OPTIMIZATION OF MRR IN WIRE CUT EDM ON MONEL K-400

(Optimization by Taguchi Technique)

[1]Jakirahemed.MD, [2]D.Bahar

[1]Assistant Professor, [2]Assistant Professor,

[1]Department of Mechanical Engineering, [2]Department of Mechanical Engineering,

[1]Rajiv Gandhi University of Knowledge Technologies, Basar, Nirmal-504107(TS), India

[2]Rajiv Gandhi University of Knowledge Technologies, Basar, Nirmal-504107(TS), India

Abstract: Wire cut electrical discharge machining (WEDM) is one of the non-traditional machining processes, based on thermo electric energy between the work piece and an electrode. In this process material removal occur electro thermally by a series of successive discrete discharges between electrode and the work piece. In the present work nine experiments were conducted on the Monel K- 400 material by using brass as tool material and distilled water as dielectric fluid. The objective of the present work is to optimize the process parameters of WEDM such as Pulse on time (T_{on}), Peak current (I_P) and Wire tension (W_T) on Material removal rate (MRR). L9 orthogonal array is constructed in designing the experiment and with the help of Taguchi method; results are analyzed by using Minitab software to optimize the process parameters. From the study it is found that the optimum value of MRR is 4.9656 mm^3/min at the following process parameters: T_{on} = 115 µs, I_P = 200 A, W_T = 5 kgf. Analysis of variance (ANOVA) also indicates that Pulse on time has highest contribution (91%) following peak current (5.5%) and wire tension has the least contribution (3.5%) on MRR. Therefore it is conspicuous from the study that dominating parameter is pulse on time and less important parameter is wire tension.

Keywords: WEDM, MRR, Taguchi, ANOVA.

1. INTRODUCTION

Electro Discharge Machining (EDM) is an electro-thermal non-traditional machining process in which electrical energy is used to generate the spark and material removal process mainly occurs due to thermal energy of the spark. EDM is mainly used to machine difficult to machine materials and high strength temperature resistant alloys and also to machine difficult geometries. Only electrically conductive work material can be machined by EDM. Spark erosion Machining is a process based on the disintegration of the dielectric and current conduction between the Job and work piece by an electrical discharge occurring between them. In this method the Job and the work piece (which act as electrodes) are separated by a certain gap filled with a dielectric medium. Depending upon the micro irregularities of Tool and Work piece surfaces, and presence of carbon and metal particles, the dielectric is broken down at several points producing, the dielectric is broken down at several points producing ionized columns which allow a focused stream of electrons to flow and produces compression shock waves and there is an intense increase in the local temperature. Due to the combined effect of these two particles of metal are thrown out. Before wire EDM, costly processes were used to produce finished parts. Now a days with the help of computer and WEDM, extremely complex shapes can be processed automatically, precisely and economically irrespective of hardness of the material. Initially WEDM machine worked simply without any complication and wire choices were limited to copper and brass only. Many researchers analyzed WEDM to modify its cutting speed as well as overall capabilities and many attempts were made to satisfy various manufacturing requirements. In accordance with applications, WEDM has huge potential in today's scenario for instance in metal cutting industry to achieve a significant dimensional accuracy, surface finish and contour generation features of products. The cost of wire is about only 10% of operating cost of WEDM process. The problems surfaced in die sinking EDM are avoided by WEDM, by replacing the complex design tool with moving conductive wire and relative movement of wire guides. It is essential to improve the Material removal rate (MRR) to meet the industrial application needs and study of the influence of the process parameters on the machining of materials helps in achieving the goal in a better way. Gostimirovic *et al*. [1] conducted the experiments for MRR of manganese vanadium tool steel, ASTM A681 on EDM by using graphite tool electrode and they concluded that the MRR is increased due to discharge current and pulse duration. Chandramouli *et al*. [2] investigated the experimental analysis to predict the MRR, tool wear rate (TWR) and surface roughness of RENE80 nickel super alloy with aluminium tool on EDM and they found that the current has more influence on MRR, TWR and surface roughness. Harpreet Singh *et al*. [3] performed the experiments on machining of AISI D3 die steel using copper and brass Electrode In wire EDM and found that the MRR is increased with increase in pulse off time, MRR is decreased with increase in pulse on time in case of brass electrode and decrease in copper electrode. Anand *et al*. [4] did the analysis on surface quality, MRR, EWR and micro hardness of OHNS tool steel by considering the various EDM parameters and they conclude that the MRR can be increased with duty cycle and peak current where as with least values of peak current and pulse on time surface roughness and

