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SURFACE ROUGHNESS AND KERF WIDTH OPTIMIZATION IN WEDM USING TAGUCHI METHOD

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ABSTRACT

Wire-cut electrical discharge machining (WEDM) is one of the most emerging non-conventional manufacturing processes for machining materials and intricate profiles which are not possible with conventional machining. In WEDM process the surface roughness and kerf width are of vital importance in machining materials. In this paper, Inconel X-750 is used as a work material and Zinc coated brass wire is used as tool. Experimentation has been carried out by using Taguchi's L16 orthogonal array. In this paper, pulse on-time, pulse-off time, gap voltage, and wire feed are taken as input parameters. Surface roughness and kerf width are taken as output parameters. Dielectric fluid pressure, wire speed, wire tension, resistance and cutting length are taken as fixed parameters. The optimal value is obtained for surface roughness and kerf width by using Taguchi optimization technique.

Keywords: Taguchi, Surface roughness, Kerf width, Zinc coated brass, Inconel X-750

INTRODUCTION

Wire EDM is an electro thermal manufacturing process. The materials are removed by repetitive spark cycle between the tool and work piece. In Wire EDM, an high electric discharge is created in the tool wire. As the spark hurdle across the gap, material is removed from work piece. A non conductive dielectric fluid is supplied continuously to prevent the shorting out of created electric discharge. The dielectric fluid supplied is utilised for flushing out of removed material from the work piece table. To conduct the sixteen experiments, brass wire of 0.25mm diameter is used as the tool-electrode and Inconel x-750 is used as the work material for the present paper.

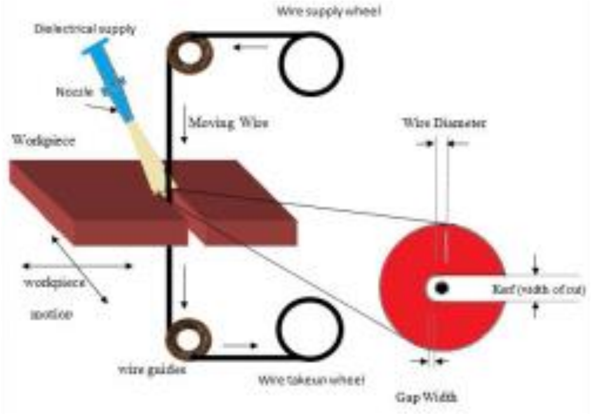

Figure1: Working Principle of WEDM

In WEDM, there is no direct contact between workpiece and tool (wire) as in conventional machining process, therefore materials of any hardness can be machined and minimum clamping pressure is required to hold the workpiece. In this process, the material is eroded by a series of discrete electrical discharges between the workpiece and tool. These discharges cause sparks and result in high temperatures instantaneously, up to about 10000º C. These temperatures are huge enough to melt and vaporize the workpiece metal and the eroded debris cools down quickly in working fluid and flushed away, the working principle is shown in the figure 1.

WORK AND TOOL MATERIAL

INCONEL is a precipitation-hardenable nickel-chromium alloy used for its corrosion and oxidation resistance and high strength at temperatures to 1300°F. Although much of the effect of precipitation hardening is lost with increasing temperature over 1300°F, heat-treated material has useful strength up to 1800°F. Alloy X-750 Also has excellent properties down to cryogenic temperatures.

The economics of INCONEL alloy X-750 coupled with its availability in all standard mill forms has resulted in applications in a wide variety of industrial fields. In gas turbines, it is used for rotor blades and wheels, bolts, and other structural members. INCONEL alloy X-750 is used extensively in rocket-engine thrust chambers. Airframe applications include thrust reversers and hot-air ducting systems. Large pressure vessels are formed from INCONEL alloy X-750. Other applications are heat-treating fixtures, forming tools; extrusion dies, and test machine grips. For springs and fasteners, INCONEL alloy X-750 is used from sub-zero to 1200°F [2].

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The various heat treatments and the properties developed are described under the section on mechanical Properties.

Table.1 Chemical Compostion Of Inconel X-750

Nickel (plus Cobalt)	70.00 min.
Chromium	14.0-17.0
Iron	5.0-9.0
Titanium	2.25-2.75
Aluminum	0.40-1.00
Niobium (plus Tantalum)	0.70-1.20
Manganese	1.00 max.
Silicon	0.50 max.
Sulphur	0.01 max.
Copper	0.50 max.
Carbon	0.08 max.
Cobalt1	1.00 max

TOOL MATERIAL

Coated wires were developed in an attempt to put Zinc on the surface of the wire, while retaining a core wire material that could be successfully drawn. Coated wires are produced by plating or hot-dipping re-draw wire (0.9mm) and subsequently drawing it to final size.

