

Prediction of Machining Parameters on Tool Steel in Wire EDM

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ABSTRACT: Non-conventional machining process like electro discharge machining (EDM) and wire electrical discharge machining (WEDM) plays important role in precision manufacturing process. WEDM is so complex in nature that the selection of appropriate input parameters is not possible by the trial and error method. The selection of machining parameters in any machining process significantly affects production rate, product quality and production cost of a finished one component. Wire EDM process involves a large number of variables that affect its performance. In this paper, an attempt is made to study the effect of various process parameters such as pulse on time, pulse off time and gap voltage for high carbon high chromium cold work tool steel (D3). The experiment has been completed with the help of Design of experiment and grey relational analysis. The grey relational analysis is used to optimize the process parameter of Surface roughness. The experimental analysis showed that the combination of pulse on time, pulse off time and gap voltage is essential to achieve minimization of surface roughness and kerf width.

KEYWORDS: WEDM, Pulse on, pulse off, gap voltage, surface roughness, GRA

I. INTRODUCTION

Machining removes certain parts of the work pieces to change them to final parts. Machining nowadays has been classified in two types are Traditional Machining and Non-traditional Machining. Traditional Machining, also known conventional machining requires the presence of a tool that is harder than the work piece to be machined. Giovanna Gautie [2015] et al in their work showed the poor machinability of gamma titanium aluminates has been reported in conventional (i.e. turning, milling, and drilling) and non-conventional machining, such as ECM. Further, machinability results strictly depend on the chemical composition of the specific alloy. This paper investigates the interactions between common process parameters of WEDM and final quality of the generated surface, through analysis of variance (ANOVA) and regression models based on experimental results. In particular, the paper is focused on the effects of pulse on time, pulse off time, servo-reference voltage, and wire tension on the surface finish during the WEDM of a Ti-48Al-2Cr-2Nb (at. %) -TiAl alloy. Results showed that, it is possible to state that all the considered variables affect directly or indirectly by means of interactions, the surface roughness indices. It is also worth to underline that the combined optimization of Ra, Rt, and R appears to be a difficult task, due to the counteracting effects of input parameters. V.Chengal Reddy [2015] in their work an attempt is made to study the effect of Various process parameters such as pulse on time, pulse off time, wire tension, current, upper flush and lower flush for Aluminium HE30. The experimentation has been completed with the help of Taguchi grey relational analysis. Taguchi grey relational analysis is used to optimize the process parameters on multiple performance characteristics such as Material removal rate, surface finish. The experimental result analysis showed that the combination of pulse on time, pulse off time, wire tension, lower flush, wire tension and upper flush is essential to achieve maximization of material removal rate and minimization of surface roughness and kerf width. Vikram Singh [2014] presented their work is to investigate the effects of various WEDM process parameters such as pulse on time, pulse off time, servo voltage and wire feed rate on the Material Removal Rate (MRR), Surface Roughness (SR) and cutting rate. Secondly, to obtain the optimal settings of machining parameters at which the Material Removal Rate (MRR) and cutting rate are maximum and the Surface Roughness (SR) is minimum in a range. The experiments were carried out as per design of experiment approach using L27 (3⁴)

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orthogonal array. In the present investigation, AISI D2 steel specimen is machined by using brass wire as electrode and the response surface methodology (RSM) is used for modeling a second-order response surface to estimate the optimum machining condition to produce the best possible response within the experimental constraints. Results showed that, The optimum parameters of combination setting is Pulse on time 112.99 μ s, Pulse off time 45 μ s, Servo Voltage 20 volts, and Wire feed 4.85mm/min for maximizing MRR and Cutting, minimize the SR.

