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Experimental Investigation of EDM Machining Parameters to Machine EN8 Material by using Heat Treated Tool

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ABSTRACT

It is observed that in recent trend EN8 material has tremendous application in aeronautical, aerospace industry and automobile engineering because of its favorable properties. Therefore EN8 material has been chosen to machine by EDM. But EDM has a disadvantage of lower MRR. So an experimental investigation has been carried out to study machining parameters of EDM to improve MRR and reducing TWR. Here heat treatment process has been studied and applied to improve tool life by reducing tool wear rate. In this experiment Copper tool has modified by changing its grain growth structure by step hardening process and results in both heat treated and without heat treated tools are compared. The objective of EDM is to get high MRR along with achieving reasonably good surface quality of machined component with reduced tool wear rate for EN8 material. Taguchi design has been implemented to investigate the effect of pulse current, Pulse on Time and Flushing pressure on the responses MRR, TWR and SR. It is being found that tool wear rate of heat treated Cu tool is less than that without heat treated Cu tool and surface roughness of work piece material i.e EN8 is better when heat treated tool is used.

***Keywords*--** Electric Discharge Machining (EDM), Taguchi method, Material Removal Rate (MRR), Tool Wear Rate(TWR), Surface Roughness(SR) etc.

I. INTRODUCTION

Electro discharge machining is an electro thermal non-traditional machining process based on removing of material from a part by means of a series of recurring electrical discharges created by electric pulse generators at short intervals between tool (electrode) and work piece in presence of a dielectric fluid[1]. It is the electrical energy which is used to generate electrical spark and material removal occurs due to thermal energy of spark.

EDM is mainly used to machine difficult-to-machine materials and high temperature resistance alloys. EDM can be used to machine difficult geometries in small batches or even on job shop basis. Any type of electrically conductive hard materials can be machined by EDM machining process[2].

II. TYPES OF EDM

Basically, there are two different types of EDM-

1. Die sinking EDM
2. Wire electro discharge machining(WEDM)

In this experiment we have used Die sinking EDM.

Die Sinking EDM: In the Die Sinker EDM Machining process, two metal parts submerged in an insulating liquid are connected to a source of current which is switched on and off automatically depending on the parameters set on the controller. When the current is switched on, an electric tension is created between the two metal parts. If the two parts are brought together to within a fraction of an inch, the electrical tension is discharged and a spark jumps across. Where it strikes, the metal is heated up so much that it melts. Sinker EDM, also called cavity type EDM or volume EDM consists of an electrode and workpiece submerged in an insulating liquid such as, more typically, oil or, less frequently, other dielectric fluids. The electrode and workpiece are connected to a suitable power supply. The power supply generates an electrical potential between the two parts. As the electrode approaches the workpiece, dielectric breakdown occurs in the fluid, forming a plasma channel, and a small spark jumps.

These spark strikes at the work surface one at a time and the material is removed in the process of melting and vaporization.

III. EQUIPMENT OF EDM

Dielectric system, Electrode, Servo System, Power Supply

Working principle of EDM-In EDM process, the principle is the conversion of electrical energy into thermal energy through a series of discrete sparks occurring between the tool electrode and a conductive work-piece immersed in a dielectric medium and separated by a small gap. Short duration discharges are generated in a liquid dielectric gap, which separates tool and work-piece. In this process electrical energy is used to generate the electrical spark and thermal energy is used for material removal. The electrode is moved towards the work-piece until the gap is small enough to ionize the dielectric. The dielectric flush eroded particles from the gap and it is really important to maintain this flushing continuously. As the work-piece remains fixed by the fixture arrangement, tool helps in focusing the discharge or intensity of generated heat at the place of shape disclose. Application of heat raises the temperature of work-piece in the region of tool position, which subsequently melts and evaporates the metal. In this way the machining process removes small volumes of work-piece material by the mechanism of melting and vaporization during a discharge. The erosion process due to a single electric spark in EDM generally passes through the following phases which shown in Fig[1].

