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Effect of Wire Diameter, Feeding Rate, Pulse (on/off) Time on Surface Roughness and Metal Removal Rate for Cr-Mo Steel (SCM425H) During Wire Electrical Discharge Machine (WEDM) Cutting Operation

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KEYWORDS

Wire Electrical Discharge Machining (EDM), wire diameter, feeding rate, pulse on/off time, surface roughness, metal removal rate, chromium molybdenum steel.

ABSTRACT

Increase the demand to produce complex shapes with high quality and dimensional accuracy such as production aerospace, cars, die sinking has been leading to increase the demand to use the non- traditional cutting operations such as wire electro-discharge machine (WEDM) rather than using the traditional operations. An idea to understand the effect of wire diameter, wire feed, pulsing (on/off) time on surface roughness, and metal removal rate of Cr-Mo steel during wire electrical discharge machining was investigated. Two Steel alloy samples with dimensions of (60 x50 x 20)mm were cut into four rectangular spaces with (5x10x20)mm at one side of each sample using wire cut (EDM) machine with a wire diameter of 0.25 mm and feeding rate 2 m/min for sample 1 and a 0.3 mm diameter and 3 m/min feeding rate for sample 2. Pulse (on, off) time was (110, 50), (112, 52), (115, 55), (116, 57) corresponds to space 1, space 2, space 3, and space 4 in both steel block. Surface roughness and metal removal rate measurements were estimated. The results showed that wire diameter, feeding rate, and pulse (on, off) time is proportional with metal removal rate, while reversed with surface roughness. The wire diameter of 0.3 mm and a feeding rate of 3m/min enhanced better surface quality and productivity. Pulse (on, off) time is the most effective parameter. Best duration time was recorded at the values (116, 57).

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1. Introduction

The industrial market that produces complex shapes of parts necessary for assembling different engineering products such as aerospace, cars, die sinking and others have been increasingly demanding production with high quality and dimensional accuracy. So, the need to use the wire electro-discharge machining (EDM) system which is defined as a computerized numerical control (CNC) system is of importance to be applied instead of using the traditional cutting operations. Many types of research in this field have been achieved in order to obtain better cutting parameters that suit with the cutting operations and the workpieces.

In 2004 Lia et al. investigated the affline surface finish in the wire-cut EDM process, in order to avoid processing secondary finishing for the workpiece while undercutting process. This was achieved by minimizing the diameter of the wire electrode in the way to be no contact between the wire electrode and the workpiece. This idea led to prevent generation residual stress [1].

Also, in 2014, Shather with the co-authors, investigated the influence of intervening variables on surface roughness and metal removal rate of medium carbon steel 133 during wire electro-discharge machining (EDM) cutting process using wire diameter of 0.25mm made from brass, the variables applied were pulse (on/off) time, servo feed rate. The investigation showed that the more influential machining variables on roughness and metal removal rates were pulse on time and servo feeding rate respectively [2].

Many attempts of optimization studies made of different alloys were also achieved in order to investigate the effect of cutting parameters of wire electro-discharge machining process. some of them used the Taguchi method for mild steel and aluminum alloys [3], others used molybdenum wire for optimization metal removal rate [4].

Later on, another study presented a problem about emitting charges on all directions during proceeding the wire, electro-discharge machine (WEDM) operation, till reaching out the cutting path and leading to a maximized charge size more than the wire diameter used in the operation causing a reduction in cutting quality and the accuracy level of dimensions. The conclusion was that the best way to avoid scattering charges more than the limited diameter was about to be by fixing the ring of the current to the wire diameter. It was found that this suggestion would be of help for correct dimensions [4, 3]