EWR can be minimized an also they found the micro hardness is increased by increasing pulse on time and duty cycle. Misbah Niamat *et al*. [5] conducted experiments on EDM to know the effect of Ton, IP on MRR, EWR and microstructures of Aluminum 6061 T6 alloy by using different dielectric fluids and they finalized that the MRR is increased with increase of Ton, EWR increases as IP increases while a varying effect was observed with increase in Ton value. Also they found higher MRR and lower EWR can be achieved by using kerosene as dielectric fluid. At higher IP values gives rougher surface when distilled water is used as dielectric as compared to kerosene. Aniza Alias *et al*. [6] performed the experiments to examine the effect of parameters on kerf width, Material removal rate (MRR) and roughness (Ra) of Ti-6Al-4V on WEDM and found that the values of MRR and R_a proportional to feed rate where as kerf width inversely proportional. Vikas *et al*. [7] carried out the experiments to find the effect of EDM parameters on MRR for EN41 and EN19a and they found that the PI has more effect on MRR. Dabade *et al*. [8] performed the analysis on MRR and dimensional deviation (DD) of Inconel 718 by considering various WEDM parameters and they confirmed that Pulse on time is more effect parameter on MRR, R_a, Kerf width and DD and they finalized that surface quality can be improved by increasing Pulse off time, WT and spark gap voltage. Ramanuj kumar *et al*. [9] conducted an experiment on EDM to investigate the effect of process parameters on MRR and R_a of Ti-6Al-4V ELI Titanium alloy and found that the MRR can be enhanced by augmenting discharge current at moderate pulse on time and at lowest voltage supply. Jaganjeet Singh *et al*. [10] done experimental analysis on MRR and R_a of P20 Tool Steel by machining on WEDM and they concluded that the MRR increases as pulse on time, peak current increase and R_a decreases as pulse off time, servo voltage and wire tension increases. However, even though some considerable experimental investigations have been done by many researchers, a huge research gap is realized. Therefore in present study, effect of process parameters such as Pulse on time, Peak current and Wire tension is analyzed and optimized on MRR in WEDM with the help of Taguchi method.

2. EXPERIMENTAL DETAILS & METHODOLOGY

The present work is carried out on a WEDM shown in figure-1 and the experimental setup is shown in firuge-2 which is carried out in the Manufacturing Laboratory of Mechanical Engineering Department, RGUKT-Basar, Telangana State, India.

2.1 Specifications of WEDM

Design	:	Fixed column, moving table
Table size	:	440 mm x 650 mm
Maximum workpiece size	:	600 mm x 780 mm x 200 mm
Maximum workpiece weight	:	400 kg
Main table traverse (X,Y)	:	300 mm x 400 mm
Auxiliary table traverse (u,v)	:	80mm x 80mm
Wire electrode diameter	:	0.25 mm (standard), 0.15 mm and 0.2 mm (optional)
Generator	:	ELPULS-40 A DLX
controlled axes	:	X,Y U,V simultaneous/independent
Interpolation	:	Linear and Circular
Least input increment	:	0.0001 mm
Least command input(X,Y u,v)	:	0.0005 mm
Input power supply	:	3 phase, AC 415V 50 Hz
Connected load	:	10 KVA
Average power consumption	:	6 KVA to 7 KVA

Figure-1: CNC Electro Discharge machine sprintcut

Figure-2: Experimental setup

2.2 Material

To investigate the effect of process parameters on MRR by using WEDM in the present work Monel K-400 material is used which is a nickel-copper alloy and is a solid solution alloy that can only be hardened by cold working. The characteristics of the alloy are good corrosion resistance, good weldability and high strength. Chemical composition of the Monel K-400 material is given in table 1. Its density is 8800 kg/m^3, melting point is 1300-1390 ^{0}C, tensile strength is 517-612 MPa, yield strength is 172-345 MPa, modulus of elasticity is 179 GPa, poissons ratio is 0.32. This material shows very good resistive properties to sea water and steam. It is a corrosion resistance material especially to hydrochloric and hydrofluoric acids when they are deaerated. This material can be used in various applications such as in marine fixtures, pumps, valves for sea water applications, aerospace applications, musical instruments, industrial heat exchangers, chlorinated solvents and crude oil distillation towers etc.

