

EXPERIMENTAL INVESTIGATION – MAGNETIC ASSISTED ELECTRO DISCHARGE MACHINING

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ABSTRACT

Emerging technology needs advanced machined parts with high strength and temperature resistance, high fatigue life at low production cost with good surface quality to fit into various industrial applications. Electro discharge machine is one of the extensively used machines to manufacture advanced machined parts which cannot be machined by other traditional machine with high precision and accuracy. Machining of DIN 17350-1.2080 (High Carbon High Chromium steel), using electro discharge machining has been discussed in this paper. In the present investigation an effort is made to use permanent magnet at various positions near the spark zone to improve surface quality of the machined surface. Taguchi methodology is used to obtain optimal choice for each machining parameter such as peak current, pulse duration, gap voltage and Servo reference voltage etc. Process parameters have significant influence on machining characteristics and surface finish. Improvement in surface finish is observed when process parameters are set at optimum condition under the influence of magnetic field at various positions.

Keywords: EDM; Surface roughness; process parameters; high carbon high chromium steel

1. INTRODUCTION

EDM have wide application in machining high strength and temperature resistance material for moulds, dies and some of aerospace engine parts. In this process, material removal takes place between the tool and the work piece, separated by a small gap filled with a dielectric fluid between the gaps without direct contact. The discharge of energy created by DC pulse generator for small pulse duration between a tool and work piece, erodes molten material from the work piece surface.

The requirement of high quality machined surface varies with field of its application. In this approach suitable generators and sub assemblies have been developed for Electro discharge machining (EDM) during last few years for improving material eroded and surface quality Yan Cherg Lin et al. [1] investigated the machining properties of titanium alloys using a combination of ultrasonic machining and EDM and concluded that the EDM / USM combination process can enhance the metal removal rate (MRR) and reduce the thickness of the luster layer. Ken Heinz et al. [2] have completed experiments for improving MMR in magnetic field assisted EDM for nonmagnetic materials. The work piece electrode is oriented to promote the directionality of the current flowing through the work piece while applying an external magnetic field to generate Lorentzian forces in the bath. By orienting the Lorentz force in the direction of the workpiece surface, the volume of material removed increased by nearly 50% and the erosion efficiency by 54%. Plasma temperature is not affected. S. Joshi et al. [3] investigated on the performance of hybrid dry EDM process in a pulsating magnetic



field to improve productivity by 130%, with enhanced surface quality and zero tool wear when compared with dry EDM process without the magnetic field.

Chattopadhyay et al. [4] evaluated MRR and electrode wear rate (EWR) results from spin-on machining. The workpiece is placed in the induced magnetic field to periodically change the polarity of the magnetic field. By reducing the processing cost, the EDM process is improved and the MRR and EWR increase and decrease. Lahiri et al. [5] have studied the effects of magnetic fields on MRR and Relative Electrode Wear (REW) per pulse during EDM of High-speed Steel work material with copper electrode immersed in kerosene oil. The results concluded that the magnetic field affects the metal removal and crater shapes was high at higher pulse widths. Ahsan A. Khan et.al [6] has introduced External Magnetic Field (EMF) which removes debris away from the machining gap and influence on the surface roughness of SUS 304 stainless steel. While EMF-EDM produces lower Ra than conventional EDM at lower current, the reverse is the case at higher current.

Luo and Chen [7] conducted an experiment to confirm that the behaviour of the pulsed electromagnetic field affects the surface roughness, especially in the case of superfinishing EDM, with an optimum surface roughness of 0.04 μm Ra. Luo et.al [8] experimented to obtain Mirror surfaced work piece using pulse electromagnetic waves in small spark gap to meet the demands for smooth plastic moulds and blanking dies.

2. EXPERIMENTAL DESIGN

For enhancement of quality of a machined surface Taguchi Design of experiments is used for experimentation. The standard Taguchi L9 Orthogonal Array (OA) may hold four parameters with each at three levels so that effect of one factor does not influence the estimation of another factor thus reduce the number of experiments.

The four parameters are peak current (I), pulse duration (T_{on}), gap voltage (V), Servo reference voltage (S_v) are selected to evaluate surface roughness in Electro Discharge Machine (EDM) and it is further investigated using magnets at various position near spark zone to know the Magnetic effect in Electro Discharge Machine (MEDM).

