factor are tackled with a total number of 9 experiments performed on die sinking EDM. The computation of material removal rates and tool wear rate of material removal by means of electronic balance machines. This precision of the machine is 0.001. Several controllable parameters such as the gap voltage, discharge current, pulse on time, have been considered for analysis during the project. However, many other parameters which may have an effect on the output have not been studied. Some of these may be beyond our control (such as environmental conditions: room temperature and humidity). However, it may be possible to control some of them (such as Z motor sensitivity and anti-arc sensitivity). During the experiments it is essential to keep such parameters at some preset values so that data obtained from different runs are comparable. To ensure this, the following minimum standard has been maintained throughout all the experiments. Wherever necessary (and possible), extra precaution has been taken. The protocol is explained below:

For making/finding zero gap tool position

(a) First the tool and work piece are set.

(b) The tool is the brought near the work piece surface.

For starting machining operation

(c) First the tool and work piece are set

(d) Machining zero (zero inter-electrode gap position) is then set.

(e) The tool-work piece gap is then to a preset value (250 μm). It is important to standardize the initial gap value since MRR may depend on it. It is found that typically the spark gap in EDM is less than 100 μm. If the starting gap is set to a very high value, the machine takes a long time before the tool-work piece gap reduces to spark gap value and machining starts. On the other hand, a very small value may lead to arcing or short circuit. Hence the starting gap is set to an intermediate value of 250 µm.

(f) Finally, the 'SPARK' operation is selected on the control panel to start machining.

The selected orthogonal array for design of experiments is listed in the table 4.7. according to the selected OA, I performed 9 experiments ELECTRONICA- ELECTRA EMS 5535 ZNC (die-sinking type), having provision of programming in the Z-vertical axis and manually operated X and Y axes. The selected process variables were varied up to three level and orthogonal arrays was adopted to design the experiments as listed in table2.

TABLE 2

L9 ORTHOGONAL ARRAY

Exp. No.	Voltage (V)	Ton (µs)	Current (amp)
1	50	40	8
2	50	80	12
3	50	120	16
4	100	40	12
5	100	80	16
6	100	120	8
7	150	40	16
8	150	80	8
9	150	120	12

IV. RESULT AND DISCUSSION

The present chapter gives the application of the Taguchi methodology. The scheme of carrying out the experiment and FEA analysis was selected and experiment and FEA analysis were conducted to investigate the effect of process parameter on output parameter material removal rate (MRR). The experimental and FEA analysis result are discussed subsequently in following section. The selected process variables were varied up to three levels and orthogonal array was adopted to design the experiment. Minitab software was used for optimal values of process parameters.

A. Experiment Analysis

- Mechanism of MRR

It is well-known that the MRM is the process by which material elements are converted between the workpiece and the electrode. The transformation will be transported in solid, liquid or gaseous condition and then alloyed by a solid, fluid or gaseous phase reaction to the contacting surface.

The material MRR is expressed as the proportion of the weight difference of the workpiece between the processing time and the material density.

$$MMR = \frac{W_{j_b} - W_{j_a}}{t \times \rho} \quad (1)$$

Where,

Wj_b = Weight of work piece before machining.

Wj_a = Weight of work piece after machining.

t = Machining time.

ρ = Density of AISI 304 steel material = 7.93 gm/cm^3

TABLE 3

EXPERIMENTAL RESULT OF MRR FOR AISI 304

Run	Voltage (V)	Spark on time (µs)	Discharge Current (A)	Wt of Workpiece (gm)		Machining Time (min)	Density (gm/mm3)	MRR (mm^3/min)
				Wjb	Wja			
1	50	40	8	82.501	82.222	18.16	0.00793	1.94
2	50	80	12	82.222	81.956	12.19	0.00793	2.75
3	50	120	16	81.956	81.678	3.79	0.00793	9.25
4	100	40	12	81.678	81.394	10.72	0.00793	3.34
5	100	80	16	81.394	81.123	5.97	0.00793	5.72
6	100	120	8	81.123	80.856	11.9	0.00793	2.82
7	150	40	16	80.856	80.569	15.44	0.00793	2.34
8	150	80	8	80.569	80.281	19.19	0.00793	1.89
9	150	120	12	80.281	80.003	13.26	0.00793	2.64

B. Evaluation of Optimal Settings

From the experimental result, the effect of process parameters on MRR are plotted by using MINITAB software as shown below.

