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Investigate WEDM Process Parameters on Wire Wear Ratio, Material Removal Rate and Surface Roughness of Steel 1012 AISI

Abstract- *This work is focused on some affecting parameters in Wire electrical discharge machining process for AISI 1012 steel by using brass wire and zinc coated brass wire with 0.25mm diameter. Pulse on time, pulse off time, spark gap voltage and servo feed had been studied as input parameters while wire wear ratio, metal removal rate and surface roughness were the outputs. The experiments showed that increasing pulse on time would increase wire wear ratio, metal removal rate and surface roughness. While, increasing pulse off time, spark gap voltage and servo feed will cause a little increase in wire wear ratio, decrease metal removal rate and improve surface roughness. Artificial Neural Network had been used to predict the process outputs for 16 samples, which gave good results and agreement with experimental results. Analysis of Variance had been used to find the contribution of the process parameters on outputs.*

Keyword- *Wire electro discharge machining (WEDM), wire wear ratio, metal removal rate*

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1. Introduction

Electrical discharge wire cutting (EDWC), commonly called wire EDM, is a special form of electric discharge machining that uses a small diameter wire as the electrode to cut a narrow kerf in the work. n wire EDM, the conductive materials used are machined with a string of electronic discharges (sparks) which are generated between an effectively located going wire and the work piece. Higher frequency pulses of alternating or guide} current is discharged from the wire to the work piece with minimal spark gap throughout an insulated dielectric fluid (water).WEDM is an essential operation in several manufacturing processes in some industries, which grants importance to variety, precision and precision. Several researchers come with attempted to improve the performance features namely the material removal rate, wire wear ratio, surface roughness [1,2]. Tosun and Cogun [3], with this research, the impact of cutting factors on WE wear was researched in "wire electrical discharge machining" (WEDM). The tests were carried out under alternatives of pulse time period, open circuit voltage, wire speed and dielectric fluid pressure. Brass wire of 0.25 mm diameter and AISI 4140 steel were employed since tools and work piece material. It noticed that the improving in pulse period and open circuit voltage increase the "wire wear ratio" (WWR) while the improving wire speed reduces it. Shather and Diana [4], in their work they were focused on machining Din17100 steel using brass wire and zinc coated brass wire with 0.25 mm diameter. Pulse on time, pulse off time, arc on time, wire tension and servo feed rate were the input parameters and material removal rate and surface roughness as output parameters in this process. They used (SPSS) to predict results of this process. They found, that when Ton increased MRR and Ra increased while when Toff increased MRR and Ra decreased. Chalisgaonkar and Kumar [5], investigated the wire wear phenomena during finish cutting operation of WEDM for commercially pure titanium. Wire used in this study was zinc coated and uncoated brass wire. Pulse on time (Ton), pulse off time (Toff), peak current (Ip), wire feed (Wf), servo voltage (Sv) and wire offset (Woff) were selected as input parameters for this study. The experimental results were analyzed by conducting ANOVA test for finding out significance of the input parameters on wire weight consumption. In this work used influenced parameters, which play an important role in machining.

2- Experimental Work

The experimental work has been performed on 3-axis (ELEKTRA Wire cut Electrical Discharge Machine) type (ELPULSE 15) which is available in Training and Workshop Center, University of

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Technology. The machine has the following specifications (Table 1). The metal machined is Low carbon steel 1012 AISI and the chemical composition given in Table 2. The dimensions of workpiece are 3x200x100 mm, and the cutting part are 3x10x10 mm as shown in Figure 1.

The cutting parameters in Table 3 were used for two types of electrode in WEDM process and the other parameters were constant in the machining.

The method used for calculation of wire wear ratio in WEDM is weight method, which is: Wire wear = weight of wire before machining – weight of wire after machining (1)

Wire wear ratio %(WWR)=((weight of wire before machining–weight of wire after machining)/ weight of wire before machining) *100% (2)

The weight of wire before machining is not available in machine but can be obtained from weight of one meter of wire before machining with long of wire after machining (The long of wire before machining = The long of wire after machining).Two types of wire cut were used namely; soft brass wire and coated brass wire with 0.25 mm diameter. Soft brass wire consists of (Cu 65 – Zn 35 %) and coated brass wire consist of ((Cu 60 – Zn 40 %) +coated layer of Zn). Pure (distilled) water was used to flush WEDM (160 L). The conductivity of water used is (25 – 50) (ohm/cm).