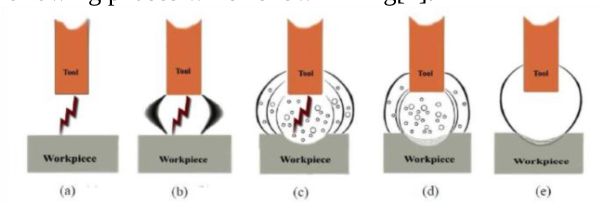

Fig.1(a) Pre-breakdown phase (b) Breakdown phase (c) Discharge phase (d) End of the discharge and (e) Post-discharge phase

Breakdown: When the applied voltage crosses the boundary limit of strength of used dielectric fluid, the breakdown of the dielectric is originated. The spot of breakdown is normally between the closest points of the electrode and the work-piece, but it is also depend on conductive particles or debris present in the gap. When the breakdown occurs the voltage falls and a current rises quickly. In this phase the dielectric gets ionized and a plasma channel is created between the electrodes.

Discharge: In this phase the flow of discharge current is maintained at constant level for a continuous attack of ions and electrons on the electrodes leads to cause strong heating of the work-piece material, leading to temperature rise between 8,000 ^{0}C and 12,000 ^{0}C. This results rapidly creating a small molten metal pool at the electrodes surface. Also a small amount of metal are directly vaporized due to the tremendous amount of heat. In this phase, the plasma channel expands; therefore the radius of the molten metal pool also increases with time. The Inter Electrode Gap is an important parameter throughout the discharge phase.

End of the discharge: In this phase, current and voltage supply are cut off and therefore, plasma collapses under the pressure enforced by the surrounding dielectric.

Post-discharge: In this phase, there will be no plasma. Here a small portion of metal will be machined and a small thin layer (white layer) will be deposited because of plasma is collapsing and cooling. Accordingly, the molten metal pool is strongly sucked up into the dielectric, producing a tiny crater on the work-piece surface.

IV. EDM PROCESS PARAMETERS

a) Spark on time (pulse time or Ton): It is the duration of time in µs that current is allowed to flow per cycle. Material removal is directly proportional to the amount of energy applied during this on time. This energy is really controlled by the peak current and the length of the on time.

b) Spark off time (pulse time or TOff): It is the duration of time in µs between the spark. This time allows the molten material to solidify and to be cleaned the arc gap. This parameter is to affect the speed and the stability of the cut. Thus, if the off time is too short, it will makes sparks to be unstable.

c) Arc gap: The arc gap is the distance between the electrode and work piece during the machining time. It may be called as spark gap. It can be maintained by servo system.

d) Discharge current (Pulse current Ip): It is the most important machining parameter in EDM, because it is related to power consumption during machining. Until reaches the preset level, the current is increased which is known as discharge current. The setting of discharge current on static pulse generators generally determines the number of power units connected parallel to the gap. The larger discharge current means the higher power intensity during electrical discharge.

e) Lift time: It is the time in which tool lifts up and fresh dielectric field entered into the inter electrode gap by flushing.

f) Duty cycle (τ): It is the percentage of the pulse on time relative to the total cycle time. This parameter is calculated by dividing the on time by the total cycle time (pulse on time plus pulse off time).

$$\tau = \frac{Ton}{Ton + Toff}$$

g) Voltage (V): It is a potential that can be measure by volt. It is also effect to the material removal rate and allowed to per cycle.

h) Polarity: It specifies to the potential of work piece with respect to the tool, depending on the application, the polarity can be changed. Carbide, Titanium and copper are generally cut with negative polarity.

i) Diameter of the electrode (D): It is the Cu electrode of diameter 10mm in this experiment.

j) Over cut: It is a clearance per side between the electrode and the workpiece after the machining operation.

k) Inter electrode gap: It is the distance between the electrode and the work part during the process of machining. It is also called as spark gap. It is most essentially required for spark stability and proper flushing. The tool servo mechanism is responsible for inter electrode gap.

l) Dielectric Fluid: The dielectric fluid acts as an electrical insulator to carry out the spark. It cools down the electrode and also provides the high pressure to remove the eroded metal. Most commonly used dielectric fluids are paraffin, de-ionized water, kerosene, and EDM oil etc.

m) Flushing pressure: Flushing is an important factor in EDM process for supplying and cleaning the Dielectric fluids into the machining zone. Flushing is difficult if the cavity is deeper. The usual range of flushing is in between 0.1 to 1.2 Kgf/ cm^2.

