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A Study and Investigation on SR in Wire Electrical Discharge Machining using Molybdenum Wire

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ABSTRACT: Wire electrical discharge machining process is a highly complex, time varying & stochastic process. The process output is affected by large no of input variables. Therefore a suitable selection of input variables for the wire electrical discharge machining (WEDM) process relies heavily on the operator"s technology & experience because of their numerous & diverse range. WEDM is extensively used in machining of conductive materials when precision is of prime importance. Rough cutting operation in wire EDM is treated as challenging one because improvement of more than one performance measures viz. Metal removal rate(MRR), surface finish & cutting width (kerf), Dimensional derivation, Cutting Speed, Machining Time are sought to obtain precision work. In this work an approach to determine parameters setting is proposed. Using taguchi"s parameter design, significant machining parameters affecting using Copper, Brass, Tungsten carbide and aluminium wire electrode, the performance measures are identified as pulse peak current , pulse on time, pulse off time, Flushing Pressure, Wire Speed, Wire tension and duty factor . The effect of each control factor on the performance measure is studied individually using the plots of signal to noise ratio, Grey relation Analysis and ANN and ANOVA Technique, The study demonstrates that the WEDM process parameters can be adjusted so as to achieve better surface finish.

KEYWORD: Wire EDM, Surface roughness, Taguchi, ANOVA.

I. INTRODUCTION

The phenomenon of erosion of metals by electric spark was first noticed by Joseph Priestily in 1878 but this was not used for machining of metals until 1930s. Controlled machining of metals by electric sparks was first done by Lazarenko in Russia in 1944 [2].

One of the most widely used Non-Conventional Machining process in industry is Electrical Discharge Machining (EDM). Electric Discharge Machining is a non- traditional concept which is based on the principle of removing material by means of repeated electrical discharges between the tool termed as electrode and the work piece in the presence of a dielectric fluid [3]. Electrical Discharge Machining (EDM) uses thermal energy to achieve a high-precision metal removal process from a fine, accurately controlled electrical discharge. The electrode is moved towards the work piece until the gap is small enough so that the impressed voltage is great enough to ionize the dielectric [1]. Short duration discharges are generated in a liquid dielectric gap, which separates tool and work piece. The material is removed with the erosive effect of the electrical discharges from tool and work piece. EDM does not make direct contact between the electrode and the work piece thus it can eliminate mechanical stresses, chatter and vibration problems during machining [3, 4].

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WEDM is considered as a unique adoption of the conventional EDM process which comprises of a main worktable, wire drive mechanism, a CNC controller, working fluid tank and attachments. The work piece is placed on the fixture table and fixed securely by clamps and bolts. The table moves along X and Y-axis and it is driven by the DC servo motors. Wire electrode usually made of thin copper, brass, molybdenum or tungsten of diameter 0.05-0.30 mm, which transforms electrical energy to thermal energy, is used for cutting materials. The wire is stored and wound on a wire drum which can rotate at1500rpm. The wire is continuously fed from wire drum which moves though the work piece and is supported under tension between a pair of wire guides located at the opposite sides of the work piece. During the WEDM process, the material is eroded ahead of the wire and there is no direct contact between the work piece and the wire, eliminating the mechanical stresses during machining. Also the work piece and the wire electrode (tool) are separated by a thin film of dielectric fluid that is continuously fed to the machining zone to flush away the eroded particles. The movement of table is controlled numerically to achieve the desired three-dimensional shape and accuracy of the work piece [6].

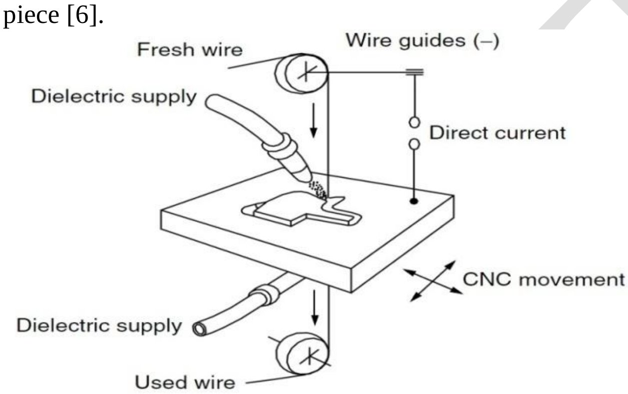

Figure 1: WEDM schematic [1]