Kashid D.V [2014] presented their work, the parametric optimization method using Taguchi method is proposed for WEDM of steel grade EN 9 component. Three process parameters are selected for this investigation; Pulse on-time, Pulse off-time and wire feed. The experimentation is conducted by using Taguchi's L_9 orthogonal array. Signal to Noise ratios of the Material removal rate for all experiments are calculated. From above results, we were concluding that material removal rate was highly influenced by pulse-on time and pulse-off time. The higher discharge energy, the more powerful explosion and the deeper crater created on the machined area. Pulse on-time (TON) with a contribution of 51.7103% has greatest effect on the machining output characteristics. Parameter pulse-off time (TOFF) is the next most significant influence 42.153% on the material removal rate. It reveals that wire feed rate has less effect on the material removal rate as compare to pulse on-time and pulse-off time. Hence if requirement of material removal rate is high, then pulse on-time and pulse-off time must high.

S V Subrahmanyam [2013] in their work an attempt is made to study the optimization of Wire Electrical Discharge Machining process parameters for the machining of H13 HOT DIE STEEL, with multiple responses Material Removal Rate (MRR), surface roughness (Ra) based on the Grey-Taguchi Method. taguchi's $L_{27}(2^1 \times 3^8)$ Orthogonal Array was used to conduct experiments, which correspond to randomly chosen different combinations of process parameter setting, with eight process parameters: TON, TOFF, IP, SV WF, WT, SF, WP each to be varied in three different levels. Data related to the each response viz. material removal rate (MRR), surface roughness (Ra) have been measured for each experimental run; With Grey Relational Analysis Optimal levels of process parameters were identified. The relatively significant parameters were determined by Analysis of Variance. The variation of output responses with process parameters were mathematically modeled by using non-linear regression analysis. The models were checked for their adequacy. Results showed that, while applying the Grey-Taguchi method using L_{36} orthogonal array. it is observed that the Material Removal Rate increased, Surface Roughness reduced, which are positive indicators of efficiency in the machining process. Thus, it can be concluded that the Grey-Taguchi Method, is most ideal and suitable for the parametric optimization of the Wire-Cut EDM process, when using the multiple performance characteristics such as MRR (Material Removal Rate), Surface Roughness for machining the H13 or for the matter for any other material. Mathematical relations between the machining parameters and performance characteristics established.

Jangra Kamal et al [2012] are study the inter-relationship among various input parameters such as Pulse on Time, Pulse off Time, Peak current, Wire speed and Wire tension with output measures namely Cutting Speed, Surface Roughness and Dimensional lag in wire electrical discharge machining of D3 tool steel as a work piece material and using Taguchi and Grey Relational Analysis techniques. It has proved using GRA, optimal setting of process parameters for multiple performance characteristics was set with $A_5B_2C_1D_1E_2$ corresponding predict values were confirmed experimentally that the cutting speed was observed 3.80mm/min and surface finish was poor and it can be improved by assigning high weightage in grey relational grade. B.K.Nanda et al [2011] have conducted the experiment on "Parametric Optimization of CNC Wire Cut Electrical Discharge Machining using grey relational Analysis". In This Experiment has been performed under different cutting conditions with the grey relational Analysis and analysis of variance (ANOVA). Grey relational grade using the optimal process parameter combinations and found that a good agreement between the predicted and actual grey relational grade. The increase of grey relational grade from initial factor setting to the optimal process parameter setting is of 0.1275. It has concluded that optimization of the complicated multiple performance characteristics using gray relation method and obtain the material removal rate, surface roughness are improved together.

MohdAmriLajis, H.C.D. MohdRadzi, A.K.M. Nurul Amin [2010] have found that these parameters have a significant influence on machining characteristics such as material removal rate(MRR), electrode wear rate(EWR) and surface roughness(SR). The analysis of the Taguchi method reveals that, in general the peak current significantly affects the EWR and SR, while, the pulse duration mainly affects the MRR. Kanlayasiriand Boonmung [2009] have investigated influences of wire-EDM machining variables on surface roughness of newly developed DC 53 die steel of width, length, and thickness 27, 65 and 13 mm, respectively. The machining variables included pulse-on time, pulse-

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off time, pulse-peak current, and wire tension. The variables affecting the surface roughness were identified using ANOVA technique. Results showed that pulse- on time and pulse-peak current were significant variables to the surface roughness of wire- EDM DC53 die steel. The maximum prediction error of the model was less than 7% and the average percentage error of prediction was less than 3%.