V. DIELECTRIC FLUID

In EDM, as has been discussed earlier, material removal mainly occurs due to thermal evaporation and melting. As thermal processing is required to be carried out in absence of oxygen so that the process can be controlled and oxidation avoided. Oxidation often leads to poor surface conductivity (electrical) of the work piece hindering further machining. Hence, dielectric fluid should provide an oxygen free machining environment. Further it should have enough strong dielectric resistance so that it does not breakdown electrically too easily but at the same time ionize when electrons collide with its molecule. Moreover, during sparking it should be thermally resistant. The dielectric fluid has the following functions:
(i) It helps in initiating discharge by serving as a conducting medium when ionized, and conveys the spark. It concentrates the energy to a very narrow region.
(ii)It helps in quenching the spark, cooling the work, tool electrode and enables arcing to be prevented.
(iii)It carries away the eroded metal along with it.
(iv)It acts as a coolant in quenching the sparks wel

There are various types of dielectric fluids are used id EDM like- EDM oil, Kerosene, Transformer oil, Distilled water etc.

In this experiment we have used the Fresh EDM oil Grade-II.

VI. SPECIFICATIONS OF EDM

Table 1 Specifications of EDM machine

Model	ZNC25
Operating platform(mm)	28X450
Operating groove(mm)	820X500X280
X-axis range Y-axis range Z-axis Range	250mm 200mm 200mm
Electric pole carrying capacity	30Kg
Maximum capacity of the operating platform	200kg
Maximum dimensions (mm)	1390X1480X2010
Weight of the machine tool	1000Kg
Motor	3phase, ½ hp, 50hz

VII. ELECTRODE AND WORK PIECE

EDM is capable of machining of hard material component such as heat treated tool steels, composites, super alloys, ceramics, carbides, heat resistant steels etc. In this experiment we have used EN-8 alloy steel as workpiece. It is an unalloyed medium carbon steels with tensile stress 700-850 Mpa.

In this experiment we have used 2 sets of copper electrode. One set is consists of 5 nos. of without heat treated CU electrode while the other sets is having similar 5 nos. of heat treated CU electrode.

VIII. HEAT TREATMENT

In this experiment we have used two set of Copper tools each set containing 5 electrode out of which one set is heat treated and other is without heat treated. One tool is heat treated in an Ashing furnace for 3 hour and temperature range was 300-350 ^{0}C.

IX. DESIGN VARIABLE

Design parameters-Material removal rate(MRR), Tool wear rate (TWR), Surface roughness(SR)
Machining parameter- Pulse current (I_P), pulse on time, pulse (T_{ON}), flushing Pressure (P).

X. TAGUCHI METHOD

Taguchi method, developed by Dr. Genichi Taguchi, is a set of methodologies for optimization of a process or product.. This method involves three stages: system design, parameter design, and tolerance design. Out of these three stages, the second stage – the parameter design – is the most important stage as the first stage – system design – is an initial functional design and may be far from quality and cost. However, the third stage – tolerance design – is dependent of cost. Therefore, the parameter design is the key step in the Taguchi method to achieving high quality without increasing cost. L9 (3^3) orthogonal array was used for conducting the experiments. The level and factor are given in table-1. L9 orthogonal array has 9 no. of experiments and 8 degrees of freedom in the basis of input parameters. The input parameters foe this experiment are Pulse current (I_P), pulse on time, pulse (T_{ON}), flushing Pressure (P). The S/N ratio for each level of process parameters is computed based on the S/N analysis. Regardless of the category of the performance characteristic, the larger S/N ratio corresponds to the better performance characteristic. Therefore, the optimal level of the process parameters is the level having highest S/N ratio. Furthermore, statistical analysis of variance (ANOVA) is performed to see which process parameters are statistically significant. The optimal combination of the process parameters can be predicted by S/N and ANOVA analysis. Finally, a confirmation experiment is conducted to verify the optimal process parameters obtained from the parameter design.