Table 1 – The chemical composition of Monel K-400

Element	Ni%	Cu%	Fe%	Mn%	Si%	C%	S%
Content	63	28-34	2.5	2	0.5	0.3	0.024

For the present work brass wire is used as a wire electrode, putting zinc coating around brass wire enhances cutting speed, straightness and tensile strength to achieve good surface finishes. To conduct the experiments Pulse on time (Ton), Peak current (IP) and Wire tension (WT) considered as process parameters and the effect of these parameters can be verified on MRR of the given material by machining it on WEDM.
The Taguchi method is used to analyze effect of process parameters on MRR in the present work and is a powerful design of experiments tool. This method allows a simple, efficient and systematic approach to find optimal machining parameters. Conventional experimental design processes are too complex and expensive. A large number of experiments have to be carried out to study these processes. Taguchi method uses an orthogonal array to analysis the entire process with only a least number of experiments. Moreover, in traditional experiments one factor is variable while the rest are held constant. The major disadvantage of traditional experimentation method is that it fails to consider possibilities of interaction between parameters. It is also not possible to find all the factors involved in the experiment and to determine their main effects in a single experimental process. Taguchi design of experiments overcomes all these drawbacks. Taguchi method is used to optimize the process parameters and finding the optimal combination of factors for the desired responses [11].

Process parameters and their levels

For the present experimental work the three process parameters at each three levels have been decided. It is desirable to have three levels of process parameters to reflect the true behavior of output parameters of study. The process parameters are called as factors. For this experimental work the remaining process parameters keep at constant. They are wire feed rate 4 m/min, servo feed 2100 mm/min, servo voltage 20 v and water pressure 1 bar.

Table 2 – Selected factors and levels

Process parameters	Units	Level 1	Level 2	Level 3
Pulse on time (Ton)	µs	105	110	115
Peak current (IP)	A	180	190	200
Wire tension (WT)	kgf	4	5	6

MRR can be calculated as per the following expression

$$MRR(mm^3/\min) = \frac{W_a - W_b}{\rho * t}$$

Where

W_a = Weight before machining (gm)

W_b =Weight after machining (gm)

ρ = Density of material (gm/mm^3)

t = Time taken for machining or fabrication (min)

Based on L-9 orthogonal array experiments are conducted on Monel K-400 nickel based alloy with brass tool and distilled water as dielectric medium for different experiment levels which are shown in Table 3 and experimental results were tabulated in table 4.

Table 3 – L-9 orthogonal array

Experiment No.	T_{on} (µs)	IP (A)	WT (kgf)
1	1	1	2
2	1	2	3
3	1	3	1
4	2	1	1
5	2	2	2
6	2	3	3
7	3	1	3
8	3	2	1
9	3	3	2

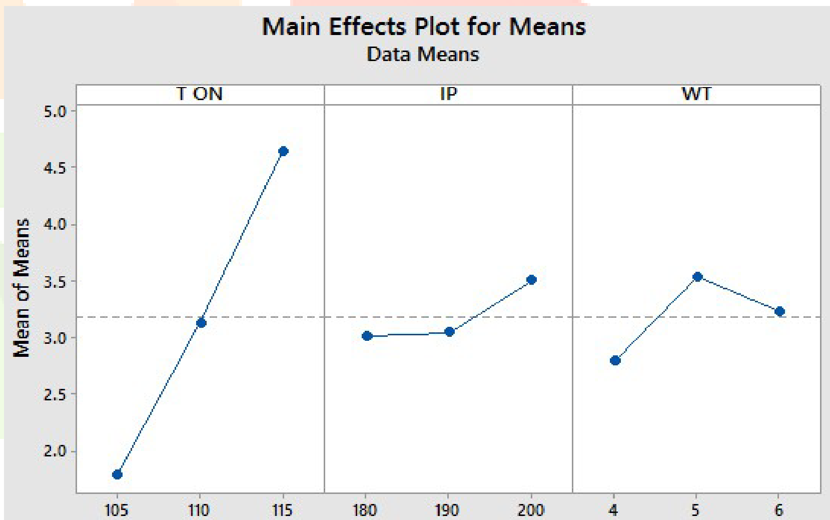


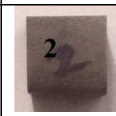
Figure 4 – Mean values of MRR Vs Process parameters

3. RESULTS AND DISCUSSIONS

3.1. Effect of process parameters on MRR

The MRR value is increases with pulse on time and peak current where as by increasing wire tension the MRR first increase and then decreases. As the increase of peak current, the spark energy and the surface temperature of workpiece increases by which material starts melting which leads to increase of MRR. Also with increase of pulse on time, the plasma channel width increases and positive ions becomes more active in cathode (workpiece). This causes more melting and evaporation of the work piece, and leads to increase of MRR. It can be seen from table 4 that the MRR achieves its higher value at the experiment number 9 and same can be observed from figure-4. Therefore the process parameters pulse on time at 115 µs, peak current at 200 A and wire tension at 5 kgf gives the larger value of MRR than other stages.

