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OPTIMIZATION OF WIRE ELECTRIC DISCHARGE MACHINING PARAMETERS ON Al 6061

Jerin Johnson [1], Bibin K.T [2], Anoop Sankar [3]

[1] PG scholar, Mechanical Engineering, Mar Baselios Institute of Technology and Science, India
[2] Asst. Prof, Mechanical Engineering, Mar Baselios Institute of Technology and Science, India
[3] Asst. Prof, Mechanical Engineering, Mar Baselios Institute of Technology and Science, India

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ABSTRACT

Optimization is one of the techniques used in manufacturing sectors to arrive for the best manufacturing conditions, and essential need for industries towards manufacturing of quality products at low cost . This paper aims to investigate the optimal set of process parameters such as current , pulse ON time, pulse OFF time, feed rate, wire tension in wire electrical discharge machining (WEDM) process to identify the variations in performance characteristics surface roughness value on the work material for machining Aluminium 6061 using brass electrode. Based on the experiment conducted on L18 orthogonal array, analysis has been carried out using Taguchi method. Response tables and graphs were used to find the optimal levels of parameters in WEDM process. The confirmation experiments were carried out to validate the optimal results. Thus, the machining parameters for WEDM were optimized for achieving lower surface roughness value.

KEYWORDS: WEDM, surface roughness, Taguchi method ANOVA.

I. INTRODUCTION

WEDM process is one of the most widely used nontraditional machining processes in current manufacturing .It involves the removal of metal by discharging an electrical current from a pulsating DC power supply across a thin inter-electrode gap between the tool and the work piece (Fig.1).. It is most commonly used for machining hard and difficult to machine materials with very close tolerances. Generally, WEDM is perceived to be an extremely actuate process and there are various reasons for this perception. Firstly, in WEDM, no direct contact takes place between the cutting tool (electrode) and the work piece; as a result, the adverse effects such as mechanical stresses, chatter, and vibration normally present in traditional machining are eliminated. Secondly, the wire used as a cutting tool has high mechanical properties and small diameter 0.076 to 0.30 mm that produces very fine, precise, clean cuts. The wire should have sufficient tensile strength and fracture toughness as well as high electrical conductivity. In wire EDM, the conductive materials are machined with a series of electrical discharges that are produced between an accurately positioned moving wire (the electrode) and the work piece. High frequency pulses of alternating or direct current is discharged from the wire to the work piece with a very small spark gap through an insulated dielectric fluid (water). Many sparks can be observed at one time. This is because actual discharges can occur more than one hundred thousand times per second, with discharge sparks lasting in the range of 1/1,000,000 of a second or less.

The volume of metal removed during this short period of spark discharge depends on the desired cutting speed and the surface finish required. The heat of each electrical spark, estimated at around 15,000° to 21,000° Fahrenheit, erodes away a tiny bit of material that is vaporized and melted from the work piece. (Some of the wire material is also eroded away) These particles (chips) are flushed away from the cut with a stream of de-ionized water through the top and bottom flushing nozzles. The water also prevents heat build-up in the work piece. Without this cooling, thermal expansion of the part would affect size and

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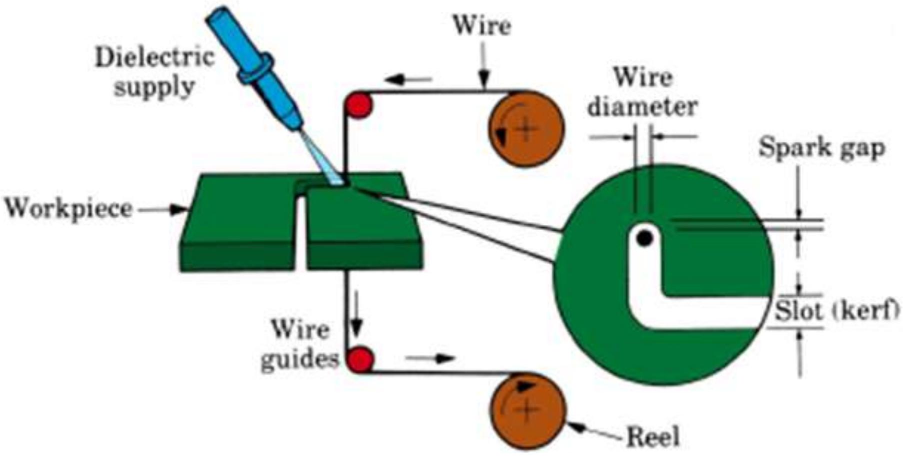