In Taguchi methods, the SN Ratio analyzes the response of the experiment using the SN (signal to noise) ratio by representing the mean (mean) and variance (scatter) of the experimental results.

In this experimentation magnetic field is introduced between the machining gaps using permanent magnet to create Magnetic field lines parallel to the work piece surface such that it is perpendicular to electrical field lines formed near spark zone as shown in figure 1. It is stated that Lorentz force is formed due to the cross product of the current with the magnetic field which helps for quick debris removal in spark zone as seen in equation [1] which can be maximized when the current vector and the magnetic field vector are mutually perpendicular.

$$F = J \times B \text{ ----- (1)}$$

Where

J= current per unit area (A/mm^2),

B = magnetic field (T)

When the electricity flows between the electrodes in presence of dielectric fluid forming ionized column with no variation of voltage, increasing current amplitude quickly to a constant value set by operator forming spark. Within the ionized column, electrons start to flow from the cathode electrode toward the anode. In ionized columns, the dielectric-positive atomic charge is due to the absence of electrons in the fluid atom. This positively charged starts attracting stream of electrons and positive ions, this forms plasma channel surrounded by bubbles which occurs by vaporization of dielectric fluid during pulse ON-time [9]. Amson [10] suggested that the droplets of molten material produced by the plasma interacting with

the electrodes were removed with the help of magnetically induced Lorentz forces that fluctuate from negative to positive during droplet formation, and again to negative. The addition of external Lorentz force will change the resulting force to enhance the separation of the number of molten droplets from the composite material and improve surface finish.

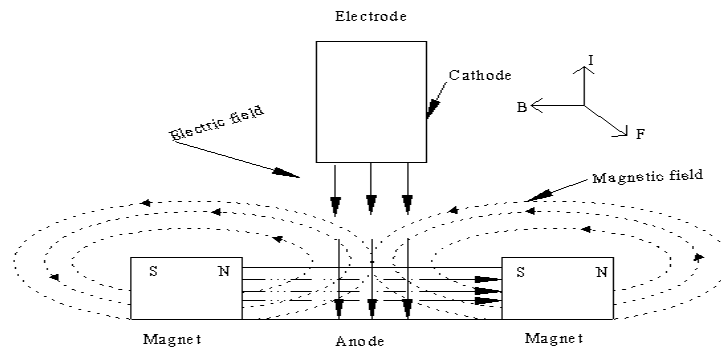


Figure 1: Experiment Setup [7]

3. MATERIALS USED

The work piece used is chosen for this research is a HCHCr die steel, that is DIN 17350-1.2080 260HBW hardness and density of 7760kg / m³. Work piece size is 30 x 20 and x 10m, which is mainly grinding and polishing to ensure parallel in advance prior to performing the experiment. Table 1 shows the chemical composition of the material.

Table 1. The chemical composition of HCHCr

C	Si	Mn	P	S	Cr	Mo	V	Ni
1.91	0.47	0.42	0.021	0.019	11.48	0.22	0.011	0.10

i) **Electrode:** Copper as electrode material is the most common tool material in EDM industries. The density of the electrode is 8960 kg/m³. The cross section of the electrode is 50 × 20 × 20 mm. The front of the electrode with 600, 800, 1200 sandpaper grounding, to ensure that the electrode surface finish and flatness.

ii) **Magnet:** Neodymium magnet N35 is a permanent magnet used to generate an external Magnetic field of 0.3T.

Table 2. Factors and Levels used in experiment

CONTROL FACTORS \ LEVELS	LEVELS		
	1	2	3
Peak Current	5	10	15
T _{on}	60	120	180
Gap voltage	30	40	50
Servo voltage	10	20	30

4. LABORATORY INVESTIGATIONS

As shown in Table 2, different processing parameters such as peak current (I), pulse duration (Ton), gap voltage (V), servo reference voltage (Sv). These factors and levels are organized in L9 Taguchi orthogonal array as presented in table 3. For each setting experiments are carried, Surface roughness (Ra) is measured using Talysurf instrument. SN ratio is calculated using equation 2 considering lower-the better performance characteristic for surface roughness and is tabulated in the table 3.

$$S/N = -10 \log_{10} [\text{mean of sum squares of Response}] \text{ ----- (2)}$$