Further study conclusion obtained by Dhruv and co-authors in 2015 who found that it is possible to use the wire electro-discharge machining operations for cutting thin metals, their thicknesses range from about (0.1-0.3)mm beside cutting thick metals [4]. Another investigation included an optimization study for selection better cutting parameters using the Taguchi Technique (statistical method was used to improve the quality of outputs) to evaluate the rate of material removal for wire-cut EDM of EN-31 alloy steel. The experimental parameters were pulsed on/off time, voltage, and wire feeding, a 0.25 mm wire diameter as a tool, and distilled water as a dielectric fluid. Analyzing data was performed using ANOVA (analysis of variance). The experimental results showed that the rate of metal removal is proportional with a pulse on time and feeding rate, while it is reversed with the pulse of time, as well as it has a nominal behavior with increasing spark voltage. However, the comparison between the experimental and analytical findings confirms that there is a need to conduct further experiments with a wider range of cutting parameters in order to confirm an agreement or not [5].

In an experimental investigation to predict metal removal rate and surface roughness in the wire cut process, Shather and his co-authors designed a mathematical model (Regression model) based on using the experimental variables which were pulse on time, pulse off time, voltage, and wire type. The analytical result was compared with the experimental and found to be consistent at about 99% for both the metal removal rate and surface roughness. Both analytical and experimental results concluded that the smaller value of pulse on time, the larger value of pulse off time, the better surface finish, on the other hand, the lower surface finish, and the higher metal removal could be obtained by using coated wire [6].

In 2018, an investigation about the surface roughness for Inconel 625 using the wire electro-discharge machining WEDM to produce electro-thermal operation was done. This work used wire as a cathodic electrode and the workpiece as an anodic electrode resulting in dielectric fluid filling the space between the cathode and anode electrodes. The results showed distributing the charges in an oriented manner [7].

In 2019 Kashif et al presented multi-objective optimization methodology by using grey relational analysis based on Taguchi method to optimized the effect of wire-cut EDM factors such as (voltage, drum speed, current, nozzle offset distance) of SS (304) on the quality characteristics such as (surface roughness, cutting speed and kerf width). the results of ANOVA (analysis of variance) showed that the current was the most important factor for kerf width and cutting speed, while the voltage was the most important factor in surface roughness [8].

However, the flexibility in use the wire electro-discharge machines (WEDM) for cutting operations by the workers without the need for high skills, besides the ability to design and produce products with high quality have been encouraging the researchers in that field to keep doing more investigation on these machines to understand well their performance through changing the variables of the cutting operations . Therefore, it is important to understand the effect of cutting parameters on surface roughness and the rate of metal removal for alloy steel during wire electrical discharge machining (EDM).
This work presents the cutting process for Cr-Mo steel alloy using the wire electro-discharge machine (WEDM) system by applying different wire diameters, feeding rates, and pulse (on/off) time. Surface roughness and metal removal rate were measured, as well as, the relevant data were analyzed and presented through this study.

2.Experimental Procedures

I. Material

In this research, a Cr-Mo Steel alloy was used for the experimental part, its chemical composition was presented in Table 1.

II. Wire Electro-Discharge Machine (WEDM)

1. Setup (WEDM) Machine System
A computerized Numerical Control (CNC) Wire Cut Electro-Discharge Machining (EDM) system shown in Figure 1 was used to cut workpieces of steel using electrodes made from brass alloy at specified cutting parameters.
The purpose was to investigate the effect of cutting parameters on the performance of the process by analyzing the outputs. Cutting parameters were selected to be wire diameters, wire feeding rate, and pulsing (on, off) time and presented in Table 2.

Table 1: Chemical composition for steel alloy used in the research

Element %	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Cu	Fe
Concentration (wt%)	0.242	0.24	0.735	0.033	0.049	0.888	0.24	0.286	0.0045	0.093	Bal

Figure 1: The wire electro-discharge machine (EDM) used in the experiment

Table 2: Cutting parameters applied in the research

Sample No.	W_D (mm)	W_f (m/min)	Pulse on (*μs)*	Pulse off *(μs)*
1	0.25	2	110, 112, 115,	50, 52, 55,
2	0.3	3	116	57

