ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 12, December 2014

Investigation of MRR and TWR on High Speed Steel Using Copper and Brass Electrode for EDM

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ABSTRACT: This paper presents the investigation on material removal rate (MRR) and tool wear rate (TWR) of high speed steel with copper and brass electrode for Electrical Discharge machining (EDM) process. The machining parameter include pulse ON time, pulse OFF time, peak current and fluid pressure. DOE with Taguchi method is used to investigate the significant effect on the performance characteristic and the optimal parameters of EDM. The obtained results evidence that as the material removal rate is increased with increase in pulse off time and peak current. Material removal rate is decreased with increase in pulse on time in case of brass electrode and decrease in cooper electrode.

KEYWORDS: Electrical Discharge Machining (EDM), High Speed steel, MRR, TWR.

I. INTRODUCTION

Electrical discharge machining (EDM) is a process that is used to remove metal through the action of an electrical discharge of short duration and high current density between the tool and the workpiece [1-2]. HSS is an important tool and die material, mainly because of its high hardness, strength and wear resistance over a wide range of temperatures. It has a high specific strength and cannot be easily processed by conventional machining techniques.

Electric discharge machining (EDM) is a non-traditional type of precision processing using an electrical spark-erosion process between the electrode and the working piece of electrically conductive immersed in a dielectric fluid [3]. Since it has more special gains, the EDM has been widely applied in modern metal industry for producing complex cavities in moulds and dies, which are difficult to manufacture by conventional machining. The use of Electrical Discharge Machining in the production of forming tools to produce plastics mouldings, die castings, forging dies etc., has been firmly established in recent years. The EDM is a well established machining choice for manufacturing geometrically complex or hard material parts that are extremely difficult-to machine by conventional machining processes [4]. Its unique feature of using thermal energy to machine electrically conductive parts regardless of hardness has been its distinctive advantage for manufacturing of mould, die, and automotive, aerospace and surgical components [5]. Thus, high speed steel, which is difficult-to-cut material, can be machined effectively by EDM [6]. Proper selection of the machining parameters can result in a higher material removal rate, higher material removal rate, and lower electrode wear ratio [7]. The electrical discharge machining (EDM) of HSS with different electrode materials has been accomplished to explore the influence of EDM parameters on various aspects of the surface integrity of HSS [8]. A study has been carried out to develop a mathematical model for optimizing the EDM characteristics on matrix composite Al/SiC material [9]. They used response surface methodology to determine the optimal setting of the EDM parameters such as the metal removal rate, electrode wear ratio, gap size and the surface finish. The effect of the thermal and electrical properties of titanium alloy Ti–6Al–4V on EDM productivity has been detected [10]. To investigate the relationships and parametric interactions between the variables on the material removal rate (MRR) using response surface methodology experiments have been conducted on AISI D2 tool steel with Cu electrode [11]. It

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

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was acquired that discharge current, pulse duration, and pulse off time affect the MRR significantly. Their observation illustrates that the highest MRR values appeared at the higher ampere and pulse on time and at the lower pulse off time. Optimal selection of process parameters is very much essential as this is a costly process to increase production rate considerably by reducing the machining time. Thus, the present paper emphasizes the development of optimization models to correlate the various machining parameters such as peak current (I_P), pulse on time (*Ton*) and pulse off time (*Toff*) on material removal rate (MRR). Machining parameters optimization for the HSS carried out using the techniques of design of experiments (DOE). The effect of input parameters on MRR in EDM process of HSS has been analysed.

II. EQUIPMENT USED IN EXPERIMENTS

EDM has maximum discharge current capacity of 20 Ampere. A servo mechanism maintains a gap of about 0.01 to 0.02 mm between the electrode & the workpiece, preventing them from coming into contact with each other. Discharge machine having 140 liters dielectric capacity and DC servo feed control system is used for experimental work. Figure 1 shows a photograph of this equipment. Standard EDM oil is used as dielectric fluid and the side injection of dielectric fluid with side jet flushing system was employed to assure adequate flushing of the EDM process debris from the gap zone during experiment Cylindrical solid rod of copper and brass with 6 mm diameter is used as tool electrode and the work piece of High Speed steel is machined for 20 minutes to record the readings.

Fig. 1 EDM used for experiment

III. MATERIAL USED IN EXPERIMENTS

The workpiece material was a High Speed Steel, which is widely employed in tool applications. The electrode material was copper and brass. The workpiece material was from M/s. Kumar Engineering materials Co, Kanpur. and its characteristics are shown in Table 1.

