

Investigation of parameters of Wire-EDM of EN-31 for Material Removal Rate and Surface Roughness

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ABSTRACT: Due to the advancement of mechanical industry, the demands for alloy materials with high hardness, impact resistance and toughness are increasing. The Wire-EDM machine is specialized in cutting complex contours that are difficult cut using traditional cutting methods. Wire-EDM is a non-contact non-conventional process that produces high quality product that is difficult to achieve by using of conventional processes. The present study on Wire-EDM performed on EN-31 using brass wire as electrode is conducted to establish the influence of process parameters on material removal rate and surface roughness. The experimental results concluded that both material removal rate and surface roughness are mainly influenced by the peak current. Pulse on time was least influencing parameter for surface roughness. Voltage was the second most influencing parameter for surface roughness. It was also observed that larger craters were obtained at higher current.

KEYWORDS: Wire-EDM, MRR, Surface Roughness, EN-31

1. INTRODUCTION

Wire-EDM is a non-traditional machining process that uses a very thin wire which serves as the electrode. Special brass wires are majorly used, the wire is slowly fed through the material and the electrical discharges through the wire cuts the work piece. The material removal take place by the action of intense energy of electrical sparks. The intense heat generated near the zone causes melting and evaporating of the materials in the sparking zone. Major works performed on Wire-EDM are to improve the productivity and surface quality of the product produced by machine. Studies have been conducted to enhance the material removal efficiency and surface finish.

Syed Asghar Husain Rizvi et al [1] conducted an investigation to optimize the surface roughness of EN-40. Current was found to be the major influencing factor for surface roughness while pulse on duration was least affecting factor. Spedding and Wang [2] conducted a study to optimize the process parameters by modeling the process using artificial neural networks. The periodic component of the surface texture is identified and an autoregressive model is used to describe its stochastic component. Klocke et al [3] tested different electrical parameters in a series of experiments. Cutting speed was found to be lower for material containing more number of electrically non-conductive particles.

Manoj Malik et al [4] conducted experiments on W-C Ceramic with graphite electrode. They concluded that current was the most significant factor for MRR and EWR while pulse duty factor was the least affecting factor. They also concluded that Ton was the most significant factor for surface roughness of the material while duty factor affect is least. Another investigation conducted by K. Kumar et al [5] concluded that factors like speed, feed, Time on and Time off were found to play an important role for MRR and surface roughness. In a study conducted by Scott et al [6] developing a mathematical model to predict MRR and surface finish while machining D-2 tool steel, it was concluded that there is no single combination of levels of different factors which can be optimal under all circumstances. Ramakrishnan et al [7] in their study described the multi objective optimization of the WEDM. It was identified that pulse on time and current intensity had influenced more than the other parameters. In an experimental study Dhruv H. Gajjar et al [8] carried experiments on EN-31 tool Steel using Molybdenum wire concluded that with increase of Pulse on time spark

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energy is generated is more as the duration of time that electricity supply increases. MRR, KERF width and SR all response increases with pulse on time. Pulse on time was found most significant parameter in all response. Surface roughness also increases with increase of pulse on time because the increases of pulse on time produce crater with broader and deeper characteristic. Parveen Kr. Saini et al [10] carried out their experiments on Titanium alloy and found that short pulse time plays a vital role for MRR with brass wire electrode. When there is increase in short pulse time and pulse width, higher MRR is achieved. This is because the discharge energy increases with increase in short pulse time and PW. R.Nagaraja et al [9] concluded that the wire feed was the most dominating machining parameter for (SR) while machining bronze-alumina (Al_2O_3) MMC. Muhammad Qaiser Saleem et al [11] comparative study on Al-7075 and D-2 to find influence of parameters on MRR concluded that the tensile strength of the wire influence the surface quality, higher tensile strength results into a higher surface finish. They also concluded that the high value of hardness of work piece results in better surface finish. Tensile strength of the wire has no effect on MRR. Rajaneesh N. Marigoudara et al [12] in their study of MRR and Surface Roughness in Machining of ZA43/ SiCp composite concluded that MRR increases with current and pulse on time and it decreases with pulse off time. It was also observed that the MRR decreases with increase in reinforcement content in MMC. The Surface roughness of machined surface is influenced by current and it increases with increase in current. They also found that SiC in MMC influences the surface roughness.

