THERMAL ENERGY DISTRIBUTION AND OPTIMIZATION OF PROCESS PARAMETERS DURING ELECTRICAL DISCHARGE MACHINING OF EN-19 AND EN-41

Hasanali A Champa[1], Prof. Dilip S. Patel[2], Mr. Umang V Patel[3]
[1]M.Tech Student, [2]Associate Professor (H.O.D), [3]Lecturer
Department of Mechanical Engineering, Sankalchand Patel College of Engineering,
Visnagar, Gujarat, India

Abstract: The apportionment of energy between tool and workpiece of EDM is of paramount importance since it dictates all the characteristics or performance of EDM process. Our current study attempts to determine distribution of energy to tool and workpiece during EDM of EN-19 and EN-41 steel using copper electrode. The influence of most significant EDM parameters like discharge current (I_p) and pulse duration (T_{on}) on the energy distribution was studied. Taguchi method consisting of an L9 orthogonal array was selected to study the effects of the various parameters on the output responses. ANOVA method was used to analyse the effect of input parameters on the energy transferred to the workpiece and tool and find the optimal process parameters. The experimental results revealed that the discharge current (I_p) was the dominant factor in determining the percentage energy responsible for material removal rate (MRR) and the pulse duration was the dominant factor in determining the percentage energy responsible for tool wear rate (TWR).
Indexterms- EDM, MRR, TWR, En-19 & En-41.

I. INTRODUCTION

Electro Discharge Machining (EDM) is an electro-thermal non-traditional machining Process, where electrical energy is used to generate electrical spark and material removal mainly occurs due to thermal energy of the spark. EDM has ability to machine structurally complex or high strength material, the materials which are difficult to machine like tools of steel which are heat treated with heat, composite materials, super alloys, Ceramics, carbides, Heat resistant steels etc. The only condition for EDM is the material should be electrically conductive.

Principle of EDM

The figure depicts the setup of whole EDM process, which includes mechanical and electrical circuit setup. Basic process occurring is rapidly and continuously of electric spark through the tool to the work piece which results in erosion of material from the work piece. A gap of 0.025 mm is continuously maintained by the servo system indicated in fig. 1. A dielectric fluid is used for immersion of both tool and work piece during the process. Mostly dielectric fluid used are Kerosene/EDM oil/Deionized water but in some special cases Gaseous dielectric fluids are also used.

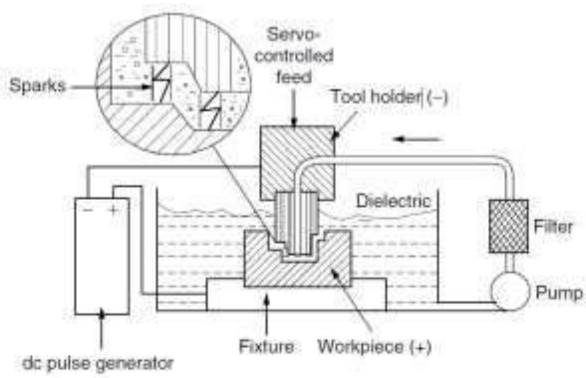

Figure 1Set up of Electric discharge machining

The Fig. 1 depicts the layout of the electric discharge machine. The cathode and anode are tool and work piece respectively. After sufficient high voltage, process of discharge starts in spark form at regular interval of 10 micro seconds, by conduction positive ions and electron starts moving. When discharged spark creates disturbance between electrons and ions and generate plasma channel. Instant loss of electric resistance of the previous channel allows high current density which creates ionization and strong magnetic field. The spark creates pressure between work and tool which ultimately reaches high temperature and melting and eradication of metal happens. This rise in temperature results in removal of metal. Instant vaporization and melting are the ways of removal of materials. Molten metal can be remove partially not totally. Plasma Channel will collapse after removal of potential difference as indicated in fig. 2. This collapsing generates pressure or shock waves, which forms a crater of unwanted metal around impacted spark area.

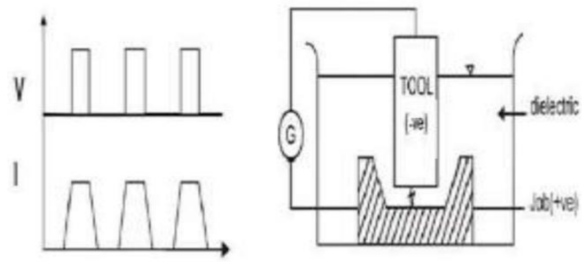

Figure 2 Working principle of EDM process

Application

- EDM is broadly used in mould manufacturing and Die industries. However it is widely common in production of prototype and partsmorevividlyinAutomobile,AerospaceandElectronicsindustries.Certainlyinindustrieswhereproductionquantityislow.

