Performance Investigation of Wire EDM Process Parameters

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Abstract. It is exceptionally difficult to create confusing geometry in such a material using traditional machining measurement. At present, companies use a non-regular machining strategy which uses energies like electricity, chemical, sound, light, etc. which are useful for machining hard materials. WEDM machines are used to cut complex and simple patterns and have the potential to achieve the maximum production capacity since the last few decades. This study was carried out in two parts. The first segment was consolidated with analyses of the Taguchi method depending on the signal-to-noise ratio (S/N) and regression modelling for the S/N ratio. In the second segment, the model condition was created using the RSM methodology. L16 orthogonal array was used with four levels of parameters namely, pulse on time, pulse off time, wire feed rate and peak current to find the effects on optimal response variables namely, cutting time, cutting rate, overcut and dimensional deviations. The results of the regression analysis showed that there was significant effect of pulse on/off and peak current on the cutting time and for cutting rate there was also significant effect of wire feed rate. Therefore, it can be concluded that all the four process parameters can affect the response variables.

Keywords: WEDM, Taguchi method, regression modelling, signal to noise ratio

1. Introduction

In today's production industry, processing measurement undertakes an important task, in which cost and quality are the main factors. Materials such as alloys, ceramics, and composite materials are created for clear purposes and have low machinability. It is very difficult to create confusing geometry in this material using traditional machining measurements. Conventional machining measurements use mechanical power to remove material, so expecting hard materials to be machined is absurd. Currently, the company uses an unconventional processing strategy that uses electricity, chemical, sound, light and other energy useful for processing hard materials.

Arikatla et al. [1] carried out an experiment on a titanium alloy (Ti-6Al-4V) and a brass wire as an electrode and selected five input parameters, i.e. pulse on time, pulse off time, servo voltage, input power and wire tension. They studied the influence of the input parameters on the MRR and the SR. They concluded that with the increase in the wire tension and the servo tension, the roughness of the surface decreases and improves the quality of the machined surface. Daneshmand et al. [2] used copper tools and deionized water to study the effect of EDM input parameters (pulse time, stop time, pulse current and voltage) on output parameters (MRR, surface roughness, relative electrode wear and tool wear rate) for the Ni-Ti alloy. The process took place in two stages. First, by increasing the pulse time and pulse current, which resulted in an increase in MRR until the part got closer to its final shape. Second, the workpiece has been machined with other tools to achieve a high quality surface finish.
In addition, Balasubarmanian and Ganapathy [3], studied to examine the effects of various factors, namely spark current, $T_{on}$, $T_{off}$, gap voltage, wire feed speed and wire voltage on the MRR and RS using gray regression analysis. They found that the optimal condition based on the method can give better surface quality. Puri and Deshpande [4] selected high chromium and high carbon matrix steel as the workpiece. They used Taguchi's method coupled with a fuzzy logic system for the optimization of multiple responses such as MRR and SR in the WEDM process. It has been observed that the approach has proven to be effective and efficient. Moreover, the result showed that the two parameters: MRR and SR were improved. In a study Alias et al. [5] investigated the effect of feed rate on wire cutting performance of titanium alloy Ti-Al-4V. Results of the study showed that the best combination of processing parameters for higher MRR and minimum SR is machine feed rate (4 mm/min), wire speed (8 m/min), wire tension (1.4kg) and voltage (60V). Shandilya et al. [6] studied the four input process parameters of WEDM, namely servo voltage (V), pulse on time, pulse off time and wire feed speed (WF) to study the cutting width (kerf) and surface deal with. The results show that the pulse on time has no significant effect on the cutting width.

Wire EDM machine has been used to cut delicate and hard modern materials into any shape with greater precision in the end result, but the ideal activity of this machine was not accomplished at this stage, so in different parts of the world, different scientists are trying to improve more and accurate working capacity. In the present investigation, this machine was chosen to explore the measurement parameters of the WEDM machine. In the process, past distributed exploration work was reviewed to uncover the research gaps for the study.