II. EXPERIMENTAL DETAILS

The work material chosen for the present study is EN-31 while the electrode is brass wire of 0.20 mm diameter. The material is machined on CNC Pulse Generator ELPULS-15.

The Taguchi approach is used, which is very effective in dealing with responses influenced by multi-variables. It is a powerful design of experiments tool that provides a simple, effective, efficient and systematic approach for determining the optimal set of machining parameters.

The current study considers peak current, pulse off time and pulse on time as Wire-EDM parameters whose influence is observed on material removal rate and surface roughness of the material.

Table 1: The levels of Wire-EDM parameters

Parameters	Unit	Levels
Peak Current (I_p)	A	1 3 5
Pulse on Time (T_{on})	μ sec	10 20 30
Pulse off Time	μ sec	5 10 15

ANOVA is performed to identify statistically significant process parameters. Based on the results of ANOVA, optimal combinations of the process parameters are predicted.

III. RESULTS AND DISCUSSIONS

3.1 Material Removal Rate

Material Removal rate is the measure of rate of removal of work piece during machining in mm^3/min . The rate of volume of material removed is studied and investigation is as follows.

Table 2: Calculation of mean S/N ratio for MRR

Level	I_p	T_{off}	T_{on}
1	10.44	11.06	13.83
2	13.08	13.30	13.84
3	17.76	16.92	13.61
Delta	7.32	5.86	0.23
Rank	1	2	3

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Based on analysis of variance, analysis of MRR is given in Table 3. It elucidates that peak current is the most dominating parameter for MRR with 56.12% contribution while pulse off time is second most significant factor with 25.58% contribution. Pulse on time has the least affect on MRR.

Table 3. ANOVA for MRR

Source	DOF	SS	Adj MS	F Value	Contribution
Ip	2	35.780	17.890	11.69	56.12%
Toff	2	22.685	11.343	7.41	25.58%
Ton	2	2.233	1.116	0.73	3.50%
Error	2	3.061	1.530		14.8%
Total	8	63.759			100%

The following main effect plot in Figure 2 shows that the MRR increases with both peak current and pulse off time. Highest MRR is achieved at 5A current, 15 μ sec Toff and 20 μ sec Ton. The plot clears that peak current is more significant than pulse off time and pulse on time. MRR increases with current and the Toff follows the same trend. This is due to the higher intensity sparks at higher current and pulse off time that strikes on the surface of work piece.

Initially with the increase of pulse on time the MRR increases. But at higher values of voltage, it is observed that due to unfavorable break down of dielectric and large amount of debris between the working gap, the material removal rate increases tends to decrease.

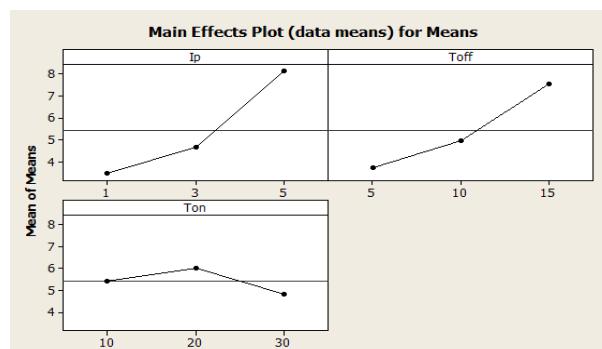


Figure 2. Main Effect Plot For Means For MRR

Figure 3 depicts the relation between MRR and pulse off time at different levels of peak current. It is clear that the material removal rate increases with Wire-EDM parameters and optimum MRR results are obtained at 5 A peak current. At lower values of current, small crater is produced and thus lower material removal rate is obtained.

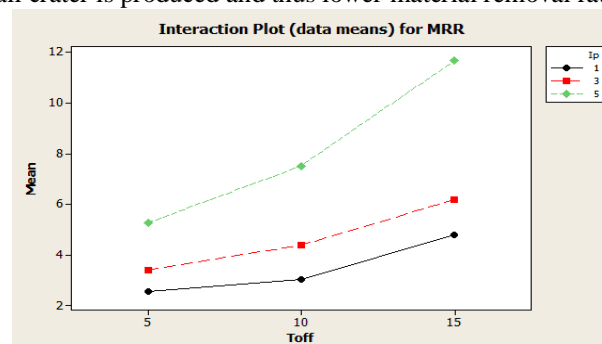


Figure 3. Relation between MRR and WEDM parameters

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3.2 Surface Roughness

In case of surface roughness, it increases with increasing the levels of all the three parameters. The investigation carried out for surface roughness is as follows.

