IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

OPTIMIZATION OF WIRE EDM PROCESS USING TAGUCHI METHODOLOGY

[1]S Pawan Kalyan, [2]Nagesh N, [3] K Ganesh,

[1]PG Student, Dept. Of Mechanical Engineering, Kuppam Engineering college, AP, India
[2]Associate Professor, Dept. Of Mechanical Engineering, Kuppam Engineering college, AP, India
[3]Associate Professor & HOD, Dept. Of Mechanical Engineering, Kuppam Engineering college, AP, India

Abstract: This paper presents the CNC Wire Cut Electrical Discharge Machining (WEDM) is a highly regarded material removal process utilized for creating components with complex shapes and profiles. An advanced form of traditional EDM, WEDM employs a continuously moving wire electrode—typically made of thin copper, brass, or tungsten with a diameter ranging from 0.05 to 0.3 mm—to initiate the sparking process, enabling the achievement of very small corner radii. This process erodes material ahead of the wire, thereby avoiding mechanical stresses during machining. The impact of various WEDM process parameters, such as discharge current, wire speed, wire tension, dielectric flow rate, pulse on time (TON), and pulse off time (TOFF), on the Material Removal Rate (MRR) of D2 (Cold Working Die Tool Steel) has been studied using the Taguchi Methodology. Experiments were designed using a standard Orthogonal Array known as the Taguchi method or OA design. The analysis of variance (ANOVA) results indicate that the proposed mathematical model reliably describes performance within the studied parameter limits. Additionally, the optimal set of process parameters for maximizing MRR has been identified.

***Index Terms* -** CNC Wire Cut Electrical Discharge Machining (WEDM), Material removal process, Tungsten, Mechanical stresses, Analysis of Variance (ANOVA), Optimal process parameters, Material Removal Rate (MRR), Dielectric flow rate.

Introduction

Electric discharge machining (EDM), also known as spark machining, spark eroding, burning, die sinking, or wire erosion, is a manufacturing process that shapes materials using electrical discharges (sparks). Material is removed from the workpiece through a series of rapidly recurring current discharges between two electrodes, which are separated by a dielectric liquid and subjected to an electric voltage. One electrode is referred to as the tool-electrode or simply the 'tool' or 'electrode,' while the other is called the workpiece-electrode or 'workpiece.' As the distance between the two electrodes decreases, the electric field intensity between them surpasses the dielectric strength at certain points, causing the dielectric to break down and allowing current to flow between the electrodes. This process is akin to the breakdown of a capacitor (see also breakdown voltage). Consequently, material is eroded from both electrodes. When the current flow ceases (or is stopped, depending on the generator type), fresh dielectric liquid is introduced into the inter-electrode space to carry away debris and restore the dielectric's insulating properties. This introduction of new dielectric liquid is commonly known as flushing. Additionally, after the current flow stops, the potential difference between the electrodes is reset to its original state, enabling a new dielectric breakdown to occur.

I. LITERATURE REVIEW

In this literature review chapter we are giving the ideas given by different scientists about the parameters which we need to analyze. In the recent years an extensive research has been carried out on W-EDM relating to improving the performance measures, optimizing the process variables, monitoring and controlling the sparking process, simplifying the electrode design and manufacture, improving the sparking efficiency by various researchers . Some of the work related to the present study given below.

Dongming Guo, et.al. In Micro Wire Electrical Discharge Machining (Micro-WEDM), the kerf width varies with different machining parameters, which will greatly influence the machining precision. In order to study the kerf variations in Micro-WEDM, the influence of kerf variation is analyzed and the experiment considering the kerf width and machining speed are performed on self- developed micro-WEDM under different machining parameters. With the reference of the experiment results, 32μm wide slot is machined with Φ30μm wire-tool on stainless steel workpiece.[1]