Dr. Josephkunju Paul et .al [10] evalutes the effect of voltage, dielectric pressure, pulse on-time and pulse off-time on spark gap of Ti6AL4V alloy. It is found that the pulse on time , pulse off time , the interaction of dielctric pressure and pulse off time, and interaction of pulse on time and pulse off time are significant parameters which affect the spark gap of WEDM. Minimum spark gap can be obtained by adopting a low value of pulse on time (20 µs), a high value of dielectric pressure (15 kgf/cm2), high value of pulse off time(50 µs) and voltage of 50V . Improper setting of pulse on time and pulse off time can lead to wire breakage which in turn leads to increase in machining time. The developed model agrees with the conformation results by less than 6%.Prof.Satyam P Patel et .al [11], have investigate the effects of the various WEDM process parameters on the machining quality of AISI 304 stainless steel. L9 Orthogonal Array is used and experiment will be performed as designed by Taguchi method. It can be concluded that Pulse on time, Input power, pulse off time and wire tension significantly effects on surface roughness. Pulse off time is found to have effect on surface roughness. Increase in pulse off time value of sur face roughness is decrease. S. B. Prajapati et .al [12] evaluates the effect of process parameter like Pulse ON time, Pulse OFF time, Voltage, Wire Feed and Wire Tension on MRR, SR, Kerf and Gap current is studied by conducting an experiment. Response surface methodology is used to analyze the data for optimization and performance. The AISI A2 tool steel is used as work piece material in the form of square bar. Finally concluded that for cutting rate and surface roughness, the pulse ON and pulse OFF time is most significant. The spark gape set voltage is significant for kerf. K. P. Rajurkar et al [13] In this paper presents an experimental investigation of wire electro-discharge machining (WEDM) of titanium alloy as work piece material. The objective is to investigate the effect of seven process parameters including pulse width, servo reference voltage, and pulse current, wire tension, cutting speed, wire rupture and surface integrity. Experiments results of WEDM of titanium indicate peak current and pulse width have significant effect on cutting speed and surface roughness. It concluded that cutting speed of machining decreases with increasing time between two pulses and when wire tension increases surface roughness also increases. The wire breakage in machining of titanium is sensitive to electrical process parameters such as time between two pulses, pulse width, wire tension and injection pressure.

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II. EXPERIMENT

The experimental setup and the experiment is designed with the primary goal of the dissertation work is to predict the MRR,surface roughness ,and kerf width the work is carried out in sprintcut wire cut electro discharge machine of HCHCR material by varying machining parameters. The machine used for experiments is electronica sprintcut Wire cut EDM, Model- ELPULS-40 A DLX, incorporated with molybdenum wire technology.

The input and fixed parameters used in the present study are also listed in Table 1.and Table2 respectively. These were chosen through review of literature, experience, and some preliminary investigations. Different settings of Pulse On Time (µs), Pulse Off Time (µs), Flushing pressure (kgf/cm^2), Wire Tension (gms), Servo Voltage (volt), Wire Feed Rate (m/min) used in experiments.

Sr. No.	Machining process parameter	Level 1	Level 2	Level 3
1	Pulse On Time (µs)	110	115	120
2	Pulse Off Time (µs)	40	45	50
3	Flushing pressure (kgf/cm^2)	8	10	12
4	Wire Tension (gms)	550	750	950
5	Servo Voltage (volt)	15	20	25
6	Wire Feed Rate (m/min)	6	8	10

Table No: 1 Input Variables with Levels value

Sr. No.	Fixed Parameters	Set Value
1	Wire material	Molybdenum (0.25mm)
2	Peak current (IP)	230
3	Pulse peak voltage	2
4	Servo feed setting	250

Table No: 2 Fixed Variables

The material selected for this dissertation work is High Carbon High Chromium Die Steel (HCHCR). The workpiece of D2 too steel (2.19% C, 11.11% Cr, 2.19%Mn, 0.021% Ph, 0.33%Si, 0.028% S, 0.04%V) was cut with 0.25 mm diameter stratified wire (Molybdeneum) with vertical configuration was used and discarded once used. The most important measures in WEDM are MRR, Surface roughness and, Kerf width. Surface roughness was obtained by measuring mean absolute deviation Ra from the average surface level using a Mitutoyo surface roughness tester SJ-201 with stylus radius of 5 µm.

