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Performance Analysis Study of WEDM Process on Cutting Rate of H-11 (Hot Die Steel)

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ABSTRACT- Wire electric discharge machining (WEDM) is used in machining of conductive material with highest accuracy. But due to complex process it is strongly felt that the performance parameters must be analysed before optimising them for getting maximum performance in WEDM process. The H11 is widely used material for die casting dies, aircraft landing gears, helicopter rotor blades and many more applications. The effect of process parameters like pulse on time, servo voltage and peak current on cutting rate had been considered for each experiment. Further experimentation was designed as per L27 orthogonal array at three level. Brass wire electrode with 0.25mm diameter was used as tool in the experiments, due to being widely available and cheap. The experimental results were analyzed and explained with the help of plotting linear and surface graphs between various parameters. The combined contribution of the process parameters were also plotted and explained with the help of 3-D graphs. SEM test was also conducted to validate the result. It was found that all the three input parameters selected were significant and contributed maximum performance at a particular value.

1. INTRODUCTION

Wire electric discharge machining (WEDM) is widely used approved non-traditional electro-thermal material removal process used to machining components with complex shape profiles. WEDM uses a continuous travel wire electrodes made of thin copper, brass or tungsten which is capable to get very small corner radius. The principle of machining is based on erosion of the work-piece material using a successive discrete discharges occurring between the electrode (wire) and work piece. De-ionized water as dielectric fluid is used in WEDM. Also the process machine is capable of enabling high strength and temperature resistant (HSTR) material and finish geometric changes in machining.

2. REVIEW OF LITERATURE

Jangra et al [1] investigated performance behavior of WEDM like surface roughness, cutting speed, and dimensional lag at the time of rough cutting operation using D3 tool steel by Taguchi & Grey relational analysis method. Peak current, pulse on time, pulse off time, wire speed and wire tension were taken as process parameter and investigated using mixed L18 orthogonal array. Using GRA, optimal setting of process parameter was set, confirmed experimentally & found cutting speed of 3.80 mm/min with a dimensional lag of 0.008 mm for acceptable surface roughness. **Sudhakara and Prasanthi [2]** said that Wire discharge machining is that the trendiest advanced production method to manufacturer subtle parts, moulds and dies with excellent dimensional accuracy. The main aim of this experimental work is to search out best process parameters to minimize the dimensional deviation as compared to needed dimensions. The method parameters of this Wire discharge machining parameter are pulse on time, pulse off time, peak current and spark gap set voltage, wire tension and water pressure .The orthogonal array of L27 Taguchi design is employed to arrange and conduct the experiments. ANOVA was used to search out the consequences of method parameters on dimensional accuracy. The process parameters were optimized measure optimized so as to attenuate the output response i.e. dimensional deviation. The VANADIS 4E (powder scientific discipline cold worked tool steel) is employed for experimental work and therefore the experiments square measure conducted on WEDM came upon of ELECTRONICA

ULTIMA-1F. **Pradhan & Pradhan [3]** investigated that the output responses always do not depend upon the single input in WEDM process but also the dependent upon a set of input conditions. H-11 tool was selected for conducting experiments. They determine an optimum set of parameters for machining of **H11** tool steel. The experiments were designed using L16 Orthogonal array and optimized the result. It was found that the individual values for the performance are not the lowest but the combination of the result is the best. **Pradhan [4]** studied the effects of input parameters on setup of machine like WEDM. Machining of **H-11**die steels in WEDM is an area of research where it has been few. Since **H-11** die steel is one of the most of the commonly used chromium hot work steels. The study was about the influences of the input parameters selected like Pulse on time (T_{ON}), Pulse off time (T_{OFF}), Peak Current (I_P) and Wire feed (Wf) on the Cutting Speed (CS) and Gap Current (GC). A L16 orthogonal array based on Taguchi method was designed. The relationship was studied using ANOVA and linear regression. It was found from the the multiple measurable outputs were dependent most of the time on a combination of the Input variables and very rare dependents only on one of the input parameters. **Kumar R [5]** performed experiments on AISI D3 die steel keeping constant cutting parameters of T_{ON}, T_{OFF}, WP, WF, WT, SV. Using brass wire and found surface roughness increases with increases in peak current as well as increase in cutting rate. It was observed that peak current have significant effect on the CR and SR. Pulse on time, pulse off time, voltage gap and duration. The work materials used was Magnesium **Bhandari R [6]** Performance of the WEDM machining process mainly depends upon the suitable selection of the suitable machining parameters. Optimization is an unique techniques used in manufacturing sectors to arrive for the best manufacturing conditions, for improving productivity of the system. The aim of the work was to investigate the effect of various WEDM parameters like pulse on time, pulse off time peak current, servo voltage and wire feed rate on cutting rate in Machining of AISI D2 Steel. Second order mathematical model for the response characteristics using central composite rotatable design has been developed using MINITAB design statistical software. The design of experiments has been done using Taguchi's orthogonal array L27. Each experiment was conducted under various conditions of input parameters as per the L27 array. The interrelation ship of various input parameters on response characteristics has been evaluated.