Yong Feng Guo. et,al. Advanced engineering ceramics are more and more widely employed in modern industries because of their excellent mechanical properties such as high hardness, high compressive strength, high chemical and abrasive resistance. This paper investigates the high speed wire electrical discharge machining (HS-WEDM) of Si3N4-based ceramics by assisting electrode method. The theory of assisting electrode method is introduced. The machining phenomena under different electrical parameters were studied and the optimized machine pulse width was got. The material removal mechanisms change with the increase in the power of single pulse.[2]

C.P.S. Prakash. et.al. Surface roughness is one of the most important parameters in machining, process parameters are to be configured to suite to required surface quality. A precise understanding of effect of controlling parameters on different workpiece of varied thickness is essential.[3]

M. Reza. Et.al. The main objective of the present research is to find the influence of process parameters on the state variables (i.e., surface roughness and material removal rate) in Wire Electrical Discharge Machining (WEDM) of Titanium Diboride (TiB2) nanocomposite ceramics. This work adopted an L32 orthogonal array based on Taguchi method for design of experiments. Statistically evaluating the obtained data is carried out by using the analysis of variance, signal to noise and artificial neural network techniques. Then, the effects of process parameters on the surface roughness and material removal rate are studied. Finally, the Multilayer Perceptron (MLP) neural network is used to model the WEDM of TiB2 nanocomposite ceramic. The obtained results have demonstrated very good modeling capacity of the proposed neural network. Furthermore, analyses have appropriately presented the influence of process parameters on state variables.[4]

Mahapatra S. S. Et.al. Wire electrical discharge machining (WEDM) is a specialized form of traditional electrical discharge machining, where the electrode is a continuously moving conducting wire. Metal removal in WEDM occurs through the complex erosion effect of electric sparks generated by a pulsating direct current power supply. These sparks are produced between two closely spaced electrodes immersed in a dielectric liquid. The dimensional accuracy and surface finish in WEDM are significantly influenced by process parameters such as discharge current, pulse duration, pulse frequency, wire speed, wire tension, and dielectric flow rate. An experimental study on a Robofil 100 WEDM machine was conducted to identify key control factors and their interactions affecting machining performance metrics like metal removal rate (MRR) and surface finish (SF) using the Taguchi method. The relationships between control factors and responses (MRR and SF) were established through non-linear regression analysis, resulting in a robust mathematical model. Additionally, a genetic algorithm, a popular evolutionary optimization approach, was applied to optimize the WEDM process for multiple objectives. The study illustrates that WEDM process parameters can be fine-tuned to enhance both metal removal rate and surface finish concurrently.[5]

II. OBJECTIVE OF THE WORK

The analysis phase is when the positive and negative information concerning the selected factors and levels is generated based on the previous two phases. The analysis phase is least important in terms of whether the experiment will successfully yield positive result.The major steps to complete an effective designed experiment are listed below. The planning phase includes steps 1 through 9, the conducting phase is step 10 and the analysis phase includes steps 11 and 12

1. State the problem or area of concern.
2. State the objectives of experiments.
3. Select the quality characteristics and measurement system.
4. Select the factors that may influence the selected quality characteristics.
5. Identify control and noise factor (Taguchi specific)

6. Select levels for the factors.
7. Select the appropriate Orthogonal array.
8. Select interactions that may influence the selected quality characteristics.
9. Assign the factors to OA and locate interactions
10. Conduct tests described by trials in OA.
11. Analyze and interpret results of the experimental trials.
12. Conduct confirmation experiment.

III. METHODOLOGY, PROBLEM IDENTIFICATION AND DESIGN PROPERTIES

A. Steps Involved In Methodology

1. **Define the Objective**: Identify the primary optimization goal, such as maximizing MRR or improving SF.
2. **Select Parameters:** Choose key WEDM process parameters (e.g., discharge current, pulse duration).
3. **Determine Levels:** Decide on the levels (high, medium, low) for each parameter.
4. **Design Experiments:** Use Taguchi Orthogonal Array to design the experiments.
5. **Conduct Experiments:** Perform the experiments as per the designed OA.
6. **Measure Metrics:** Record outcomes focusing on MRR and SF.
7. **ANOVA Analysis:** Conduct ANOVA to determine the significance of each parameter.
8. **Develop Model:** Use regression analysis to create a mathematical model.
9. **Optimize with GA:** Apply a genetic algorithm to find the optimal parameters.
10. **Validate Model:** Perform confirmation experiments to verify improvements.
11. **Analyze Results:** Compare confirmation results with predictions.
12. **Implement Findings:** Document and apply the optimized parameters in practice.