Zinc coated Brass wires was one of the first attempts to present more Zinc to the wire's cutting surface. This wire consists of a thin (approximately 5 micron) zinc coating over a core which is one of the standard EDM brass alloys. This wire offers a significant increase in cutting speed over plain brass wires, without any sacrifice in any of the other critical properties. Zinc Coated Brass wires produce exceptional surface finishes when cutting Tungsten Carbide and are often utilized for cutting PCD and graphite.

EXPERIMENTAL DETAILS

TOOL SELECTION

- Zinc coated brass tool

WORK MATERIAL SELECTION

- Inconel x-750

INPUT PARAMETERS:

- Gap voltage
- Wire feed
- Pulse on time
- Pulse off time

Gap voltage: It is potential difference applied in between electrode and work piece. It is given in units of volts.

Wire feed: It is amount of wire drawn per minute for machining. It's drawn with the help of automatic wire threading (AWT). Their unit is mm/min.

Pulse on time: The duration of time for the current is allowed to flow per cycle. Its unit is μs.

Pulse off time: The duration of time in between the sparks generated. During this time the molten material gets removed from the gap between the electrode and the work piece. Its unit is μs.

OUTPUT PARAMETERS

- Surface roughness
- Kerf width

Surface roughness: The surface roughness is defined as the measure of the texture of the surface.

Figure 2:Surf Coder

Figure 3: Video Measurimg System

Kerf width: The kerf width is the measure of the amount of the material that is wasted during machining.

DESIGN OF EXPERIMENTS

Taguchi's design of experiments uses various numbers of levels and parameter for making orthogonal array. Here we use four levels (1, 2, 3, and 4) and four parameters (gap voltage, wire feed, pulse on time, and pulse off time) the alternative method to Taguchi's design of experiment is full factorial method. The disadvantage of using this method is that an interaction obtained by using full factorial method is 486 experiments. Hence design of experiments were using Taguchi's L_{16} orthogonal array.

Table.2. Design of Experiment

Process parameters	Units	Level 1	Level 2	Level 3	Level 4
Pulse-on time	**μs**	4	6	8	10
Pulse-off time	**μs**	2	4	6	8
Wire feed	**Mm/min**	2	4	6	8
Gap voltage	**Volts**	30	40	50	60

Using the above process parameters and levels an array is formed. This array of data's are called as orthogonal array having four process parameters like pulse on time, pulse off time, wire feed, and gap voltage. Each parameter having four levels which are taken using the range taken from WEDM machine specification. Taguchi's L_{16} orthogonal array was selected for experiments

Table.3 L_{16} Orthogonal Array

Pulse on time(μs)	Pulse off time(μs)	Wire feed (mm/min)	Gap voltage (volts)
4	2	2	30
4	4	4	40
4	6	6	50
4	8	8	60
6	2	6	40
6	4	8	30
6	6	2	60
6	8	4	50
8	2	8	50
8	4	6	60
8	6	4	30
8	8	2	40
10	2	4	60
10	4	2	50
10	6	8	40
10	8	6	30

MEASUREMENT OF SURFACE ROUGHNESS AND KERF WIDTH

Roughness plays an important role in determining how an object will interact with the environment. Rough surfaces usually wear more quickly and have higher friction coefficient than smooth surfaces. Roughness is often a good predicator of performance of a mechanical component. The kerf width is the measure of amount of material that is wasted during machining. It determines accuracy of the finished part.

DETEMINATION OF S/N RATIO

The response of surface roughness and kerf width is used to calculate the signal to noise ratio(S/N). Since surface roughness is desired to be at minimum, the lower the better characteristic is used for S/N ratio calculation. The formula for S/N ratio is

$$S/N=-10 \log \left(1/r \sum_{i=1}^{r} Y_i^2\right)$$

The effects can be evaluated using the following statistics

-Smaller is better or S-type statistics

-Bigger is better or B-type statistics

-Nominal is better or N-type statistics

In this study smaller is better principle is considered to minimize the surface roughness.