2. Cutting Procedure
Two samples of steel alloy with dimensions of (60 x50 x 20)mm were prepared as a block. Then, the block samples of steel were cut again into four rectangular spaces on one side of each sample with dimensions of (5x10x20)mm. Both samples were subjected to the cutting process by different wire diameters and feeding rates. The first sample was cut with a wire diameter of a 0.25 mm and wire feeding rate 2 m/min, while the second with a 0.3mm diameter and a 3 m/min feeding rate. However, the process was conducted at the same range of pulsing (on/off) time for both samples.
Pulse (on, off) time was (110, 50), (112, 52), (115, 55), (116, 57) corresponds to space 1, space 2, space 3, and space 4 in both steel block. The sketch below shows the cutting conditions (Figure 2).

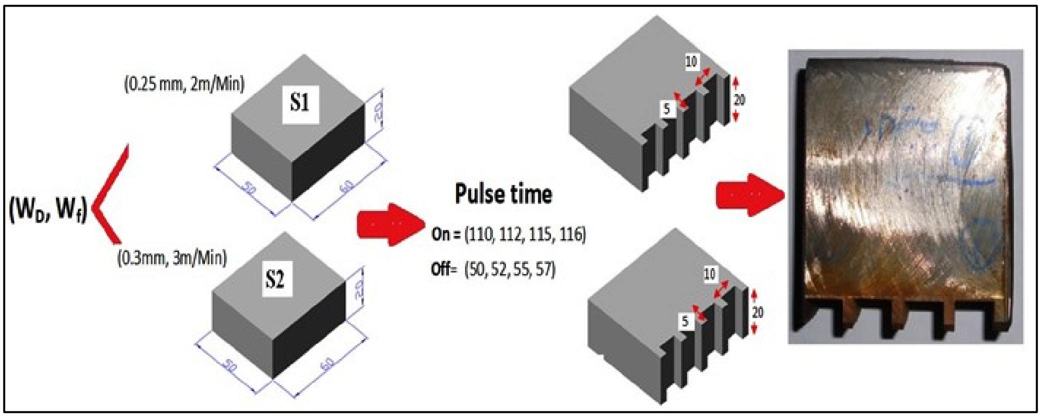


Figure 2: Cutting procedure using (WEDM) system for steel alloy samples and all dimensions in (mm) units

III. Measurements

1. Surface Roughness (Ra)

Surface roughness of the cut surfaces of both steel samples was measured using Pocket Surf the Portable Roughness of the surface gage Maher federal's patented.

For each sample, four values were measured corresponded to the values of Pulse (on, off) time, that were (110, 50), (112, 52), (115, 55), (116, 57) correspond to space 1, space 2, space3, and space4 in sample 1, and sample 2.

Every value was an average value of three taken readings recorded from the (Ra) instrument. Figure 3 shows the instrument used in the experiments, and the results were presented in Figure 4.

Figure 3: Measure of surface roughness

2. Metal Removal Rate (MRR)

Weight measurement before and after cutting process for the two steel samples were achieved using *Balance*, the purpose was to identify the amount of material removed. For each sample, four values of weight and time were measured related to each space in the sample, corresponded to the values (110, 50), (112, 52), (115, 55), (116, 57) of pulse (on, off) time. The measured values before and after cutting were applied in the equation (1) to calculate the material removal rate [2-5]. The measured values presented in Table 3 and the (MRR) determination were presented in Figure 5.