Table 4. Calculation of mean S/N ratio for Surface Roughness

Level	Ip	Toff	Ton
1	-16.96	-18.15	-17.89
2	-17.92	-18.50	-18.24
3	-20.52	-18.75	-19.27
Delta	3.56	0.61	1.38
Rank	1	3	2

Table 5 depicts that current is the most influential factor and has major effect on surface roughness with 85.56% contribution while pulse on time is the second most dominating parameter with a contribution of 11.85%. Pulse off Time has least effect on surface roughness with only 1.23% contribution.

Table 5. ANOVA for Surface Roughness

Source	DOF	SS	Adj MS	F Value	Contribution
Ip	2	20.9287	10.4643	64.46	85.56%
Toff	2	0.3002	0.1501	0.92	1.23%
Ton	2	2.8963	1.4481	8.92	11.85%
Error	2	0.3247	0.1623		1.36%
Total	8	24.4498			100%

Figure 4 presents the main effect plot for means for the surface roughness. It is clear that the surface roughness is directly influenced by WEDM parameters and increases with them, but peak current and pulse on time are the major influencing parameters. The curve obtained for pulse off time is almost flat and it is the least affecting parameter.

Better surface finish is obtained at lower levels of WEDM parameters.

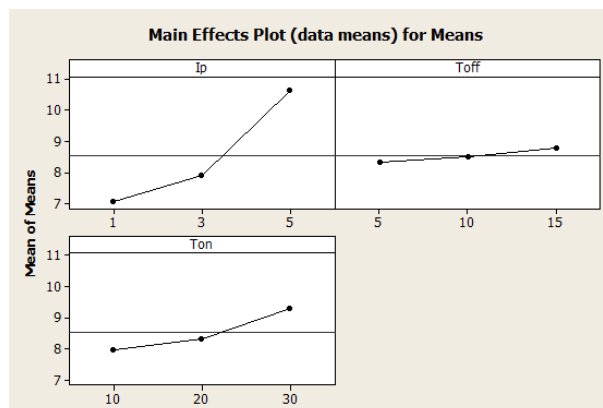


Figure 4: Main Effect Plot For Means For Surface Roughness

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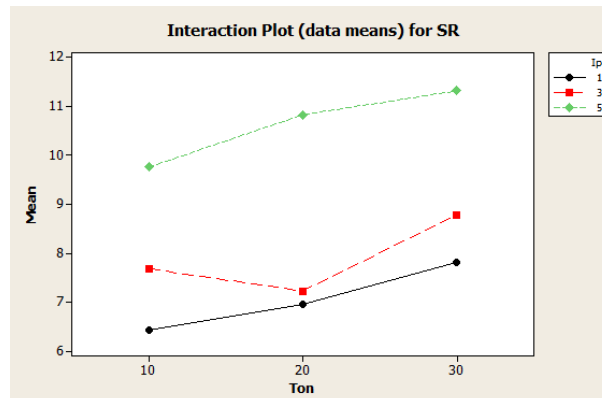


Figure 5: Relation between Surface Roughness and WEDM parameters

Figure 5 presents the interaction plot between surface roughness and Wire-EDM parameters. It is observed that surface roughness increases with pulse on time with constant peak current. At 3A current, the surface degradation initially decreases with pulse on time but with further increase in its value, increases the surface roughness. This is due to the fact that the debris of molten metal is not initially removed from the gap between tool and work, thus the intensity of sparks striking the surface is reduced and hence the surface roughness also gets reduced.

IV. CONCLUSIONS

In the present investigation performed on EN-31 using Brass wire to determine the relationship between the parameters of Wire-EDM with MRR and surface roughness, the following conclusions were made:

1. The MRR is mainly influenced by peak current (I_p) and Pulse off time (T_{OFF}). However pulse on time (T_{ON}) has least effect on MRR.
2. Moreover, it is observed that MRR is majorly influenced by the intensity of spark which is achieved at higher levels of the parameters.
3. The SR is mainly influenced by peak current (I_p). There is a small influence of Pulse on time (T_{ON}) on surface roughness. On the other hand, pulse on time (T_{OFF}) has almost negligible influence on surface roughness.

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