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Research paper



Optimization of Parameters in WEDM Using CCF Design

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Abstract

The research work is to investigate the influence of WEDM process parameters such as pulse on time(T_{on}),pulse off time(T_{off}), peak current (IP), servo voltage (SV), and wire feed (WF) on response parameters as Material Removal Rate (MRR), Surface roughness(SR). Experimentation work carried out on Titanium 5 Grade work material with tool electrode as annealed brass wire. Every process parameter was set at three levels and the output variables were Surface roughness (SR) and Material removal rate (MRR). Central Composite Face centered (CCF) design was used to conduct the experiments. According to the experimental results the model equations for SR and MRR were developed using multiple linear regression. Modeling and optimization of process parameters had been performed with the help of model equations, level means and response graphs. From the analysis it was identified that the effect of servo voltage on surface roughness and pulse on time for MRR is more significant.

Keywords:*WEDM, Modeling, Optimization, Surface Roughness (SR), Material Removal Rate(MRR).*

1. Introduction

NTM (Non-Traditional Machining process) is one of the modern manufacturing technology, it energize economically to machining the materials which are difficult by traditional tools [1]. Newer and harder materials like advanced composites, high strength temperature resistance alloys, ceramics plays a significant role in the advanced technical industries such as tools and die making industries, aerospace, automobiles, nuclear reactors, medical ,computer and electronics [2]. WEDM is the process of NTM with unique machining technique used for specific application where dimensional accuracy, close tolerance and high degree of precision are very important for conductive materials. The basic principle in wedm is thermal energy conservation. High temperatute Electrical sparks are generated between the work piece and the wire electrode, the material is eroded and vaporized form the work piece. A continuous supply of dielectric fluid is flushed out the eroded metal in the machining zone. The conductive tool electrode wire with diameter less than 300 microns is controlled and monitored by the CNC machine [3]. Titanium alloy is a material for aerospace, aircrafts, missile components and bio implants [4]. The properties of these materials have high strength maintained at high temperature, and it has excellent environment, chemical & wear resistance. Titanium and its alloy are winning materials due to their unique combination of properties high specific strength maintained at elevated temperature, high hardness, chemical wear resistance and excellent resistance to most environments is the result of its strong affinity for oxygen and tendency to form a stable, tightly adherent protective surface film [5]. WEDM is still remains an important issue regarding machining characteristics that would be very valuable information for the manufactures and to the society. Sourav et al.[6] conducted experiments for 201LN grade of 200 series stainless steel with process parameters T_{on}, T_{off}, peak current, WF & Wire Tension, to obtain the maximum MRR and minimum SR. The responses are optimized by simulated Annealing followed by Response Surface Methodology. The output from the study will be useful for manufactures to select the optimal levels of parameters. Sunil et al. [7] investigated the optimum machining parameters for the AISI D2 tool steel. The input parameters such as peak current, WF, T_{on}, T_{off}, Servo voltage are used to know the effect on response characteristics namely cutting speed, surface roughness and identified that T_{on} is the most significant parameter on response parameters. Srinivasarao et.al [8] experiments were conducted by CCF to optimize the WEDM process variables as pulse on time, pulse off time, peak current, servo voltage and wire feed for Titanium-alloy material with a brass wire as tool electrode. A mathematical model was developed to response parameters MRR and SR by SPSS software. Desirability function is used to optimize the multi response characteristics. Srinivasarao et.al [9] did experiments by using a CCF design on AISI 52100 steel as work material to know the effect of process parameters as pulse on time, pulse off time, water pressure and wire feed on response parameters. It was found that pulse on time is more significant parameter for the surface roughness rather than other machining parameters. Bharathi et al.[10]studies carried out on WEDM for SS304 the process parameters pulse on time, pulse off time, wire feed & voltage are selected for high metal removal rate & lower surface roughness as well as kerf width, a multi objective optimization method is adopted to optimize the responses & achieved better predicted result than experimental value. Liao et al. [11] used neural network to predict the relationship between process parameters and response characteristics. Optimum technique genetic algorithm is employed to get the optimal combination of machining parameters and save a substantial amount of time and cost. Ramakrishnan et al. [12] the performance characteristics like MRR and SR were optimized concurrently using multi response signal-to-noise ratio. The study carried out by assigning

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equal weight factors. The machining parameters like pulse on time, delay time and ignition current were influenced more than wire feed speed. By an increase of pulse on time and ignition current the effect of MRR was improved. But at higher rate of pulse on time and ignition current gives the lower surface quality of the work piece. Amitesh et al.[13] investigated the performance measure on surface integrity and material removal rate on wedm process parameters found that T_{on} and T_{off} were the most significant factors for the response parameters.

