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OPTIMIZATION OF CNC WEDM PROCESS PARAMETERS OF HIGH CHROMIUM HIGH CARBON (HCHC) DIE STEEL USING TAGUCHI METHODOLOGY

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Abstract- This paper presents an investigation on the effect and optimization of machining process parameters on the Material removal rate (MRR) and surface roughness (SR) in CNC wire electrical discharge machining (WEDM) operations. The cutting of High Chromium High Carbon (HCHC) die steel work piece using CNC WEDM by using Taguchi methodology has been reported. Many experiments were conducted to consider the effect of Current, Voltage, Wire speed and Wire tension on the MRR and SR response. An L9 (3*4) Taguchi standard orthogonal array (OA) is chosen for design of experiments and the main influencing factor are determined for each given machining criteria by using Analysis of variance (ANOVA). We found out the optimal parameter setting for MRR and SR. The analysis of the Taguchi methodology reveals that. In general the Current significantly affect the MRR and SR. Experimental observed values are provided to verify this methodology.

Keywords- CNC WEDM, Taguchi methodology, HCHC die steel, Material removal rate and Surface roughness.

I. INTRODUCTION

CNC 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 traveling wire electrode made of thin copper, brass or tungsten of diameter 0.15–0.25mm, which is capable of achieving very small corner radii. 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. The hardness and strength of the difficult to machine work material are no longer the dominating factors that affect the tool wear and hinder the machining process. This makes the CNC WEDM process particularly suitable for machining hard, difficult to machine materials. In addition, the cutting force in CNC WEDM process is small, which makes it ideal for fabricating miniature parts [1]. The variation of MRR and SR with machining parameters and optimization of machining settings for maximum MRR minimum SR should be investigated experimentally and the obtained results should be interpreted and modeled statistically to understand closely the behavior of machining rate and accuracy in CNC WEDM [3]. In this study, the effect of the machining parameters and their level of significance on the MRR and SR are statistically evaluated by using analysis of variance (ANOVA). Experiments were conducted under different machining parameters, namely, current, open circuit voltage, wire speed and wire tension. The settings of machining parameters were determined by using Taguchi experimental design method.

II. METHODOLOGY

A. Design of parameter setting for Experiment
The Experiment setup design for the machining process parameter using of the L9(3*4) standard orthogonal array were used in this works. These orthogonal array design with consists of three level and four control parameter, as shown in table 3. In the Taguchi methodology all observed most values are calculated based on “the higher the better” and “Smaller the better”. Thus in this work, the observed values of MRR and SR were set to Maximum and minimum respectively. The optimization of the observed values was found by comparing the standard analysis and analysis of variance (ANOVA) for each experimental trial were performed with three replications at each set values.

TABLE I. CONTROL PARAMETER AND THEIR LIMITS

Control Parameter	Level			Observed Values
	1	2	3	
P: Current (Amp)	8 100 8.5	16 120 9.5	32 160 10.5	(a) Material Removal Rate (g/min) (b) Surface Roughness(Ra)
Q: Voltage (Volt)	100 0	110 0	120 0	
R: Wire Speed (m/min)				
S: Wire Tension (g)				

B. Analysis of Variance (ANOVA):

Analysis of variance (ANOVA) and the F-test (standard analysis) are used to analyse the experimental data (4, 5, 6):

$$CF = T^2/n$$

$$S_T = \sum_{i=1}^{1027} Y_i^2 - CF$$

$$S_x = (Y_{x1}^2/N_{x1} + Y_{x2}^2/N_{x2} + Y_{x3}^2/N_{x3}) - CF$$

$$f_x = (\text{number of levels of parameter } x) - 1$$

$$f_e = f_T - \sum f_x$$

$$f_T = (\text{total number of results}) - 1$$

$$V_x = S_x/f_x$$

$$S_e = S_T - \sum S_x$$

$$F_x = V_x/V_e$$

$$V_e = S_e/f_e$$

$$P_x = S_x'/S_T * 100\%$$

$$S_x' = S_x - (V_e * f_x)$$

$$P_e = (1 - \sum P_x) * 100\%$$

S_x → sum of squares due to parameter x (x= P, Q, R And S)

