Optimizing Process Parameters on SR and MRR of Steel by EDM

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Abstract: *Electric discharge machining (EDM) is a successful non-conventional machining technology that is chosen for cutting hard materials, geometrically complicated products, microscopic holes, and other challenging applications. EDM, on the other hand, cannot be used to manufacture non-conductive materials. It is the purpose of this paper to examine the practical impact of different Electric Discharge Machining process parameters on surface roughness (SR) and materials removal rate in a manufacturing setting (MRR). It was decided to machine the SS 316 steel samples with a Copper electrode and to measure the flushing pressure, discharge current, pulse off-time, and pulse on-time as process parameters for the experiment. In this article, stainless steel 316 workpiece was employed using Taguchi L18 design to perform tests on electrical discharge machine (EDM) (EDM). Pulse-on-time (Ton), Current (A), and Voltage (V) are treated as separate factors and optimize the response variables material removal rate (MRR), tool wear rate (TWR) and surface roughness (SR) (SR). Analysis of variance (ANOVA) and signal-to-noise (S/N ratio) was performed to figure out optimal independent parameters and their values.*

Keywords: Electric Discharge machining; Material Removal rate; Surface roughness; ANOVA.

Abbreviations: MRR: Material Removal Rate, TWR: Tool Wear Rate, SR: Surface Roughness

1. Introduction:

Innovative manufacturing principles such as acoustic, chemical, mechanical, and electrons are used in non-conventional machining processes. Increasingly difficult to manufacture materials are being developed as the industry progresses, with a high strength-to-weight ratio and a broad variety of uses in semiconductors, nuclear power, and aerospace engineering, among other fields of endeavor. EDM has taken the role of grinding, drilling, rolling, and other conventional machining methods, and it is capable of machining difficult-to-machine materials such as heat-treated tool steels, heat resistant steels, composites, ceramics, and so on. It is often used in the processing of difficult-to-machine materials such as temperature-resistant metals.

Strake and Husova [1] studied the effects of various EDM settings on MRR and Tool Wear Rate (TWR) on tool steels (ENX210Cr12), using copper as the electrode. The results showed that copper had the greatest influence on MRR and TWR. Ton, discharge current, TOFF, and gap voltage were selected as the input parameters for this experiment. The combination of these components had a substantial impact on the magnitude of the crater. A study conducted by Kumar et al. [2] evaluated the impact of EDM parameters such as gap voltage, discharge current, and other variables on the machining of AlSi420 stainless steel. The output responses that were recorded were the MRR and TWR values. Taguchi and Taguchi grey techniques were utilized to optimize the control variables of the machine under consideration. Khan [3] investigated the mechanical resistance and thermal conductivity of an aluminum oxide/copper composite. The experiment was optimized with the help of the L8 Orthogonal array. The machining parameters EDM TON, TOFF, current, and voltage were selected based on their performance. Surface morphology and composite analysis were investigated using SEM and EDX techniques.

Researchers Rao et al. [4] looked at the experimental findings of canola oil being used as a dielectric on the MRR and TWR. The input machine parameters selected were the pulse on time, the gap voltage pulse off time, and the pulse on time. Electrodes made of copper, brass, and tungsten were used in this experiment (alloy). Vimala et al. [5] performed an experimental inquiry in which copper was used as an electrode to manufacture hot die steel, and the results were published. In EDM, the parameters that are employed include current, tone, voltage, and magnetic field. The output reactions MRR, Surface Roughness (SR), and TWR are examples of the types of reactions. Verma and Sajeevan [6] used a L9 orthogonal array to optimize parameters in EDM using titanium Alloy Grade -V, and the results were promising (Ti6Al4V). A significant amount of energy is released as a result of high voltage and pulse on time combined with low dielectric fluid pressure, causing the temperature to increase and a deeper crater to form on the surface of the planet. As the Ton grew, the MRR and SR increased as well, owing to the fact that the spark stayed in contact with the workpiece for a greater length of time.