XI. EXPERIMENTAL WORK

Table 2selected process parameters

Machining parameter	Symbol	Unit	Level		
			Level 1	Level 2	Level 3
Pulse on Time	T_{ON}	μs	30	150	300
Pulse Current	I_P	A	2	6	9
Flushing Pressure	P	Kg/ cm^2	0.5	1.0	1.2

Experiments have been conducted in die sinking EDM shown in fig.2 (a). Target is 2mm for machining the work piece. Time is not constant. TWR and MRR have been calculated by measuring the electrode and work piece respectively with the help of semi micro balance, shown in fig.2 (b). SR has been calculated with the help of profilometer, shown in fig.3.

Fig.2(a) Die sinking EDM (b) Semi-micro balance

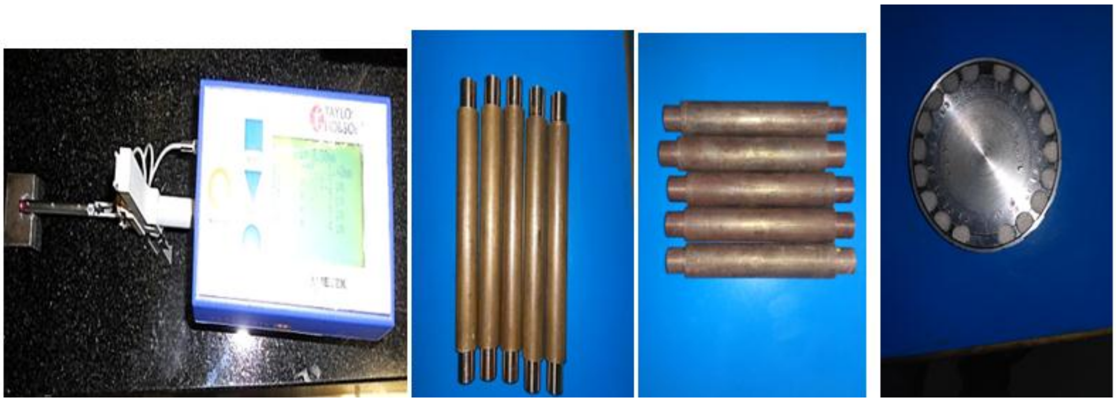

Fig.3(a) Profilometer (b) without heat treated and heat treated copper tool after machining (c) Workpiece(EN 8) after machining

Table 3 Experimental result for heat treated copper tool

Sl No.	TON (µm)	IP (A)	P Kg/ cm^2	MRR (gm/min)	TWR (gm/min)	SR (µm)	S/N Ratio (for MRR)	S/N Ratio (for TWR)	S/N Ratio (for SR)
1	30	2	0.5	0.02632	0.00532	1.6	-31.594	34.481	-4.082
2	30	6	1.0	0.09262	0.00649	2.2	-20.665	34.212	-6.848
3	30	9	1.2	0.19196	0.01039	2.8	-14.335	39.667	-8.943
4	150	2	1.0	0.01298	0.00012	1.2	-37.734	78.416	-1.583
5	150	6	1.2	0.11258	0.00055	4.8	-18.970	65.192	-6.812
6	150	9	0.5	0.28946	0.00045	5	-10.768	66.935	-13.979
7	300	2	1.2	0.012	0.00007	1	-38.416	83.098	0
8	300	6	0.5	0.13536	0.00008	2.6	-17.370	81.938	-8.299
9	300	9	1.0	0.33731	0.00122	5.2	-9.439	58.272	-14.320

Table 4 Experimental result for without heat treated copper tool

Sl No.	TON (µm)	IP (A)	P Kg/cm^2	MRR (gm/min)	TWR (gm/min)	SR (µm)	S/N Ratio (for MRR)	S/N Ratio (for TWR)	S/N Ratio (for SR)
1	30	2	0.5	0.02160	0.00715	1.8	-33.310	42.913	-5.105

