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"Experimental Investigations and Optimization of Wire Electro Discharge Machining of SS410 Material using Taguchi Methodology"

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Abstract- *In this paper, the cutting of SS410 Steel material using Wire electro discharge machining (WEDM) with a copper wire by using Taguchi methodology has been reported. The Taguchi method is used to formulate the experimental layout, to analyze the effect of each parameter on the machining characteristics, and to predict the optimal choice for each WEDM parameter such as Pulse on time, Pulse off time, Current. It is found that these parameters have a significant influence on machining characteristic Surface Roughness (Ra). The analysis using Taguchi method reveals that, in general the pulse on time and current significantly affects the SR*

Key Words: WEDM,Taguchi, ANOVA, SR, S/N Ratio, L-9 orthogonal array, Optimization.

1.INTRODUCTION- Electrical Discharge Machining (EDM) is a controlled metal-removal process that is used to remove metal by means of electric spark erosion. In this process an electric spark is used as the cutting tool to cut (erode) the work piece to produce the finished part to the desired shape. The metal-removal process is performed by applying a pulsating (ON/OFF) electrical charge of high-frequency current through the electrode to the work piece. This removes (erodes) very tiny pieces of metal from the work piece at a controlled rate.Electric Discharge Machining is also called as Spark Erosion Machining, Die Sinking, Spark-over-initiated Discharge Machining, Electro-erosion Machining, Wire Erosion or simply Spark Machining.

This wire, which varies from 0.02 mm to 0.03 mm in diameter, is fed continuously into the machining area under the water beam. In this process only through machining is possible where a small hole is drilled in the work piece and the same mounted on the work table. The feed wire is passed through this hole and held tight between the feeding and pickup units so that it runs in a straight line in the machining area by following the programmed contour. Thus the machining is carried out rest of the process is almost similar to EDM .

Wire electrical discharge machining (WEDM) is a widely accepted non-traditional material removal process used to manufacture components with intricate shapes and profiles. It is considered as a unique adaptation of the conventional EDM process, which uses an electrode to initialize the sparking process. However, WEDM utilizes a continuously travelling wire electrode made of thin copper of diameter 0.05–0.3 mm, which is capable of achieving very small corner radii. The wire is kept in tension using a mechanical tensioning device reducing the tendency of producing inaccurate parts. 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 [1].

Wire electrical Discharge Machining (WEDM) is defined as the non-traditional process of material removal of electrically conductive materials to produce the part with intricate shapes and profiles. This process is done by using a series of spark erosion process. These spark erosion is produced between the work piece and a wire electrode which is separated by a dielectric fluid. The sparks produced heating and melting work piece surface to form debris then it is flushed away by dielectric pressure. During the cutting process there is no direct contact between the work piece and the wire electrode.

To get the perfect result of the machining process by using the WEDM we need to find the correct parameter setting. Until now, there is no perfect parameter setting for any type of materials. So, it is important to find the best parameter setting before start the machining process in order to achieve the maximum result in its material removal rate (MRR) and surface roughness (Ra).

EDM spark erosion is the same as having an electrical short that burns a small hole in a piece of metal it contacts. With the EDM process both the work piece material and the electrode material must be conductors of electricity. The EDM process can be used in two different ways:

1. A pre-shaped or formed electrode (tool), usually made from graphite or copper, is shaped to the form of the cavity it is to reproduce. The formed electrode is fed vertically down and the reverse shape of the electrode is eroded (burned) into the solid workpiece.

2. A continuous-travelling vertical-wire electrode, the diameter of a small needle or less, is controlled by the computer to follow a programmed path

2.EXPERIMENTATION-

Fig-WEDM Machine

The experiments were performed on Charmilles Robofil 300 Series Wire Electrical Discharge Machine (WEDM) manufactured by Charmilles Technology, Switzerland which provides full flexibility to the operator in choosing parameter values with in a wide range. A brass wire is used as the tool material. De-ionized water is used as the dielectric.