Dhar and Purohit [7] utilized the PS LEADER ZNC EDM machine to compute the MRR and TWR on Al-4Cu-6Si alloy-10wt percent siCp composites using the MRR and TWR formulas. Karthikeyan and colleagues [8] performed research and developed a mathematical model to predict the effects of current, pulse length, and SiC volume percent on the performance of a semiconductor laser. The ANOVA test was used to evaluate the whole factorial design with three levels. Mohan and Satyanarayana [9] studied the effects of discharge current, pulse length, and electrode rotation on the M.R.R., T.W.R., and S.R. electrodes, as well as the effects of electrode rotation on the T.W.R. and S.R. electrodes. According to Narender Singh et al. [10], the impact of discharge current, Ton, and dielectric pressure on the magnetic resonance resonance, time-domain reflectance, taper (t), S.R, and other parameters was examined. Soveja et al. [11] investigated the surface laser texturing of TA6V alloy in further detail. Taguchi and RSM were the experimental approaches used in this study. It was decided to develop an empirical model to evaluate the link between operational parameters and performance indicators such as the standard deviation and mean relative deviation (SDR). It is critical to evaluate the MRR and SR features in this research since they have an impact on machining performance. It was decided to utilize stainless steel 316 grade for this investigation since it includes 18 percent Cr and 8-10 percent Ni. It is sometimes referred to as 18-8 stainless steel according to the composition of the steel. The material is non-magnetic at room temperature, but following exposure to cold, its structure changes to martensite and the material becomes weekly magnetic. It has a high level of resistance to corrosion caused by the environment. Ton, Toff, discharge current, dielectric pressure, gap voltage, and other essential machining parameters, such as corrosion, are all discussed in detail in this section.

2. Methodology and Work Plan:

It was decided to employ an EDM model of the die sinking type with a servo head for the experiment. The positive polarity of the electrode is attached to it. In order to perform experiments, a round electrode with a diameter of 2.5 mm is employed. Different stages in positive polarity were subjected to different levels of discharge current application. The stainless steel is being utilized for the experiments. The stainless steel 316 grade is often chosen since it is commonly seen in daily life. The mechanical and chemical characteristics of stainless steel are mentioned in the following table.

2.1. *Mechanical Properties:*

Mechanical properties such as density(kg/m3), elastic modulus (GPa), coefficient of thermal expansion (mm/min/°c) , thermal conductivity(w/mk) hardness, specific heat (kJ/kgk) etc. of stainless steel 316 are listed below in Table 1.

Table 1 Mechanical properties of stainless steel 316.

Density (g/cm^3)	**Yield point (MPa)**	**Tensile strength (MPa)**	**Modulus of elasticity (GPa)**	**Strength at break (MPa)**	**Elongation at break (mm)**
7.99	332	673	165	586	35.5

2.2. *Chemical properties: -*

Stainless steel 316 is composed of following elements with their percentage amount listed in the table 2.

Table 2 Chemical composition of the stainless steel 316.

Elements	**Cr**	**Ni**	**Mn**	**Si**	**Mo**	**C**	**N**	**S**	**P**	**Fe**
Wt.%	18	10	2	0.75	1.66	0.08	0.10	0.03	0.045	Balance

2.3. *Pilot Study* :

Ton, Toff, current, and dielectric fluid are the parameters that were employed in the experiment. S.R. and M.R.R. are the output responses that have been computed. A pilot research was carried out to examine the effects of different parameters on material removal rate and surface roughness. During the pilot research, just one parameter was changed at a time. These Experiments were carried out using a computerized system. During the course of the pilot project, one parameter was modified while the other parameters were maintained constant. Iterating this procedure many times results in a set of graphs being displayed using the values acquired. The influence of each parameter on the M.R.R and S.R. is shown in Table 3 as a result of utilizing the values obtained.

Table 3. Pilot Study Input and Output Responses Values

S.NO	Current (A)	Pulse on time (µSec)	Pulse off time (µSec)	Dielectric pressure (kg/cm^3)	Material removal rate (mg/min)	Surface roughness (µm)
1.	7	6	6	1	5.3	2.76
2.	11	6	6	1	111.4	9.14
3.	15	6	6	1	190.3	18.98
4.	19	6	6	1	350.4	19.76
5.	23	6	6	1	515.7	23.45
6.	23	6	6	2	915.8	19.23
7.	23	6	6	3	1050.3	16.12
8.	23	6	6	4	1180.8	15.67
9.	23	6	6	5	1320.33	15.65
10.	23	2	6	5	1610.9	10.67
11.	23	3	6	5	1515.1	11.48
12.	23	4	6	5	1480	11.90
13.	23	5	6	5	1420	15.60
14.	23	5	2	5	508.3	19.10
15.	23	5	3	5	509.6	19.20
16.	23	5	4	5	511.5	18.90
17.	23	5	5	5	510.6	19.01