RESULTS AND DISCUSSION

The results showed with actual value made in S/N ratio and practical value in the following table

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Table.4: Result values for Surface Roughness and Kerf Width

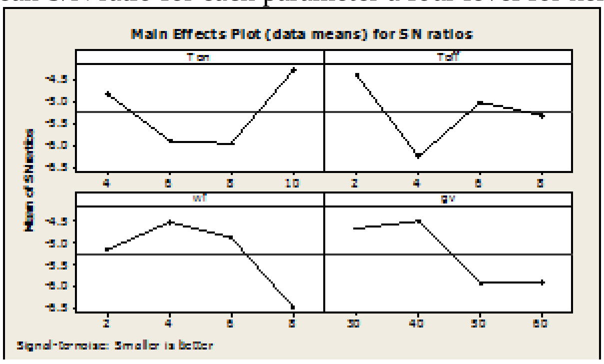
Surface roughness (Ra) µm	S/N Ratio µm	Kerf width mm	S/N Ratio mm
1.5	-3.521	0.281	11.02
1.68	-4.506	0.295	10.60
1.75	-4.860	0.297	10.54
2.1	-6.444	0.301	10.42
1.72	-4.710	0.29	10.75
2.35	-7.421	0.285	10.90
2.1	-6.444	0.292	10.69
1.79	-5.057	0.286	10.87
1.89	-5.529	0.291	10.72
2.85	-9.096	0.3	10.45
1.69	-4.557	0.298	10.51
1.72	-4.710	0.312	10.11
1.56	-3.862	0.298	10.51
1.59	-4.027	0.311	10.14
1.62	-4.190	0.305	10.31
1.79	-5.057	0.286	10.87

Mean S/N ratio for each parameter at four levels for surface roughness Ra

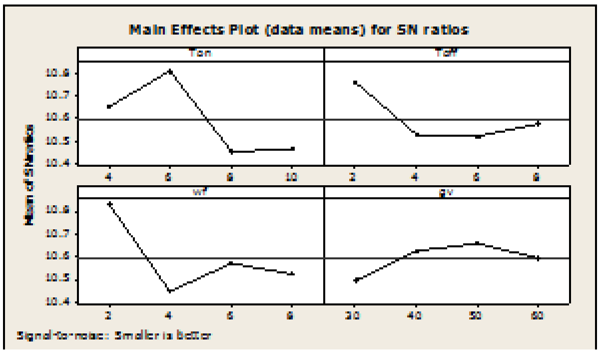
Table.4: Result values for Surface Roughness and Kerf Width

Factor	S/N ratio mean			
	Level 1	Level 2	Level 3	Level 4
Gap voltage	-4.83	-4.40	-5.13	-4.67
Wire feed	-5.90	-6.26	-4.52	-4.49
Pulse on time	-5.97	-5.01	-4.86	-5.93
Pulse off time	-4.28	-5.31	-6.46	-5.89

Mean S/N ratio for each parameter a four level for kerf width



Graph1: Mean S/N Ratio for Surface Roughness



Graph 2: Mean S/N Ratio for Kerf Width

Table 6: Mean S/N Ratio for Kerf Width

S.No	factor	S/N ratio mean			
		Level 1	Level 2	Level 3	Level 4
1	**Gap voltage**	10.65	10.75	10.83	10.49
2	**Wire feed**	10.81	10.53	10.45	10.63
3	**Pulse on time**	10.45	10.52	10.57	10.66
4	**Pulse off time**	10.46	10.57	10.52	10.59

Optimized value for surface roughness and kerf width: The optimized value for minimum surface roughness is

Factor	Level	Optimum value
Gap voltage	4	60 volts
Wire feed	1	2 mm/min
Pulse on time	3	8 µs
Pulse off time	2	4 µs

The optimized value for machining for good minimal is

Factor	Level	Optimum value
Gap voltage	4	60 volts
Wire feed	1	2 mm/min
Pulse on time	2	6 µs
Pulse off time	3	6µs

CONCLUSION

In this paper, an attempt has been made to find the optimal solution of process parameters to obtain minimum surface roughness and kerf width using Taguchi technique. The optimal combination of process parameters for obtaining minimum surface roughness through Taguchi technique is

1. 60V of Gap voltage
2. 2mm/min of Wire feed
3. 8 µs of pulse on time
4. 4 µs of pulse off time

The optimal combination of process parameters for obtaining minimum kerf width through Taguchi technique is

1. 60V of Gap voltage
2. 2mm/min of Wire feed
3. 6 µs of Pulse on time
4. 6µs of Pulse off time

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