2. Procedures and Methods

2.1. Work Piece Material & Tool electrode

The work material Titanium 5 Grade in the form of rectangular plate had been taken for experimentation, the cutting tool was annealed brass wire with a diameter 250microns and 1 Gpa tensile strength to produce very fine, precise and accurate cuts. The chemical composition of the Titanium 5 Grade is shown in Table 1[14].

Table 1: Chemical composition of Titanium 5 grade

Element	N	C	Fe	O	Al	V	Ti
Composition	0.1	0.1	0.3	0.2	6.8	4.5	88.08

2.2. Design of Experiments

The experiments were conducted based on the central composite face centered design which provides the effects of process parameters to be calculated. The eNova IS submerged type travelling WEDM was used to perform the machining of Titanium 5 grade with a annealed brass wire electrode. Table 2. Shows the levels of input parameters.

Table 2: Process Parameters and their respective levels

Factor symbol	Factors	Level1 (-1)	Level 2 (0)	Level 3 (+1)
T_{on}(µs)	Pulse on time	107	113	119
T_{off}(µs)	Pulse off time	51	57	63
IP(amp)	Peak current	10	11	12
SV (V)	Servo voltage	30	40	50
WF(m/min)	Wire feed	3	6	9

Table 3: The Experimental Design:(Central composite design)

S.No	T_{on}	T_{off}	IP	SV	WF	SR (µm)	MRR (m^3/min)
1	-1	-1	-1	-1	1	2.277681	2.5922
2	-1	-1	-1	1	-1	1.90308	1.4566
3	-1	-1	1	-1	-1	2.210506	3.2552
4	-1	-1	1	1	1	2.012075	2.4550
5	-1	1	-1	-1	-1	1.867521	2.1581
6	-1	1	-1	1	1	1.850418	1.0581
7	-1	1	1	-1	1	1.950014	2.0572
8	-1	1	1	1	-1	1.929723	1.5341
9	1	-1	-1	-1	-1	2.807857	4.2226
10	1	-1	-1	1	1	2.719945	4.1184
11	1	-1	1	-1	1	2.722118	9.9642
12	1	-1	1	1	-1	2.714272	9.1055
13	1	1	-1	-1	1	2.816634	2.0750
14	1	1	-1	1	-1	2.812232	1.8000
15	1	1	1	-1	-1	3.166216	4.9403
16	1	1	1	1	1	2.741563	3.4448
17	-1	0	0	0	0	2.221794	4.6020
18	1	0	0	0	0	2.828008	7.9351
19	0	-1	0	0	0	2.60048	6.9026
20	0	1	0	0	0	2.748393	3.2774
21	0	0	-1	0	0	2.400441	1.7172
22	0	0	1	0	0	2.635899	3.2272
23	0	0	0	-1	0	2.646849	5.1636
24	0	0	0	1	0	2.408315	3.3653
25	0	0	0	0	-1	2.632992	4.6191
26	0	0	0	0	1	2.534864	3.8043
27	0	0	0	0	0	2.630565	3.2719
28	0	0	0	0	0	2.617442	4.9107

3. Analysis of Data and Discussion of Results

3.1. Analysis of Surface roughness

Surface roughness is one of the measurable response parameter. The instrument is used to measure surface roughness is MITUTOTYO SURFTEST SJ-210. The specimen is attached to the probe of the instrument which traces the micro irregularities of the specimen surface. Based on the intensity of the roughness the instrument calculates the roughness and display the outcome on the screen. Table 4. Shows the level means of surface roughness. This gives that significance hierarchy of process parameters on surface roughness.

Table 4: SR Level Means

Level	T_{on}	T_{off}	IP	SV	WF
-1	2.0001	2.4209	2.3819	2.4773	2.4264
1	2	2.421	2.382	2.477	2.4264

3.2. Analysis of Material Removal Rate

Material Removal Rate is one of the measurable response parameter. MRR is the product of kerf width (m), thickness (m) of the specimen and cutting velocity (m/min). Kerf width can be measured by using tool makers microscope and cutting velocity is the ratio of length of the cut to time duration. Table 5. Shows the MRR. Level means gives the order of significance for process parameters on MRR.