2.4. Input factors and output responses

A variety of graphs have been created for a variety of factors to examine their impact on the S.R. and M.R.R. This graph analysis demonstrates that when current grows, the M.R.R. increases as well. The higher the amount of current, the greater the material removal rate discovered in the pilot research analysis, according to the graph. This happens because an increase in current causes a rise in the intensity of the spark, which results in an increase in temperature. As a result, the material is removed by the process of melting and vaporization. According to the results of the pilot research, surface roughness (SR) rises with an increase in current, and a lower amount of current suggests a lower level of surface roughness. This happens as a result of an increase in spark intensity, which results in a huge discharge energy and an increase in surface roughness. Material removal rate happens in EDM as a result of the melting and vaporization of the material in successive phases, which results in the formation of crater volume. The relationship between pulse on time and MRR has been established as a result of the pilot research testing. With a rise in Ton, the M.R.R. lowers as a result of a reduction in the intensity of the spark, which results in the expansion of the plasma channel. If the pulse on time is longer, more current will flow, resulting in an increase in SR and a degradation in the quality of the surface. Therefore, the optimal value of the pulse on time is required while doing tests; otherwise, the experiments would fail.

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 09 Issue: 04 | Apr 2022 www.irjet.net p-ISSN: 2395-0072

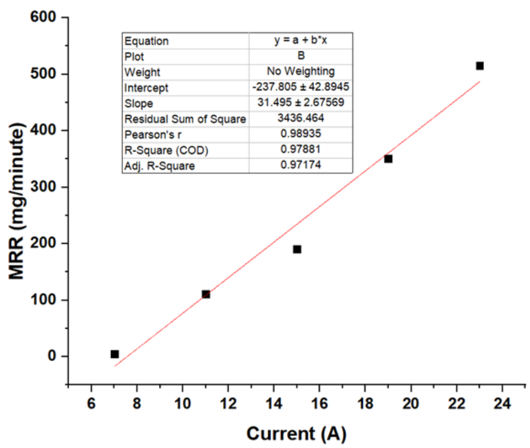

Fig. 1. Graph b/w MRR and Current.

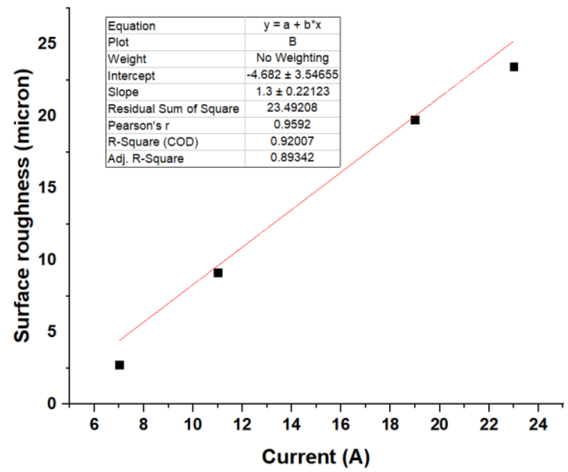

Fig. 2 Graph b/w SR and Current

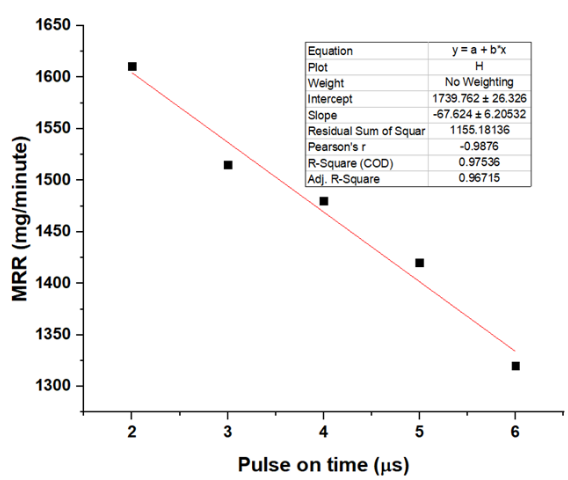

Fig. 3 Graph b/w MRR and Pulse on time.

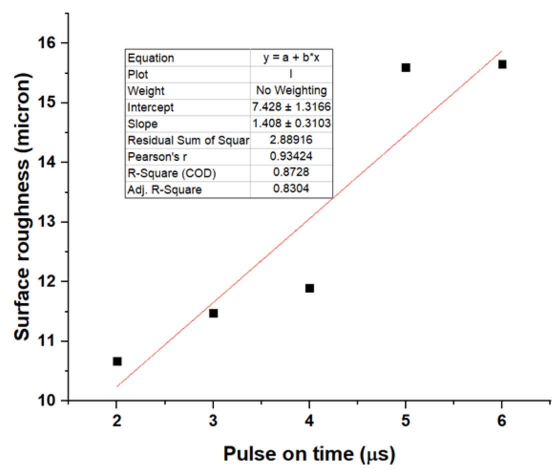

Fig. 4. Graph b/w SR and Pulse on time.