The work piece / part / job is clamped on machine table with the help of Straight Clamp & Allen screws, job zero setting is carried with the help of lever type dial indicator on upper edge right side corner for X, Y &Z direction taking rear side surface, right side surface and top surface of job as reference respectively. Machine parameters are set as per explained in Design of Experiments plan section 3.6 keeping fixed parameters as it is & variable parameters i.e. Ton: Pulse on-time (μs), T off: Pulse off-time (μs), Current I variable at different levels. factors like SR

3.SELECTION OF LEVELS

The basic criteria for selection of levels of factors for Electrical Discharge Machining of various mould steels is selected from technology guidelines of machine

Pulse ON Time: 16, 18, 20, 22, 24 Sec

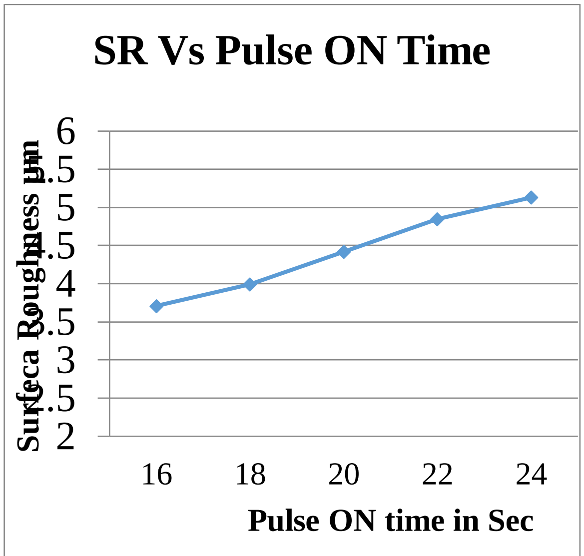
Pulse OFF Time: 2, 3, 4, 5, 6 Sec

Peak Discharge Current: 30 35 40 45 50 A

3.1 O-VAT for Pulse On Time

It is the duration of time for which the current is allowed to flow in each cycle. It is denoted as Ton

Pulse duration, also called pulse on time, its time during machining performed. During the pulse on time, the voltage is applied in the gap between work piece and the electrode thereby producing discharge. Higher the pulse on time, higher will be the energy applied there by generating more amount of heat energy during this period.



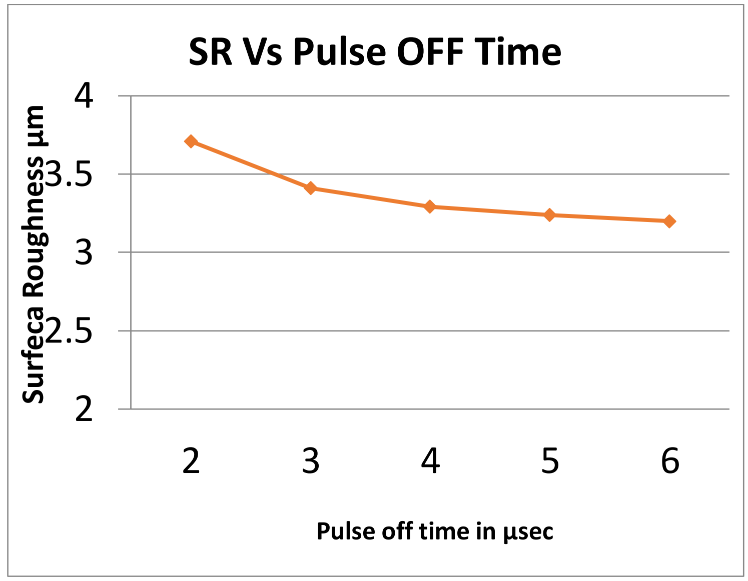
Graph3.1 Pulse ON Time Vs SR

Graph - Pulse ON Time Vs Surface Roughness

From the above graph is was observed that, the rate of change of Surface Roughness rate is found higher in region 18-20 sec. hence, the Ton selected for experimentation is 18-20 sec.