TABLE 4

S/N RATIO FOR AISI 304 MATERIAL

Expt. No.	Voltage (V)	Spark on time (µs)	Discharge Current (A)	MRR (y_i) mm^3/min	S/N ratio $n_o = -10\ln_{10}\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y_i^2}$
1	50	40	8	1.94	5.7560
2	50	80	12	2.75	8.7867
3	50	120	16	9.25	19.3228
4	100	40	12	3.34	10.4749
5	100	80	16	5.72	15.1479
6	100	120	8	2.82	9.0050
7	150	40	16	2.34	7.3843
8	150	80	8	1.89	5.5292
9	150	120	12	2.64	8.4321

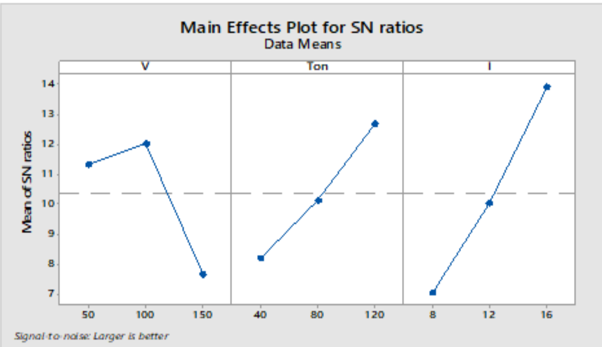

Figure 4: Individual (main) effect plot for S/N ratio (larger-the-better) for AISI 304 material

C. Optimal Values of Process Parameter

An optimal values of process parameter is also obtained and given in table 5.

TABLE 5

OPTIMAL VALUES OF PROCESS PARAMETERS

Process Parameters	Units	optimum Values
Voltage	V	100
Spark on Time	t	120
Discharge Current	A	16

D. Regression Equations

Moreover, it is possible to obtain regression equation correlating the dependent response with the independent variable using MINITAB software as listed below.

- The calculated mathematical regression equation of MRR for AISI304 Material is

  MRR= -1.70 -0.0236 V + 0.0295 Ton + 0.444 C (2)

E. ANOVA

Analysis of variance is done using MINITAB software to find out the influencing process parameter as listed below.

TABLE 6

INFLUENCING PROCESS PARAMETER

Term	Coefficient	SE Coefficient	T	P
Constant	0.44	2.52	0.18	0.867
V	-0.0402	0.0187	-2.15	0.084
Ton	0.0273	0.0128	2.17	0.082
C	0.440	0.140	3.14	0.026

TABLE 7

ANOVA FOR AISI 304 OF EXPERIMENT

Source	DF	SS	MS	F	P
Regression	3	36.262	12.087	6.41	0.036
Voltage	1	8.736	8.736	4.63	0.084
Ton	1	8.905	8.905	4.72	0.082
Current	1	18.621	18.621	9.87	0.026
Error	5	9.429	1.886		
Total	8	45.691			

F. Finite Element Analysis

i. ANSYS Model Validation

Firstly, we have developed a model of EDM process for AISI 304 tool steel with parameter V=50, Ton=40, I=8.

Later, as the element size is 10µs, the value was compared with Shankar et al. so we are getting 40µs at node 6, as shown in figure 5. The temperature at node 6 is 2942 K, roughly the same as the one shown by Shankar et al. so we are going right. The EDM problem is further extended in the analysis.