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2	30	6	1.0	0.10206	0.00532	2.4	-19.823	45.481	-7.604
3	30	9	1.2	0.18533	0.01255	3.4	-14.641	38.027	-10.629
4	150	2	1.0	0.01240	0.00008	1.8	-38.131	81.938	-5.105
5	150	6	1.2	0.08207	0.00040	3.2	-21.716	67.958	-10.102
6	150	9	0.5	0.22957	0.00188	4.0	-12.781	54.516	-12.041
7	300	2	1.2	0.01406	0.00001	1.2	-46.582	100.00	-1.583
8	300	6	0.5	0.11976	0.00083	3.0	-18.433	61.618	-9.542
9	300	9	1.0	0.28788	0.00077	3.2	-10.815	62.270	-10.102

Table 5 Response table for S/N ratio of MRR for Without Heat treated tool

Level	Pulse on time	Pulse current	Flushing pressure
1	-22.59	-36.16	-21.51
2	-24.21	-19.99	-22.92
3	-22.10	-12.75	-24.47
Delta	2.11	23.41	2.96
Rank	3	1	2

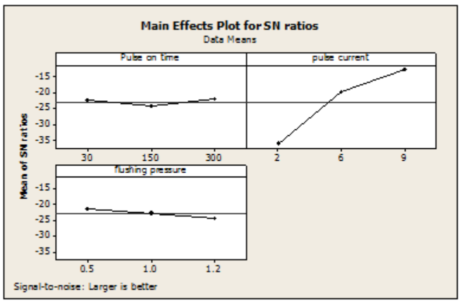

Fig.4 Ratio curves of Process parameters of MRR for without heat treated tool

Table 6 Response table for S/N ratio of TWR for Without Heat treated tool

Level	Pulse on time	Pulse current	Flushing pressure
1	42.14	74.95	53.02
2	68.14	58.35	63.23
3	74.63	51.60	68.66
Delta	32.49	23.35	15.65
Rank	1	2	3

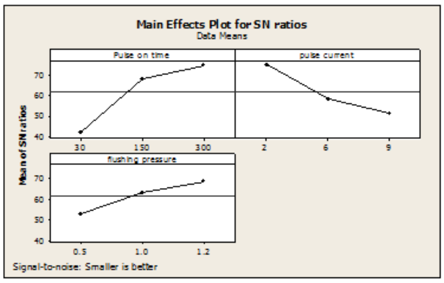

Fig.5 Ratio curves of Process parameters of TWR for without heat treated tool

Table 7 Response table for S/N ratio of SR for Without Heat treated tool

Level	Pulse on time	Pulse current	Flushing pressure
1	-7.780	-3.404	-8.896
2	-9.083	-9.083	-7.604
3	-6.548	-10.925	-6.911
Delta	2.535	7.521	1.985
Rank	2	1	3

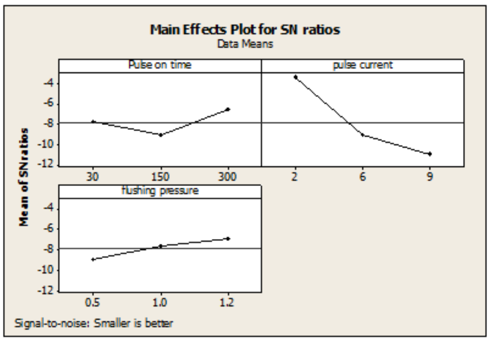

Fig.6 Ratio curves of Process parameters of SR for without heat treated tool

Table 8 Response table for S/N ratio of TWR for Heat treated tool

Level	Pulse on time	Pulse current	Flushing pressure
1	-22.20	-35.92	-19.91
2	-22.49	-19.00	-22.61
3	-21.74	-11.51	-23.91
Delta	0.75	24.40	4.00
Rank	3	1	2

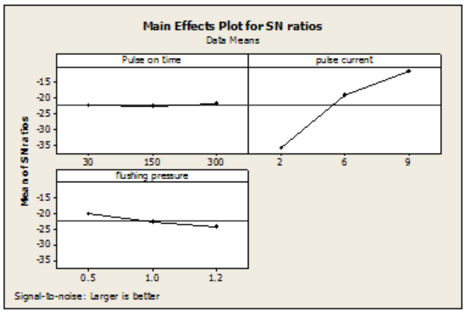

Fig.7 Ratio curves of Process parameters of MRR for Heat treated tool

Table 9 Response table for S/N ratio of TWR for Heat treated tool

Level	Pulse on time	Pulse current	Flushing pressure
1	42.97	69.00	64.79
2	70.18	63.63	60.15
3	74.44	54.96	62.65
Delta	31.47	14.04	4.64
Rank	1	2	3

