International Journal of Applied Engineering Research ISSN 0973-4562 Volume 14, Number 9, 2019 (Special Issue)
© Research India Publications. http://www.ripublication.com

EXPERIMENTAL INVESTIGATION OF MRR AND TWR ON EDM FOR M2 HIGH SPEED STEEL USING TAGUCHI METHOD

Vijay Singh Chauhan
Assistant Professor, Department of Mechanical Engineering,
Dev Bhoomi Group of Institutions,
Dehradun-248007, Uttarakhand, India

Tirath Singh
Assistant Professor, Department of Mechanical Engineering,
Dev Bhoomi Group of Institutions,
Dehradun-248007, Uttarakhand, India

Rahul Chamola
Assistant Professor, Department of Mechanical Engineering,
Dev Bhoomi Group of Institutions,
Dehradun-248007, Uttarakhand, India

Faraz Ahmad
Assistant Professor, Department of Mechanical Engineering Research,
Dev Bhoomi Group of Institutions,
Dehradun-248007, Uttarakhand, India

Abstract
In this research paper, different process and response parameters of EDM are studied. Work-piece material for which input variables are to be feasible is M2 High speed steel. It is very essential to discover excellent operating conditions for any manufacturing technique now days. Especially in case of non-conventional machining such as, abrasive jet machining, electro chemical machining, electro discharge machining, ultrasonic machining etc. In these techniques operating cost is higher than the conventional machining processes. Response parameters which are to be optimize is TWR and MRR and process parameters are I_p, T_{on} and electrode diameter.for optimizing process parameters Taguchi's methodology was used. L9 orthogonal array was used for statistical analysis and MINITAB software was used to get optimum values for the test.

Keywords: EDM, Tool Wear Rate (TWR), Material Removal Rate (MRR), Peak current ($I_{p)}$), Pulse on time ($T_{on)}$), Pulse off time ($T_{off),}$, ANOVA, Taguchi method.

Introduction
The electric discharge machining process contributes significant role in most of the manufacturing industries now a days. EDM process cuts intricate and complex shapes of machining components with better precision and accuracy in all electrically conductive materials regardless of its mechanical properties, chemical composition and internal structure. In EDM tool do not contact directly the job, therefore for cutting the work piece hardness is not a constrictive factor for this machining process. In this process material is take away from any material which is electrically conductive by striking continuous repeated spark between tool electrode and job. In order to provide better cutting condition and cooling effect of dielectric fluid is supplied continuously to flush away the eroded particles of work-piece. There are umpteen types of EDM process based on working principle and tool material shape and size selection.

Working Principle of EDM
In electrical discharge machining process material is take away by striking of continuous spark discharges between the tool and job. In EDM process tool is made up of cathode and work material as anode. In this process workpiece and tool are separated by a small gap of about 0.01 to 0.50 mm and both are completely immersed in dielectric fluid. In EDM metal can be removed partially by melting and partially by vaporization.

Literature Review
Tzeng et al.[1] have conducted a study on castek-03 using medium carbon steel on EDM machine. They reported that EDM is highly effected by the supply current in low voltage spark current in high voltage and Ton. They also suggested that machining speed influenced by Ton and low voltage.
Kumar et al.[2] have worked on input process variables of WEDM operation by visualizing the impact of input

parameters such as Ton, Toff, wire speed (WS) and wire feed (WF) on response characteristics namely MRR and SR while processing Alsic (20%) plate by taking molybdenum wire. The RSM regression equation model has been opted to observe the response of variables as a function of initial variables. The Taguchi method is widely adopted for reducing the surface roughness (SR). It was noted that parameters like Ton, Toff, WS and WF play a paramount role for MRR and SR.

M. Kunieda et al.[3] investigated the effect of the pulse period on the ratio of volumetric wear (VW) of the tool material to volumetric removal (VR) of job material when a round hollow cylindrical electrode of thickness 0.3mm is selected. The tool wear ratio is always reaches to zero in air and it is unaffected of the pulse duration. In other condition like in oil with decreasing in pulse duration the tool wear ratio increases sharply.

Prajapati et al.[4] investigated the effect of process parameters like Ton, Toff, Voltage, WF & WT on MRR, SR, Kerf. Square shaped bar of AISI A2 tool steel was employed as a workpiece. Response surface methodology (RSM) was used to analyze the data obtained from the experiment for optimization and performance. Researchers reported that for CR and surface roughness (SR), Ton and Toff are the most influencing process parameters. The spark gap voltage (SGV) is significant for kerf.