Mahapatra et al [2008] have identified discharge current, pulse duration, pulse frequency, wire speed, wire tension, and dielectric flow as the significant control parameters which affect the performance of Wire EDM during rough cutting operation, by using Taguchi's parameter design method. Work piece material taken for conducting experiment was D2 Tool Steel and wire taken is zinc coated copper wire. A nonlinear regression model has been used for establishing a relationship between the control factors and response parameters such as MRR, SF and kerfs. Further Genetic Algorithm approach has been applied in order to optimize for maximization of MRR, SF as well as minimization of kerfs, separate models were developed and errors associated with MRR, SF and Kerf were found out to be 3.14, 1.95 and 3.72% respectively. It has been thus concluded that different combinations of parameters lead to optimization of performance measure and thus the parameters can be adjusted for better MRR, Surface finish and cutting width simultaneously.

Chiang et al [2007] have been investigated on "Optimization of the WEDM process of particle- reinforced material with multiple performance characteristics using grey relational analysis" employed grey relational analysis to optimize the input parameters are pulse on time, pulse off time, arc on time, arc off time, servo voltage, wire feed and water flow are optimized parameters for Al₂O₃ particle reinforced material with two response parameters are material removal rate and surface roughness. It have concluded the response table and response graph for each level of the machining parameters are obtained from the grey relational grade, and select the optimal levels of machining parameters. This works established based on Response Surface Methodology (RSM).

II. MATERIAL AND METHODOLOGY

2.1 D3 Tool Steel - High-Carbon, High-Chromium, Cold-Work Steel

The principal steels of wide application for long-run dies are steels in this group. Grade D2 containing 1.50% carbon is of moderate toughness and intermediate wear resistance. Selection between the grades is based on the length of run desired, machining and grinding problems. From D3 steel all group D steels have 1% Mo and are air hardened. Type D3 steel is oil-quenched; though small sections can be gas quenched after austenitization using vacuum. As a result, tools made with type D3 steel tend to be brittle during hardening. Type D2 steel is the most commonly used steel among the group D steels. The D3 steels contain 1.5 to 2.35% of carbon and 12% of chromium.

Table 3.1 Physical properties

Properties	Metric	Imperial
Density	7.7 x 1000 kg/m ³	0.278 lb/in ³
Melting point	1421°C	2590°F

2.2 Mechanical Properties

The mechanical properties of D3 steels are given Table 3.2.

Table 3.2 Mechanical properties

Properties	Metric	Imperial
Izod impact un notched	28.0 J	20.7 ft-lb
Poisson's ratio	0.27-0.30	0.27-0.30
Elastic modulus	190-210 GPa	27557-30457 ksi

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2.3 Thermal Properties

The following Table 3.4 shows the thermal properties of D3 steels.

Table 3.3 Thermal properties

Properties		Conditions	
		T (°C)	Treatment
Thermal expansion	12 x 10 ⁻⁶ /°C	20-100	-

The AISI D3 tool steel sheets are used many commercial and industrial applications because excellent mechanical property. The pulse on, pulse of machining parameters are affected by the material parameters, properties of WEDM materials, WEDM tools and methods etc.

2.4 Design of Experiment

In this project, three welding parameters were selected as control factors, and each parameter was designed to have three levels, denoted 1, 2, and 3. The experimental design was according to an L27 array based on Taguchi method, while using the Taguchi orthogonal array would markedly reduce the number of experiments.

