S.H. Aghdeab
Production & Metallurgy Engineering Department, University of Technology, Baghdad, Iraq
Shukry-hammed@yahoo.com

V.N. Najm
Production & Metallurgy Engineering Department, University of Technology, Baghdad, Iraq
Vean.nihad@gmail.com

A.M. Saleh
Production & Metallurgy Engineering Department, University of Technology, Baghdad, Iraq

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Surface Roughness Evaluation in WEDM Using Taguchi Parameter Design Method

Abstract- *Machining of hard metal is difficult by conventional method to obtain high accuracy where the dimensional accuracy is the main factor. Wire electrical discharge machining (WEDM) extensively used, which is mostly used in machining of conductive materials by using precisely controlled sparks that occur between a very thin wire and a workpiece in the presence of a dielectric fluid. This study serves in studying surface roughness (SR) of high speed steel (HSS) using taguchi method to design the experiment, this was achieved with utilizing different wire cut machining parameters and study the behavior of these control parameters such as pulse duration (µs), pulse interval (µs), Servo feed and Servo voltage (V) on surface roughness. It can be noticed that when servo voltage and servo feed increase the surface roughness decreases and when pulse duration and pulse interval increase the surface roughness increases too, and It was found with using taguchi parameter design that the best machining variables of combination setting is Servo Voltage (22) volts, Pulse on time (110) µs, servo feed (450) mm/min and Pulse off time (30) µs to reach to the minimum value of surface roughness and hence better surface finish.*

Keywords- *WEDM, Surface roughness (SR), Taguchi method.*

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1. Introduction

Wire cut electrical discharge machining (WEDM) is one of the significant non-traditional machining processes that are implemented for machining hard to machine materials such as composites and inter-metallic materials [1]. WEDM is a unique appearance of electrical discharge machining which utilizes a constantly moving electrical conductive wire electrode. Remove of material happens as a consequence of spark erosion as the wire is moving [2]. WEDM is doubtless the most inspiring and extending process developed for industry in the previous 50 years, and has many benefits to put forward. It can machine whatever thing that is electrically conductive in spite of the hardness [3]. WEDM process uses wire with small diameter as an electrode to generate thermal energy form transforming the electrical energy for cutting materials [4]. Since the machining is finished automatically so that Wire EDM offers engineers more scope in designing dies, and running additional control of manufacturing. This process don't need you to depend on special ability levels or multiple tools that have tolerances and multifaceted geometry [3]. A stainless steel 15-5 PH workpiece was machined with wire cut machine and the influence of different machining parameters was studied. Taguchi design method was used to set the experimental parameters, the analysis of variance was used to analyze the experimental results and determine the optimal set of machining parameters that achieve the best surface roughness [4]. The influence of various wire electrical discharge machine parameters were examined to determine the best surface roughness in machining EN36 alloy steel. The researchers used thin brass wire as the cutting tool in the wire cut machine and select the process parameters like pulse on time (µs), pulse off time (µs), peak current (A) and voltage (V) and they were used Taguchi design method. They were noticed that the surface roughness was more affected with current variation than other parameters [5]. The wire electrical discharge machining parameters on surface roughness of titanium (Ti-6Al-4V) alloy were studied. The analysis of variance (ANOVA) method was utilized in order to decide the level of importance of the WEDM process parameters TON, TOFF, voltage and dielectric flushing pressure were investigated on the surface roughness [6]. A study on the material removal rate, surface roughness and Cutting Width in wire electrical discharge machining of AISI H13 tool steel. The machining parameters that were studied in this paper such as gap voltage, pulse on time, pulse off time and wire feed in order to improve the material removal rate, surface roughness and Cutting Width. ANOVA was utilized to find the optimal level of the machining parameters [7]. The importance of wire cut machining is that the ability of machining the workpiece material with high degree of dimensional accuracy with the absence of any mechanical contact between wire electrode and work piece less finishing operations are required in this process as a result of a well surface finish are obtained which minimize finishing procedure time [8].