ISSN: 2319-8753

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Table.1. Chemical composition of the HSS Workpiece

C%	Mn%	Si%	Cr%	V%	W%	Mo%	Co%	Ni%
0.75	-	-	4	1	18	-	-	-

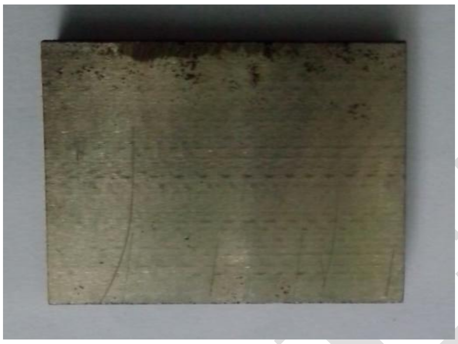


Fig.2 High Speed Steel used for experiment as workpiece.

IV. ELECTRODE USED IN THE EXPERIMENTS

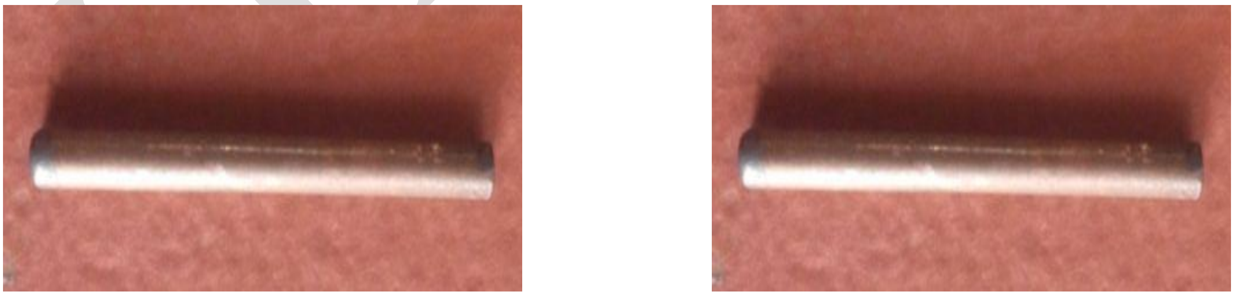
The tool material was copper and brass, which is widely employed in tool applications. The electrode (tool) material was from M/s. Kumar Engineering materials Co, Kanpur. and its characteristics are shown in Table 2 & Table 3.

Table.2. Chemical composition of the copper electrode

Cu%	Zn%	Al%	Bi%	Pb%
99.8	0.057	0.15	0.0011	0.0008

Table.3. Chemical composition of the brass electrode

Cu%	Zn%	Pb%	Sn%	Fe%	Ni%
58.8	37.2	2.7	0.5	0.9	0.16



(a) (b)

Fig. 3 Electrode used for experiment (a) Copper electrode (b) Brass electrode

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V. MATERIAL REMOVAL RATE AND TOOL WEAR RATE

Material removal rate was calculated from weight difference of work piece and machining time.

$$MRR = \frac{W_{wb} - W_{wa}}{T} \text{ gm/min}$$

Tool wear rate was calculated from weight difference of Tool and machining time.

$$TWR = \frac{W_{tb} - W_{ta}}{T} \text{ gm/min}$$

Where:

W_{wb} = weight of workpiece before machining.
W_{wa} = weight of workpiece after machining.
W_{tb} = weight of tool before machining.
W_{ta} = weight of tool after machining.
T = machining time

VI. S-N RATIO

For this experiment

For MMR:

S/N ratio, is taken as the "**Larger is Better**" so the equation to find out signal to noise ratio is,

$$S/N = -10 * \log (\Sigma (1/Y^2)/n)$$

For TWR:

S/N ratio, is taken as the "**Smaller is Better**" so the equation to find out signal to noise ratio is,

$$S/N = -10 * \log (\Sigma (Y^2)/n)$$

VII. DESIGN OF EXPERIMENT

The main objective of the experimental design is studying the relations between the response as a dependent variable and the various parameter levels. It provides a prospect to study not only the individual effects of each factor but also their interactions. The design of experiments for exploring the influence of various predominant EDM process parameters as peak current, pulse on time, pulse off time and fluid pressure on the machining characteristics such as material removal rate and tool wear rate was modeled. In the present work experiments were designed on the basis of design of experimental technique using L9 orthogonal array. The coded levels for all process parameters used are displayed in Table 4. The experiment was design with 4 factors at 3 levels each; the fractional factorial design used is L9 orthogonal array. There are 9 trials in the control factor array and each row of the matrix represents one trial. This orthogonal array is use due to its simplicity and versatile for data analysis. The design of the L9 orthogonal array of EDM is shown in table 5. The selection of level for this experiment is good since certain unique features. If closely observed, the levels of various factors are balanced between one another. This makes the orthogonal arrays a balanced matrix of levels and factors, without any interruptions from other factors that will affected the outcome or response of the experiment. In other words, the effects of one factors is not confused with any effects of other levels or factors. Analysis of variance is a method of partitioning variability into identifiable sources of variation and the associated degrees of freedom in an experiment.