Sharma et al.[5] have been observed the effect of process parameters such as I_p, Ton, Toff, servo voltage (V) and WT on process responses such as MRR and SR while machining HSLA using brass wire as electrode. RSM was used to formulate mathematical model and to optimize the process parameter for MRR and SR. MRR was being affected by Ton, Toff and servo voltage and surface roughness is a function of Ton.

Puertas et al.[6] conducted experiments on conductive ceramic Boron carbide and optimize various machining parameter for SR, electrode wear, and MRR.

Chalisgaonkar et al.[7] have performed the various input parameters such as Ton, Toff, I_p, WF, WT, and servo voltage (SV) for optimization of variables using Wire EDM process. The capability index was utilized to check response characteristics like surface roughness. Taguchi's method was performed to study the impact of initial parameters on the process capability index. They conducted that the capability of wire EDM can be improved by single response optimization techniques.

Yen-Cherng Lin et al.[8] use electrolytic copper electrode in machining of cemented carbide using electric discharge energy. Author reviewed the influence of electric discharge on machining characteristics like MRR, TWR, SR etc. The main study is done on effect of electric discharge on heat affected zone, surface cracks etc. The result of experiment show those at high level of electric discharge energy, serious crack on surface of cemented carbide were evident.

Sohani et al.[9] explain the effect of tool size and shape of sink electric discharge machining using response surface methodology RSM, process parameter like pulse on time, pulse off time, discharge current. The RSM modeling of material removal rate and tool wear rate has been develop using design matrix. Analysis of variance was used to evaluation, optimization and develop model of design matrix. Different type of tool circular, triangular, rectangular, square cross section is used for analysis. It is observed that current discharge, and on time of pulse is infuencing factor which affect material removal rate and rate of tool removal followed by tool shape and size.

Puertas and Luis[10] explain the evaluation and optimization of machining parameter for EDM using conductive ceramic material, boron carbide. Author checks the result for surface roughness, tool wear and material removal rate. Result was obtained by series of mathematical modeling using design of experiment techniques by linear regression method.

Methods

The experiments were carried out on Electric Arc Machine, model C-3822 with PSR-220 EDM (Fig.1). The electrode material was cylindrical shaped copper tool. Kerosene is supplied as Dielectric fluid for cutting process. A Workpiece made up of M2 high speed steel has been taken during the experiments.

Fig 1:- Experimental Setup

Table 1:- Experimental Setup Used During Experiment

Work-piece Material	M2 HSS
EDM m/c	Electric Arc Machine, model C-3822
Tool material	Copper
Dielectric fluid	Kerosene
Dielectric fluid pressure	10 kgf/cm^2

Measurement of Tool Material Removal Rate

MRR is expressed as the magnitude relation of distinction of weight of the job prior to and at the end of machining divided by time of machining and density material density. Mathematically

$$MRR = \frac{Wjb - Wja}{t \times p}$$

Whereas Wjb = weight of job prior to machining.
Wja = weight of job at the end of machining.
T = Time (1.00 hr).
ρ = M2 HSS, density = 7972 kg/m^3

Measurement of Tool Wear Rate

TWR is expressed as the weight of the tool prior and at the end of machining divided by the time of machining. It can be expressed as

$$TWR = \frac{wtb - wta}{t}$$

Where, wtb = Weight of the tool before machining.
wta = Weight of the tool after machining.
t = Time of machining i.e. 1hr.

Table 2:- Levels of Input Process Parameters

Factors	EDM Machining parameters	Symbols	Levels		
			L1	L2	L3
A	Peak current	I_p	10	15	20
B	Pulse on time	Ton	30	60	90
C	Electrode Diameter	-	10	13	16

Table 1 shows experimental setup and experiments were performed on the basis of Taguchi method. Three different machining parameters I_p, Ton and electrode diameter are shown in the Table 2. L9 orthogonal arrays were preferred for the evaluation of process parameters.

Results

Table 3 indicates different values of MRR and TWR before and after conducting machining process. It is obvious from the table data that there is slight reduction in weight of the tool due to wear and tear because of machining and vaporization or melting of tool material.

Table 3:- Experimental Value of Weight of the Tool

Run	I_p	Ton	Electrode Diameter	weight of tool (gm)		weight of work piece (gm)	
				Wtb	Wta	Wjb	Wja
1	L1	L1	L1	31.7484	31.7478	52.4252	52.3138
2	L1	L2	L2	40.7034	40.6990	53.9171	53.0376
3	L1	L3	L3	53.8388	53.8380	54.5039	53.5877
4	L2	L1	L2	33.7732	33.7530	51.0806	50.6515
5	L2	L2	L3	41.2098	41.1874	54.4514	53.7506
6	L2	L3	L1	53.7968	53.7234	53.3487	49.7488
7	L3	L1	L3	32.1732	32.1512	55.5390	54.9245
8	L3	L2	L1	41.2051	41.1015	52.1991	51.0134
9	L3	L3	L2	53.2602	53.1202	51.5820	50.7466