3.2 O-VAT for Pulse Off Time

Pulse interval, also referred as Pulse off time, is also expressed in micro seconds. This is the time between discharges. Off Time has no effect on discharge energy. Off Time is the pause between discharges allows the debris to solidify and flushed away by the dielectric prior to the next discharge. Reducing Off Time can dramatically increase cutting speed, by allowing more productive discharges per unit time.

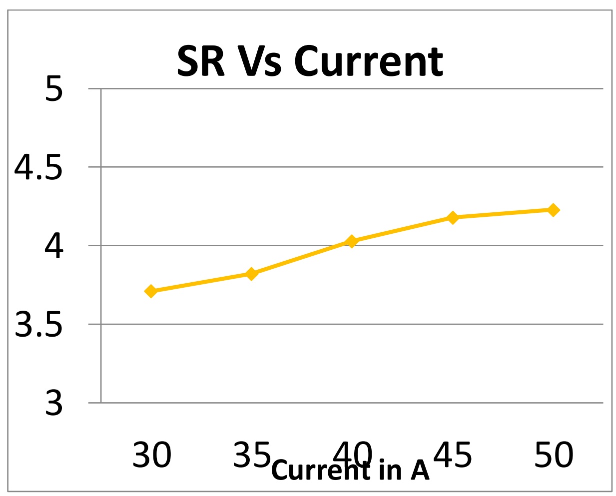


Graph 3.2-Pulse Off Time Vs SR

From the above table it is observed that, the rate of change of Surface roughness is lower in the region of T-off is 2-4 sec hence this level of factor is selected.

3.3 O-VAT for Peak Current

It is the maximum value of the current passing through the electrodes for the given pulse. It is denoted by IP and expressed in amperes (A)



Graph 3.2-Current Vs SR

From the above table it is observed that, the rate of change of Surface Roughness is Higher in the region of peak current is 35-40A hence this level of factor is selected.

Levels of Input Parameters

Sr. No	Level 1	Level 2	Level 3
Pulse ON Time	18	20	22
Pulse OFF Time	2	3	4
Current	35	40	45

4. MODEL ANALYSIS FOR SR

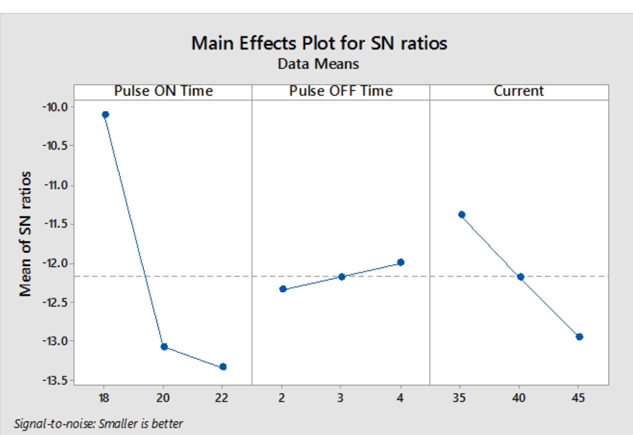
Sr. No	Level 1	Level 2	Level 3
Cutting Speed (mm/min)	1100	1200	1300
Laser Power (Watt)	850	900	950
Gas Pressure (bar)	0.9	1.0	1.1

SN

Ratio SR

Shows the L_9 orthogonal array with repeat measurement of responses for runs one to nine. Repeats of response measurement technique is used overcome the drawback of saturated design in MINITAB software. It also shows that the SN ratio for run one and ten are same as it is calculated for the repeats measurement. The SN ratio values are calculated with help of MINITAB 17 software.