Table 1: Machine specifications

Specification	Dimensions
Maximum work pieces dimensions.	630 × 440 × 200 mm.
Maximum work piece weight.	500 kg.
Wire diameter range.	0.1 - 0.33 mm.
Wire tension(WT)	2-10 kg
Tolerance.	± 0.001 mm.
Work fluid.	Distilled water.
Software.	CAD /CAM.

Table 2: Chemical composition

Sample	C%	Si%	Mn%	P%	S%	Cr%	Mo%	Ni%	Al%	Co%	Cu%	Fe%
Workpiece material	0.127	0.01	0.474	0.007	0.006	0.007	0.002	0.038	0.045	0.004	0.028	Balance

Table 3: Cutting parameters

No.	parameters	symbol	Level 1	Level 2	Level 3	Level 4	unites
1-	Pulse on time	Ton	105	110	115	120	μsec
2-	Pulse off time	Toff	20	25	30	35	μsec
3-	Spark gap voltage	Sv	20	30	40	50	V
4-	Servo feed	Sf	600	700	800	900	Mm/min

Current (Ip) =12 Amper, water pressure (WP) = 1 Pascal, Wire feed (WF) =4 (mm/min) and wire tension (WT) =6Kg.

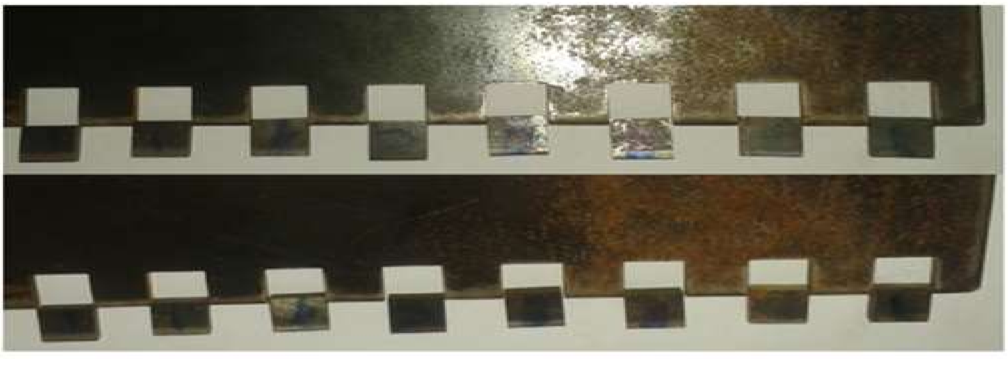


Figure 1: workpiece cutting

Material removal rate can be calculated from the following equations:

b= d wire + 2*S (mm) (4)

$$Vc = L / T \quad (5)$$

$Vc = cutting\ speed\ in\ (mm/min)$

L= length of cut (L=30 mm), (straight cutting).

T= time (min)

b= width of cut in (mm)

d wire= diameter of wire in (mm),(d wire=0.25 mm)

S = spark gap in (mm), (S = 0.175 mm)

h = workpiece thickness in (mm), (h = 3 mm)

b*h= (0.25 + (2*0.175) *3 = 1.8 mm^2

$MRR = Vc * 1.8\ mm^3/min.$

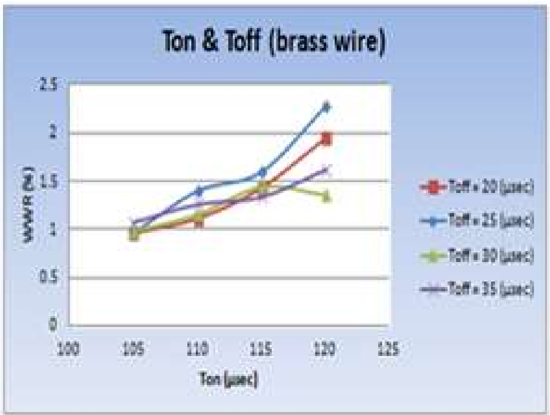
Pocket Surf, the convenient surface unpleasantness gage Mahr Government's was utilized as a part of this work. The outline of examinations has an essential part on the quantity of trials needed. The aggregate number of cutting trials is (16 trials) based on four levels and four parameters (4*4). An incomplete factorial plan was performed to get WWR, MRR and Ra esteems. The parameters were Ton, Toff, SV and SF.Analysis of variance (ANOVA) is an accumulation of statistical models applied in order to test out the differences between group options and their associated operations.