3. EXPERIMENTAL PROCESS

The experiments have performed on the machine named "Electronica Sprintcut WEDM734", at M/S Krishna Tools, DLF Industrial Area, Faridabad, Haryana, India. Following steps were followed during the cutting operation:

Workpiece and Tool Material: H11 (hot Die Steel) of lenghh 245 mm, width 50 mm and thickness 24 mm with composition shown in table 1 was used as a workpiece material shown in figure 1. and the brass wire of 0.25 mm diameter was used as wire electrode.

Table 1. Chemical Composition of Workpiece Material

Constituent	C	Si	Mn	P	S	Cr	Mo	V
%	0.39	0.81	0.028	0.025	0.023	4.97	0.28	0.46

Design of process parameters: Process parameter like pulse on time, servo voltage and peak current used in this study as shown in table 2. The three levels of the parameters were mandatory for L27 orthogonal array.

Table 2: Control Parameters for Cutting Rate

SR. NO.	CONTROL PARAMETER	LEVEL 1 (1)	LEVEL2 (2)	LEVEL3 (3)
1	Pulse on time (A)	106	116	126
2	Voltage (B)	10	30	50
3	Peck current value(C)	50	140	230

The experimental design layout for the machining parameters using the L27 orthogonal array is shown in Table 3

Table 3: Experimental Design

Exp. No.	**Pulse on time (T_{ON})**	**Servo Voltage (SV)**	**Peak current value (Ip)**
1	1	1	1
2	1	1	2
3	1	1	3
4	1	2	1
5	1	2	2
6	1	2	3
7	1	3	1
8	1	3	2
9	1	3	3
10	2	1	1
11	2	1	2
12	2	1	3
13	2	2	1
14	2	2	2
15	2	2	3
16	2	3	1
17	2	3	2
18	2	3	3
19	3	1	1
20	3	1	2
21	3	1	3
22	3	2	1
23	3	2	2
24	3	2	3
25	3	3	1
26	3	3	2
27	3	3	3

Table 4: Experimental result

Exp. No.	Pulse on time T_{ON} (µs)	Servo Voltage SV (V)	Peak current I_P (A)	Cutting rate CR (mm/min)
1	106	10	50	0.37
2	106	10	140	0.49
3	106	10	230	0.53
4	106	30	50	0.31
5	106	30	140	0.36
6	106	30	230	0.40
7	106	50	50	0.22
8	106	50	140	0.32
9	106	50	230	0.35
10	116	10	50	0.66
11	116	10	140	1.07
12	116	10	230	1.26
13	116	30	50	0.60
14	116	30	140	0.95
15	116	30	230	1.10
16	116	50	50	0.50
17	116	50	140	0.69
18	116	50	230	0.87
19	126	10	50	0.76
20	126	10	140	1.71
21	126	10	230	2.15
22	126	30	50	0.65
23	126	30	140	1.45
24	126	30	230	1.77
25	126	50	50	0.50
26	126	50	140	1.11
27	126	50	230	1.39

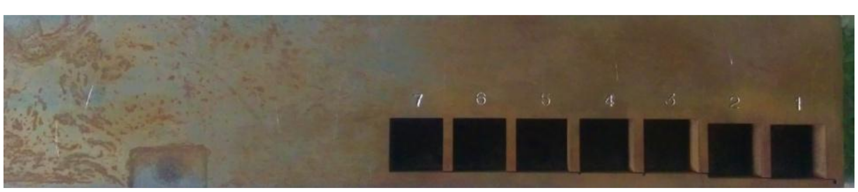


Fig. 1 Workpiece Material cut on WEDM

4. RESULT AND DISCUSSION

Cutting rate were directly measured for each experiment from display unit of WEDM as shown in table 4.Individual and combined effects of process parameters for cutting rate as shown in below fig.2-7 studied by ploting grapgs with the help of mini tabs and ANOVA used to see the main effects.