2- Experimental Part

I-Experimental Procedure

Cutting process was performed on 4-axis Smart DEM (ELEKTRA DEM 400 A) EL PULSE 5 wire cut machine in the laboratory of the technology university at Baghdad/Iraq, as shown in Figure 1. Specification of the machine has written in table 1, have CAD/CAM software, consistent wire diameter allows high cutting accuracy, cutting wire runs through only once, independent programming of X/Y and U/V axes, automatic positioning. A key board is used to program the geometry of the workpiece and the motion of wire electrode along the workpiece and also enter the parameters for each cutting process and (14) color monitor. The workpiece is fitted on the work-holding structure. The upper and lower wire-guide helps to straighten the wire on the part being machined. The wire is held between upper and lower steel guides. These guides are usually CNC-controlled, move in the x–y plane and the wire is constantly fed.

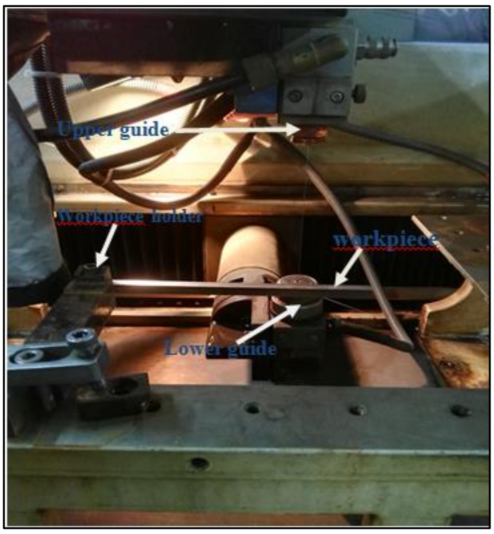

Figure 1: Wire cut machine

Table 1: WEDM machine specification

Maximum work pieces size	350 × 450 × 200 mm
Maximum work piece weight	300 Kg
X,Y table travel	250×350 mm
Machine weight	2000 kg
(U/V) axis travel	30×30 mm
Wire cut diameter	0.25 mm
Max. Wire tension	1600 g
Max cutting angle	± 5/100
Guide of wire	steel
Dielectric fluid	pure distilled water
Maximum current	12A
Power needed	4.5 KVA

In these experiments, a coated brass wire with 0.25 mm diameter is used as a cutting tool in order to machine a workpiece material of high speed steel. Workpiece dimensions were (120x10x10) mm Figure 2, have been cut to a nine pieces of (3×10×10) mm dimensions Figure 3, Table 2 shows chemical composition of the workpiece this test was carried out in (Midland refineries company/ general company MRC baghdad). The parameters were changed at each cutting process. Experiments were conducted to compute the surface quality of the workpiece with change in input variables, Digital surf test portable device (pocket surf of surface roughness) These tests has been carried out in (Department of Production Engineering and Metallurgy, University of Technology) is used to measure the surface roughness with three different lengths (L, K, M), and measured roughness (SR). Pure (distilled) water was used as a dielectric fluid. The machining parameters used and kept constant in experimental work is shown in Table 3.

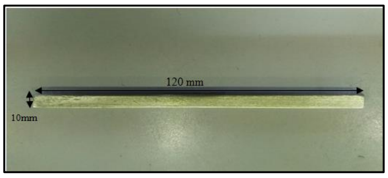

Figure 2: shows the workpiece before machining

The experiment was designed to minmize the number of trails in order to shorten the time of the experiment as well as achieve the optimum study of the influence of different main. WEDM process parameters, pulse on time, and pulse off time, servo feed and servo voltage on the surface roughness. In this work, Taguchi method was used to design the experiment and determine optimal machining parameters to minimize surface roughness in wire cut process, with using MINITAB17 software, the levels of cutting parameters are listed in Table 4.

The design of experiments factors are shown in table 5, with number of factors equal to (4) and with (3) levels.

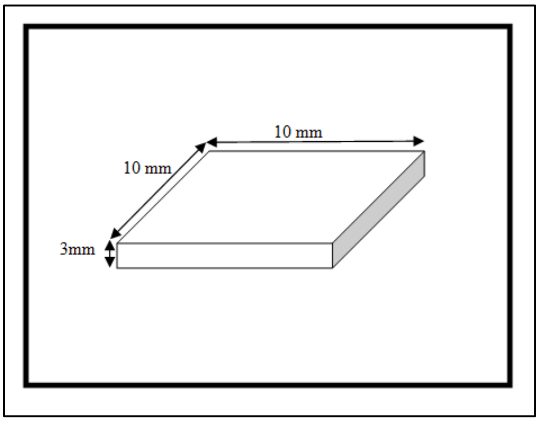

Figure 3: A magnified picture of the workpiece after machining process

Table 2: Chemical composition of the workpiece

Material	C	Si	Mn	Cr	Mo	Ti	V	Fe
Chemical analysis%	1.1	1.28	0.26	1.08	0.08	0.007	0.01	**balance**

