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Study of WEDM Process on Surface Roughness of H-11 (Hot Die Steel)

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Abstract

Wire electrical discharge machining (WEDM) process is a unique option for machining of conductive material with highest accuracy. But it is not easy to determine optimal parameters for the best performance because of its complex process. Hence the study for analyzing the performance parameters needed before their optimization to get maximum performance. Objectives of this analysis study was to investigate and evaluate the effect of selected input parameters for machining of Hot die steel H11 (work material) which is used in 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 surface roughness response had been considered for each experiment. Further, experimentation was planned as per L27 Orthogonal array provided by Taguchi method for Design of Experiments (DOE). Brass wire electrode with 0.25mm diameter was used as tool in the experiments. 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 conducted to validate the result with measured values of surface roughness of machined surfaces. It was found that all the three input parameters selected were significant and contributed maximum performance at a particular value.

Key words :- WEDM, SR, T_{ON}, I_P, SV

Introduction

Wire electric discharge machining (WEDM) is widely used Non-Traditional Thermo-Electrical material removal process used to create components of complex shape profiles. WEDM uses a continuous travel wire electrodes made from thin copper, brass, molybdenum or Tungsten 0.05-0.3 mm diameter, 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.

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Working Principle of WEDM

WEDM works on the principle of electro thermal process which states that thermal energy of the spark is used to remove material of the conductive work piece. WEDM process involves complex erosion effect by different rapid and repetition sparks discharges between the wire tool electrode and work piece. Spark theory on WEDM is basically similar to the EDM process vertically. Conductive materials in WEDM are machined with a series of electric discharges spark produced between moving wire electrode and alternating or direct current of high frequency pulses with a very small spark gap through an insulated dielectric fluid.

Experimental Work

Experiments were planned for three levels to be put in L27 array for conduct of experiment. The three levels of the parameters were mandatory for L27 orthogonal array. Values in Table 1 were taken as reference for three levels to be put in L27 array for conduct of experiments and obtaining the output performance parameters, for the combinations of OA.

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Table 1. Levels of Input Control Parameter

Sr. No.	Control Parameters	Level 1	Level 2	Level 3
1	Pulse on time	106	116	126
2	Servo Voltage	10	30	50
3	Peck current	50	140	230

Table 2. Experimental Design Using L_{27}OA

Exp. No.	Pulse on time (T_{ON})	Servo Voltage (SV)	Peak current value
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

For carrying out experiments and noting down the results, simple specimens of cuboids shape were cut out. The H-11 hot die steel bar of 245 mm length, 50 mm breadth and 24 mm in thickness was mounted on the WEDM Elektra Sprintcut machine tool and specimens of 15mm x 15mm x 24mm size were cut as shown figure 1 below :

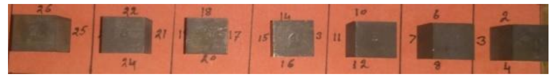

Fig. 1 Work pieces after Cutting

Table 3.Experimental Result

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Exp.No.	Pulse on time T_{ON} (µs)	Servo Voltage SV (V)	Peak current I_P (A)	Surface Roughness SR (Ra)
1	106	10	50	1.32
2	106	10	140	1.39
3	106	10	230	1.64
4	106	30	50	1.30
5	106	30	140	1.32
6	106	30	230	1.60
7	106	50	50	1.13
8	106	50	140	1.23
9	106	50	230	1.45
10	116	10	50	2.51
11	116	10	140	3.87
12	116	10	230	3.90
13	116	30	50	1.72
14	116	30	140	1.87
15	116	30	230	2.10
16	116	50	50	1.70
17	116	50	140	1.84
18	116	50	230	1.88
19	126	10	50	3.76
20	126	10	140	4.70
21	126	10	230	4.78
22	126	30	50	3.10
23	126	30	140	3.36
24	126	30	230	4.02
25	126	50	50	1.80
26	126	50	140	1.89
27	126	50	230	2.10

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

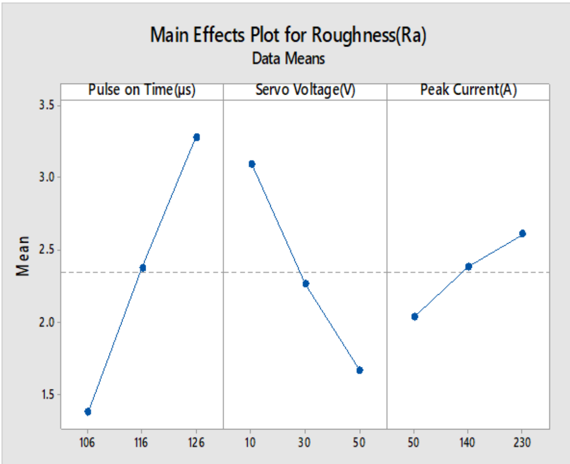

Fig. 2. Effect of Process Parameters on SR

In the fig.2, the effect on surface roughness has shown. The roughness increases with increase in the pulse on time as well as on increasing of peak current, I_P. On increasing the pulse larger spark with higher thermal energy is produced and a large amount of transfer of heat to the work piece which causes to increase in SR.