Table 3: Weight measurements for a) Sample 1; b) Sample 2

(a)

Pulse On time	Pulse Off time	Weight (gm)	Time (min)
110	50	463	37.37.56
112	52	453	36.16.54
115	55	441	34.11.39
116	57	430	31.21.46

(b)

Pulse On time	Pulse Off time	Weight (gm)	Time (min)
110	50	402	35.14.85
112	52	391	32.37.44
115	55	380	30.41.96
116	57	370	27.42.31

$$MRR = W_b - W_a / T \quad (1)$$

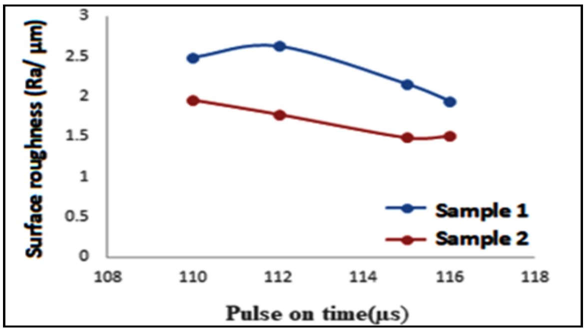
Where:

MRR: Metal removal rate (gm/min)
W_b: Weight before cutting (gm)
W_a: Weight after cutting (gm)
T: Time (min).

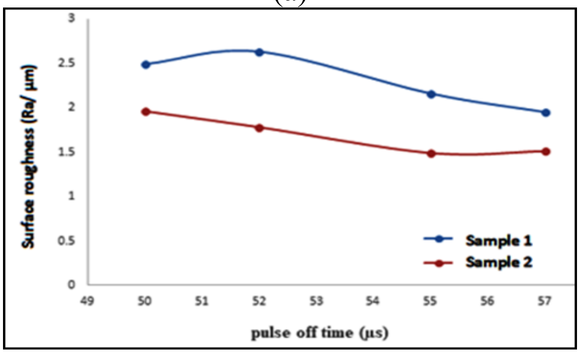
3. Results and Discussions

I. Surface Roughness (Ra)

According to Figure 4, the general trend is decreased. Surface roughness decreased with an increasing wire diameters and increasing pulsing (on, off) time.
This indicated that the selected combination of increasing pulsing (on, off) time with increasing wire diameter from 0.25 mm in sample 1 to 0.3 mm in sample 2 recorded an improvement in surface quality for steel samples. This is because increasing wire diameter led to increase the contact area between the wire cut for the EDM machining and the surface area for the workpiece. The reduction percent recorded about 78% and 77% for samples 1 and 2 respectively equivalent to duration pulse time of (116, 57).
In conclusion, the higher pulse (on, off) time, the lower surface roughness with a wire diameter of 0.3 mm is the best combination to be selected for better surface quality.



(a)

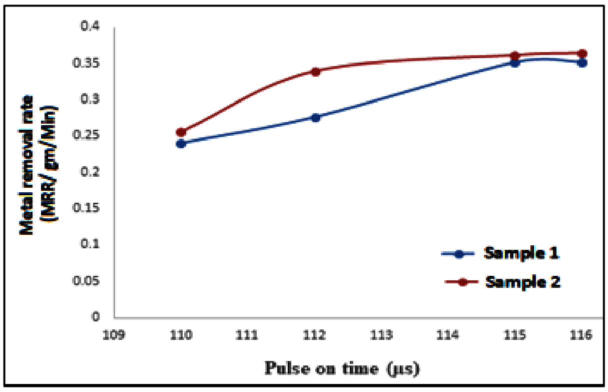


(b)

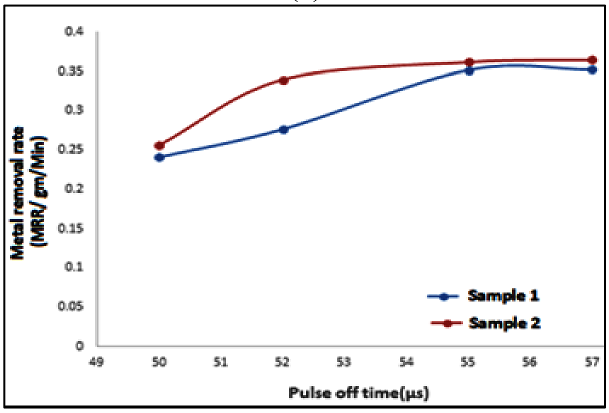
Figure 4: Pulse time as a function of surface roughness (Ra); (a) On, (b) Off