B. Problem Identification

In the optimization of Wire EDM processes using Taguchi Methodology, problem identification entails several crucial steps. Firstly, it involves defining clear objectives, such as maximizing material removal rates or improving surface finish quality. Secondly, it requires selecting key process parameters that significantly influence Wire EDM performance, such as discharge current, pulse duration, and wire tension. Thirdly, determining the appropriate range and levels for each parameter is essential to ensure comprehensive experimentation. Subsequently, designing experiments using Taguchi Orthogonal Arrays enables efficient exploration of parameter interactions while minimizing the number of trials. Furthermore, establishing measurement metrics, such as material removal rates, surface finish, and electrode wear, is vital for evaluating performance accurately. Once data is collected from experiments conducted on the Wire EDM machine, statistical analysis techniques like Analysis of Variance (ANOVA) help identify significant parameters and interactions. Additionally, developing mathematical models correlating process parameters to performance metrics facilitates optimization. This optimization often involves implementing algorithms like genetic algorithms to identify optimal parameter settings. Finally, validation through confirmation experiments ensures the practical applicability of the optimized parameters, leading to enhanced Wire EDM process performance.

C. MATERIAL Properties

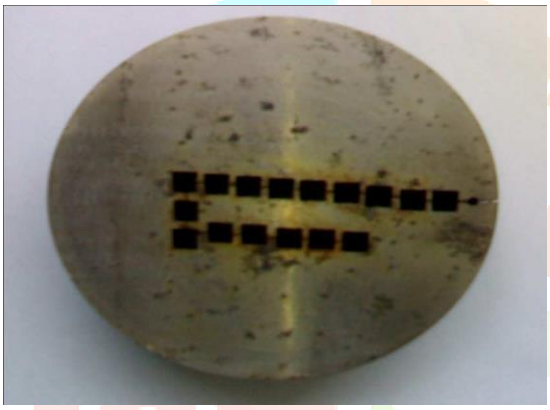
Material properties play a critical role in the optimization of Wire EDM processes using Taguchi Methodology. Identifying the appropriate material properties is essential for achieving desired machining outcomes such as surface finish, dimensional accuracy, and material removal rates. Factors such as material hardness, thermal conductivity, and melting point significantly influence the efficiency and effectiveness of the Wire EDM process. For instance, harder materials may require adjustments to process parameters such as discharge current and pulse duration to achieve optimal machining results without excessive tool wear. Likewise, materials with higher thermal conductivity may dissipate heat more efficiently during machining, affecting the rate of material removal and electrode wear. Moreover, understanding the material's melting point is crucial for preventing undesirable effects such as recast layers or material adherence to the workpiece. By considering these material properties during the experimental design phase and incorporating them into the optimization process, it is possible to tailor Wire EDM parameters effectively, leading to improved machining performance and overall process efficiency.

*D. **PEPARATION OF SPECIMEN FOR EXPERIMENT***

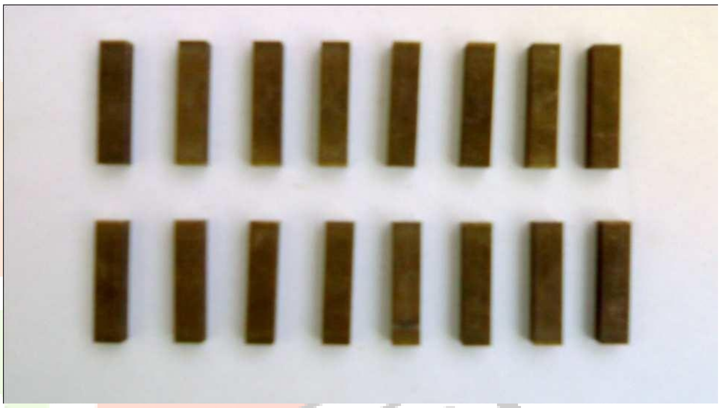
The material has undergone following processes before experimentation in WEDM :