Moreover as the peak current increases, the speed of striking the discharge to the surface of the work piece increases due to which an impact force is created on the surface of molten material in the crater and more molten metal will be ejected out of the crater, so the roughness of machined surface increases. The surface roughness shows the effect of servo voltage also, it decreases on increasing of voltage.

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

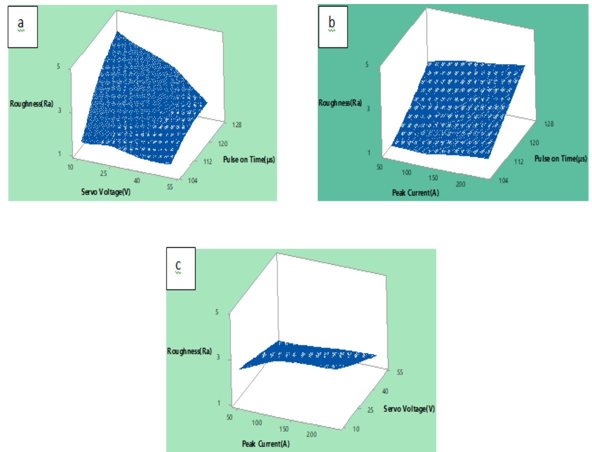

Fig. 3 Plots for Combined Effect on SR

Fig. 3 (a, b, c) describes the isolated effects of all three process parameters on surface roughness . It can clearly be seen from Fig. 6.5 (a) the surface roughness increases with the increase of pulse on time and it decreases with the increase of servo voltage at the same time. The trends are similar to previous ones except that the ranges are varied now. Here the servo voltage SV has the highest ranging effect on roughness, where as I_P has a small sloping curve for the mean range of roughness values. But seeing the combined effects of Ton and SV on roughness shows that although SV tends to retard the surface of roughness curve and T_{ON} parameter tends to play a little role on this surface even if in isolation it makes a dominating effect. The effect can be explained by the fact that the amount of discharge energy which increases with increase in pulse on-time affects surface roughness the most. The surface roughness also depends on the size of spark crater. A small crater along with larger diameter leads to a better surface roughness. To obtain a flat crater, it is necessary to control the electrical discharging energy at a smaller level by small decreasing in pulse on time (T_{ON}). High discharge energy will produce a larger crater, which is a cause of increasing surface roughness value.

It is observed from Figure 3 (b) that on increase in servo voltage surface roughness decreases. With the higher servo voltage, the discharge time gets larger. To get the higher discharge time and the machining speed will be slow down. This increases the discharge gap. So the discharge condition becomes more stable but decreases the number of discharge cycles within a given period. Because of this there is a stable machining surface accuracy becomes better and decreases in surface roughness value.

It can be seen from Fig. 3 (c) that the surface roughness decreases slightly on increase in the peak current values. The larger is the peak current setting, the higher is the discharge energy. This is a cause to increase in surface roughness.

SEM Views for Validation of SR

The above fig. 4 (a, b, c) shows the SEM view of the machined surface of the work piece at which the surface roughness found minimum, average and maximum respectively. The process parameter's values on these experiments of SEM view surfaces were found of fig.4 (a) as T_{ON} at level 1, SV at level

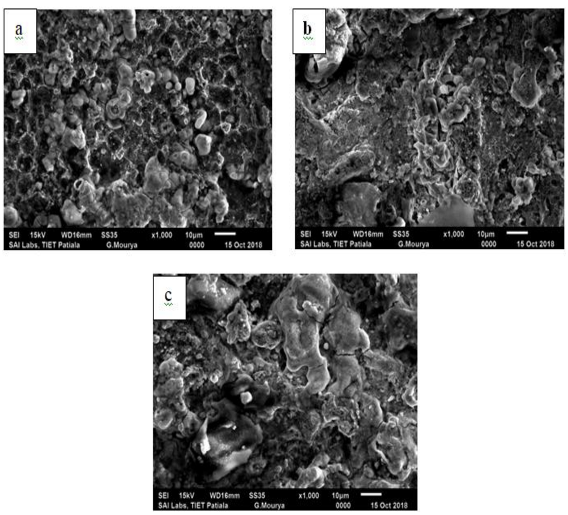

Fig. 4 SEM at Lowest, Average and Highest SR

3 and I_P at level 1, fig.4(b) as T_{ON} at level 3, SV at level 2 and I_P at level 1 and fig.4 (c) as T_{ON} at level 3, SV at level 1 and I_P at level 3. It can be seen from the SEM view of above fig. 4 (a, b, c) the crater size as well as depth on the surface are very small, average and big. Hence it is observed that these combinations of process parameters compare the surface roughness as measured and validate the result.

Conclusion

From literature review, 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 surface roughness whereas increase in servo voltage leads to decrease in surface roughness. Combined effect of these parameters was also studied and concluded that surface roughness not only affected by single input parameter but combination of input has main role. The maximum surface roughness found at T_{ON} 126, SV 10 and I_P 230 and the minimum surface roughness found at T_{ON} 106, SV 50 and I_P 50. The SEM views of machined surface revealed the same pattern as observed the experiment.

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