- Hard materials like alloys, steel, tungsten and carbide are machined byEDM.
- EDM is used in forging, extrusion, wire drawing, threadcutting.
- Curved holes are drilled byEDM.
- EDM is used for internal thread cutting and helical gearcutting.
- It resolves the limitation of other machining processes by machining sharp edges andcorners.
- High surface accuracy can be achieved due to high tolerance limit inEDM.
- Ceramic materials that are too brittle for machining can also be machined byEDM.
- EDM is wide spread in many new field like Sports, medical, surgical instruments and optical instruments also in R&Dfields.
- EDM is also useful in highly complicated areas, multifunctional parts up to micro level inmicro-electronics.

II. LITERATUREREVIEW

Rajarshi Mondala, Sourav Deb, Sangram Keshari Mohantyc, and Soumya Gangopadhyaya study was solely dedicated to calculate the fraction of energy transferred to each of tool and workpiece and energy responsible for material removal and tool wear. Thus the conclusions of the above research are as follows: Input energy is a function of current, pulse duration and voltage. The percentage of energy responsible for material removal rate increases with increase of discharge current for a constant pulse duration. The percentage of energy responsible for tool wear rate decreases with increase in pulse duration for a given discharge current. [1]

Akira okada, Yoshiyuki uno and IsaoIn this paper to study the energy distribution in the edmprocess with the graphite electrode is investigated by measuring the temperatures of electrode and work piece. Also effect the removal rate depends on energy density, while electrode wear mainly depends on the adhesion of heat resolved carbon from machining fluid.The ratios of energy distributed into electrode and workpiece are almost constant regardless of discharge duration.The ratio of energy distributed into workpiece becomes larger with an increase of discharge current.The ratios of energy distributed into electrode and workpiece in the EDM process with deionizer water are much smaller than those with kerosene type fluid because of high cooling effect of deionizer water. (2)

Niraj Kumar Ohdar, Babuli Kumar Jena, and SaumyaKantaSethi the effect of input parameter such as peak current, pulse on time, pulse off time and flushing pressure on output parameter as material removal rate (MRR) and tool wear rate (TWR) have been studied which is based on EDM machining process. The Experiments were conducted under various parameters by considering Taguchi L9 orthogonal array and taking mild steel as work piece and copper electrode as tool material. From the result it is considered that:For MRR, the most significant factor is found to be pulse on time followed by pulse off time.With change in input parameter the material removal rate changes accordingly.At peak current 12(A), pulse on time 15(μs), pulse off time 3(μs) and flushing pressure 0.3(kg/cm2) it is observed that the material removal rate becomes high.For TWR, the most significant factor is found to be peak current followed by pulse on time.With change in input parameter the Tool wear rate changes accordingly.At peak current 14(A), pulse on time 5(μs), pulse off time 7(μs) and flushing pressure 0.3(kg/cm2) the tool wear rate reduces significantly. (3) Harmanpreet, Manpreet Singh, and Bipendeep From the study can be concluded that the Taguchi Method is most effective technique for the optimization of machining parameters. Review also reveals that machining by EDM and WEDM is generally assessed on the basis of MRR, TWR & SR. Paper also revealed that Pulse on Time, Pulse off Time, Duty Cycle, Dielectric Flushing Pressure, Peak Current, Cycle Voltage are some of the factors that affects the machining characteristics of EDM process.(4) Marin Gostimirovic, Pavel Kovac, MilenkoSekulic and BrankoSkoric, to experimental investigations yield the following conclusions: Efficiency of EDM directly depends on the power and du-ration of the discharge energy which is transformed into thermal energy in the discharge zone;The increase of discharge energy increases the material removal rate. However, there exists an optimal discharge energy which yields maximum material removal rate. For an optimal discharge duration (pulse duration), the material removal rate increases with the increase of the dis-charge power (discharge current);When the discharge energy is increased, either through discharge duration or discharge power, the gap distance exerts greater influence on the machining accuracy of EDM. Moreover, the discharge power is more significant than discharge duration;Surface roughness directly depends on the discharge energy, so that the discharge power and discharge duration cause a uniform increase of surface roughness;Heat affected zone is present at all levels of discharge energy. The increase of discharge energy increases the recast layer thickness. The formed recast layer is influenced by heat source parameters, while the discharge du-ration has a more pronounced influence on the recast layer. (5)