Table 4 – Results of MRR

S.NO.	T_{on} (µs)	IP (A)	WT (kgf)	Time (min)	Initial weight (gm)	Final weight (gm)	MRR (mm^3/ min)	Final workpiece image
1	105	180	5	17.8	264.35	264.02	2.1067	
2	105	190	6	13.43	264.02	263.86	1.354	
3	105	200	4	14.87	259.85	259.6	1.9104	
4	110	180	4	9.183	259.6	259.42	2.227	
5	110	190	5	8.38	259.42	259.16	3.526	
6	110	200	6	8.13	250.6	250.34	3.634	
7	115	180	6	5.8	245.74	245.5	4.7022	
8	115	190	4	5.62	241.42	241.21	4.2462	
9	115	200	5	5.9	237.28	237.02	4.9656	

3.2. Analysis of Variance (ANOVA)

In the present work ANOVA is used to know the significance of each parameter on MRR which can be calculated by find the signal to noise ratios(S/N) at various levels. The S/N ratio is used to study the machining deviation. Which can be determined as -10log (MSD), where MSD is mean square deviation for the output characteristics. The list of S/N ratio for MRR is given in table 5.

$$MSD = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{1}{Y_i^{\,2}}\right)$$

For larger is better i.e. for Material removal rate (MRR)
Where n is the number of experiments (for one set of parameter, n=1) and Y represents the value of MRR obtained by the experiments.

After the collection of experimental data the calculated S/N ratio value for MRR is shown in Table 5. The response table for means of MRR is shown in table 6. It can be observed from table 6 that the pulse on time, peak current and wire tension assigned as rank 1, 3 and 2 respectively according to their larger value of delta. Delta represents the overall change in value. Delta is considered the difference between an initial and end value, irrespective of fluctuations that might occur between these points. Rank 1 means highest contribution factor for MRR and Rank 3 means lowest contribution for MRR. From this table peak current has least contribution, wire tension has moderate contribution and pulse on time has highest contribution to increase MRR. From the figure-5, the optimal value for MRR is Ton -115 µs, IP-200 A and WT-5 kgf. The contribution percentage of each parameter to increase MRR can be calculated by considering "higher is best" ANOVA principle It can be observed from table 7 that the Pulse on time (T_{on}) has the highest contribution (91%) followed by Wire tension (WT) (5.5%) and Peak current (IP) (3.5%).

Table 5- ANOVA data

Parameter	Level	Expt. No.	S/N(MRR)	S/N_{ij}(MRR)
Pulse on time (Ton)				
		1	6.4721	
Level 1	105	2	2.6324	4.909
		3	5.6225	
		4	6.9544	
Level 2	110	5	10.9456	9.702
		6	11.2077	
		7	13.446	
Level 3	115	8	12.56	13.308
		9	13.9194	
Peak current (IP)				
		1	6.4721	
Level 1	180	4	6.9544	8.9575
		7	13.446	
		2	2.6324	
Level 2	190	5	10.9456	8.712
		8	12.56	
		3	5.6225	
Level 3	200	6	11.2077	10.25
		9	13.9194	
Wire Tension (WT)				
		1	6.4721	
Level 1	5	5	10.9456	10.44
		9	13.9194	
		2	2.6324	
Level 2	6	6	11.2077	9.09
		7	13.446	
		3	5.6225	
Level 3	4	4	6.9544	8.378
		8	12.56	
$\left(\frac{\bar{S}}{N}\right)_{MRR} = 9.306$				

Table 6- Response table for signal to noise ratios Larger is better for MRR

Level	T_{on}	IP	WT
1	4.909	8.957	8.379
2	9.703	8.713	10.446
3	13.308	10.250	9.095
Delta	8.400	1.537	2.067
Rank	1	3	2

Table 7- Contribution of process parameter on MRR and Surface Roughness

Process parameters	Sum of Squares (SSi) for MRR	%Contribution (MRR)
Pulse on time(T_{on})	35.5028	91
Peak current (IP)	1.3643	3.5
Wire tension(WT)	2.197	5.5