Table 3. The Average value in EDM

S.no	Peak Current	Ton	Gap voltage	Servo voltage	Ra	S/N Ra
1	5	60	30	10	5.33	-14.53
2	5	120	40	20	6.11	-15.72
3	5	180	50	30	6.28	-15.96
4	10	60	40	30	6.09	-15.70
5	10	120	50	10	7.91	-17.97
6	10	180	30	20	8.74	-18.84
7	15	60	50	20	7.14	-17.08
8	15	120	30	30	6.62	-16.42
9	15	180	40	10	11.90	-21.51

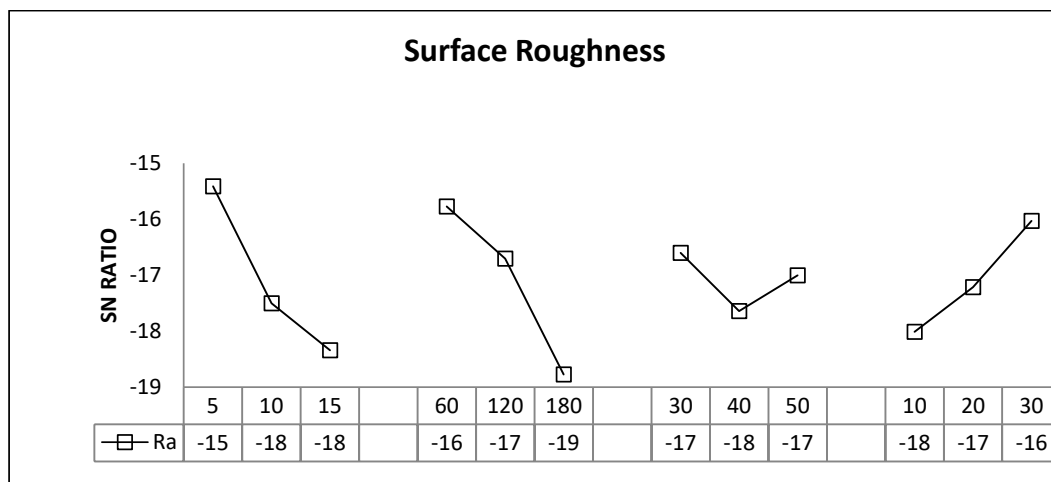
Table 4 Average for SN ratio and main effect of Ra

Parameters	1 st Level	2 nd level	3 rd level	Max-Min	Rank
Peak Current	-15	-18	-18	2	2
Ton	-16	-17	-19	3	1
Gap.Voltage	-17	-18	-17	1	4
Servo reference voltage	-18	-17	-16	2	3

Average S/N and main effect are calculated in table 4. It is observed Ton is contributing more than peak current. ANOVA results closely match with Taguchi results as presented in the table 5 and it is perceived that Ton is contributing 40 % compared with peak current which is contributing 39 %.

Table 5. ANOVA of Ra

CONTROL FACTORS \ LEVELS	1	2	3	Degrees of Freedom	Sum of Squares	Mean Square	Factor Effect (percent)
Peak Current	-15	-18	-18	2	14	7	39
Ton	-16	-17	-19	2	14	7	40
Gap Voltage	-17	-18	-17	2	2	1	5
Servo voltage	-18	-17	-16	2	6	3	17

