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Streamlining of Process Parameters For Machining of Aisi 4130 Steel Alloy Using Wire – Electric Discharge Machine

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ABSTRACT

One of the most important aspects of hard metal machining is the correct selection of the production environment and Electrical Discharge Machine (EDM) is one of the most suitable machining techniques for hard alloys. This research paper examines the effect of performance parameters on AISI 4130 Steel alloy machining using Wire Electrical Discharge Machine (WEDM). Pulse on time, pulse off time, pulse peak current and water pressure are selected at three different levels for this investigation and brass wire of 0.25 mm diameter is chosen as the tool. The experiments are considered based on the Taguchi experiment design with L9 Orthogonal Array. Process parameter effects are analyzed on performance parameters such as Kerf width and Material Removal Rate (MRR) by machining 10 mm diameter hole on AISI 4130 steel alloy at different experiment levels. The output parameters are analyzed using S / N ratios and ANOVA identifies the most important parameters of the process for individual responses.

KEYWORDS: 4130 Steel Alloy, Wire EDM, Taguchi Method, Orthogonal Array, Kerf Width, Material Removal Rate, S/N Ratios, ANOVA

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INTRODUCTION

Wire EDM machining is an electro – thermal procedure where a flimsy single strand metal wire (typically Brass) allied to de – ionized water enables the wire to slice through metal utilizing heat from electrical sparkles. Wire EDM is commonly used to slice sheets up to a thickness of 300 mm and to make punches; instruments and dies from hard metals that are hard to machine with different techniques. Wire EDM is generally utilized when low residual burdens are required, as high cutting powers are not required for material evacuation[1]. On the off chance that the energy per strike is moderately low (as in completing tasks), because of these low residual burdens, little change in the mechanical properties of a material is usual, in spite of the fact that non – stress material can harm the procedure. Due to the inherent properties of the process, Wire EDM can without much of a stretch machine complex parts and accuracy segments from hard conductive materials[2].

At the point when the wire approaches the part, the fascination of electrical charges makes a controlled flash, soften and vaporize minuscule material particles. The spark also removes a small portion of the wire, so once the wire passes through the workpiece, the machine discards the wire used and automatically moves new wire forward. The procedure is quick and a huge number of flashes are created every second, except the wire never contacts the workpiece. Wire EDM machines utilize a de – ionized water as dielectric liquid for ceaselessly cool and flush the machining zone amid EDM. Figure 1 shows the working principle of wire EDM[3].

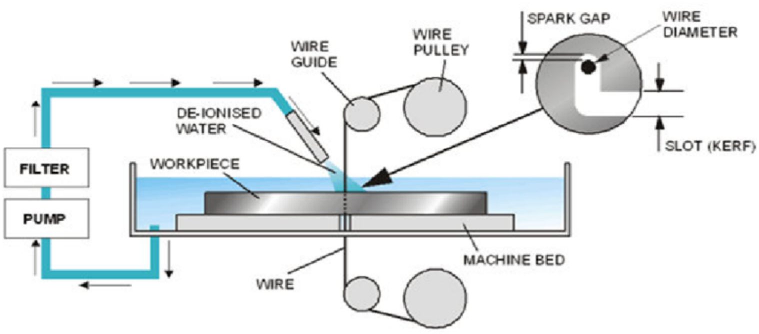

Figure 1: Working principle of wire EDM process

In this work, the following objectives are addressed:

- Machining of AISI 4130 steel alloy by using Wire EDM.
- To conduct the experiments by varying the control parameters such as Pulse on time, Pulse off time, Pulse peak current and Water pressure with de – ionized water is utilized as a dielectric liquid during machining of 10 mm diameter hole on AISI 4130 Steel Alloy.
- To optimize process parameters to improve machining features such as Kerf Width and Material Removal Rate (MRR) using S/N ratios.

- Find out the most influential process parameters of AISI 4130 Steel Alloy using Wire EDM by ANOVA.

EXPERIMENTAL SETUP

The experimental setup of the wire EDM is shown in Figure 2. Mainly, it consists of six parts which are explained below[4].

Figure 2: Experimental setup of MIG welding

1. **Dielectric Reservoir, Pump and Circulation System:** For each run of the experiment, dielectric reservoirs and pumps are used to circulate the EDM oil and the EDM oil filter is also used.
2. **Power Generator and Control Unit:** It has a time control function that controls the length of time during each pulse that the current flows; this is called "on time". The amount of current allowed to flow during each pulse is then controlled. These pulses are measured in microseconds and of very short duration. The control unit controls machining functions such as Ton, Ip, Duty Cycle, setting values and maintaining the tool gap on the workpiece.
3. **Working Tank with Work Holding Device:** All the EDM oil in the working tank is utilized to supply the liquid amid the machining procedure and the work holding gadget is utilized to hold the workpiece in a fixed position amid the machining procedure..
4. **X – Y Table Accommodating the Working Table:** It is used to give the workpiece moment in X and Y directions.
5. **Servo System to Feed the Tool:** To maintain the predetermined gap, the servo control unit is provided. It senses the gap voltage and compares it to the current value and then the different voltage is used to control the servo motor movement to adjust the gap.
6. Tool Holder