4.1 Main Effects of SR



4.1 Graph Main effect plots for mean of SN ratio of SR

4.2 ANOVA Result

Experiments	Inputs Factors			Output Responses	
Trial No.	**P-ON**	**P-OFF**	**Current**	**SR**	**SNRA1**
1	18	2	35	2.98	-9.4843
2	18	3	40	3.17	-10.0212
3	18	4	45	3.47	-10.8066
4	20	2	40	4.65	-13.3491
5	20	3	45	4.93	-13.8569
6	20	4	35	3.99	-12.0195 -
7	22	2	45	5.12	14.1854
8	22	3	35	4.29	-12.6491
9	22	4	40	4.56	-13.1793

Source	DF	Adj SS	Adj MS	F-Value	P-Value	% Contribution
T-ON	2	3.85389	1.92694	612.81	0.002	0.800

T-OFF	2	0.08882	0.04441	14.12	0.056	0.011
Current	2	0.85129	0.42564	135.36	0.007	0.177
Error	2	0.00629	0.00314			
Total	8	4.80029				

In ANOVA, the ratio between the variance of the cutting parameter and the error variance is called Fisher's ratio (F). It is used to determine whether the parameter has a significant effect on the quality characteristic by comparing the F test value of the parameter with the standard F table value at the P significance level. If the F test value is greater than P test the cutting parameter is considered significant.

relevance of the models is tested by analysis of variance (ANOVA). It is a statistical tool for testing the null hypothesis for planned experiments, in which several different variables are studied simultaneously. ANOVA is used to quickly analyze the variances in the experiment using the Fisher test (F test).

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relevance of the models is tested by analysis of variance (ANOVA). It is a statistical tool for testing the null hypothesis for planned experiments, in which several different variables are studied simultaneously. ANOVA is used to quickly analyze the variances in the experiment using the Fisher test (F test). anova table shows the result of the ANOVA analysis. The ANOVA analysis makes it possible to observe that the value of P is less than 0.5 in the three parametric sources. It is therefore clear that (1) the pulse on time, (2) the pulse off time, (3) the Current of the material have an influence on the SS410 steel material. The last column of cumulative anova shows the percentage of each factor in the total variance that indicates the degree of impact on the outcome.

Table shows the ANOVA of SS410 Steel & copper wire. The table shows that the pulse on time (80.22%), the Current (17.77 %%) and the pulse off time (1.19%) have a major influence on the surface roughness.

4.3 Optimum level of parameters

Sr. No.	Parameter	Optimum level
1	Pulse ON time(Level 1)	18
2	Pulse OFF time (Level 3)	4
4	Peak Current (Level 1)	35

5.CONCLUSIONS

- This study covers the observations about the surface roughness over SS410 steel material by the process of WEDM machine for the different input parameters to thoroughly study over the effect of EDM machining process on the SS410 steel material. Throughout the experimentation I got some results as under.
- This study covers the observations about the Material surface roughness over SS410 steel material by the process of WEDM machine for the different input parameters to thoroughly study over the effect of WEDM machining process. Throughout the experimentation we got some results as under,
- The optimal solution obtained for SR based on the combination of WEDM parameters and their levels is (i.e. Pulse ON Time18 s at level 1, Current 35A at level 1and Pulse OFF Time 4 s at level 3). The Pulse on Time and pulse on time are more significant Machining Parameters than Pulse off time.
- ANOVA results indicate that pulse on time plays prominent role in determining the surface roughness. The contribution of pulse on time, current and pulse off time to the quality characteristics surface roughness Ra is 80%, 17.7% and 1.1% respectively.
- SR increases with Pulse on Time and Current as they provide high discharge energy.
- SR decreases with increases Pulse off Time.

- The optimal cutting parameters are determined using Taguchi methods match with the experimental values by minimum errors i.e4.82% for SR.
- Through the developed mathematical models, any experimental results of surface roughness with any combination of laser cutting parameters can be estimated.

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