Fig.1. WEDM processes schematic representation

positional accuracy. Keep in mind that it is the ON and OFF time of the spark that is repeated over and over that removes material, not just the flow of electric current. Finally, in WEDM, the movements of the work piece during cutting are controlled by a highly accurate CNC system (with positioning accuracy up to ±0.5 μm) as a result, the effects of positioning errors present in conventional machining are significantly diminished. Surface roughness is a qualitative measure of a product, which influences the manufacturing cost to a great extent. The term surface texture refers to the fine irregularities (peaks and valleys) produced on a surface by machining process

II. LITERATURE REVIEW

Amit Chauhan&Singh Bhatia [3] have studied the effects of various WEDM process parameters such as pulse on time, pulse off time, servo voltage, peak current, dielectric flow rate, wire speed, wire tension. The main objective of present work is to investigate of the influence of input WEDM parameters on machining characteristics like cutting speed and surface roughness and the effects of various WEDM process parameters. From the study we observe that Higher the pulse-on time, higher will be the energy applied there by generating more amount of heat energy during this period. Material removal rate and wire wear rate increase with increase in pulse on time where as surface finish will decrease.

Bibin K.T.et al.[2] studied about the optimization of Surface Roughness during the Wire Electrical Discharge Machining on AISI 202 Using ABC Algorithm. The experiments were planned according to Taguchi's L18 orthogonal array and experimental models were developed. The important process parameters identified for the present study were pulse on time, peak current, pulse off time, wire feed, wire tension, dielectric flushing pressure, servo feed and gap voltage. Analysis of variance test has also been carried out to check the adequacy of the developed models and to identify the level of significance of each process parameters. In addition to the developed models, ABC optimization has been performed to identify the optimum parameter combination for minimum surface roughness

Y. Chandra Sekhar Reddy et.al [4], have presented a multi-objective optimization of Wire Electrical Discharge Machining parameters of SS 317 was performed using grey relational analysis which converts the multi responses into a single grade. Taguchi based L9 orthogonal array is used for plan of experiments. The objectives chosen are the Maximum Material removal rate and Minimum surface roughness using process parameters viz., pulse on time, pulse off time and Peak Current. The optimal machining parameters results better quality and ANOVA.
Kishore G C et.al [5]conducted experiments using Taguchi design of experiment inorder to optimize parameters such as voltage, Pulse OFF, Pulse ON, current, bed speed & significant factors which maximize MRR and minimize surface roughness are found out.

V. Devkumar et.al (2015**)** have presented a work deals with the mathematical modeling and analysis of machining response such as the surface roughness and tool wear in the turning of aluminum alloy 6061. There are several process parameters namely spindle speed, depth of cut and feed rate used to determine the quality of

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surface roughness. Experiments are conducted as per central composite face centered design. Among the following process parameter the spindle speed, depth of cut and feed rate for the purpose of analysis. Response surface methodology is utilized to develop an effective mathematical model to predict optimum level. A comparison study is made for tabulated values and experimental values for surface roughness by using analysis of variance. The model found statistically fit for 95% confidence level.

Rao et.al (2009) developed a hybrid model and optimized surface roughness in electric discharge machining of Ti6Al4V, HE15, 15CDV6 and M-250 using artificial neural networks and genetic algorithm. And from the sensitivity analysis he concluded that type of material is the most significant parameter affecting the performance measure.

Siva Prasad et.al [1] optimized MRR, surface roughness and kerf width in WEDM using response surface methodology. Further it is observed that as and when the wire tension and servo voltage increases the surface roughness decreases and it improves the quality of machined surface.

III. EXPERIMENTAL WORK

Workpiece Material

Al 6061 is the material selected because it it the most significant and widely used material in the industries now a days. Al6061 is an easily available metal which is prepared by the precipitation of hardened aluminium alloy, containing magnesium and silicon as its major alloying elements. Originally called Alloy 61S , it was developed in 1935.It has good mechanical properties, exhibits good weldability, and is very commonly extruded (second in popularity only to 6063). It is one of the most common alloys of aluminium for general purpose use.