The mathematical model in this study is established utilizing ANN. ANN can be defined depending on these three parameters (WWR & MRR & Ra), where ANN is a multilayered architecture made up of one or more hidden layers placed between the input and output tiers.

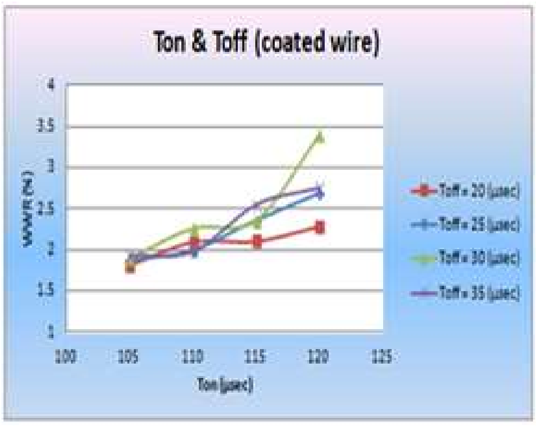
3. Results and Discussion

I. Effect of pulse on time and pulse off time on wire wear ratio (WWR)

The results of the effect of pulse on time (Ton) and pulse off time (Toff) on wire wear ratio (WWR) at different values of spark gap voltage (Sv) and servo feed (Sf) in two types of tools (brass wire and zinc coated brass wire) as in Figure (2). From this figure, the increase in Ton leads to increase WWR and the increase in Toff leads to little increase in WWR. Due to growth of Ton the rate of discharge energy increases that might significantly have an affect on wire wear ratio. At the minimum value of Toff the spark takes long time to generate the dis-charge leads to little increase in WWR. The values of WWR in zinc coated brass wire (coated wire) higher than values of brass wire because the coated wire owns high ability to cut than the brass wire.



a



b

Figure 2: Effect of pulse on time and pulse off time on WWR in (a- brass wire, b- coated wire).

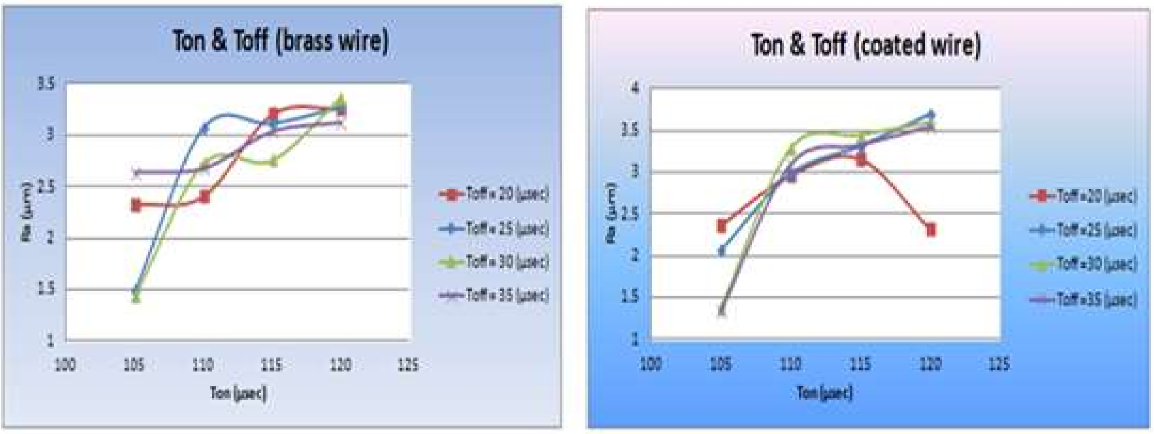


Figure 3: Effect of pulse on time and pulse off time on MRR in (a- brass wire, b- coated wire).