Table 4:- Material Removal Rate Response Table

Run	Peak Current	Pulse On Time	Electrode Diameter	TWR	SNRA1
1	10	30	10	0.2328	-12.6603
2	10	60	13	1.8380	5.2869
3	10	90	16	1.9150	5.6434
4	15	30	13	0.9117	-0.8030
5	15	60	16	1.4650	3.3168
6	15	90	10	1.2541	1.9666
7	20	30	16	1.2870	2.1916
8	20	60	10	2.4788	7.8848
9	20	90	13	1.7465	4.8434

Table 5: Tool Wear Rate Response Table

Run	Peak Current	Pulse On Time	Electrode Diameter	TWR	SNRA1
1	10	30	10	0.0000100	100.000
2	10	60	13	0.0000733	82.698
3	10	90	16	0.0000133	97.523
4	15	30	13	0.0003367	69.455
5	15	60	16	0.0003733	68.559
6	15	90	10	0.0012230	58.251
7	20	30	16	0.0003660	68.730
8	20	60	10	0.0017200	55.289
9	20	90	13	0.0023300	52.653

Response values for S/N ratio using larger is better criteria for MRR are expressed in Table 4 and table 5 represents response values using smaller is better criteria for TWR.

Table 6:- Analysis of Variance for SNRA1, Using Adjusted SS for MRR

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Peak Current	2	47.20	47.20	23.60	0.85	0.542
Pulse On Time	2	149.98	149.98	74.99	2.69	0.271
Electrode Diameter	2	38.39	38.39	19.20	0.69	0.592
Error	2	55.77	55.77	27.89		
Total	8	291.34				
S = 5.28072, R-Sq = 80.86, R- Sq(adj) = 23.43						

Table 7:- Analysis of Variance for SNRA1, Using Adjusted SS for TWR

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Peak Current	2	2017.18	2017.18	1008.59	62.06	0.016
Pulse On Time	2	210.02	210.02	105.01	6.46	0.134
Electrode Diameter	2	158.79	158.79	79.40	4.89	0.170
Error	2	32.51	32.51	16.25		
Total	8	2418.49				
S = 4.03149, R-Sq = 98.66, R- Sq(adj) = 94.62						

Table 8:- Response for Signal to Noise Ratio for MRR

Level	Peak Current	Pulse On Time	Electrode Diameter
1	-0.5767	-3.7572	-0.9363
2	1.4935	5.4962	3.1091
3	4.9733	4.1511	3.7172
Delta	5.5499	9.2534	4.6535
Rank	2	1	3

Table 9:- Response for Signal to Noise Ratio for TWR

Level	Peak Current	Pulse On Time	Electrode Diameter
1	93.41	79.40	71.18
2	65.42	68.85	68.27
3	58.89	69.48	78.27
Delta	234.52	10.55	10.00
Rank	1	2	3

After using MINITAB software analysis of variance was calculated and S/N data for MRR and TWR are shown in Table 6 and 7 respectively .Response data (rank and delta) for S/N ratio for MRR and TWR are given in Table 8 and 9 respectively.