Table 3.4 Wire EDM parameters and levels

Sl No.	Parameters	Level 1	Level 2	Level 3
1	Pulse ON time (µs)	110	115	120
2	Pulse OFF time (µs)	50	55	60
3	Spark gap voltage (Volt)	23	26	29

2.5 Grey Relational Analysis

In grey relational analysis, the function of factors is neglected in situations where the range of the sequence is large or the standard value is enormous. However, this analysis might produce incorrect results if the factors, goal and directions are different. Therefore one has to preprocess the data which are related to a group of sequence which is called "grey relational generation". Data preprocessing is a process of transferring the original sequence to a comparable sequence for this purpose the experimental result are normalized in the range between zero and one the normalization can be done from three different approaches.

III. RESULTS AND DISCUSSION

After performing the experiment for all 27 runs and measuring the output parameters like surface roughness for wire cut EDM of High Carbon High Chromium Cold Work Steel, whatever results generated are discussed in this chapter.

The first graph of Fig 4.1 shows the effect of pulse on time on surface roughness. From fig.4.1, it is clearly shown that with increase in pulse on time, surface roughness suddenly increases. When pulse on time increases from 110 to 115 µs, surface roughness increases from 1.312 to 1.495 µm. When pulse on time again increases from 115 to 120 µs then surface roughness increases from 1.289 to 1.559 µm.

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Main Effects Plot for SR (μm)

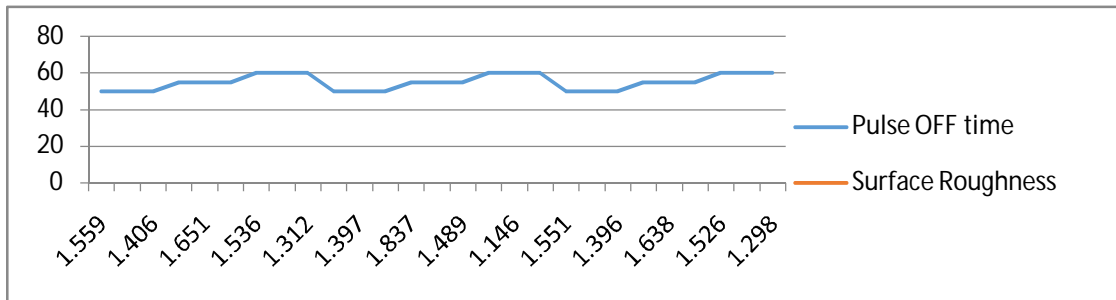
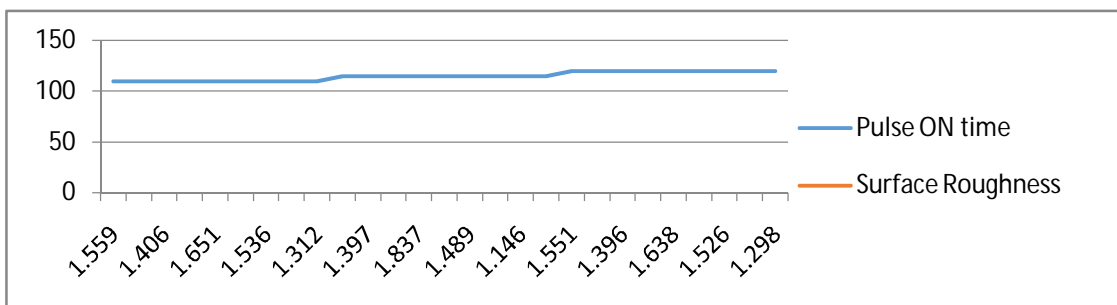
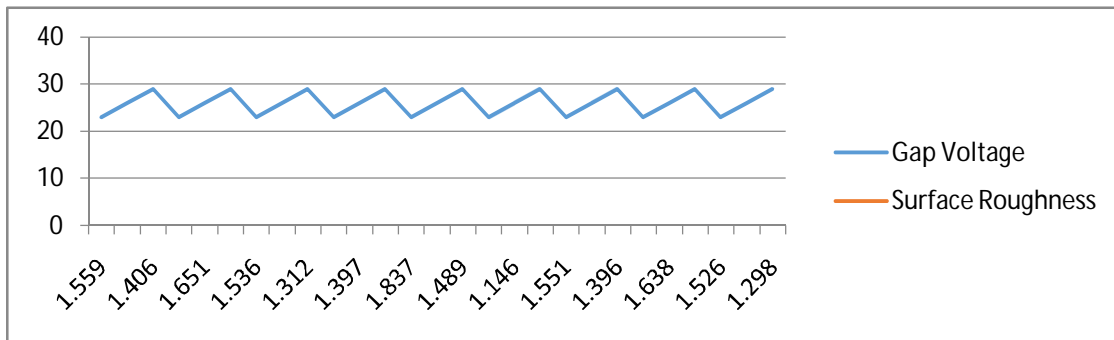