2. Method

2.1. Design of Experiments

This study was carried out in two parts. The first segment was consolidated with analyzes of the Taguchi method depending on the signal-to-noise ratio (S / N) and regression modeling for the S / N ratio. In the second segment, the model condition was created using the RSM methodology. L16 orthogonal array was used with four levels of parameters namely, pulse on time, pulse off time, wire feed rate and peak current (Table 1 and Table 2) to find the effects on optimal response variables namely, cutting time, cutting rate, overcut and dimensional deviations. The trials were performed in a local industry in Jaipur, Rajasthan, India. In the present work, pilot tests were also performed to recognize the impact of cycle parameters on machine reactions. The analysis were carried out on a wire EDM machine (Maxicut-e WEDM) from Electronica Machine Tools Ltd.

| Factor | Parameter Name | A | B | C | D |
|--------|----------------|---|---|---|---|
| $T_{on}$ | Pulse on time | 4 | 6 | 8 | 10 |
| $T_{off}$ | Pulse off time | 4 | 6 | 8 | 10 |
| Feed | Wire Feed rate | 3 | 5 | 7 | 9 |
| Current | Peak Current | 2 | 4 | 6 | 8 |

2.2. Work Piece Selection

Modern 75mm x 75mm x 0.75mm steel sheet (Figure 1) was used as the part material for the present analyses. This modern industrial steel is normally hot worked industrial steel with moderate hardness and strength properties. It is used for medium load conditions. The service life and dimensional accuracy of this steel and instruments can be improved with proper heat treatment.
Table 2 L16 Orthogonal array design of experiment

| S. No. | T_on | T_off | Feed (mm/min) | Current |
|-------|------|-------|---------------|---------|
| 1     | 4    | 4     | 3             | 2       |
| 2     | 4    | 6     | 5             | 4       |
| 3     | 4    | 8     | 7             | 6       |
| 4     | 4    | 10    | 9             | 8       |
| 5     | 6    | 4     | 5             | 6       |
| 6     | 6    | 6     | 3             | 8       |
| 7     | 6    | 8     | 9             | 2       |
| 8     | 6    | 10    | 7             | 4       |
| 9     | 8    | 4     | 7             | 8       |
| 10    | 8    | 6     | 9             | 6       |
| 11    | 8    | 8     | 3             | 4       |
| 12    | 8    | 10    | 5             | 2       |
| 13    | 10   | 4     | 9             | 4       |
| 14    | 10   | 6     | 7             | 2       |
| 15    | 10   | 8     | 5             | 8       |
| 16    | 10   | 10    | 3             | 6       |

Figure 1 Design of cut for present experimental work

3. Data analysis
The L16 orthogonal array was used with four parameter levels, namely pulse on time, pulse stop time, wire feed rate and peak current, as shown in Table 1. The parameters of the processes and their levels for the Taguchi method were shown in Table 2. Table 3 showed the experimental results of cutting time and cutting speed. Each experiment was performed three times to find differences between the selected responses. In addition, the experimental results of dimensional deviation and kerf are shown in Table 4. Table 5 showed the results for the cut time (Ct) and the cut speed (Cr). Table 6 shows the summary of the results for overcuts and dimensional deviations. Table 7 shows the rank of each factor for each response variable.
The results showed the optimal solution (A1B4C1D4) for the cutting time with predicted optimal solution A1B4C4D1. In the current experimental work, the effect of process parameters on the response parameters of dimensional deviation (DD) and kerf was studied. Table 3 presents the experimental results of cutting time and cutting rate. Table 4 shows the results of dimensional deviation and kerf. 

4. Results and discussion
In the current experimental work, the effect of process parameters on the response parameters of the wire electric discharge machining process was investigated. A total of 4 process parameters were selected, each with 4 levels to investigate the effects on four response variables (CT, CR, OC, and DD). The results showed the optimal solution (A1B4C1D4) for the cutting time with predicted optimal value of 150.398 seconds; however the experiment value for the cutting time was 151.517 seconds. In
In addition, the optimal solution (A3B4C4D1) for cutting rate with the predicted optimal value was 0.389 mm/sec; however, the experiment value for the cutting rate was 0.381. Also the results showed decrease in over cut rate with the optimal solution (A4B1C3D1) with the predicted optimal value of 0.0035 as compared with the experimental result (0.0049). There was also decrease in dimensional deviation using the optimal solution (A2B2C1D4) with the predicted optimal value of 0.322 as compared to the experimental result (0.677).

Table 5 Summary of the results for cutting time (Ct) and cutting rate (Cr)