**Figure.2:** SN Ratio of Various factors

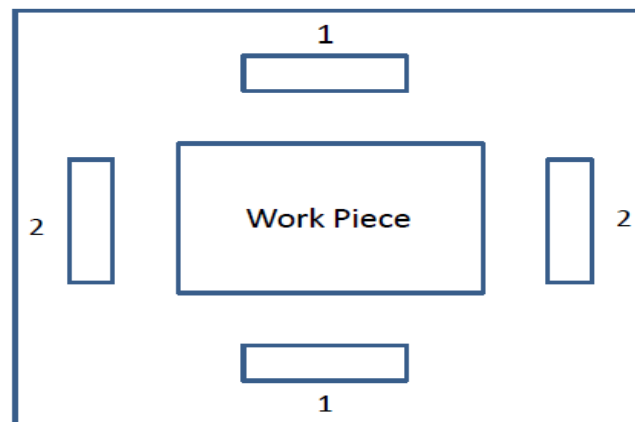


Figure 3: Various Positions of Magnets

The optimum setting of parameters for getting good surface quality in EDM is Peak Current 5, Ton 60, Gap Voltage 30, Servo voltage 30 as shown in figure 2. Setting EDM machining parameters in the optimum setting, the work piece is machined under influence of magnet at various positions as shown in the figure 3 to improve surface quality. The surface roughness is measured at this condition and is tabulated in table 6. If surface roughness value is decreases it is considered as surface quality is improving to know how much there is improvement by calculating relative decrement compared with without magnetic effect is tabulated in the table 6. It is observed that setting 1-1-2-2 setting gives better surface quality with relative decrement of 2.74 as shown in figure 4.

Table 6. Relative decrement of Ra

Exp no	Position	Ra	Relative decrement of Ra	Rank
1	Nil	5.901	0	3
2	1-1	5.798	1.74	2
3	2-2	5.946	-0.76	4
4	1-1, 2-2	5.739	2.74	1

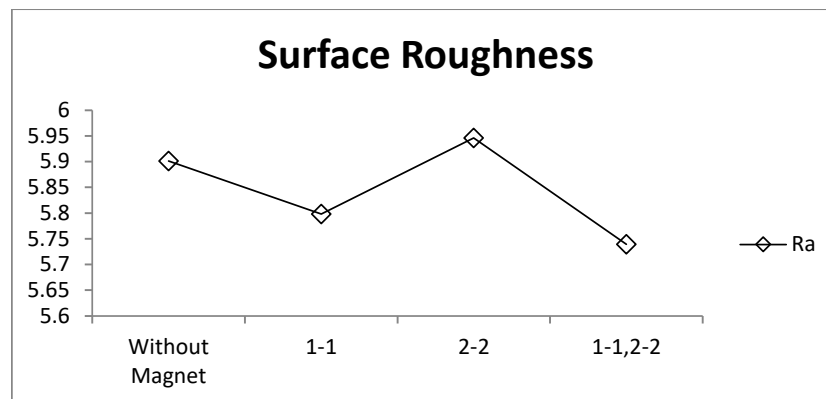


Figure 4: Surface Roughness at various Positions

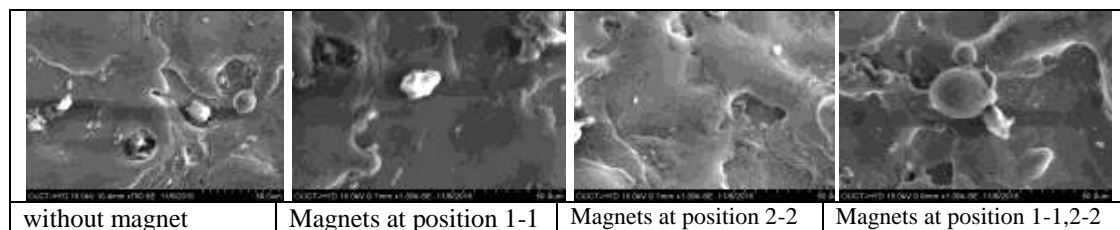


Figure 5: SEM of Machined surface

SEM analysis is conducted on samples machined at optimum setting at various position of magnet and it is observed that debris recast are reduced on surface in 1-1, 2-2 setting as shown in figure 5.

5. CONCLUSIONS

The effect of magnetic force on the EDM was determined and the optimal machining parameters were expected based on the Taguchi method. As per the experimental results and ANOVA statistical analysis, the below conclusions were drawn.

- (1) The MEDM has a better machining stability, since the debris expel more quickly by the magnetic assisted force to avoid the abnormal discharge.
- (2) The surface roughness of MEDM was almost small compared to the value of standard EDM.
- (3) The peak current and pulse duration were the significant parameters affecting surface roughness associated with EDM. Moreover, the optimal combination levels of machining parameters of minimizing surface roughness of EDM on HCHCr steel were 5A peak current, 60 μ s pulse duration; 30 V gap voltage, 30 servo reference voltages .
- (4) The surface roughness is improved when using magnets in all side of the square shape.
- (5) The relative decrement is observed in all the arrangement but in 2-2 position the surface roughness is not improve instead reduced so that we observe negative value.

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