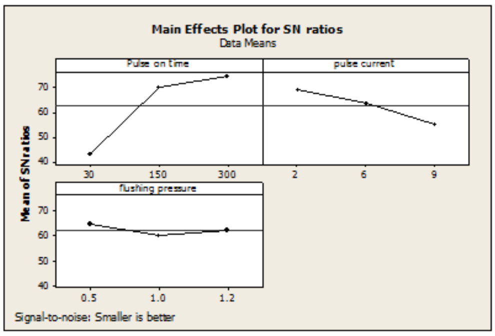

Fig.8 Ratio curves of Process parameters of TWR for Heat treated tool

Table 10 Response table for S/N ratio of SR for Heat treated tool

Level	Pulse on time	Pulse current	Flushing pressure
1	-6.625	- 1.889	-8.787
2	-9.729	- 9.591	-7.584
3	-7.540	-12.414	-7.523
Delta	3.105	10.526	1.264
Rank	2	1	3

XII. DISCUSSION

For **without heat treated tool**, the response table for S/N ratios for MRR, TWR and SR are shown in tables 5,6 and 7 respectively graphical representation of the three control factors i.e $T_{ON,}$ $I_{P,}$ and P on MRR, TWR and SR are shown in figure 4,5, and 6 respectively.

Referring to the table5, it was observed that pulse current is the main parameter for increasing the MRR, whereas the effect of Pulse on time and flushing pressure are equal. The MRR gives highest value in case of run no 9 and lowest value in case of run no 7.

Referring to the table 6, it was observed that pulse on time is the main parameter for reducing the TWR and pulse current and flushing pressure are also playing as main effective parameters for TWR. The TWR gives highest value in case of run no 3 and lowest value in case of run no 7.

Referring to the table 7, it was observed that pulse current is the main parameter for reducing the SR and whereas the effect of Pulse on time and flushing pressure are equal. The SR gives highest value in case of run no. 6 and lowest value in case of run no 7,

For **Heat treated tool**, the response table for S/N ratios for MRR, TWR and SR are shown in tables 8, 9 and 10 respectively graphical representation of the three control factors i.e. $T_{ON,}$ $I_{P,}$ and P on MRR, TWR and SR are shown in figure 7,8 and 9 respectively.

Referring to the table8, it was observed that pulse current is the main parameter for increasing the MRR, Pulse on time also gives average effect whereas flushing pressure gives least effect. The MRR gives highest value in case of run no 9 and lowest value in case of run no 7.

Referring to the table 9, it was observed that pulse on time is the main parameter for reducing the TWR and pulse current and flushing pressure are also playing as main effective parameters for TWR. The TWR gives highest value in case of run no 3 and lowest value in case of run no 7.

Referring to the table 10, it was observed that pulse current is the main parameter for reducing the SR and whereas the effect of Pulse on time and flushing pressure give equal effects. The SR gives highest value in case of run no 6 and lowest value in case of run no 7.

XIII. CONCLUSIONS

1. For MRR, the most significant factors were found to be pulse current and flushing pressure followed by pulse on time.
2. For TWR, the most significant factor was Pulse on time, pulse current.
3. For SR, the most significant factor was pulse current .
4. Increase in pulse current and pulse on time, the MRR, SR and TWR were increased.
5. TWR can be reduced by heat treatment process and it gives better surface finish as compare to without heat treated tool.
6. The best condition for minimize the SR for both Heat Treated and without heat treated tool is 2A pulse current, 300µs of pulse on time and 1.2kg/cm^2.
7. The best condition for minimize the TWR for both Heat Treated and without heat treated tool is 2A pulse current, 300µs of pulse on time and 1.2kg/cm^2.
8. The best condition for MRR for both Heat Treated and without heat treated tool is 9A pulse current, 300µs of pulse on time and 1.0kg/cm^2.

From confirmation test it has been observed that the experimental values give better result as compare to predicted values. So the Taguchi Method is most effective technique for better solution of single objective optimization process.

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