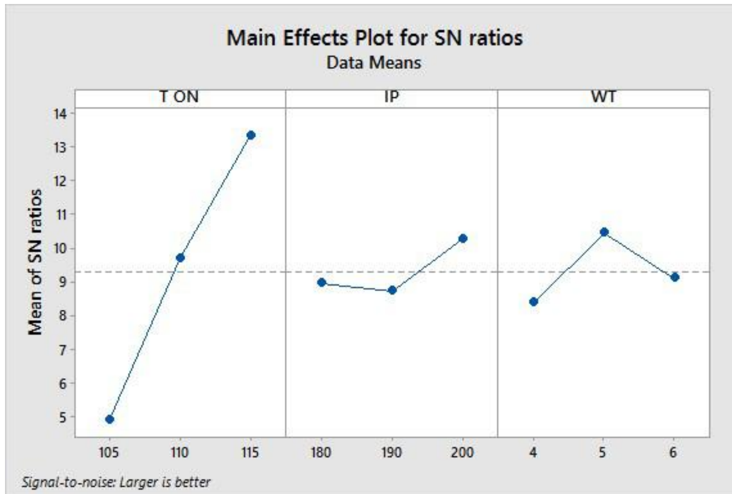


Figure 5 – Mean of S/N ratio Vs Process parameters

4. CONCLUSION

The result shows that peak current, pulse on time and wire tension have significant effect on MRR. The results of this project reveals that the proper selection of input parameters will play a significant role in WEDM to machine Monel K-400 material .For MRR, pulse on time is most influencing factor and then wire tension and at last is peak current. For optimum of MRR, Ton-115 (µs), IP-200 (A), WT-5 (kgf) levels must be selected. Pulse on time with 91% contribution is the most significant factor for MRR, wire tension with 5.5% contribution and peak current with 3.5% contribution are the least significant factors for MRR.

REFERENCES

[1] M. Gostimirovic, P. Kovac, B. Skoric and M. Sekulic, "Effect of electrical pulse parameters on the machining performance in edm", Indian Journal of Engineering & Materials Sciences, Volume 18 (2012), pp.411-415.

[2] S. Chandramouli, U.S. Balraj and K. Eswaraiah, "Optimization of electrical discharge machining process parameters using taguchi method", International Journal of Advanced Mechanical Engineering, Volume 4, No.4 (2014), pp.425-434.

[3] H. Singh, A. Singh, " Effect of pulse on/pulse off time on machining of AISI D3 die steel using copper and brass electrode in edm", International Journal of Engineering and Science, Volume 1, Issue 9 (2012), pp.19-22.

[4] A.N. Nikalje, U.V. Hambire, "Analysis of the influence of EDM parameters on surface quality, MRR, EWR and micro hardness of AISI O2 (1.2842)", International Journal of Scientific & Engineering Research, Volume 5, Issue 3 (2014), pp.850-857.

[5] M. Niamat, S. Sarfraz, H. Aziz, M. Jahanzaib, E. Shehab, W. Ahmad, S. Hussain, "Effect of different dielectrics on material removal rate, electrode wear rate and microstructures in edm", 27th CIRP 60 (2017), pp.2-7.

[6] A. Alias, B. Abdullah, N.M. Abbas, "Influence of machine feed rate in WEDM of titanium Ti-6AL-4V with constant current (6A) using brass wire", Procedia Engineering 41 (2012), pp.1806-1811.

[7] Vikas, Shashikant, A.K. Roy, K. Kumar, "Effect and optimization of machine process parameters on MRR for EN19 & EN41 materials using Taguchi", Procedia Technology 14 (2014), pp.204–210.

[8] U.A. Dabade, S.S. Karidkar, "Analysis of response variables in WEDM of Inconel 718 using Taguchi technique", Procedia CIRP 41 (2016), pp.886–891.

[9] R. Kumar, S. Roy, P. Gunjan, A. Sahoo, D.D. Sarkar, R.K. Das, "Analysis of MRR and surface roughness in machining of Ti-6Al-4V ELI titanium Alloy using EDM process", Procedia Manufacturing 20 (2018), pp.358-364.

[10] J. Singh and S. Sharma, " Effects of process parameters on material removal rate and surface roughness in WEDM of P20 tool steel", International Journal of Multidisciplinary and Current Research, Volume 1(2013), pp.230-235.

[11] P.M. George. B.K. Raghunath, L.M. Manocha, A.M. Warrior, "EDM machining of carbon-carbon composite-a Taguchi approach", Journal of Materials Processing Technology, Volume 145 (2004), pp. 66-71.