N_{x1}, N_{x2}, N_{x3} → repeating number of each level (1, 2, 3) of parameter x

Y_{x1}, Y_{x2}, Y_{x3} → value of results of each level (1, 2, 3) of parameter x

f_x → degree of freedom (DOF) of parameter x

f_e → degree of freedom (DOF) of error term

f_T → total degree of freedom

V_x → variance of parameter x

S_e → sum of squares of error term

F_x → F- ratios of parameter x

V_e → variance of error term

P_x → percentage contribution of parameter x

S_x' → pure sum of square

P_e → percentage contribution of error term

Where;

CF → correction factor

n → total number of experiment

T → total of all results

S_T → total sum of squares to total variation

Y_i → value of results of each experiment (i= 1 to 27)

C. Work piece material

We used workpiece material High Chromium High Carbon die steel (HCHC) in this experiments. Which have a cold work tool steel with substantial amounts of Chromium and Carbon (HCHC) tool steels offer good dimensional accuracy, wear resistance and machinability.

TABLE II L9 ORTHOGONAL ARRAY AND OBSERVED VALUES

No. of Trial	Control Parameter (level)				Observed/Response value					
	P	Q	R	S	MRR (g/min)			SR (Ra)		
					1	2	3	1	2	3
1	8(1)	100(1)	8.5(1)	1000(1)	1.203	1.136	1.112	4.18	4.81	4.28
2	8(1)	120(2)	9.5(2)	1100(2)	0.938	0.933	0.935	3.06	2.86	2.88
3	8(1)	160(3)	10.5(3)	1200(3)	0.893	0.751	0.778	3.68	3.77	3.31
4	16(2)	100(1)	9.5(2)	1200(3)	0.991	0.989	0.895	3.49	3.64	3.33
5	16(2)	120(2)	10.5(3)	1000(1)	0.731	0.698	0.701	1.89	1.8	1.98
6	16(2)	160(3)	8.5(1)	1100(2)	0.631	0.665	0.678	1.38	1.4	1.35
7	32(3)	100(1)	10.5(3)	1100(2)	0.738	0.879	0.733	1.88	1.89	1.8
8	32(3)	120(2)	8.5(1)	1200(3)	0.939	0.985	0.896	3.3	3.45	3.32
9	32(3)	160(3)	9.5(2)	1000(1)	0.879	0.901	0.86	2.03	2.38	2.35

TABLE III ANALYSIS OF VARIANCE AND F TEST FOR MRR

Parameter (x)	DOF (f _x)	Sum of Square (S _x)	Variance (V _x)	F-ratio (F _x)	Pure Sum (S _x ')	Percent (P _x)
P	2	0.160582	0.080291	34.2139**	0.155889	27.10431
Q	2	0.150163	0.075081	31.99394*	0.145469	25.2927
R	2	0.141592	0.070796	30.16781*	0.136899	23.80249
S	2	0.080565	0.040283	17.16538*	0.075872	13.19181
e	18	0.042241	0.002347			

TABLE IV ANALYSIS OF VARIANCE AND F TEST FOR SR

Parameter (x)	DOF (f _x)	Sum of Square (S _x)	Variance (V _x)	F-ratio (F _x)	Pure Sum (S _x ')	Percent (P _x)
P	2	10.05072	5.025359	170.2443**	9.991681	40.25876
Q	2	3.316007	1.658004	56.16826*	3.25697	13.12308
R	2	1.784585	0.892293	30.22823*	1.725548	6.952626
S	2	9.136007	4.568004	154.7504*	9.07697	36.57318
e	18	0.531333	0.029519			