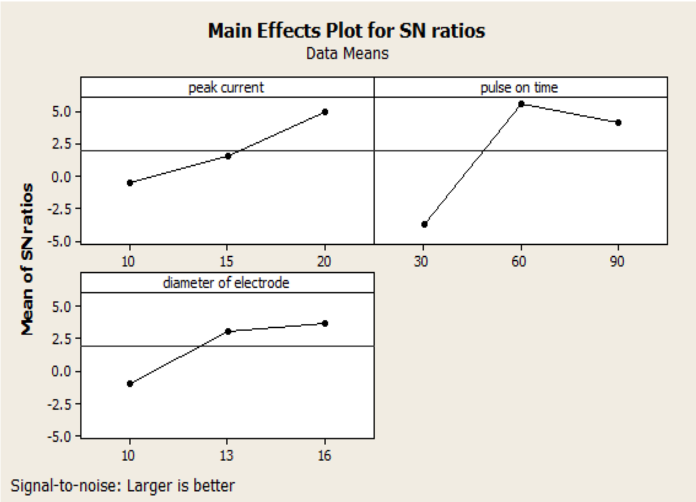

Fig. 4:- S/N Ratio Plot for MRR

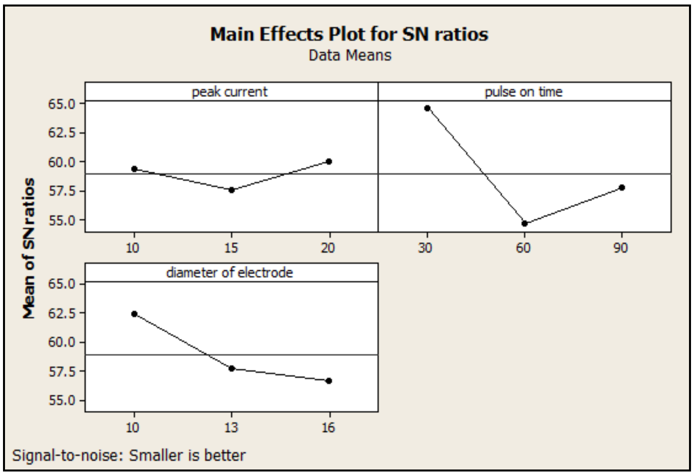

Fig. 5:- S/N Ratio Plot for TWR

Fig 4 and 5 gives the idea of S/N ratio plots for the MRR and TWR respectively. MRR is the "larger the better" type quality characteristic plotted in Fig 4, It can be observed that the third level of I_p (A3), second level of Ton (B1) and third level of electrode diameter (C1) provide utmost outcomes of

MRR. tool wear rate is the "lower the better" type quality characteristic from Fig 5, It is noted that third level of I_p (A3), first level of Ton (B1) and first level of electrode diameter (C1) provide peak value of TWR. The ranks and the delta values for different parameters show that Ton has the crucial consequences on MRR and is followed by I_p, and electrode diameter and I_p has the greatest effect on TWR, followed by Ton, and electrode diameter respectively.

Discussion

Following conclusions can be drawn on the basis of optimization as discussed above:

1. For all levels of Ip, the metal removal rate increases with increase in Ip
2. It has been obser4ved that MRR shows sharp growth with Ton and after attaining the maximum value it abates.
3. MRR is directly proportional to the all electrode diameter.
4. As Ip augments the value of TWR also expands up to the certain points and then it diminishes.
5. TWR increases with Ton and then it shows a gradual fall in its slope.
6. From the above experiments it is clear that TWR inversely related to electrode diameter.

Conclusion

1. Larger value of electrode diameter is suggested for high MRR and close tolerance.
2. It can be concluded that MRR is highly influenced by the Ton and least affected by different size of electrodes. Peak current has moderate impact on MRR.

References

[1] Tzeng, Y.F. and Chiu, N.H.Electrical-discharge machining process using a Taguchi dynamic experiment. *International Journal of Advanced Manufacturing Technology*, 21: 1005-1014, 2003.

[2] Kumar, K. and Ravikumar, R. Modeling and Optimization of Wire EDM Process‖ . *International Journal of Modern Engineering Research*, 3(3): 1645-1648, 2013.

[3] M. Kunieda, M. Yoshida, N. Taniguchi, "Electrical Discharge Machining in Gas", Annals of the CIRP, Vol. 46, No.1, pp. 143-146, 1997.

[4] Prajapati, S.B. and Patel, N.S., Effect of Process Parameters on Performance Measures of Wire EDM for AISI A2 Tool Steel. International Journal of Computational Engineering Research, 3(4): 274-278, 2013.

[5] Sharma, N., Khanna, R. and Gupta, R., Multi Quality Characteristics of WEDM Process Parameters with RSM‖ . International Conference on Design and Manufacturing 64: 710-719, 2013.

[6] Puertas, I. And Luis, C.J., A study of optimization of machining parameters for electrical discharge machining of boron carbide. Materials and Manufacturing Processes, 19(6), 1041-1070, 2004.

[7] Chalisgaonkar, R. and Kumar, J., Process capability analysis and optimization in WEDM of commercially pure titanium. Procedia Engineering, 97: 758 – 766, 2014.

[8] Yan-Cherng Lin, Yuan-feng chen, Ching-tien Lin, and Hsinn-jyh Tzeng Feasibility studyof rotary electrical discharge machining with ball burnishing for Al2O3/6061Al composite 2008, vol.23: 391–399.

[9] Sohani, M.S., Gaitonde, V.N., Siddeswarappa, B. And Deshpande, A.S., 2009.Investigations into the effect of tool shapes with size factor consideration in sink electrical discharge machining (EDM) process. International Journal of Advanced Manufacturing Technology, 1-15.

[10] Puertas, I. And Luis, C.J., 2004. A study of optimization of machining parameters for electrical discharge machining of boron carbide. Materials and Manufacturing Processes, 19(6),1041-1070.

[11] www.ethesis@nitrkl.ac.in

[12] www.sciencedirect.com.

[13] www.scopus.com

[14] www.efunda.com

[15] www.meetminitab.com