DOI: 10.15680/IJIRSET.2014.0312068

IJIRSET

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

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Table 4: Controlled factor and level unit of experiment

CONTROL	DISCRETION	LEVEL 1	LEVEL 2	LEVEL 3
A	Pulse on time (μs)	5	7	11
B	Pulse of time (μs)	3	6	9
C	Peak Current (A)	6	9	12
D	Fluid pressure	1	2	3

Table 5: Design Matrix of L9 Orthogonal Array

Exp. No.	A	B	C	D
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

Table 6: Design Matrix of L9 Orthogonal Array for machining of HSS with copper tool

Exp. No.	Pulse on Time (μ Sec)	Pulse off Time (μ Sec)	Current (A)	Fluid Pressure (Kg/cm^3)	M.R.R gm/min	T.W.R gm/min	S/N Ratio (MRR)	S/N Ratio (EWR)
1	5	3	6	1	0.250	0.030	-38.0618	56.4782
2	5	6	9	2	1.290	0.170	-23.8088	41.4116
3	5	9	12	3	0.960	0.130	-26.3752	43.7417
4	7	3	9	3	1.240	0.060	-24.1522	50.4576
5	7	6	12	1	1.330	0.020	-23.5436	60.0000
6	7	9	6	2	0.530	0.015	-31.5351	62.4988
7	11	3	12	2	0.140	0.005	-43.0980	72.0412
8	11	6	6	3	0.070	0.004	-49.1186	73.9794
9	11	9	9	1	0.160	0.006	-41.9382	70.4576

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

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Table 7: Design Matrix of L9 Orthogonal Array for machining of HSS with brass tool

Exp. No.	Pulse on Time (µ Sec)	Pulse off Time (µ Sec)	Current (A)	Fluid Pressure (Kg/cm^3)	M.R.R gm/min	T.W.R gm/min	S/N Ratio (MRR)	S/N Ratio (EWR)
1	5	3	6	1	0.160	0.418	-41.9382	33.5971
2	5	6	9	2	0.440	1.040	-33.1515	25.6799
3	5	9	12	3	0.340	1.010	-35.3910	25.9342
4	7	3	9	3	0.240	0.660	-38.4164	29.6297
5	7	6	12	1	0.230	0.870	-38.7860	27.2302
6	7	9	6	2	0.210	0.360	-39.5762	34.8945
7	11	3	12	2	0.300	0.380	-36.4782	34.4249
8	11	6	6	3	0.120	0.100	-44.4370	46.0206
9	11	9	9	1	0.240	0.470	-38.4164	32.5786

VIII. RESULT AND DISSECTION

Because the experimental design is orthogonal, it is possible to separate out the effect of each process parameter at different levels. The mean or average values and S/N ratio of the MRR and TWR for each trial run (1 through 9) have been calculated from experimental data and are summarized in table 6 for copper electrode and in table 7 for brass electrode.

Table 8: S/N Ratio Table for TWR of AISI D3 using Copper electrode

LEVEL	Pulse on	Pulse off	Current	Fluid pressure
1	47.21	59.66	64.32	62.31
2	57.65	58.46	54.11	58.65
3	72.16	58.90	58.59	56.06
DELTA	24.95	1.20	10.21	6.25
RANK	1	4	2	3

Table 9: S/N Ratio Table for TWR of AISI D3 using Brass electrode

LEVEL	Pulse on	Pulse off	Current	Fluid pressure
1	28.40	32.55	38.17	31.14
2	30.58	32.98	29.30	31.67
3	37.67	31.14	29.20	33.86
DELTA	9.27	1.84	8.97	2.73
RANK	1	4	2	3

Table 10: S/N Ratio Table for MRR of AISI D3 using Copper electrode

LEVEL	Pulse on	Pulse off	Current	Fluid pressure
1	-29.42	-35.10	-39.57	-34.51
2	- 26.41	-32.16	-29.97	-32.81
3	-44.72	-33.28	-31.01	-33.22
DELTA	18.31	2.95	9.61	1.70
RANK	1	3	2	4