1. ***STRESS-RELIEVING:***
   After rough machining the tool should be heated through to 1200*F (650*C), holding time 2 hours.Cool slowly to 930*F (500*C), then freely in air.
2. ***HARDENING:***
   Preheating temperature: 1110–1290*F (650–750*C). Austenitizing temperature: 1810–1920*F (990–1050*C)
3. ***SOFT ANNEALING***
   Protect the steel and heat through to 1560*F (850*C). Then cool in the furnace at 20*F (10*C) per hour to 1200*F (650*C), then freely in air.
4. ***TEMPERING***
   Choose the tempering temperature according to the hardness required by reference to the tempering graph. Temper twice with intermediate cooling to room temperature. Lowest tempering temperature 360*F (180*C). Holding time at temperature minimum 2 hours. High temperature tempering at greater than 950*F (510*C) is recommended if dimensional stability of tooling is critical, if significant wire EDM operations are planned in the hardened state, or if tools are to be coated.

PROCEDURE



I



II

Fig. Specimen after experiments/ square bars cut from the experiments

IV. RESULT AND DISCUSSION

ANOVA ANALYSIS RESULT OF TAGUCHI DESIGN WITH SOFTWARE

Taguchi Design

Taguchi Orthogonal Array Design L16(4**1 2**5)

Factors: 6

Runs: 16

Interactions AB

AC

Taguchi Analysis: MRR (mm/min) versus Discharge Cu, T on (micro , ... Linear Model Analysis: SN ratios versus Discharge Cu, T on (micro , ... Estimated Model Coefficients for SN ratios

Term			Coef	SE Coef	T	P
Constant			-5.49825	0.09052	-60.742	0.010
Discharg 3			-0.82948	0.15678	-5.291	0.119
Discharg 6			-0.22189	0.15678	-1.415	0.392
Discharg 9			-0.90639	0.15678	-5.781	0.109
T on (mi 110			-1.80380	0.09052	-19.928	0.032
T Off (m 45			0.46297	0.09052	5.115	0.123
Wire Spe 8			-0.54870	0.09052	-6.062	0.104
Wire Ten 6000			0.08612	0.09052	0.951	0.516
Dielectr 5			-0.89721	0.09052	-9.912	0.064
Discharg*T on (mi	3	110	-0.27581	0.15678	-1.759	0.329
Discharg*T on (mi	6	110	1.91726	0.15678	12.229	0.052
Discharg*T on (mi	9	110	0.18124	0.15678	1.156	0.454
Discharg*T Off (m	3	45	0.57767	0.15678	3.685	0.169
Discharg*T Off (m	6	45	-1.22101	0.15678	-7.788	0.081
Discharg*T Off (m	9	45	2.25103	0.15678	14.358	0.044

S = 0.3621, R-Sq = 99.9% , R-Sq(adj) = 98.8%

This table appears to present the results of a regression analysis performed on the Wire EDM process, specifically focusing on various parameters and their coefficients. Each row represents a different parameter or combination of parameters, with corresponding coefficient values, standard error of the coefficients, t-values, and p-values.