3. Results and Discussion

Electric discharge machining parameters include discharge current, Ton, Toff, Dielectric pressure. Current has considerable influence in MRR, MRR increase with increase in current. Because higher current causes greater spark, high temperature may be obtained owing to which melting, and vaporization of material takes place. Other variables have less effect as comparison to other factors although the MRR drop with rise in Ton.

3.1. Effect of MRR

Since spark energy increases as a consequence of the increase in the value of Ton, the rate of material removal increases when the value of Ton is low. Material removal rate decreases as the value of Ton, M.R.R. is raised because the inter electrode gap and energy transfer hiders are impeded, resulting in a fall in material removal rate. Ton, M.R.R. is a constant value.

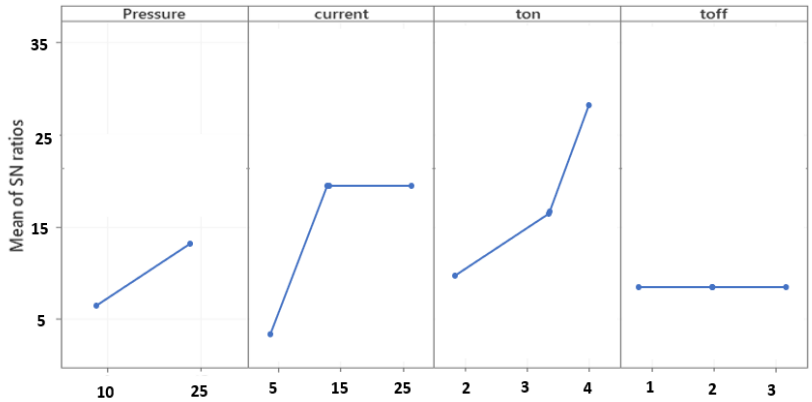

Fig.5 Main effect plot for mean.

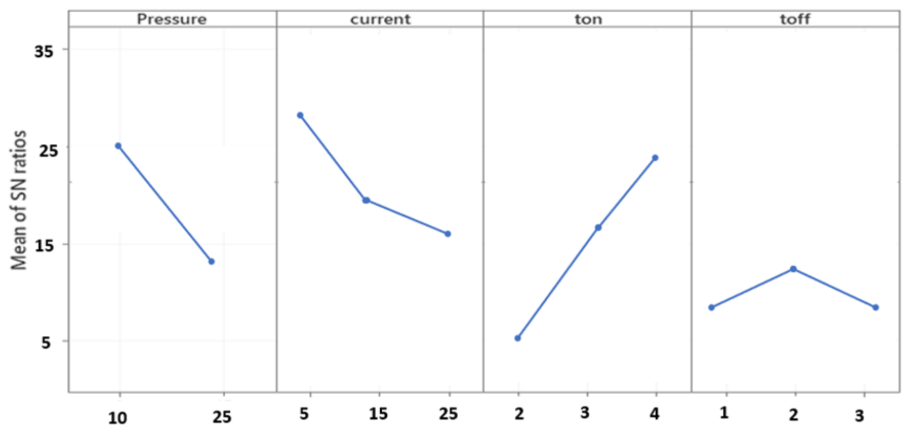

Fig.6 Main effect plot for S/N Ratio: -

Figure 6 shows that the ton and discharge current are the significant parameters that have the greatest influence on the material removal rate (MRR). As the current increases, the material removal rate increases due to the increasing spark intensity, and the material is removed by melting and vaporization, as shown in the previous paragraph. The material removal rate reduces as the pulse on time is increased because it extends the width of the plasma channel, which results in a drop in the material removal rate as the pulse on time increases. It is possible that the dielectric pressure has some impact on the material removal because as the dielectric pressure increases, the debris that is removed stops the material from solidifying. The amount of time between pulses has no major impact on the outcome. Analysis of Variance (ANOVA) for surface roughness shows that the lesser the value, the better. From the table above, it can be seen that Toff has the least impact on the S.R. current and Ton has the most significant influence.

CONCLUSION

The M.R.R. and S.R. of stainless steels are investigated in this study, which makes use of a flat base copper tool. The discharge current, Ton, Toff, and dielectric pressure are the machining parameters that will be used for the tests.. The L18 orthogonal array was applied with the help of the Minitab program. By using ANOVA, the researchers were able to confirm their findings. The MRR is significantly influenced by the discharge current and the Ton. Toff is the person who has the least amount of influence. Because of the increase in discharge current, the strength of the spark rises, which causes the temperature to rise, resulting in the removal of material, which takes the shape of cavities, via the process of melting and vaporization.

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