Table5: MRR Level Means

Level	T_{on}	T_{off}	IP	SV	WF
-1	2.07081	4.64621	2.43512	3.90809	3.55904
1	4.95884	2.38345	4.59454	3.12156	3.47061

3.2. Development of Mathematical models

To develop the mathematical relation between the process & response parameters the experimental data were used to obtain from the Central Composite Face Centered Design and fit a second order model for Surface Roughness and MRR. The factor levels which are in coded form i.e. -1 to +1 were inserted into SPSS software to predict the model equation as shown equations (1) and (2).

$$SR=2.610 + 0.394\ T_{on} - 0.076\ SV + 0.086\ T_{on}T_{off} - 0.054\ IP\ Wf \text{ --(1)}$$

(R-square value 0.9279)

The R-square value of 0.9279 shows that 92.79% of the variability in Surface Roughness as shown in the equation (1). The mathematical model emphasizes that the SR decreases with an increase in the SV. The interaction of T_{on} with T_{off} and peak current with wire feed has most significant effect on Surface Roughness.

$$MRR = (4.550) + 1.468\ T_{on} - 1.207T_{off} + 1.403IP - 0.449SV - 0.762T_{on}T_{off} - 0.469T_{on}IP + 1.6028(T_{on})^2 - 2.193(IP)^2 \text{ --(2)}$$

(R-square value 0.963)

The R^2 value 0.963 implies that 96.3% of the variability in material removal rate is described by the model as given in the equation (2). The mathematical model emphasizes that the MRR increases with an increase in the T_{on} and IP. The MRR decreases with increases in T_{off} and servo voltage. The interaction of T_{on} with peak current and T_{off} has most significant effect on MRR.

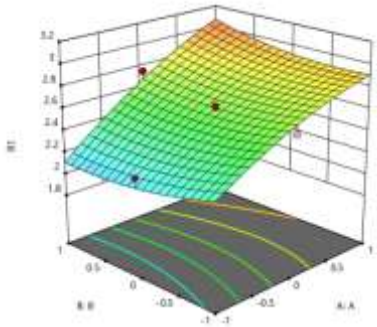

Fig .3(i): Effect of T_{off} and T_{on}on SR (T_{off} =0, SV=0, WF=0)

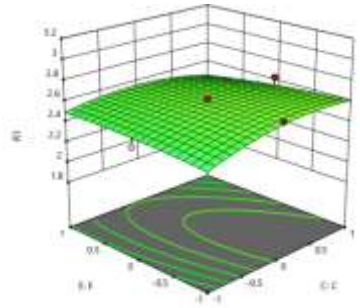

Fig.3(ii): Effect of IP and WF on SR (T_{on}=0,T_{off}=0,SV=0)

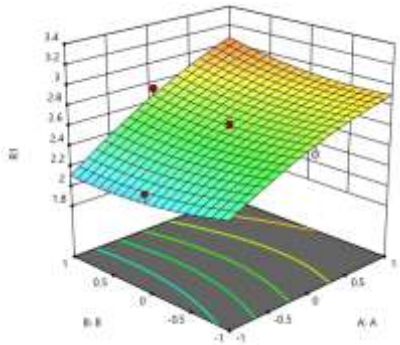

Fig.4 (i): Effect of T_{off} and T_{on} on MRR (IP=0, SV=0, WF=0)

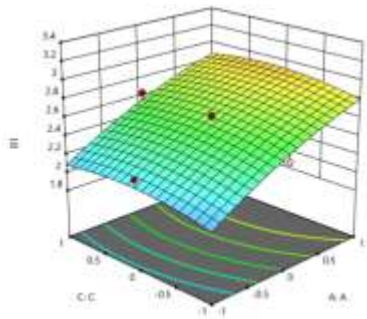

Fig.4 (ii): Effect of IP and T_{on} on MRR (T_{off} =0, SV=0, WF=0)

3.3. Effect of Process Parameters on Surface Roughness

The combined effect of two input parameters on the response is known as Interaction effects, out of five process parameters, two parameters were varied. The interaction effect of pulse on time and pulse off time on surface roughness shown in Fig 3(i) & 3(ii) that SR goes to a minimum value at lower value of pulse on time and base level of pulse off time, while it reaches maximum value where pulse on time and pulse off times are in higher level.

3.4. Effect of Process Parameters on Material Removal Rate

The interaction effect of pulse on time and pulse off time on MRR shown in Fig 4(i) & 4(ii) MRR goes to a maximum value at higher value of pulse on time and pulse off time, while it reaches minimum value where pulse on time is at lower level and pulse off time were at higher level. The interaction effect of pulse on time with peak current on MRR maximum value at higher level of pulse on time and base level of peak current , while it reaches minimum value at lower level of pulse on time and peak current.

4. Conclusions

The effect of servo voltage on surface roughness is more significant followed by pulse-off time peak current and, pulse on time.

The factor servo voltage had positive effect on surface roughness whereas pulse-on time had negative effect.

The quadratic effect of pulse-on time and peak current on MRR is also identified as significant.

The effect of pulse on time on MRR is more significant followed by peak current and servo voltage.

Modeling and Optimization had been performed for response parameters i.e., Surface Roughness and Material Removal Rate.

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