III. EXPERIMENTALDETAILS

Work piece material: En-19& En-41

Electrode material:Copper

Electro discharge machining of En-19& En-41 as work piece was carried out in die sinking electric discharge machining with copper as tool electrode and by varying different input parameters. Three levels of discharge current and pulse duration have been taken into consideration.

The thermocouples used in the experiment were k-type thermocouple. A k-type thermocouple has two legs, the positive leg is chromel and the negative leg is alumel. Chromel is an alloy with the following composition: 90% nickel,10% chromium whereas alumel has the composition as: 95% nickel, 2% manganese, 2% aluminium and 1% silicon. This is the most commonly used thermocouple with temperature range of -200°C to +1260°C / -328°F to +2300°F. The most important behaviour of this thermocouple is its sensitivity; its sensitivity is approximately 41µV/°C, chromel positive relative to alumel.

Input Parameters	Current Ip (Amp)	Pulse Duration (µs)
Symbol	A	B
Level 1	2	50
Level 2	10	100
Level 3	18	200

From the above table according to design of experiments with L9 orthogonal array total no of experiments to be performed are 9.

Thermocouples were placed at each position in order to note down the temperature at different points in due time.
Values of all the temperature reading at each different input parameter are given in the table. The voltage supplied is 50Volt and initial temperature was 36°C.
Table 2: Temperature values at various point in En-19 work piece, tool and dielectric

Current I_p(A)	Pulse duration T_{on} (µs)	T_1(°C)	T_2(°C)	T_3(°C)	T_4(°C)	T_{d1}(°C)	T_{d2}(°C)
2	50	38	39	38	38	37	39
2	100	39	40	39	40	38	40
2	200	41	42	42	41	39	41
10	50	43	44	45	46	40	42
10	100	46	47	48	50	42	41
10	200	49	50	50	53	40	39
18	50	50	53	53	57	39	40
18	100	53	56	56	60	39	41
18	200	55	59	60	62	40	39

Table 2: Temperature values at various point in En-41 work piece, tool and dielectric

Current I_p(A)	Pulse duration T_{on} (µs)	T_1(°C)	T_2(°C)	T_3(°C)	T_4(°C)	T_{d1}(°C)	T_{d2}(°C)
2	50	38	40	39	41	39	40
2	100	40	42	41	43	40	41
2	200	43	44	40	44	39	40
10	50	46	46	43	45	42	39
10	100	49	48	45	47	40	38
10	200	51	50	47	49	41	41
18	50	50	52	49	51	39	40
18	100	52	53	51	53	40	41
18	200	55	56	53	55	39	40

IV. RESULT ANDDISCUSSION

Sr. No.	current Ip (amp)	pulse duration (µs)	Tool wear rate	Material Removal Rate (gm/sec)
1	2	50	0.016507	0.440189281
2	2	100	0.005839	0.56640682
3	2	200	0.011922	0.494754411
4	10	50	0.168308	7.068921989
5	10	100	0.190749	7.439198856
6	10	200	0.102187	9.094624974
7	18	50	0.178827	15.91559371
8	18	100	0.204374	17.78050276
9	18	200	0.238436	22.17453505

En19 Output

Sr. No.	current Ip (amp)	pulse duration (µs)	Tool wear rate	Material Removal Rate (gm/sec)
1	2	50	0.005524	0.441888854
2	2	100	0.011726	0.545275452
3	2	200	0.018033	0.528966952
4	10	50	0.168308	7.405537322
5	10	100	0.178827	8.85193133
6	10	200	0.095374	6.390081068
7	18	50	0.408747	16.55426119
8	18	100	0.238436	21.22079161
9	18	200	0.286123	23.17596567