III. ANOVA for individual machining characteristics result table for surface roughness

Sr. No	T_{on} (µs)	T_{off} (µs)	F_p (Kgf/cm2)	W_t (gms)	S_V (volts)	W_f (m/min)	SR(µm)
1	110	40	8	550	15	6	2.5113
2	110	40	8	550	20	8	2.4556
3	110	40	8	550	25	10	2.3718
4	110	45	10	750	15	6	2.8031
5	110	45	10	750	20	8	2.8094
6	110	45	10	750	25	10	2.6778
7	110	50	12	950	15	6	2.7224
8	110	50	12	950	20	8	2.7346

9	110	50	12	950	25	10	2.7365
10	115	40	10	950	15	8	3.4251
11	115	40	10	950	20	10	3.3952
12	115	40	10	950	25	6	3.3846
13	115	45	12	550	15	8	3.4652
14	115	45	12	550	20	10	3.4458
15	115	45	12	550	25	6	3.518
16	115	50	8	750	15	8	3.4982
17	115	50	8	750	20	10	3.4446
18	115	50	8	750	25	6	3.3661
19	120	40	12	750	15	10	3.5325
20	120	40	12	750	20	6	3.4913
21	120	40	12	750	25	8	3.4284
22	120	45	8	950	15	10	3.5976
23	120	45	8	950	20	6	3.3147
24	120	45	8	950	25	8	3.4225
25	120	50	10	550	15	10	3.4394
26	120	50	10	550	20	6	3.4425
27	120	50	10	550	25	8	3.3981

Table No. 3 Experimental result for surface roughness

IV. CALCULATION OF GREY RELATIONAL COEFFICIENT & GREY RELATIONAL GRADE

The distinguishing coefficient can be substituted for the grey relational coefficient in Eq6.5 If all the process parameter has equal weighting, ζ is 1. Table 12 lists the grey relational coefficient and grade for each experiment of the L_{27} orthogonal array by applying Eqs.6.5, 6.7 and 6.8

$$\Delta\min = \min_{i\in I}\min_{k}\left|x_0(k)-x_i(k)\right| \quad \ldots\ldots (6.5)$$

$$\gamma_i = \frac{1}{n}\sum_{k=1}^{n}\zeta i(k) \quad \ldots\ldots\ldots\ldots\ldots (6.7)$$

$$\gamma_i = \frac{1}{n}\sum_{k=1}^{n}W_k\zeta i(k) \quad \ldots\ldots\ldots.. (6.8)$$

Where, Wk represents the normalized weighting value of factor k.

Exp No:	Grey Relation Co-efficient			Grey Relational Grade	Orders
		SR			
1		0.8138		1.9180	4
2		0.8787		2.2605	2
3		0.9987		2.3902	1
4		0.5865		1.4929	18

5		0.5830		1.4749	19
6		0.6664		1.6191	11
7		0.6356		1.4005	20
8		0.6277		1.3575	22
9		0.6265		1.5246	16
10		0.3677		1.8496	5
11		0.3744		1.8162	6
12		0.3769		1.8013	7
13		0.3591		1.5288	15
14		0.3632		1.5617	14
15		0.3483		1.5684	13
16		0.3523		1.3083	23
17		0.3635		1.2687	25
18		0.3812		1.2019	27
19		0.3454		2.0333	3
20		0.3537		1.7963	8
21		0.3671		1.7747	9
22		0.3332		1.6601	10
23		0.3938		1.5755	12
24		0.3683		1.5012	17
25		0.3646		1.3797	21
26		0.3640		1.2849	24
27		0.3738		1.2532	26

Table No. 5 Calculation of Grey relational coefficient & Grey relational grade

According to performed experiment design, it is clearly observed from Table 5. that the 'wire cut EDM process parameters' setting of experiment no. 03 has the highest grey relation grade. Thus, the third experiment gives the best multi-performance characteristics among the 27 experiments.

Machining parameters	Average grey relational grade by factor level		
	Level 1	Level 2	Level 3
Pulse On Time, A	1.7153*	1.4098	1.3605
Pulse Off Time, B	1.5450*	1.2750	1.2400
Wire Feed Rate, C	1.5843*	1.1002	1.1845
Wire Tension, D	1.6828*	1.5522	1.6096
Servo Voltage, E	0.1870*	0.1725	0.1788
Flushing pressure, F	0.0208*	0.0192	0.0199

Table No. 6 Response table for grey relational grade

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Table 6 shows average grey relational grade by factor level. From this table, one has concluded optimum parameter levels which are indicated by "*". In this table, higher grey relational grade from each level of factor indicates the optimum level. From this table it is concluded that the optimum parameter level for Pulse on time, Pulse off time, Flushing pressure, Wire tension, Servo voltage, Wire feed rate is (110 µs), (120 µs), (8 kgf/cm^2), (550gms), (15volts), and (6 m/min) respectively.