EXPERIMENTATION

A series of experiments are carried out based on the Taguchi design on AISI 4130 steel alloy workpiece by using wire EDM with de – ionized water is utilized as a dielectric medium[5]. The details of the experiment are as follows:

AISI 4130 steel alloy workpiece is machined using distinctive control factors such as Pulse on time, Pulse off time, Pulse peak current and Water pressure. The Chemical composition, Physical properties of AISI 4130 steel alloy and the chosen control parameters & their levels are scheduled in Table 1, Table 2 and Table 3.

Table 1: Chemical Composition of AISI 4130 Steel Alloy

C	Cr	Fe	Mn	Mo	P	Si	S
0.28 – 0.33	0.80 – 1.1	97.03 – 98.22	0.40 – 0.60	0.15 – 0.25	≤ 0.035	0.15 – 0.30	≤ 0.040

Table 2: Mechanical properties of AISI 4130 steel alloy

Yield Strength (MPa)	Tensile Strength (MPa)	Modulus of Elasticity (GPa)	Poisson's Ratio	Hardness (HB)	Bulk Modulus (GPa)	Machinability
435	670	205	0.29	197	140	70%

Table 3: Process parameters and their levels

Process Parameter	Level 1	Level 2	Level 3
Pulse on time (µsec.)	100	102	104
Pulse off time (µsec.)	50	51	52
Pulse peak current (Amps)	1	2	3
Water pressure (Kg/cm^2)	80	85	90

Based on the control parameters and their levels, the experiments are carried out on the basis of Taguchi experiment design with L_9 Orthogonal Array and the responses are shown in Table 4.

Table 4: Experimental results for 4130 steel alloy

S. No.	Pulse on Time (µsec.)	Pulse off Time (µsec.)	Pulse Peak Current (Amps.)	Water Pressure (Kg/cm^2)	Kerf Width (mm)	MRR (g/sec)
1	100	50	1	80	0.09	0.00121
2	100	51	2	85	0.46	0.00036
3	100	52	3	90	0.07	0.00045
4	102	50	2	90	0.64	0.000769
5	102	51	3	80	0.41	0.000287
6	102	52	1	85	0.01	0.0001
7	104	50	3	85	0.38	0.00129
8	104	51	1	90	0.20	0.0016
9	104	52	2	80	0.29	0.00156

The machined workpieces after cutting are shown in Figure 3.

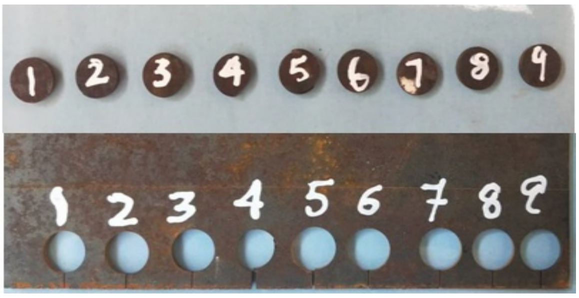

Figure 3: Machined workpieces after cutting

RESULTS AND DISCUSSION

Based on the resonances obtained in Table 4, the S/N ratios and ANOVA responses for Kerf width and Material Removal Rate are calculated using Minitab software[6].

Kerf Width Vs Process Parameters

Equation (1) is used to calculate the S / N ratios for kerf width. The Taguchi method is used to analyze the results of the machining parameter response in categorize to smaller the better criteria. For smaller the better:

$$S/N = -10*\log_{10} (\Sigma (Y_i^2/n)) \quad \text{----------} \quad (1)$$

Where, Y_i = investigational value in the i^{th}, n = number of replications. Where the S/N proportions are determined from experimental values, y_i represents the experimentally observed value of the i^{th} experiment and n=1 is the repetitive number of each investigation in L9 is conducted.

Table 5: Response table for S/N ratios (smaller the better) for kerf width

Level	Pulse on Time	Pulse off Time	Pulse Peak Current	Water Pressure
1	16.919	11.065	24.965	13.137
2	17.207	9.490	7.124	18.383
3	11.045	24.617	13.082	13.651
Delta	6.162	15.127	17.840	5.246
Rank	3	2	1	4