EN41 Output

THE ANALYSIS OF VARIANCE (ANOVA):
The analysis of variance is the statistical treatment most commonly applied to the results of the experiment to determine the percentage contribution of each factors. Study of ANOVA table for a given analysis helps to determine which of the factors need control and which do not. Once the optimum condition is determined, it is usually good practice to run a confirmation experiment. In case of fractional factorial only some of the tests of full factorial are conducted. The technique does not directly analyze the data, but rather determines the variability(variance)of the data. Analysis provides the variance of controllable and noise factors. By understanding the source and magnitude of variance, robust operating conditions can be predicted. The analysis is made with the help of a software package MINITAB 18. The main effect plots are showninFig.4 and Fig 5. These show the variation of individual response with the three parameters i.e. Peak current, Pulse on time and Pulse off time separately. In the plots, the x-axis indicates the value of each process parameter at three level and y-axis the response value. Horizontal line indicates the mean value of the response.

Themaineffectsplotsareusedtodeterminetheoptimaldesignconditionsto obtain the optimum surface finish.

Analysis of Variance for En19 MRR:

Source	DF	Adj SS	Adj MS	F-Value	P-Value
current Ip (amp)	2	498.41	249.206	93.41	0.000
pulse duration (µs)	2	12.32	6.158	2.31	0.215
Error	4	10.67	2.668		
Total	8	521.40			

R-sq
97.95%

Analysis of Variance for En19 Tool Wear Rate:

Source	DF	Adj SS	Adj MS	F-Value	P-Value
current Ip (amp)	2	0.061448	0.030724	21.73	0.007
pulse duration (µs)	2	0.000429	0.000214	0.15	0.864
Error	4	0.005657	0.001414		
Total	8	0.067534			

R-sq
91.62%

Regression Equation for En19:

Material Removal Rate (gm/sec) = 8.997 - 8.497 current Ip (amp)_2 - 1.130 current Ip (amp)_10 + 9.626 current Ip (amp)_18 - 1.189 pulse duration (µs)_50 - 0.402 pulse duration (µs)_100 + 1.591 pulse duration (µs)_200

Tool wear rate = 0.1241 - 0.1127 current Ip (amp)_2 + 0.0296 current Ip (amp)_10 + 0.0831 current Ip (amp)_18 - 0.0029 pulse duration (µs)_50 + 0.0095 pulse duration (µs)_100 - 0.0066 pulse duration (µs)_200

Analysis of Variance:

Source	DF	Adj SS	Adj MS	F-Value	P-Value
current Ip (amp)	2	605.133	302.567	66.17	0.001
pulse duration (µs)	2	7.926	3.963	0.87	0.487
Error	4	18.291	4.573		
Total	8	631.349			

R-sq
97.10%

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
current Ip (amp)	2	0.134796	0.067398	20.41	0.008
pulse duration (µs)	2	0.006440	0.003220	0.98	0.452
Error	4	0.013208	0.003302		
Total	8	0.154444			

R-sq
91.45%

Regression Equation for En41:

Material Removal Rate (gm/sec) = 9.457 - 8.95 current Ip (amp)_2 - 1.91 current Ip (amp)_10 + 10.86 current Ip (amp)_18 - 1.32 pulse duration (µs)_50 + 0.75 pulse duration (µs)_100 + 0.57 pulse duration (µs)_200

Tool wear rate = 0.1568 - 0.1450 current Ip (amp)_2 - 0.0093 current Ip (amp)_10 + 0.1543 current Ip (amp)_18 + 0.0374 pulse duration (µs)_50 - 0.0138 pulse duration (µs)_100 - 0.0236 pulse duration (µs)_200