** Significant Parameter, * sub significant parameter

TABLE V SUMMARIZATION OF SIGNIFICANT PARAMETER ON MACHINING OF CNC WEDM

Parameter	MRR	SR
P	**	**
Q	*	*
R	*	*
S	*	*

D. Conformation test

We have found optimal parameter setting for MRR as (P1, Q1, R2, S1) and for SR optimal parameter setting as (P2, Q3, R3, S2). According to predicted parameter setting with ANOVA calculation. We have conducted the experiments and found MRR is 1.15 Wire Cut EDM works on the principle of Electrical Discharge Wire Cutting (EDWC), most commonly known as Wire Cut EDM. It is a spark erosion procedure to produce complex 2-Dimensional and 3-Dimensional shapes through electrically conductive work pieces. This machine is used only for manufacture parts which are electrically conductive. Wire Cut EDM differs from conventional EDM is that a thin, 0.05-0.3 mm in diameter wire used for manufacturing of our product. The wire wound around a spool, feeds through the work piece and is takes upon two section spool. A D.C. power supply devices, high frequency pulses of electricity required for wire and work piece for get required process using discharge of electron. This can be achieved with the help of gap which is provided in between wire and work piece so the electric discharge occur and metal removing process done by the use of which we have produce required produce on the Wire Cut EDM. With Wire Cut EDM technique complicated cutting process can be achieved very easily as compare to either our conventional manufacturing process or use of high cost and very precise manufacturing machine which are very expensive. The high degree of accuracy obtainable and the fine surface finish is also achieved with the help of this machine. Finishes make Wire Cut EDM particular valuable for the applications of involving the material of press stamping dies, extrusion dies, prototype parts and excess the fabrication of conventional EDM electrode.

B. Technical specifications for CNC WEDM

Control Panel EZ-01

Control Mode : CNC close loop
 Simultaneously Controlled Axis : X, Y, U, V.
 Control Panel Size : 550 X 800 X 1830 mm.
 Control Panel Weight : 175 kg.
 Input Program Form : G code
 Display : 15" color CRT

g/min and SR is 1.87 Ra. Which shows the successful validation of the technique.

III. EXPERIMENTS

A. Experimental Setup

Minimum Input Command : 0.001 mm.
 Minimum Increment : 0.001 mm.
 Interpolation Function : Linear, Circular
 Power Requirement : 415V/50Hz/3ph/1.5Kva max.

Machine Tool

X, Y axis travel : 250 X 320 mm
 Maximum work piece size : 450 X 300 mm.
 Max thickness machinable : 140 / 200 / 400 mm.
 Max work piece weight : 120 kg.
 Max taper cutting angle : 3 degrees at 100 mm job height
 Machine Tool Size(LxWxH): 1400X700X 1700 mm.
 Machine Tool Weight : 800 kg.
 Wire Diameter : 0.15-0.25 mm. (0.25 mm. std.)
 Best Surface Finish (Ra) : $\leq 3 \mu$ m.
 Max Cutting Speed : 50 mm/min.
 Max Dry Run Speed : 25 mm/min.
 Table Movement Using Pendant Unit: 120 mm/min.
 Heat Affected Zone : 10 μ m.

IV. RESULTS AND DISCUSSION

The Taguchi methodology based following discussion focuses on the effect of parameters to the observed Results of MRR is maximum and SR is minimum of the shown in fig 2. and fig 3. respectively.

Fig-1: -Schematic Diagram of EzeCutPlus Wire EDM

Fig 2 Main effects of each parameter on MRR

Fig 3 Main effects of each parameter on SR

TABLE VI RESULTS OF THE CONFIRMATION EXPERIMENT FOR MRR AND SR

Parameter	MRR (g/min) & Level	SR (Ra) & Level
P: current (Amp)	8 (1)	16 (2)
Q: Voltage (Volt)	100 (1)	160 (3)
R: Wire speed (m/min)	9.5 (2)	10.5 (3)
S: Wire Tension (g)	1000(1)	1100 (2)

IV. CONCLUSION

This paper has presented and investigation on the optimization and the effect of machining parameter on the MRR and SR. experiments conducted operations on CNC WEDM using (HCHC) die steel work piece martial. In this work were found most effective parameter of current for MRR because MRR higher is better and wire tension for SR because lower is better by the Taguchi methodology.

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