II. Metal Removal Rate (MRR)

According to Figure 5, the general trend is proportional. The rate of metal removal (MRR) increases with increase wire diameters and pulsing (on, off) time for both samples.
The increase percent was from about 68% for sample 1 to 70% for sample2 equivalent to duration pulse time of (116, 57). However, the maximum rate of metal removal was recorded with sample 2.
The wire diameter of 0.3 mm and feeding rate of 3 m/min, satisfied an improvement in surface quality as it recorded the maximum rate of metal removal than its counterparts of 0.25 mm wire diameter and feeding rate of 2 m/min. This is, in turn, leads to better productivity.
it is concluded that the higher pulse (on, off) time with a 0.3 mm diameter, and feeding rate of 3m/min the better productivity.



(a)



(b)

Figure 5: Pulse time as a function of Metal removal rate (MRR); (a) On, (b) Off

4. Conclusions

with increase pulse (on/off) time, the following findings were obtained:

1. Increase wire diameter allowed increase the contact area between the EDM wire cut area and the workpiece area for steel.
2. Increase wire diameter decreased surface roughness.
3. Surface roughness decreased from 78% to 77% for wire diameters range from (0.25-0.3) mm equivalent to duration pulse time of (116, 57).
4. A maximum reduction in surface roughness was recorded by the condition of a wire diameter of 0.3 mm.
5. Increasing both feeding rates with wire diameter increased the rate of metal removal from 68% for wire diameter of 0.25 mm and feeding rate 2 m/min, to 70% for wire diameter of 0.3 mm and feeding rate of 3 m/min.
6. The maximum metal removal rate was enhanced by the condition of wire diameter of 0.3 mm and feeding rate of 3 m/min equivalent to duration pulse time of (116, 57).
7. The condition of a (0.3 mm) wire diameter with a (3 m/min) feeding rate recorded best surface quality and better productivity.
8. Pulse (on, off) time is the most effective cutting parameter on the behavior of surface roughness and the rate of metal removed for steel alloys.
9. The best duration time of pulse (on, off) was recorded at the values (116, 57).

References

[1] Y.S. Lia, J.T. Huang and Y.H. Chen, "A study to achieve affine surface finish in wire EDM," Journal of Materials Processing Technology, Vol. 149, pp. 165-171, 2004.

[2] S. K. Shather, D. A. Noori. "Influence of Intervening variables on surface roughness and metal removal rate during WEDM process," Eng. &Tech. Journal, Vol. 32, Part A, No. 5, pp. 1141-1148, 2014 .

[3] Shivkanthtilekar, S. Das, P. K. Patowari, "Process parameter optimization of wire EDM on aluminum and mild steel by using taguchi method," International conference on AMME, 2014.

[4] D. H. Gajjar et al. “Optimization of MRR, SR, kerf width in WEDM using molybdenum wire,” IJER,Vol. 4, | Issue 2, 2015.

[5] S. Kumar and P. Kumar, “Investigation of material removal rate for wire-cut EDM of EN-31 alloy steel using taguchi technique,” International Journal of Scientific & Engineering Research, Vol. 7, Issue 12, pp. 155-161, 2016.

[6] S. K. Shather, A. F. Ibrahim, D. A. Noori, “Experimental investigation to predict metal removal rate and surface roughness in wire cut process,” Diyala Journal of Engineering Science, Vol. 09, No. 03, pp. 49-58, 2016.

[7] A. Goyal, A. Pandey, P. Sharma, “Investigation of surface roughness for inconel 625 using wire electric discharge machining,” IOP Conf. Series: Materials Science and Engineering, 377, pp. 1-7, 2018.

[8] K. Ishfaq, N. Ahmad, M. Jawad, M. A. Ali and A. M. Al-Ahmari, “Evaluating material’s interaction in wire electrical discharge machining of stainless steel (304) for simultaneous optimization of conflicting responses,” Materials, Vol. 12, 2019.