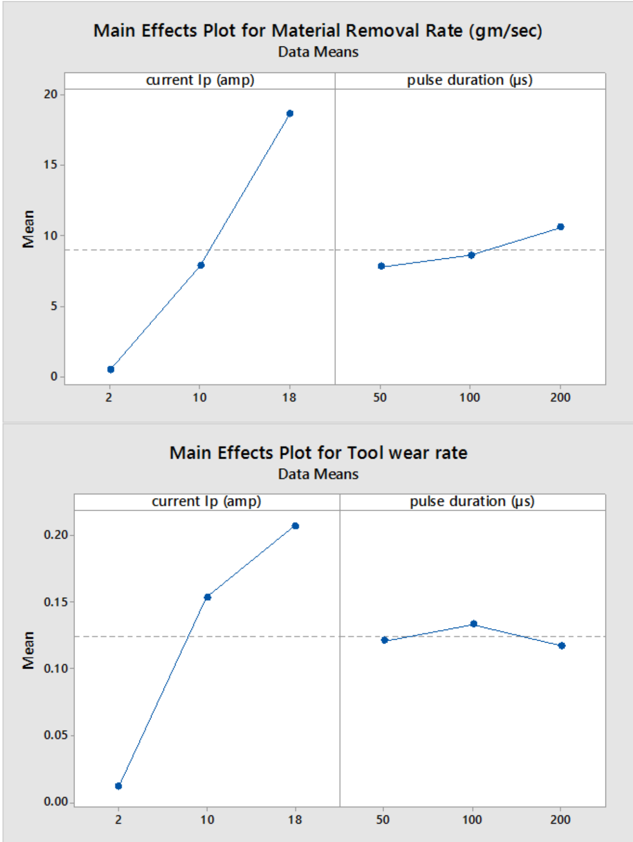

Figure 4Main effect plot for En19

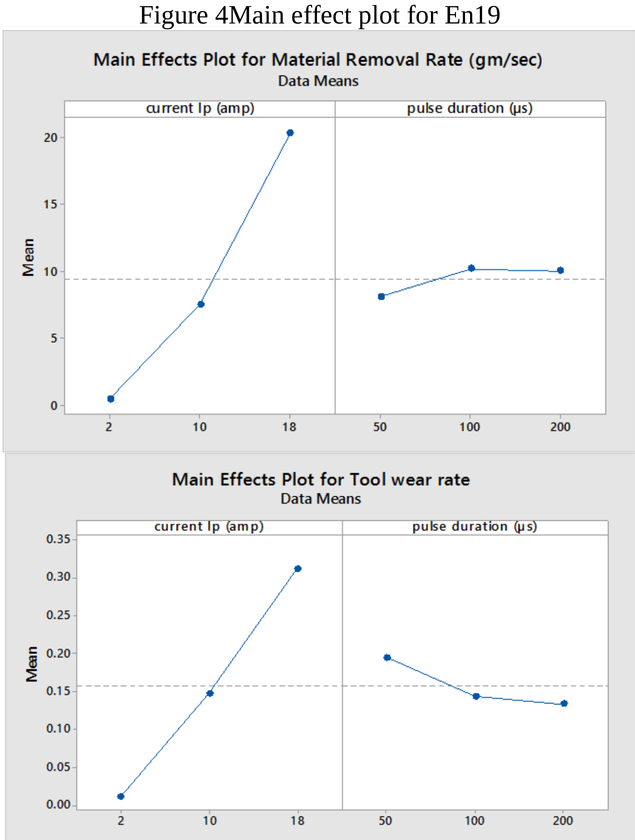

Figure 4 Main effect plot for En41

V. CONCLUSION

The above study was solely dedicated to calculate the fraction of energy transferred to each of tool and workpiece and energy responsible for material removal and tool wear. Thus the conclusions of the above research are as follows:

- Input energy is a function of current, pulse duration and voltage.
- The percentage of energy responsible for material removal rate increases with increase of discharge current for a constant pulse duration.
- The percentage of energy responsible for tool wear rate decreases with increase in pulse duration for a given discharge current.

REFERENCES

[1] Rajarshi Mondal, Sourav De, Sangram Keshari Mohanty, Soumya Gangopadhyay, “Thermal energy distribution and optimization of process parameters during electrical discharge machining Of AISI D2 Steel “, International Conference on Materials Processing and Characterization, Department of Mechanical Engineering, NIT Rourkela, Odisha

[2] Akira Okada, Yoshiyunkiuno And Isao Okajima; “Energy distribution in electrical discharge machine with graphite electrode”, memoirs of the faculty of engineering, vol.34,no.1,2, pp19-26, march 2000

[3] Azizul Bin Mohamad, Arshad Noor Siddique, Ghulam Abdul Quadir, Zahid A. Khan, V.K.Saini, “Optimization of EDM process parameters using Taguchi method” – ICADMIE 2012, 27-28 Feb, Penang, Malayasia

[4] Harmindersingh;“Experimental study of distribution of energy during EDM process for utilization in thermal models”.International journal of heat and mass transfer 55 (2012) 5053-5064.

[5] Marin Gostimirovic, Pavel Kovac, MilenkoSekulic and BrankoSkoric; “Influence of discharge energy on machining characteristics in EDM”, Journal of mechanical science and technology 26 (1) (2012) 173-179.