V. ANALYSIS & DISCUSSION PARAMETER

Optimal parameter combination the work-piece kerf width, material removal rate and surface roughness for different combinations of WEDM parameter of 27 experimental runs are listed in table no: 10.

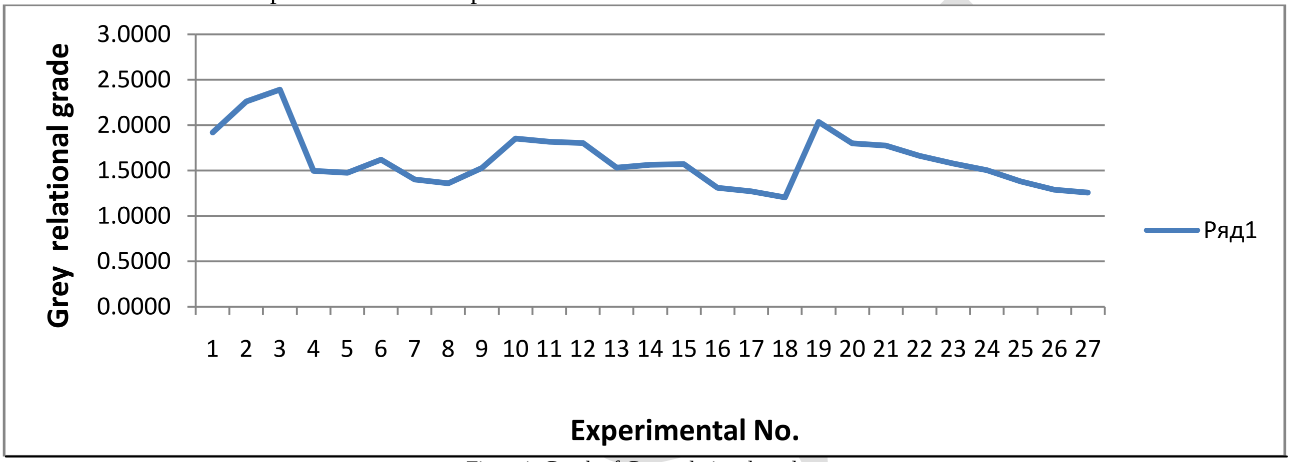

Figure1. Graph of Grey relational grades

According to performed experimental design, it is clearly observed from Table 4. and the Grey relational grade graph (Figure 3) which shows the change in the response when the factors go from one level to other that the WEDM parameters setting of experiment no. 3 has highest grey relation grade. Thus, the tenth experiment gives the best multi-performance characteristics of the WEDM process among the 27 experiments.

VI. CONFIRMATION TEST

The final step in the experiment is to do confirmation test. The purpose of the confirmation runs is to validate the conclusion drawn during the analysis phases. In addition, the confirmation tests need to be carried out in order to ensure that the theoretical predicted parameter combination for optimum results using the software is acceptable or not. The parameters used in the confirmation test are suggested by grey relational analysis. The confirmation test with optimal process parameters is performed for Wire cut EDM of HCHCR at levels A1 (110 µs Pulse on time), B1 (120 µs Pulse off time), C1 (8 kgf/cm^2 Flushing pressure), D1 (550gms Wire tension), E1(15volts Servo voltage) , F1(6 m/min Wire feed rate) and surface roughness of 3.7822 µm with the error in surface roughness is 9 %.
In this chapter, one has done grey relational analysis based optimization of WEDM process parameters for HCHCR. In this chapter, from the values of normalization and grey relational coefficient, grey relational grade is calculated. Higher grey relational grade gives better multi performance characteristics and from the table of average grey relational grade, optimum parameter levels are obtained. With the next chapter, one has discussed the obtained results.

VII. CONCLUSION

In this work an attempt was made to consider the effects of different settings of Pulse On Time (µs), Pulse Off Time (µs), Flushing pressure (kgf/cm^2), Wire Tension (gms), Servo Voltage (volt), Wire Feed Rate (m/min) on surfrace roughness in WEDM in D2 tool steel. Above analysis shows the percentage contribution of individual process input parameters of WEDM on HCHCR for surface roughness. The percentage contribution of Pulse on time is 93.23364%,

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Pulse off time is 1.63756%, Flushing pressure is 1.72681%, Wire tension is 1.42617%, Servo voltage is 0.67121%, Wire feed rate is 0.01312% and error is 1.29146%. This error is due to machine vibration.

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