Table 3: Machining parameters used in experimental work

Working Parameters	Description
Workpiece	High speed steel (10 mm)
Wire-cut	Coated brass (0.25 mm diameter)
Wire tension	6
Dielectric	Pure (distilled) water
Voltage	11 V
Current	12 A

Table 4: The levels of cutting parameters

Variables	Level(1)	Level (2)	Level (3)
Servo voltage(V)	20	21	22
Pulse duration (μs)	110	115	120
Pulse interval (μs)	30	35	40
Servo feed (mm/min)	350	400	450

Table 5: The design of experiments factors and response of (SR) and a result of analyze with TOA L9 (3^4).

NO.	Servo voltage (V)	Pulse duration (μs)	Pulse interval (μs)	Servo feed (mm/min)	SR_1 (μm)	SR_2 (μm)	SR_3 (μm)	Mean (μm)	S/N (decibel)
1	20	110	30	350	2.23	2.3	2.8	2.44333	-7.8063
2	20	115	35	400	3.29	3.3	3.5	3.36333	-10.5390
3	20	120	40	450	3.39	3.35	3.54	3.42667	-10.6999
4	21	110	35	450	2.16	2.48	2.6	2.41333	-7.6780
5	21	115	40	350	3.38	3.97	3.8	3.71667	-11.4224
6	21	120	30	400	3.12	3.38	3.87	3.45667	-10.8082
7	22	110	40	400	2.08	2.93	2.14	2.38333	-7.6569
8	22	115	30	450	2.96	2.92	2.64	2.84000	-9.0773
9	22	120	35	350	3.6	3.82	3.48	3.63333	-11.2126
Mean								3.07518	9.6556

II- Taguchi Design

Taguchi's orthogonal array is extremely practical design, used to evaluate the central effects using a small number of experimental tests only. These designs able to examine the prime effects when factors have more than two levels [10]. In Taguchi method, the analysis of variation is accomplished using Signal – to – Noise ratio (S/N). The purpose from this work is to reduce the surface roughness parameter. Therefore, the S/N ratio for each experiment of L9 estimated using smaller the better approach.

Factors: 4

Runs: 9

Columns of L9 (3^4) Array

1 2 3 4

After working on a design as shown in table 4, the output of this work was surface roughness and three measuring readings have been taken for each piece (Ra_1, $Ra_{2,}$ $Ra_{3)}$ by using Digital surf test.

3. Results and Discussion

Experimental results reveal the virtual effect of each control factor on surface roughness in addition to the level to be selected for the ideal cutting parameters. The result, of nine experimental presented in table 6. Taguchi Analysis: SR1; SR2; SR3 versus servo voltage; pulse on time; pulse off time; servo feed**.**

Table 6: Response for Signal to Noise Ratios

level	Servo voltage	Pulse on time	Pulse off time	Servo feed
1	-9.682	-7.714	-9.231	-10.147
2	-9.970	-10.346	-9.810	-9.668
3	-9.316	-10.907	-9.926	-9.152
delta	0.654	3.193	0.696	0.995
rank	4	1	3	2

It can be observed from the Figure 4 that with the increase in servo voltage value, the amount of SR drops. The motive for this, as the servo voltage growths; the gap between the two electrodes come to be broader. So that the amount of the sparks decreases, although the rate of machining speed decelerated. The amount of surface roughness rises, as the value of servo voltage decreases, this risen occurs for the reason that the gap becomes narrower, which leads to an increase in amount of the sparks, It is also rush the rate of machining speed. when the pulse on time rises the discharge will stay longer in turn high energy will be generated this would lead to increase in surface roughness values, The amount of surface roughness grows with the elevation in pulse interval, the increase in pulse interval causes more periodic ionization of dielectric and leading to frequent melt explosion. This rises the density of globules accumulated at machining zone and results in poor surface finish. It can be also noticed that when servo feed increases the surface roughness decreases. The lower value of (SR) is the best with effect of S/N ratio which computed from [1].