Al6061 is commonly used for the following:

- Construction of aircraft structures,
- Yacht construction, including small utility boats.
- Automotive parts, such as the chassis of Audi A8.
- Some tactical flashlights
- Aluminium cans for the packaging of food and beverages.

Table 1.material composition of al 6061

Components	Al	Mg	Si	Fe	Cu	Zn	Cr	Ti	Other elements
Wt.%	98.5-98.56	0.8-1.2	0.4-0.8	0.7	0.15-0.4	0.25	0.04-0.35	0.15	0.05-.15

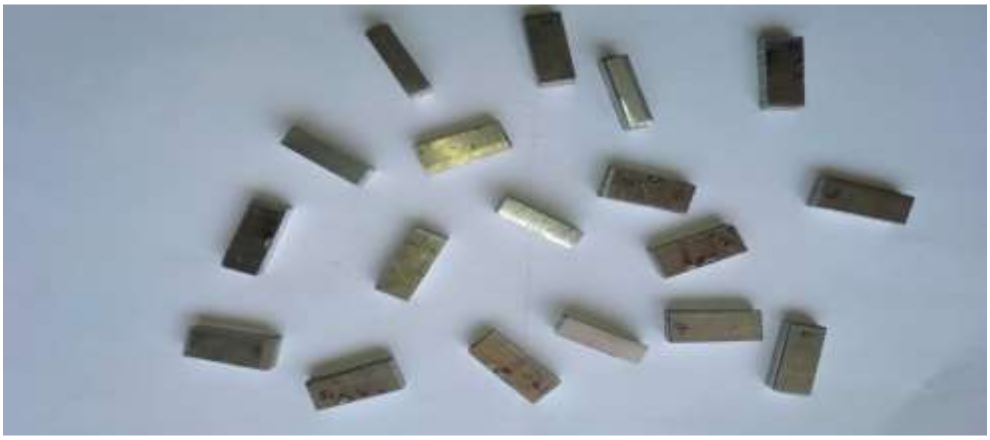

Fig2. Work piece in whichthe machining is done

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Wedm Parameter And Range

In this research, 4 parameters are maintained in 3 levels and 1 in 2 level. The level settings of the factors were found out using 'one factor at a time approach'. Factors are shown in table 2 given below.

Table 2. paramters and its levels

Sl no.	Factor	Unit	symbols	Level1	Level 2	Level 3
1	Current	Ampere	A	11	12	-
2	Pulse ON time	Micro seconds	B	105	110	115
3	Pulse OFF time	Micro seconds	C	52	55	58
4	Wire feed rate	mm/min	D	5	10	15
5	Wire tension	newton	E	5	10	15

Experimental design based on L18 orthogonal array is designed by MINITAB 15.0. Experiments are planned according to Taguchi's L18 orthogonal array. L18 orthogonal array conducts 18 experimental runs. The experiments were carried out on a wire-cut EDM machine (ELECTRONICA ULTRACUT S1 WEDM) of KELTRON.