Figure 4.1 Graph of input parameters v/s Surface roughness

The second graph of Fig 4.1 shows the effect of pulse off time on surface roughness. From fig.4.1, it is clearly shown that with increase in pulse off time, surface roughness increases. When pulse off time increases from 50 to 55 μs , surface roughness increases from 1.559 to 1.855 μm . When pulse off time again increases from 55 to 60 μs then surface roughness further decreases from 1.511 to 1.312 μm .

The third graph of Fig 4.1 shows the effect of servo voltage on surface roughness. It is shown that with increase in servo voltage, surface roughness gradually decreases. When servo voltage increases from 23 to 26 volts, surface roughness decreases from 1.536 to 1.152 μm . when servo voltage again increases from 26 to 29 volts the surface roughness further decrease from 1.396 to 1.376 μm .



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Table No. 4.1 The Gray coefficient and Gray grade for Individual Trail

Exp. No	A	B	C	D
	SR	Normalization Of SR	Grey Relational Grades	Rank Orders
1	1.559	0.415147	0.54636	21
2	1.515	0.476858	0.511845	16
3	1.406	0.629734	0.442582	10
4	1.855	0	1	27
5	1.651	0.286115	0.54636	22
6	1.511	0.482468	0.508922	14
7	1.536	0.447405	0.527757	19
8	1.152	0.985975	0.336479	3
9	1.312	0.761571	0.396331	6
10	1.495	0.504909	0.497558	12
11	1.397	0.642356	0.437692	9
12	1.376	0.671809	0.426691	7
13	1.837	0.025245	0.951936	25
14	1.649	0.28892	0.633778	23
15	1.489	0.513324	0.493426	11
16	1.519	0.471248	0.514801	17
17	1.146	0.99439	0.334585	2
18	1.289	0.793829	0.38645	4
19	1.551	0.426367	0.539743	20
20	1.511	0.482468	0.508922	15
21	1.396	0.643759	0.437155	8
22	1.837	0.025245	0.951936	26
23	1.638	0.304348	0.621622	23
24	1.503	0.493689	0.503176	13
25	1.526	0.461431	0.520058	18
26	1.142	1	0.333333	1
27	1.298	0.781206	0.390257	5

IV. CONCLUSION

The grey relational analysis is done to find out optimal parameter levels. After grey relational analysis, it is found that optimal input parameter pulse on time (120 μ s), pulse off time (60 μ s) and servo voltage (26 volts) the results of optimum parameters for surface roughness of 2.2152 μ m.

The process parameters do not have some little effect for every response. Significant parameters and its percentage contribution change the behavior of the parameter with objective response. Increase of Pulse on time generates more .Spark energy as the length of time that electricity supply increases. Surface Roughness is increasing with pulse on time. Pulse on time 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. The pulse off time has opposite effect to pulse on time. Increase of pulse off time, while surface roughness reduces. Servo voltage has little effect on SR. Surface roughness reduces with increase of servo voltage.

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