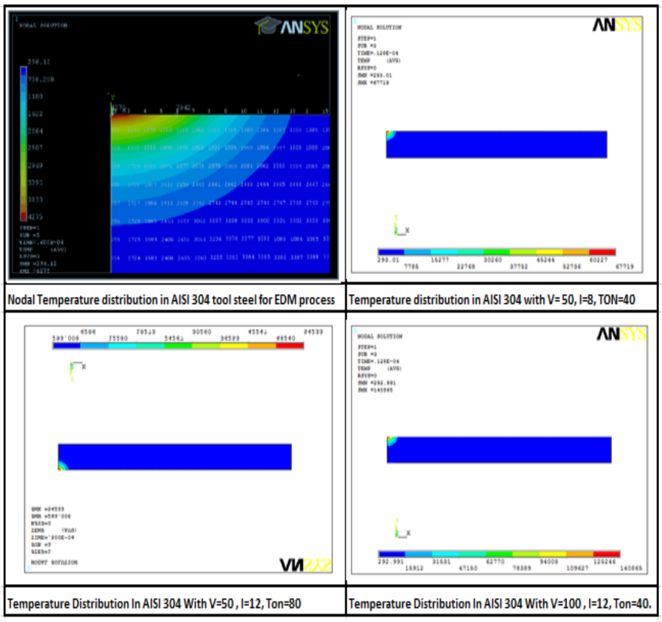

Figure 5. FEA of EDM to find our MRR

TABLE 8

FEA RESULT OF MRR FOR AISI 304

Run	Voltage (V)	Spark on time (µs)	Discharge Current (A)	MRR
1	50	40	8	1.86
2	50	80	12	3.14
3	50	120	16	8.63
4	100	40	12	3.55
5	100	80	16	5.57
6	100	120	8	3.23
7	150	40	16	2.57
8	150	80	8	1.90
9	150	120	12	2.88

ii. Evaluation of Optimal Settings

The effect of process parameters for the MRR is indicated by means of MINITAB software, as illustrated below.

TABLE 9

S/N RATIO FOR AISI 304 MATERIAL

Expt. No.	Voltage (V)	Spark on time (µs)	Discharge Current (A)	MRR (y_i) Mm³/min	S/N ratio
1	50	40	8	1.86	5.3903
2	50	80	12	3.14	9.9386
3	50	120	16	8.63	18.72
4	100	40	12	3.55	11.004
5	100	80	16	5.57	14.917
6	100	120	8	3.23	10.184
7	150	40	16	2.57	8.1987
8	150	80	8	1.9	5.5751
9	150	120	12	2.88	9.1878

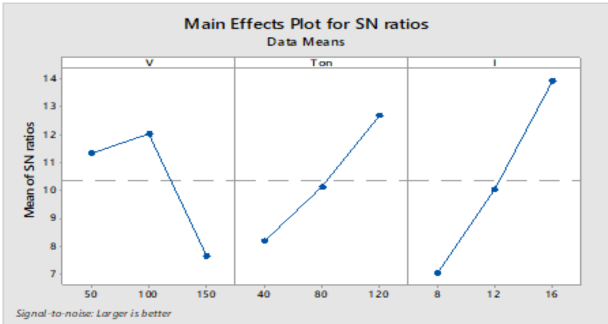

Figure 6. Individual (Main) effect plot for S/N ratio (larger-the-better) for AISI 304 material

V. CONCLUSION

In present work the finite element analysis using ANSYS and experiment were conducted and study the effect of parameters i.e. voltage, spark on time, discharge current on MRR for AISI 304. L9 orthogonal array based on Taguchi was used for design of experiments. MINITAB software used for DOE and analysis of finite element analysis results as well as experimental results. The FEA and experimental results of MRR are compared and following observation are noted.

- Material removal rate increases with the increase in current.
- From the S/N plot it can be observed that the optimal parameter settings are same for FEA and experimental analysis. i.e. V=100V, Ton=120µs, I=16A.

- It can also observe that for FEA and experiment the discharge current is most prominent factor affecting the response.
- ANOVA showed that the main factor affecting the material removal rate was the percent contribution of discharge current, whereas the second factor was the voltage. The percentage of Spark in time was found respectively to be in third place.
- An estimation of the material removed, surface roughness and maximum heat reached in the discharge channel can be carried out using the new FEA model for the EDM process. The maximum temperature is an indicator of the thermal behavior of the model.
- The 2D axisymmetric finite element analysis can be solved easily and computation takes few seconds only.

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