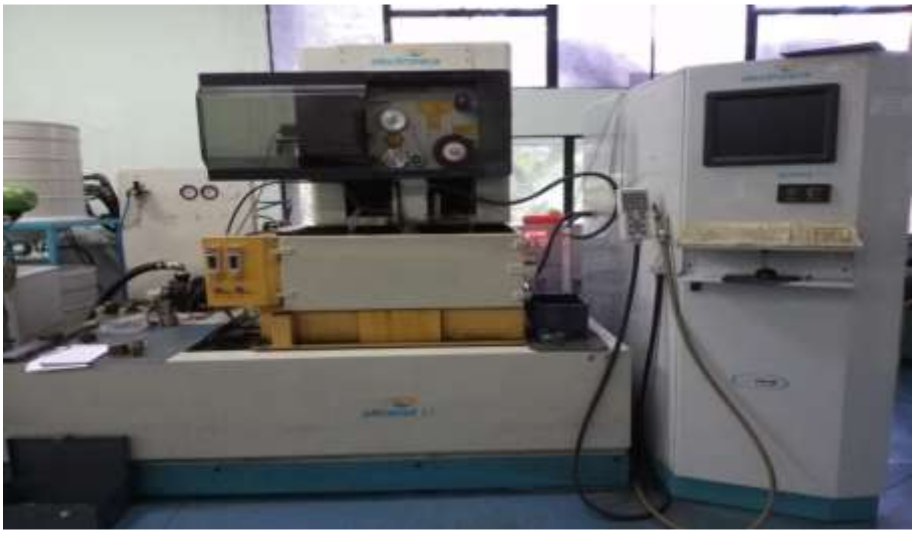

Fig3. Electronica Ultracut S1 Wedm

Copper was the first electrode material used in wire EDM. Brass was the first material which replaced copper when the performance became its main objective. Generally brass EDM wire is alloyed with 63-65% copper (Cu) and 35-37% zinc (Zn). Zinc addition provides significantly higher tensile strength, higher vapour pressure rating and a lower melting point. Thus brass wire quickly became the right one for the general purpose WEDM machines. In this experiment, brass wire of 0.25mm is used. .Surface roughness values were recorded in µm.

Fig4. Surface Roughness Tester

A portable surface roughness tester with a LCD.Table :3 shows the corresponding designof expriment (18 different combinations) and the corrresponding recorded surface roughness value.

Table 3:Design of experiment and recorded Ra value

Exp no	CURRENT	PULSE ON	PULSE OFF	FEED RATE	WIRE TENSION	Ra
1	11	105	52	5	5	2.83
2	11	105	55	10	10	2.87
3	11	105	58	15	15	2.85
4	11	110	52	5	10	3.31
5	11	110	55	10	15	3.29
6	11	110	58	15	5	3.51
7	11	115	52	10	5	3.86
8	11	115	55	15	10	3.81
9	11	115	58	5	15	4.02
10	12	105	52	15	15	2.98
11	12	105	55	5	5	3.12
12	12	105	58	10	10	3.08
13	12	110	52	10	15	3.59
14	12	110	55	15	5	3.46
15	12	110	58	5	10	3.53
16	12	115	52	15	10	3.78
17	12	115	55	5	15	4.13
18	12	115	58	10	5	4.04

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IV. RESULT AND DISCUSSIONS

The WEDM experiments were conducted by using the parametric approach of the Taguchi's method. The effects of individual WEDM process parameters, on the surface roughness. The average value and S/N ratio of the response characteristics for each variable at different levels were calculated from experimental data.

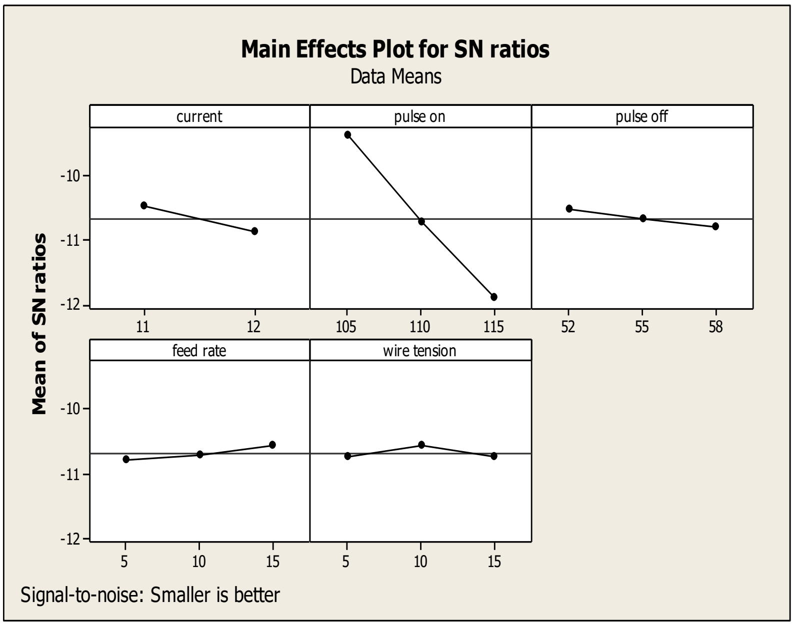

Fig5. Main effects plot for SN Ratio

From the fig 5. Main effects plots for SN ration we conider the signal to noise ratio as smaller the best.after the corresponding tabulation analysisthe corresponding plot is obtained from minitab 15. From the graph we can identify the optimal combination, which is A1,B1,C1,D3,E2