| Run Order | Pt Type | Blocks | T_on | T_off | Feed | Current | Cutting Time | Cutting Rate |
|-----------|---------|--------|------|-------|-------|----------|--------------|--------------|
| 1         | 0       | 1      | 7    | 7     | 6     | 5        | 151.828      | 0.326        |
| 2         | 2       | 1      | 10   | 4     | 6     | 5        | 153.378      | 0.337        |
| 3         | 0       | 1      | 7    | 7     | 6     | 5        | 152.352      | 0.328        |
| 4         | 2       | 1      | 7    | 7     | 6     | 8        | 151.575      | 0.344        |
| 5         | 2       | 1      | 7    | 7     | 6     | 9        | 151.722      | 0.342        |
| 6         | 2       | 1      | 10   | 4     | 6     | 5        | 153.111      | 0.347        |
| 7         | 2       | 1      | 10   | 7     | 3     | 5        | 152.975      | 0.323        |
| 8         | 2       | 1      | 4    | 7     | 3     | 5        | 149.946      | 0.361        |
| 9         | 2       | 1      | 10   | 7     | 6     | 2        | 154.883      | 0.379        |
| 10        | 2       | 1      | 10   | 7     | 9     | 5        | 153.762      | 0.342        |
| 11        | 2       | 1      | 7    | 7     | 9     | 8        | 151.380      | 0.356        |
| 12        | 2       | 1      | 4    | 7     | 9     | 5        | 150.868      | 0.342        |
| 13        | 2       | 1      | 7    | 4     | 9     | 5        | 152.320      | 0.324        |
| 14        | 0       | 1      | 7    | 7     | 6     | 5        | 151.941      | 0.344        |
| 15        | 2       | 1      | 7    | 4     | 6     | 2        | 153.206      | 0.365        |
| 16        | 2       | 1      | 4    | 7     | 6     | 2        | 151.381      | 0.349        |
| 17        | 2       | 1      | 4    | 10    | 6     | 5        | 150.680      | 0.319        |
| 18        | 2       | 1      | 10   | 7     | 6     | 8        | 152.950      | 0.342        |
| 19        | 2       | 1      | 7    | 10    | 3     | 5        | 151.704      | 0.312        |
| 20        | 2       | 1      | 7    | 7     | 9     | 2        | 152.991      | 0.342        |
| 21        | 2       | 1      | 4    | 7     | 6     | 8        | 150.155      | 0.364        |
| 22        | 2       | 1      | 7    | 10    | 6     | 8        | 150.547      | 0.354        |
| 23        | 2       | 1      | 4    | 4     | 6     | 5        | 150.987      | 0.360        |
| 24        | 2       | 1      | 7    | 7     | 3     | 8        | 151.363      | 0.353        |
| 25        | 2       | 1      | 7    | 7     | 3     | 2        | 153.071      | 0.340        |
| 26        | 2       | 1      | 7    | 4     | 3     | 5        | 151.574      | 0.330        |
| 27        | 2       | 1      | 7    | 10    | 6     | 2        | 153.060      | 0.358        |

In addition, the model equations were generated for each response variable using RSM technique. Therefore, the regression coefficient (R2 =95.21%) and the equation for response cutting time (sec) was

\[ CT = 150.885 + 0.4734 \ T_{on} - 0.0616 \ T_{off} + 0.0670 \ Feed - 0.595 \ Current + 0.0300 \ Current*Current \]

In addition, the regression coefficient (R2 =98.88%) and the equation for response cutting rate (mm/sec) was

\[ CR = 0.32766 + 0.009460 \ T_{on} - 0.00359 \ T_{off} - 0.00147 \ Feed - 0.000770 \ Current + 0.000317 \ T_{off}*T_{off} + 0.000188 \ Feed*Feed \]
Further, the regression coefficient (R² = 98.31%) and the equation for response overcut (mm) was

\[ OC = -0.000641 + 0.000686 T_{on} + 0.000397 T_{off} + 0.000031 \text{ Feed} + 0.000296 \text{ Current} - 0.000015 T_{on} \times T_{on} - 0.000015 T_{off} \times T_{off} - 0.000012 \text{ Current} \times \text{ Current} - 0.000019 T_{on} \times \text{ Feed} \]

However, the regression coefficient (R² = 89.58%) and the equation for response dimensional deviation (mm) was

\[ DD = 0.550 - 0.0013 T_{on} - 0.0143 T_{off} + 0.0031 \text{ Feed} - 0.0607 \text{ Current} + 0.00643 T_{on} \times T_{off} + 0.00593 \text{ Feed} \times \text{ Current} \]

Therefore, the results of the regression analysis showed that there was significant effect of pulse on/off and peak current on the cutting time and for cutting rated wire feed rate there was also significant effect of wire feed rated. In addition, there was significant effect of all four process parameter on the
overcut and the dimensional deviation. Moreover, using S/N ratio analysis, rank of each factor for each response variable were also presented in Table 8 in which pulse on time was ranked 1 for the dimensional deviation, pulse off time for the cutting rate and peak current for the cutting time and overcut. However, Shandilya et al. [6] studied the four input process parameters of WEDM, namely servo voltage (V), pulse on time, pulse off time and wire feed speed (WF)) to study the cutting width (kerf) and surface finish. The results show that the pulse on time has no significant effect on the cutting width. Therefore, it can be concluded that all the four process parameters can affect the response variables.

Conflict of Interest
None to report.

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