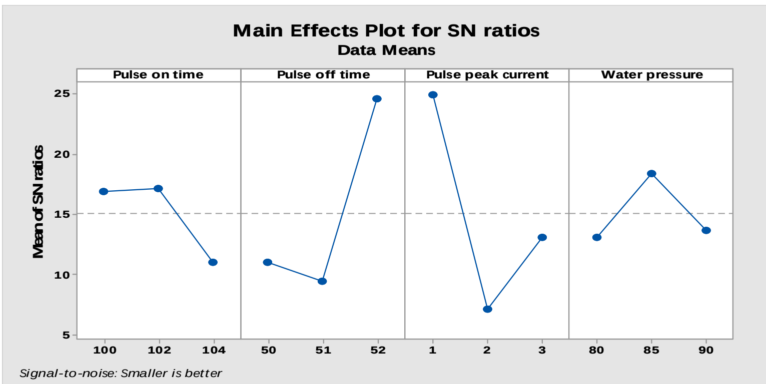

Figure 4: Main effects plot for kerf width

Table 6: Analysis of Variance Results for Kerf Width

Source	DF	Seq SS	Adj SS	Adj MS	% Cont.
Pulse on Time	2	72.55	72.554	36.277	7.025
Pulse off Time	2	414.95	414.955	207.477	40.183
Pulse peak current	2	494.97	494.973	247.486	47.932
Water pressure	2	50.17	50.173	25.087	4.841
Total	8	1032.65			100

From Table 5 and Figure 4, the optimum parameters for a smaller Kerf width are observed is obtained at pulse on time 104 µsec, pulse off time 51 µsec, pulse peak current 2 Amp and water pressure 80 Kg/cm^2 and also from ANOVA Table 6, pulse peak current (47.932%) is the most influential parameter.

MRR Vs Process Parameters

Based on Equation (2), the S / N ratios for material removal rate are calculated. Taguchi method is used to analyze the result of the machining parameter response in order to larger the better criteria[7& 8]. For larger the better

$$S/N = -10*\log_{10}(\Sigma (1/Y_i^2)/n) \qquad \text{----------} \qquad (2)$$

Where, Y_i = investigational value in the i^{th}, n = number of replications. Where the S/N proportions are determined from experimental values, y_i represents the experimentally observed value of the i^{th} experiment and n=1 is the repetitive number of each investigation in L9 is conducted.

Table 7: Response table for S/N ratios (larger the better) for material removal rate

Level	Pulse on Time	Pulse off Time	Pulse Peak Current	Water Pressure
1	– 64.72	– 59.47	– 64.75	– 61.77
2	– 71.04	– 65.21	– 62.43	– 68.89
3	– 56.61	– 67.69	– 65.19	– 61.71
Delta	14.43	8.22	2.76	7.18
Rank	1	2	4	3

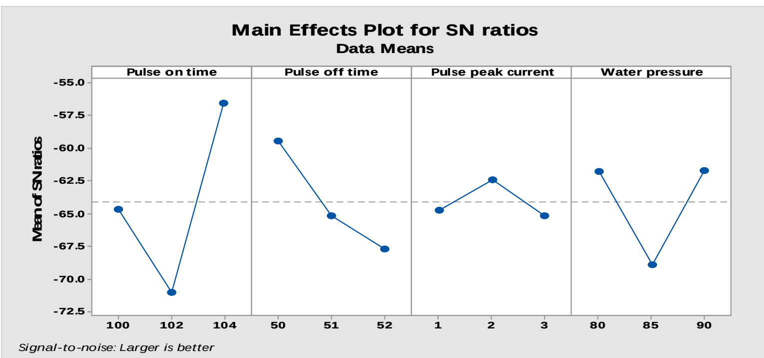

Figure 5: Main effects plot for material removal rate

Table 8: Analysis of variance results for material removal rate

Source	DF	Seq SS	Adj SS	Adj MS	% Cont.
Pulse on Time	2	313.785	313.785	156.893	58.57
Pulse off Time	2	106.661	106.661	53.331	19.90
Pulse peak current	2	13.191	13.191	6.595	2.46
Water pressure	2	102.086	102.086	51.043	19.063
Total	8	535.723			100

From Table 7 and Figure 5, the optimum parameters for a larger material removal rate is observed at pulse on time 104 µsec, pulse off time 50 µsec, pulse peak current 2 Amp and water pressure 80 Kg/cm^2 and also from ANOVA Table 8, pulse on time (58.57%) is the most influential parameter.

CONCLUSION

The following conclusions are drawn:

- Using brass wire of 0.25 mm electrode with de – ionized water as a dielectric medium, 10 mm holes are machined on AISI 4130 steel alloy by varying the control parameters such as pulse on time, pulse off time, pulse peak current and water pressure.
- From the results of S/N ratios:
  - It is observed that the optimum parameters are obtained at pulse on time 104 µsec, pulse off time 51 µsec, pulse peak current 2 Amp and water pressure 80 Kg/cm^2 exhibits minimum Kerf width than the other machined holes.
  - It is observed that the optimum parameters are obtained at pulse on time 104 µsec, pulse off time 50 µsec, pulse peak current 2 Amp and water pressure 80 Kg/cm^2 exhibits maximum Material Removal Rate than the other machined holes.
- From the ANOVA results:
  - It is observed that based on % contribution values, pulse peak current has great influence on kerf width
  - It is observed that based on % contribution values, pulse on time has great influence on material removal rate.

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