A_1 corresponds to Current = 11

B_1 corresponds to Pulse ON time = 105µsec

C_1 corresponds to Pulse OFF time = 52 µsec

D_3 corresponds to Feed Rate = 15 mm/min

E_2corresponds to Wire Tension=10 N

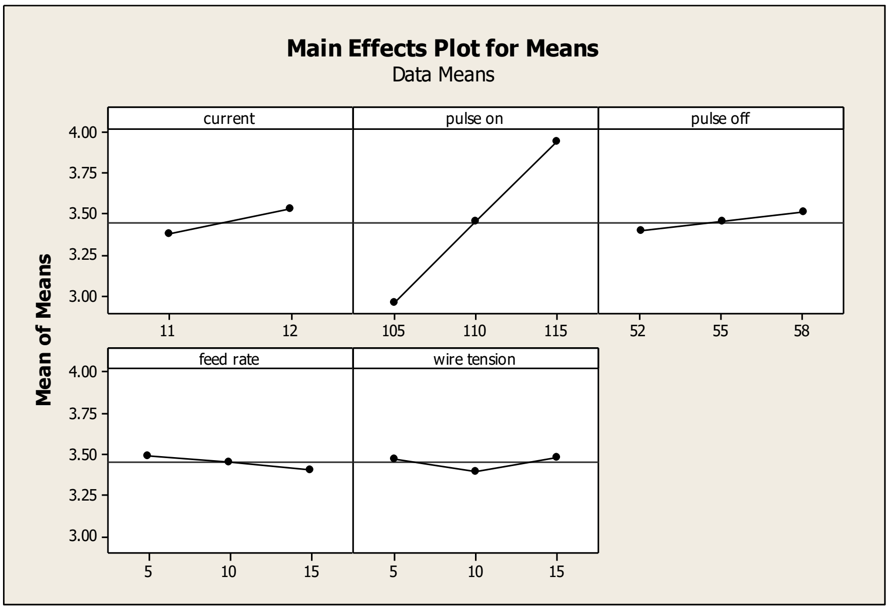

Fig6. Main effects plot for means

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Main effects plot is used to examine differences between level means for one or more factors. There is a main effect when different levels of a factor affect the response differently. A main effects plot graphs the response mean for each factor level connected by a line. The main effects plot for surface roughness is shown in the fig 6.
In Taguchi designs, a measure of robustness used to identify control factors that reduce variability in a product or process by minimizing the effects of uncontrollable factors (noise factors). Control factors are those design and process parameters that can be controlled. Noise factors cannot be controlled during production or product use, but can be controlled during experimentation. In a Taguchi designed experiment, you manipulate noise factors to force variability to occur and from the results, identify optimal control factor settings that make the process or product robust, or resistant to variation from the noise factors. Higher values of the signal-to-noise ratio (S/N) identify control factor settings that minimize the effects of the noise factors.
The S/N ratios have been calculated to identify the major contributing factors on Surface Roughness. Smaller the better" approach is been done for analysis of Ra which is a logarithamic function "based on mean square deviation (MSD), given by eqt 1.

$$(S/N)_{LB} = -10 log \frac{1}{n} \sum_{i=1}^{n} y_i^2 \quad (1)$$

Table4: ANOVA for Ra based on S/N data

Source	DF	Seq SS	Adj SS	Adj MS	F	P	Percentage
Current	1	0.10276	0.10276	0.10276	13.05	0.007	3.247469
Pulse on	2	2.91068	2.91068	1.45534	184.77	0	91.98467
Pulse off	2	0.03854	0.03854	0.01927	2.45	0.148	1.217959
Feed rate	2	0.02568	0.02568	0.01284	1.63	0.255	0.811551
Wire tension	2	0.02364	0.02364	0.01182	1.5	0.28	0.747082
Error	8	0.06301	0.06301	0.00788			1.991271
Total	17	3.16431					100

From the ANOVA for SN ratio parameter B(Pulse ON) was found to be the most significant parameter affecting the Surface Roughness with a contribution of 92.00 % . The least significant parameter is parameter E (Wire Tension) with a contribution of 0.74 % on Ra.