Individual Effect of T_{ON}, I_P and SV on CR

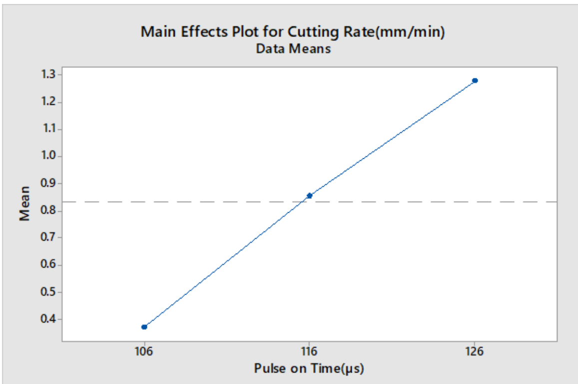


Fig.2 Main Effect of T_{ON} on CR

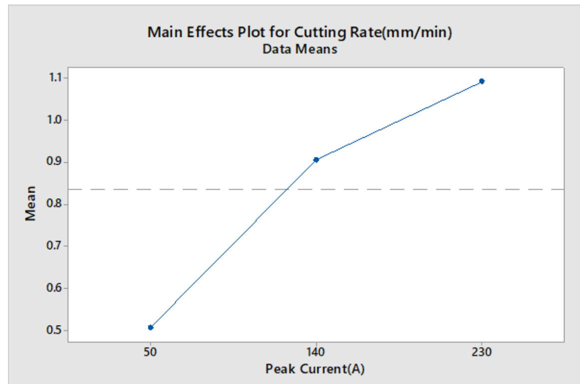


Fig.3 Main Effect of I_p on CR

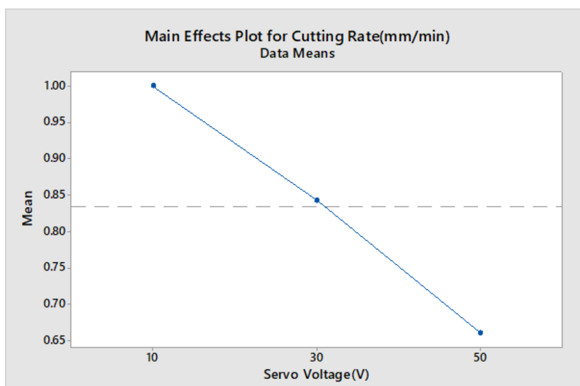


Fig. 4 Main Effect of SV on CR

From the above fig.2, 3 and 4 it can be seen that pulse on time and peak current has positive trends whereas servo voltage has negative trend of cutting rate. It is due to increase in no. of discharge on increasing of pulse on time as well as peak current and discharge decreases on increasing in servo voltage.