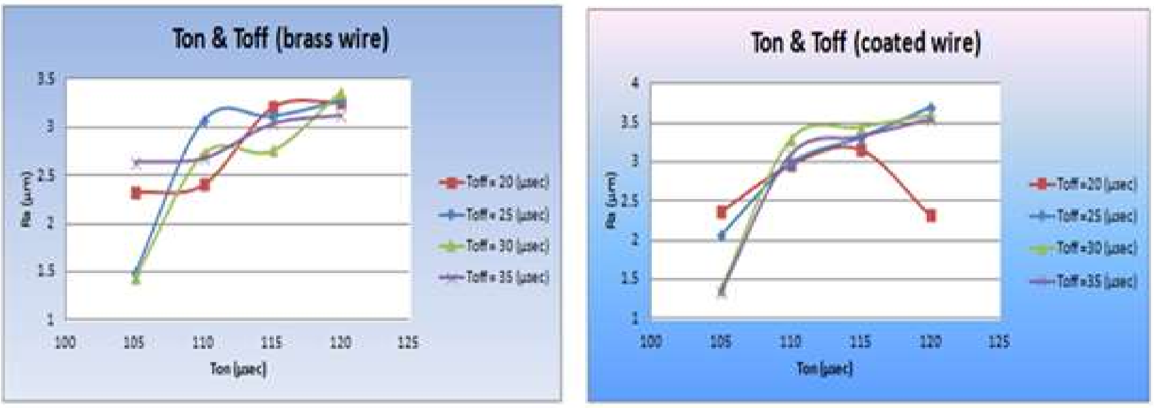


Figure 4: Effect of pulse on time and pulse off time on Ra in (a- brass wire, b- coated wire).

Table 4: Wire wear and wire wear ratio for brsss wire

No	Ton (µm)	Toff m)(µ	Sv (V)	Sf (mm/min)	Length (m)	Weight before(g)	Weight after(g)	Wire Wear (g)	WWR (%)
1	105	20	20	600	97.74	39.8779	39.4975	0.3804	0.954
2	105	25	30	700	89.0	36.3120	35.9626	0.3493	0.962
3	105	30	40	800	39.38	16.0711	15.9124	0.1587	0.988
4	105	35	50	900	37.27	15.2061	15.0417	0.1642	1.08
5	110	20	30	800	37.51	15.3062	15.1379	0.1682	1.106
6	110	25	20	900	24.93	10.1714	10.0288	0.1426	1.401
7	110	30	50	600	50.41	20.5672	20.3283	0.2389	1.161
8	110	35	40	700	18.97	7.7396	7.6417	0.0979	1.265
9	115	20	40	900	18.94	7.7297	7.6193	0.110	1.426
10	115	25	50	800	20.67	8.4333	8.2981	0.1352	1.603
11	115	30	20	700	24.73	10.0898	9.9444	0.1454	1.441
12	115	35	30	600	33.0	13.4640	13.2836	0.1804	1.339
13	120	20	50	700	14.24	5.8099	5.6970	0.1129	1.943
14	120	25	40	600	11.15	4.5492	4.4451	0.1041	2.288
15	120	30	20	900	32.02	13.0641	12.8868	0.1773	1.357
16	120	35	20	800	17.3	7.0584	6.9441	0.1143	1.619

In coated wire:

Table 5: Wire wear and wire wear ratio for coated wire

No	Ton (µm)	Toff (µm)	Sv (V)	Sf (mm/min)	Length (m)	Weight before(g)	Weight after(g)	Wire Wear (g)	WWR (%)
1	105	20	20	600	7.76	3.1955	3.1379	0.0575	1.802
2	105	25	30	700	13.61	5.6045	5.4997	0.1047	1.869
3	105	30	40	800	16.24	6.6876	6.5608	0.1267	1.895
4	105	35	50	900	28.28	11.6457	11.4208	0.2248	1.931
5	110	20	30	800	6.86	2.8249	2.7658	0.0591	2.092
6	110	25	20	900	5.46	2.2484	2.2037	0.0448	1.992
7	110	30	50	600	6.42	2.6437	2.5840	0.0597	2.258
8	110	35	40	700	13.39	5.5140	5.4050	0.1089	1.975
9	115	20	40	900	8.64	3.5579	3.4831	0.0748	2.102
10	115	25	50	800	6.72	2.7672	2.702	0.0652	2.356
11	115	30	20	700	5.86	2.4131	2.3562	0.0569	2.357
12	115	35	30	600	5.33	2.1948	2.1389	0.0559	2.546
13	120	20	50	700	7.76	3.1955	3.1224	0.0731	2.287
14	120	25	40	600	5.46	2.2484	2.1881	0.0603	2.682
15	120	30	20	900	4.64	1.9107	1.8459	0.0648	3.391
16	120	35	20	800	5.96	2.4543	2.3869	0.0674	2.746

II .Effect of pulse on time and spark gap voltage on WWR

Figure 2 shows the effect of pulse on time and spark gap voltage on wire wear ratio at different values of pulse off time and servo feed in two types of tools (brass and coated wire) from this Figure the increase in Ton lead to increase **WWR** and the increase in **SV** lead to little increase in **WWR** (little than Toff effect) .effect of Ton mentioned in section (3.1) and higher values for **SV** , the wider the gap between the workpiece and electrode also decreases the number of electric spark , stabilizing electric discharge, also the values of **WWR** in coated wire are higher than the values of **WWR** in brass wire.

III. Effect of pulse on time and pulse off time on MRR

The consequences of the impact of heartbeat on time (Ton) and heartbeat off time (Toff) on Material evacuation rate (MRR) at various estimations of start hole voltage (Sv) and servo bolster (Sf) in two sorts of instruments (metal wire and zinc covered metal wire) as in Figure (5). From this figure, the expansion in Ton prompts increment MRR and the increment in Toff prompts diminish MRR. Because of increment of Ton the high vitality created amid machining which prompts high start. Then high melting rates of material, in increase of Toff, low rates of melting at high values of Toff. The values of MRR in zinc coated brass wire (coated wire) are higher than values of brass wire, the coated wire was originally called (speed wire) due to its ability to cut at a significantly higher MRR.

IV. Effect of pulse on time and servo feed on MRR

Figure 3 show the effect of pulse on time and servo feed on material removal rate at different values of
pulse off time and spark gap voltage in two types of tools (brass and coated wire). From this Figure the increase in Ton leads to increase MRR and the increase in sf leads to decrease MRR . Effect of Ton is mentioned in section (3.3).Also the maximum values of MRR in coated wire are (16.119 mm³/min) higher than values of MRR in brass wire (7.448 mm³/min).

V. Effect of pulse on time and pulse off time once surface roughness (Ra)

The results of the effect of pulse on time (Ton) and pulse off time (Toff) on Surface roughness (Ra) at different values of spark gap voltage (Sv) and servo feed (Sf) in two types of tools (brass wire and zinc coated brass wire) as in Figure (6). From this figure, the increase in Ton leads to increase Ra and the increase in Toff leads to decrease Ra. Due to increase of Ton the high melting rates that occur which caused surface irregularities. With the increase of Toff, low rates of melting at high values of Toff caused a decrease in Ra. The results of the ANOVA with WWR for four machining variables. This perception was carried out for great importance degree of α= 0.05, i.e. for a confidence level of 95%. In brass wire the F ratio value of 13.79 for the Ton is bigger among the parameters. Therefore, the the majority of strong parameters are Ton (70.63%), Toff (11.51%), Sv (10.65%) and Sf has a small influence w(2%).In coated wire the F ratio value of 21.64 for the Ton is greater among the parameters. Therefore, the most influential parameters are Ton (69.81%), Toff (13.01%), Sv (9.07%) and Sf has a small influence with (4.86%).

4. Conclusions

Form this work the following conclusions can be drawn:

1- Minimum wire wear ratio from brass wire (0.954%) which is less than from coated wire (1.802%).

2- Maximum material removal rate from brass wire (7.448 mm^3/min) which is less than from coated wire (16.119 mm^3/min).

3- Minimum surface roughness from brass wire (1.44 μm) which is more than from coated wire (1.34 μm).

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