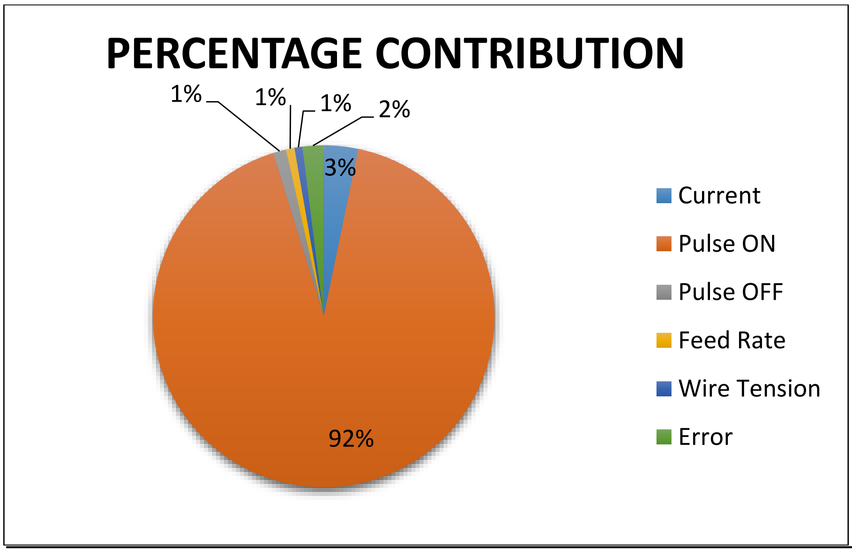

Fig7 . S/N data ANOVA based on Pie chart

The response table for Signal to Noise ratio also confirms the same by ranking the 5 parameters according to their contribution on Ra.From the response table we have obtained the rank for the given input parameters.

Table 5: ANOVA for Ra based on S/N data

Level	Current	Pulse on	Pulse off	Feed rate	Wire tension
1	-10.486	-9.405	-10.55	-10.779	-10.744
2	-10.886	-10.748	-10.684	-10.706	-10.575
3		-11.905	-10.824	-10.573	-10.738
Delta	0.4	2.5	0.274	0.206	0.169
Rank	2	1	3	4	5

Mathematical relationship between the control factors and the performance measure has been established. Regression analysis was used to generate the mathematical model by using MINITAB 15.0 software.
The regression equation in terms of coded factors is given by eqt 2.

Ra = - 10.1 + 0.151 current + 0.0985 pulse on + 0.0189 pulse off- 0.00917 feed rate + 0.00067 wire tension (2)

From the sn ratiographs plots we foundout the best parameter vaues which results in better Ra value so by substituting the corresponding values in equation 2 will give the expected best Ra value

Ra = - 10.1 + (0.151×11)+ (0.0985 ×105) + (0.0189×52) - (0.00917 ×15)+ (0.00067×10)

Ra = 2.755 µm.

So the predicted value for Ra is 2.755 µm. Now by using the above obtained combination of paramaters (A1,B1,C1,D3,E2) we conducted a confirmatory experiment and the corresponding Ra value is observed.

Table 6: confirmatory experiment values

Paramter	Predicted	Experimental
Ra	2.755 µm	2.89 µm

V. CONCLUSIONS AND FUTURE SCOPE

In the presented work, experiments are carried out for surface roughness with variables as wire tension pulse on time, pulse off time, feed rate and current. Based on the experimental analysis carried out by conducting wire electric discharge machining on Al 6061 alloy, the following points were concluded:

- Most significant parameter affecting Ra is Pulse On,then followed by the, Peak Current,Pulse Off,Feed Rate,Wire Tension in the respective order.
- The least affecting paramter is the wire tension.
- A slight change in the pulse on time will also affect the Ra value.
- Optimal combination using S/N ratio was found to be Peak current 11A, Pulse on time 105µs, Pulse off time 52µs, Wire feed 15m/min, Wire tension 10 N
- Wire breakage is a common phenomenon due to the incorrect setting of peak current and pulse on time.
- Generated mathematical model have a high degree of compactability with an average error of 1.99%.

WEDM plays a important role machining of electrically conducting material in today's world where accuracy and precision are important. The mathematical model can be developed with different work piece and electrode materials for WEDM processes While machining with WEDM, there are lot of parameters involved in the process influencing its efficiency. These processes with multiple objective can be effectively optimized with grey based taguchi design and can be verified using artificial neural network model and thermo physical model in ANSYS.Instead of copper electrode we can try other electrode for doing the cutting operation.We can also different combination of parameters instead of this specific combination.

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