1. **Constant:** The intercept term in the regression equation. A negative coefficient indicates that when all other factors are zero, the response variable is expected to decrease.
2. **Discharge (3, 6, 9):** Represents different levels of discharge current. Negative coefficients suggest that increasing the discharge current leads to a decrease in the response variable, although not all coefficients are statistically significant.
3. **T on (110) and T off (45):** Refers to the pulse on time and pulse off time, respectively. Negative coefficients for T on suggest that longer pulse on times decrease the response variable, while positive coefficients for T off indicate that longer pulse off times increase the response variable.
4. **Wire Speed (8) and Wire Tension (6000):** These coefficients represent the effect of wire speed and wire tension on the response variable. Negative coefficients for wire speed suggest that increasing wire speed decreases the response variable, while the positive coefficient for wire tension indicates that higher wire tension increases the response variable.
5. **Dielectric (5):** Represents the effect of dielectric flow rate on the response variable. A negative coefficient suggests that increasing dielectric flow rate decreases the response variable.
6. **Interaction Terms:** These coefficients represent the combined effect of two or more parameters on the response variable. Positive coefficients indicate a synergistic effect, while negative coefficients suggest an antagonistic effect.

Overall, the interpretation of these coefficients helps understand how changes in each parameter or combination of parameters impact the Wire EDM process's performance, aiding in its optimization.

ANALYSIS OF VARIANCE FOR SN RATIOS

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Discharge Current (Amp)	3	21.566	21.5665	7.1888	54.84	0.099
T on (micro sec)	1	52.059	52.0591	52.0591	397.11	0.032
T Off (micro sec)	1	3.429	3.4295	3.4295	26.16	0.123
Wire Speed (m/min)	1	4.817	4.8172	4.8172	36.75	0.104
Wire Tension (g)	1	0.119	0.1187	0.1187	0.91	0.516
Dielectric Flow Rate (bar)	1	12.880	12.8798	12.8798	98.25	0.064
Discharge Current (Amp)* T on (micro sec)	3	28.428	28.4281	9.4760	72.28	0.086
Discharge Current (Amp)* T Off (micro sec)	3	37.905	37.9055	12.6352	96.38	0.075
Residual Error	1	0.131	0.1311	0.1311		
Total	15	161.335				

CONFIRMATION EXPERIMENT

The optimal combination of machining parameters has been determined in the previous analysis. Once the optimum condition is determined, it is usually a good practice to run a confirmation experiment. It is , however possible to estimate performance at the optimum condition from the result the experiments conducted at non – optimum condition. It should be noted that the optimum condition may not necessarily be among the many experiments already carried out, as the OA represents only a small of all the possibilities. So here we perform confirmation experiment by mathematically modelling.

Modified Array (one four level factor) : L16 (4*1x 2*5) Layout of array :