DOI: 10.15680/IJIRSET.2014.0312068

ISSN: 2319-8753

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Table 11: S/N Ratio Table for MRR of AISI D3 using Brass electrode

LEVEL	Pulse on	Pulse off	Current	Fluid pressure
1	-36.83	-38.94	-41.98	-39.71
2	-38.93	-38.79	-36.66	-36.40
3	-39.78	-37.79	-36.89	-39.41
DELTA	2.95	1.15	5.32	3.31
RANK	3	4	1	2

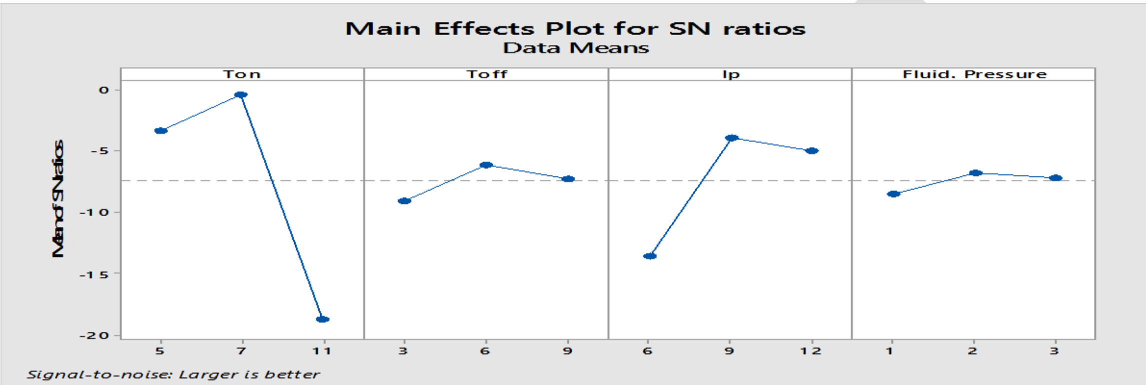

Fig 4: S/N Ratio Table for MRR of AISI D3 using Copper electrode

From the Fig 4 it is found that the MRR will be maximum when the value of Ton= 7 µ Sec, Toff = 6 µ Sec, Ip= 9 Amp, and the Fluid pressure = 2 kg/cm^3. The MRR will be minimum when the value of Ton= 11 µ Sec, Toff = 3 µ Sec, Ip= 6 Amp, and the Fluid pressure = 1 kg/cm^3.

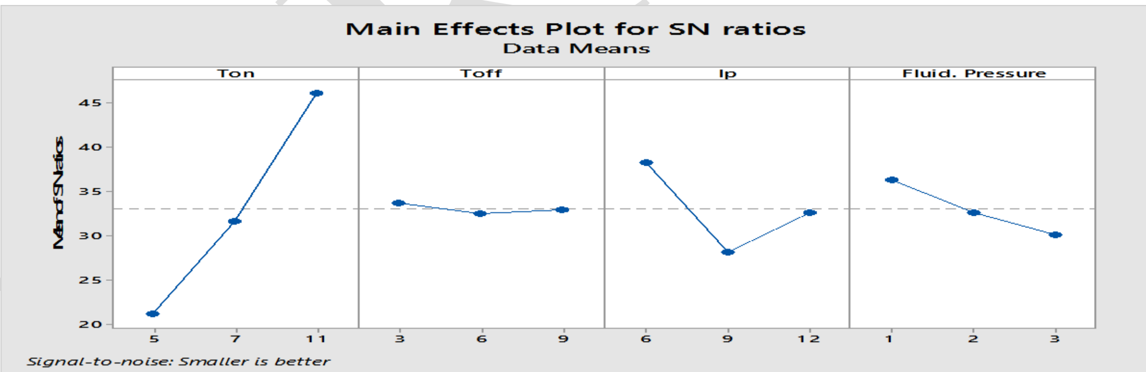

Fig 5: S/N Ratio Table for TWR of AISI D3 using Copper electrode

From the Fig 5 it is found that the TWR will be minimum when the value of Ton= 5 µ Sec, Toff = 6 µ Sec, Ip= 9 Amp, and the Fluid pressure = 5 kg/cm^3. The TWR will be maximum when the value of Ton= 11 µ Sec, Toff = 5 µ Sec, Ip= 6 Amp, and the Fluid pressure = 1 kg/cm^3.