Combined Effect of T_{ON}, SV and I_P on CR

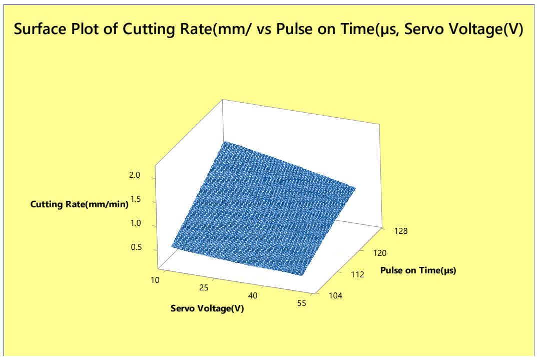


Fig. 5 Combined Effect of $T_{ON,}$ and SV on CR

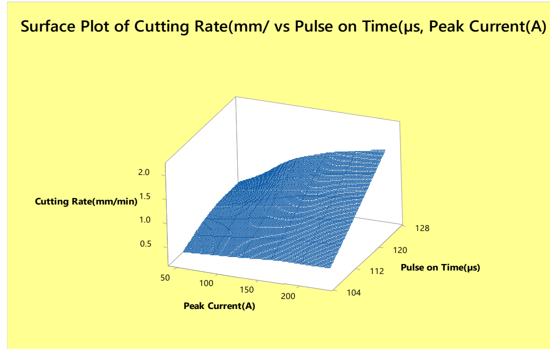


Fig. 6 Combined Effect of $T_{ON,}$ and SV on CR

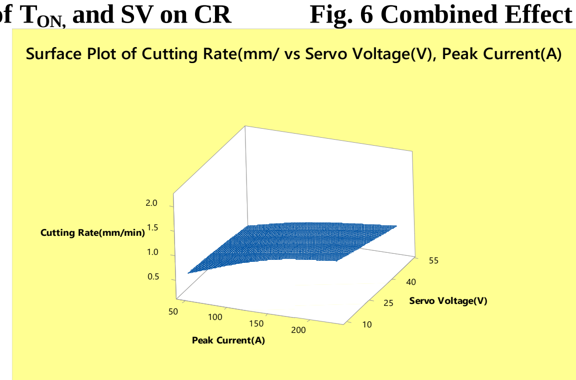
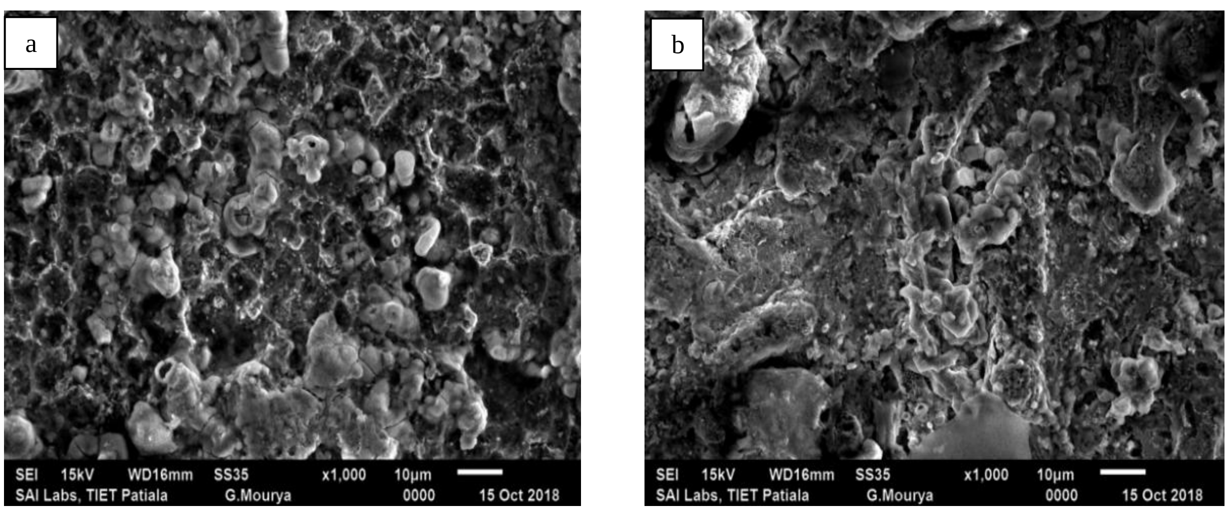


Fig. 7 Combined Effect of $T_{ON,}$ and SV on CR

SEM Views Related to Cutting Rate

SEM is employed to look at textures for validation the result as below fig. 8 a,b and c at the lowest average and highest cutting rate measured



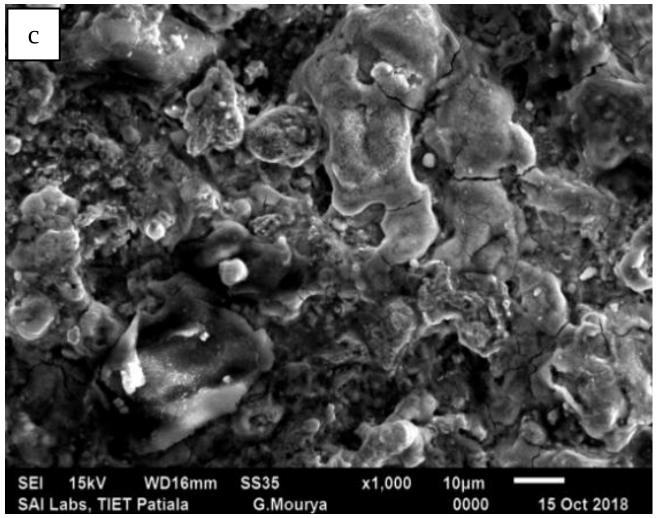


Fig.8 SEM View Showing Lowest, Average and Highest CR

5. CONCLUSION

From review of literature and experimental study it is concluded that materials that are difficult to be machined by traditional machining, can be machined by non-traditional machining i.e.by using WEDM process. On the basis of results it was concluded that increasing in pulse on time and peak current leads to increase in cutting rate, whereas increase in servo voltage leads to decrease in cutting rate Combined effect of these parameters was also studied and concluded that cutting rate not only effected by single input parameter but combination of input has main role.

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