TABLE 1 MODIFIED ARRAY L16 (4*1*2*5) LAYOUT OF ARRAY

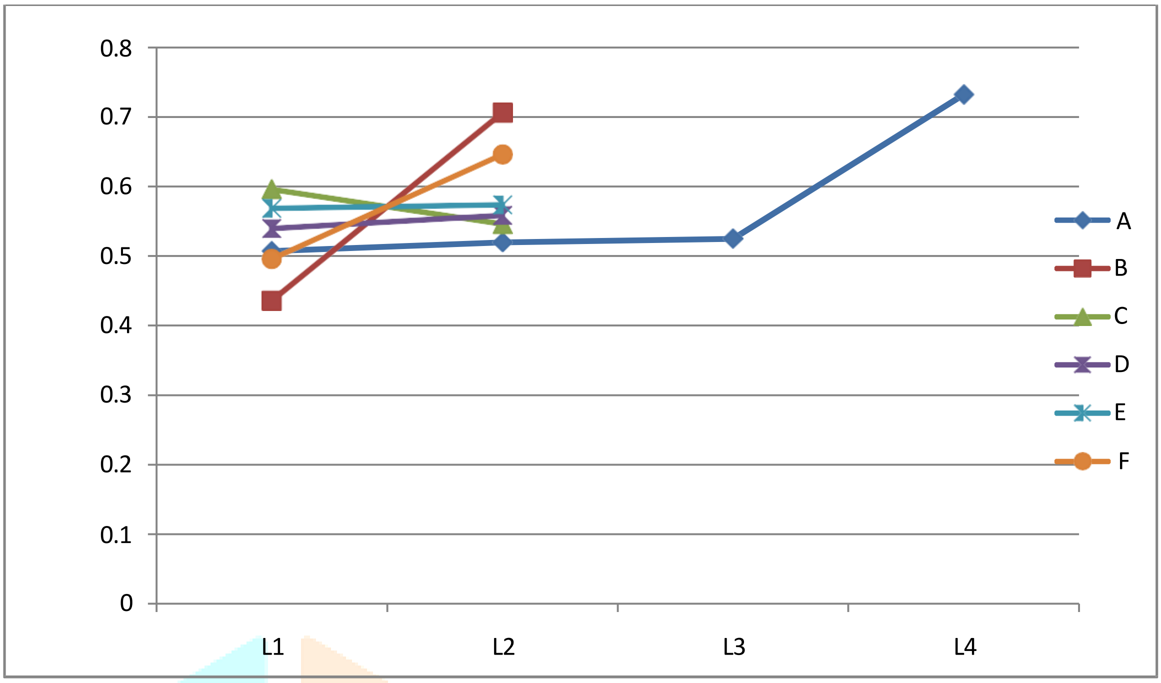
FACTORS/RUNS	A (1)	B (2)	AxB (3)	C (6)	AxC (7)	D (10)	E (11)	F (12)	Y
1	1	1	1	1	1	1	1	1	0.37
2	1	1	1	2	2	2	2	2	0.39
3	1	2	2	1	1	2	2	2	0.80
4	1	2	2	2	2	1	1	1	0.47
5	2	1	1	1	1	1	1	2	0.50
6	2	1	1	2	2	2	2	1	0.55
7	2	2	2	1	2	2	2	1	0.45
8	2	2	2	2	2	1	1	2	0.58
9	3	1	2	1	1	1	2	1	0.45
10	3	1	2	2	2	2	1	2	0.35
11	3	2	1	1	1	2	1	2	0.95
12	3	2	1	2	2	1	2	1	0.35
13	4	1	2	1	1	1	2	2	0.40
14	4	1	2	2	1	2	1	1	0.48
15	4	2	1	1	2	2	1	1	0.85
16	4	2	1	2	1	1	2	2	1.20
								TOTAL	9.14

Main effect table of design

Table 2 MAIN EFFECTS OF DESIGN

SN	Col	Factor	L1	L2	L3	L4	Δ
1	1	A	0.50750	0.52000	0.52500	0.73250	0.22500
2	2	B	0.43625	0.70626	-	-	0.27007
3	3	A×B	0.64500	0.49750	-	-	-0.1475
4	6	C	0.59625	0.54625	-	-	-0.0500
5	7	A×C	0.56250	0.58000	-	-	0.01750
6	10	D	0.54000	0.55875	-	-	0.01875
7	11	E	0.56875	0.57375	-	-	0.00050
8	12	F	0.49625	0.64625	-	-	0.14625

GRAPH PLOT FOR MAIN EFFECTS



Form the graph of main effect if we Ignoring interaction effect and assuming the "Larger is better" character is desired the optimum condition become **A_4 B_2 C_1 D_2 E_2 F_2**

Interaction effect are always mixed with the main effect of the factors assigned to the column designated for interaction. He relative significance of the interaction effects is obtained by ANOVA just as are the relative significane of factor effects.To determine whether two factor A , B and A ,C interact, following calculations are performed.

Level totals and their average for A & B :

A1B1' = (0.37 + 0.39)/ 2 = 0.380
A1B2' = (0.80 + 0.47)/ 2 = 0.635
A2B1' = (0.50 + 0.55)/ 2 = 0.525
A2B2' = (0.45 + 0.58)/ 2 = 0.515
A3B1' = (0.45 + 0.35)/ 2 = 0.400
A3B2' = (0.95 + 0.35)/ 2 = 0.650
A4B1' = (0.40 + 0.48)/ 2 = 0.440
A4B2' = (0.85 + 1.20)/ 2 = 1.025

Level total and their average for A & C :