IJIRSET

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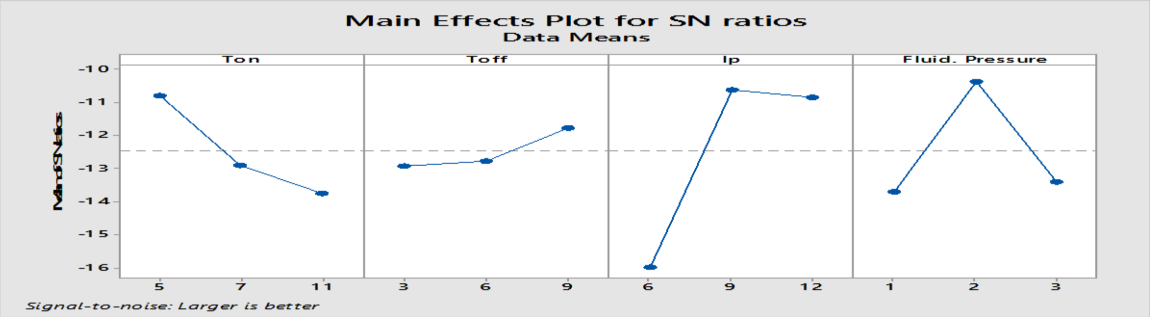

Fig 6: S/N Ratio Table for MRR of AISI D3 using Brass electrode

From the Fig 6 it is found that the MRR will be maximum when the value of Ton= 5 µ Sec, Toff = 9 µ Sec, Ip= 9 Amp, and the Fluid pressure = 2 kg/cm^3. The MRR will be minimum when the value of Ton= 11 µ Sec, Toff = 5 µ Sec, Ip= 6 Amp, and the Fluid pressure = 1 kg/cm^3.

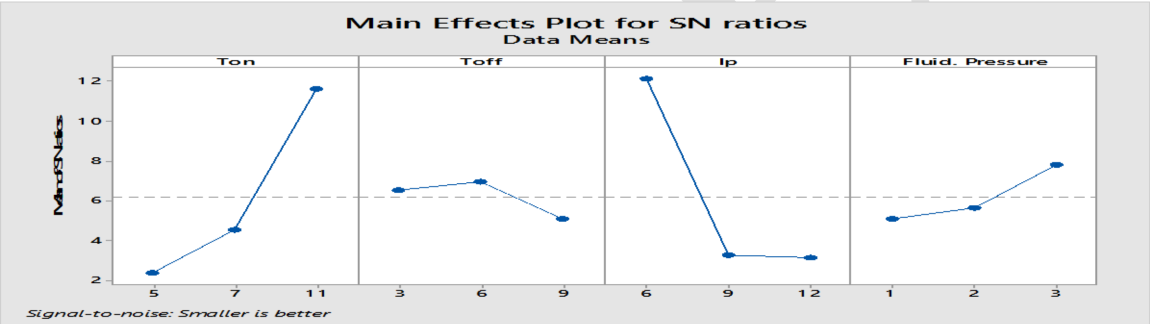

Fig 7: S/N Ratio Table for TWR of AISI D3 using Brass electrode

From the Fig 7 it is found that the TWR will be minimum when the value of Ton= 5 µ Sec, Toff = 9 µ Sec, Ip= 12 Amp, and the Fluid pressure = 1 kg/cm^3. The TWR will be maximum when the value of Ton= 11 µ Sec, Toff = 6 µ Sec, Ip= 6 Amp, and the Fluid pressure = 3 kg/cm^3.

IX. CONCLUSION

In this experiment two electrodes are used for investigation of MRR and TWR.
From the experimental table and graphs it is clear that:

1. The material removal rate is increased with increase in pulse off time and peak current. Material removal rate is decreased with increase in pulse on time in case of brass electrode and decrease in cooper electrode.
2. Copper is found to be having the highest MRR as compare to Brass. The EWR of Brass is very high and Copper has less EWR.

X. ACKNOWLEDGMENT

The authors are thankful to faculty members of Bhabha Institute of Technology, Kanpur Dehat, Affiliated to UPTU Lucknow and M/s Rajat Engineers, Dada Nagar Kanpur and their Technical assistance, for giving full support during

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

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the performance of the experiment. The authors are also extremely thankful to the director of BIT Kanpur Dehat for their support and research advisor Mr. Rahul Bajpai for their motivation during research work.
The authors are once again extremely thankful to Mr. vivek srivastava Assistant Professor of AIMT, Lucknow for their support and motivation during Experiment work.

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