(S/N) = -10* log10 (sum(y^2)/n) (1)

Where: Y: is a value measuring of (SR)

N: is a number of noise factor

If it is supposed that the values at a table 5 that the servo voltage is A, pulse on time is B, pulse off time is C, servo feed is D, so the best optimal parameter will be [A3, B1, C1 and D3] with neglecting the minus sign, The predicted mean value of (SR) can be computed by using the optimum parameters that selected above [2].

Predicted mean (RA) = A3 + B1 + C1 + D3 – 3*(average mean) (2)

=9.316+7.714+9.231+9.152-3*(9.6556) =6.4462

Table 7 present, the measured of (SR) with respect off the average mean, the main effect mean the smaller is the best so the process with optimal value of (SR) will be at points [A3, B1, C1, and D3].

Figure 5 Explains the effect of the variables with the average mean measuring on surface roughness. The predicted mean value of (SR) can be computed by using the optimum parameters that selected above by using [3].

Predicted mean Ratio(SR) = A3 + B1 + C1 + D3 – 3*(average mean) (3)

= 2.952 + 2.413 + 2.913 + 2.893 – 3*(3.07518) = 1.94546 μm

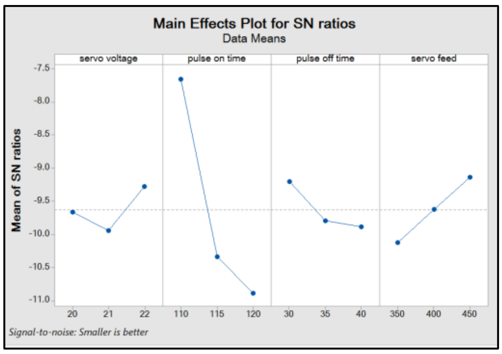

Figure 4: Main Effects Plot for SN ratios

Table 7: Response Table for Means

level	Servo voltage	Pulse on time	Pulse off time	Servo feed
1	3.078	2.413	2.913	3.264
2	3.196	3.307	3.137	3.068
3	2.952	3.506	3.176	2.893
delta	0.243	1.092	0.262	0.371
rank	4	1	3	2

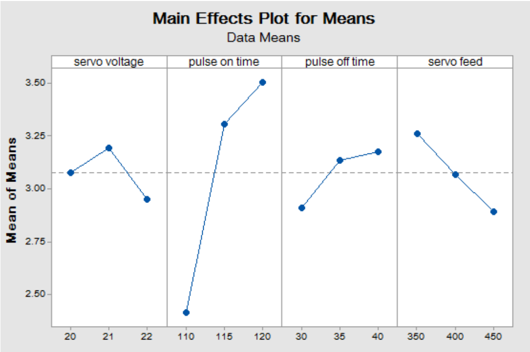

Figure 5: Main Effects Plot for means

4- Conclusions

In this work, surface roughness has been investigated experimentally using four process parameters on workpiece of high speed steel which is done on wire electrical discharge machine, using taguchi design method. The variable Surface Roughness has been investigated by varying the four Process machining parameters on high speed steel workpiece with coated brass wire as electrode in wire electric discharge machine. The following conclusions are listed:

1. When servo voltage and servo feed increase the surface roughness decreases.
2. When pulse duration and pulse interval increase the surface roughness increases too.
3. It was found with taguchi parameter design that the best machining variables of combination setting is Servo Voltage (22) volts, Pulse on time (110) µs, servo feed (450) mm/min and Pulse off time (30) µs to reach to the minimum value of surface roughness and hence better surface finish.
4. Surface roughness has been predicted by using taguchi design method which is predicted mean (1.94546) µm and predicted signal to noise ratio (6.4462).

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Author's biography

Shukry H. Aghdeab, Ass. Prof. Dr. Shukry H. Aghdeab recived his B.Sc. M.Sc. degrees in 1994, 2000 and 2008 and Ph.D. in production engineering from the University of Technology, Iraq. He has published many papers international conference and journals in the field of cutting materials for electrical discharge machining and others.

Vian N. Najm, recived her B.Sc.degrees in 2006, and M.Sc. degree in 2014 in production engineering from the University of Technology, Iraq.

Athraa M. Saleh, recived her B.Sc.degrees in 2007, and M.Sc. degree in 2014 in production engineering from the University of Technology, Iraq.