A1C1' = (0.37 + 0.80)/ 2 = 0.585
A1C2' = (0.39 + 0.47)/ 2 = 0.430
A2C1' = (0.50 + 0.45)/ 2 = 0.475
A2C2' = (0.55 + 0.58)/ 2 = 0.565
A3C1' = (0.45 + 0.95)/ 2 = 0.700
A3C2' = (0.35 + 0.35)/ 2 = 0.350
A4C1' = (0.40 + 0.85)/ 2 = 0.625
A4C2' = (0.48 + 1.20)/ 2 = 0.840

ANNOVATABLE

TABLE 3 : ANNOVA TABLE OF EXPERIMENTAL PERCENTAGE CONTRIBUSTION OF EACH CONTROL factor for optimization

SOF	f (degree of freedom)	Sum of squared	V (variance mean sum)	F (variance ratio)	S' (Pure sum of squared)	Percent contribution
A	3	0.13935	0.04645	6.519298	0.117975	12.78
B	1	0.29160	0.2916	40.926315	0.284475	30.82
AxB	3	0.17825	0.059417	8.339649	0.156675	16.996
C	1	0.010025	0.10025	14.070175	0.0029	0.314
AxC	3	0.190850	0.063657	8.9287017	0.169475	18.36
D	1	0.01565	0.01565	2.196491	0.008525	0.92
E	1	0.000125	0.000125	0.0175438	-0.0070	-0.758
F	1	0.090025	0.090025	12.635087	0.0829	8.98
e	1	0.007125	0.007125	1.00	0.106875	11.579
Total	15	0.92300				100

V. CONCLUSION

Following are the conclusions drawn from the work done in this investigation:

1. MRR increases with an increase of Discharge current
2. MRR increases with an increase of pulse on time.
3. MRR decrease with an increase of pulse off time.
4. MRR increases with an increase of Wire speed.
5. MRR slightly increases with an increase of Wire tension.
6. MRR increases with an increase of Dielectric flow rate.
7. MRRopt obtained from software analysis is equal to MRRopt obtained from mathematically modeling which is equal to Control factor A4B2C1D2E2F2
8. In WEDM Process, use of control factor A4B2C2D2E2F2 as high Discharge current (12 amp), pulse on time (120 micro sec), Pulse off time (55 micro sec), Wire speed (9 m/min), Wire tension (12000 g), and Dielectric flow rate (10 bar) are recommended to obtain optimum MRR for the specific test range in a D2 material. The optimal value of MRR is 1.24125 mm/ min
9. Control factor sequence A4B2C2D2E2F2 results higher value of resultant Material removal rate for the specific test range.

REFERENCES

1. Designing experiments for robust-optimization problems: the V s -optimality criterion (Citations: 2) Hilla Ginsburg, Irad Ben-Gal , vol. 128, no. 4, 2006.
2. R. Ramakrishnan • L. Karunamoorthy, Multi response Optimization of WEDM processesusing robust design of experiment, Int J Adv Manuf Technol (2006) 29: 105–112.
3. S. S. Mahapatra & Amar Patnaik, Optimization of wire electrical discharge machining (WEDM) process parameters using Taguchi method, Int J Adv Manuf Technol(2006).
4. A. Manna • B. Bhattacharyya, Taguchi and Gauss elimination method: A dual response approach for parametric optimization of CNC wire cut EDM of PRAl SiCMMC, Int J Adv Manuf Technol (2006) 28: 67–75.
5. A.B. Puri • B. Bhattacharyya, Modeling and analysis of white layer depth in a wire cut EDM process through response surface methodology, Int J Adv Manuf Technol (2005) 25: 301–307.
6. K.H. Ho, S.T. Newman, . Rahimifard, R.D. Allen, State of the art in wire electrical discharge machining (WEDM), International Journal of Machine Tools & Manufacture 44 (2004) 1247–1259.
7. Nihat Tosun , Can Cogun, A study on kerf and material removal rate in wire electrical discharge machining based on Taguchi method, Journal of Materials Processing Technology 152 (2004) 316–322.