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Comparative Experimental Investigation with different wire electrodes on SS440C component using Wire cut EDM

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Abstract

Today Competition among the manufacturing industries at global scale is looking for creating faster production with precision and tight tolerances. Wire cut Electric Discharge Machining (W-EDM) is one of the latest non traditional machining processes used in industrial applications. It is suitable for machining works on a variety of materials like aluminium, titanium and alloys, super alloys, maraging steel. Among these materials very few studies are performed on SS440C which has high hardness, superior corrosion resistance and strength These materials are widely used in aerospace, defence industries for making complex parts. In this paper our target is to select the best possible outcomes in terms of Material Removal Rate and surface Roughness. Wire electrodes of Brass wire and zinc coated brass wire with 0.25 mm diameter are used .Experiment is based on Taguchi L_9 orthogonal array. Signal to Noise Ratio (S/N) and ANOVA is performed using MINITAB statistical software.

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Keywords: WEDM, SS440C, Material Removal Rate, Surface Roughness, S/N Ratio, ANOVA;

1. Introduction

New materials are critical components of emerging technologies that assure to be the major growth areas for the economy. To create more advanced products and intricate parts manufacturers need new materials. The requirements for materials having high hardness, high wear resistance, good resistance to corrosion and tensile strength have resulted to look forward for new non-traditional material removal process. These non- traditional machining processes are classified based on the energy they use as mechanical, thermal, chemical and electrochemical [1]. WEDM is a thermoelectric process in which heat energy of spark is utilized to remove material from the workpiece. Being a highly complex and stochastic process the proper selection of process parameters are required to avoid any false influence on the responses like material removal rate or surface roughness. It is a distinctive modification of conventional EDM process, by using a continuously travelling wire electrode of brass, molybdenum, tungsten, zinc coated of diameters ranging from 0.05 – 0.3 mm. A spark between the two electrodes (tool and workpiece) is determined to occur at the narrowest gap between the two. The temperature under the spark is very high results in partly melting and vaporizing material on both the electrodes [2]. A continuous thin wire is travelling from the spool bore which passes between the upper wire guide and lower guide as depicted in Figure 1. During machining process, material is eroded by generating series of discrete sparks between the electrode and workpiece. No direct contact is required between the wire electrode and workpiece which is immersed in dielectric fluid. Stainless steel 440 grade C has been considered as our base material in the present research work because of its excellent machining properties which are required to meet the challenging needs of present world. Harsh saini et.al [3] attempted to optimize WEDM parameters with the performance parameter like Material Removal Rate on mild steel. The analysis indicates that Pulse on Time and current have strong influence on the response parameters. A Ibrahim et.al [4] carried out a experimental work on Cr- Ni stainless steel using Box-Behnken design with parameters like voltage, pulse duration (i.e. pulse on time & pulse off time) ,wire feed. The results indicate that pulse on time shows positive impact while surface roughness is minimised by peak voltage. S Abdulkareem et.al[5] conducted a study by investigating the variables which affect the surface topography of stainless steel. Dwaipayan et.al [6] studied the effects caused by the machining parameters with Response Surface Methodology. The response parameters like kerf width, overcut was able to achieve the set target values. M. Geetha et.al [7] conducted modelling and analyses with parameters like pulse-on time, pulse-off time, wire tension, water pressure. The second order model describes variation in Ra and MRR of about 89% and 97%. Ramanujam R et.al [8] performed an investigation with end milling operation for Inconel 718 material based on Taguchi technique and desirability function analysis. Cutting velocity is the most significant machining parameter which is obtained from Analysis of Variance. Optimization with desirability function gives better results. Suresh et.al [9] attempted a comparative study with different wire electrodes. Manish et.al [10] studied different optimization techniques used to effectively obtain the performance characteristics. The outcomes are to Maximize the MRR, reduced the TWR, improve the Surface Roughness.

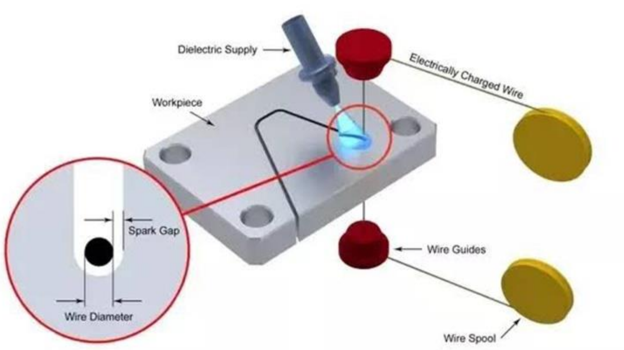

Fig.1. Schematic diagram of Wire EDM process

From the literature review conducted we obtained that very few studies are performed between the comparative studies of wire electrodes with Stainless Steel 440 material. In the present work, an experimental investigation on Wire cut EDM is performed at SS440C. Based on Taguchi L9 Orthogonal Array experiments are performed with the two different wire electrodes. The main focus of our research works is to find the effects of input parameters parameters on the response parameters by analysing the best wire electrode.

2. Experimental setup

2.1 Work Piece Material

Grade 440C stainless steels are high carbon steels, which attain the highest hardness, wear resistance and strength of all stainless steel grades after heat treatment. These properties make this grade suitable for applications such as valve components and ball bearings. However, grade 440C is more readily available than the other standard grades. They are used in ball bearing balls and races, high pressure nozzles, valve seats and high wear components. It has 0.95 to 1.20 percent carbon. We perform machining on Electro Hydraulic Servo Valve component of Stainless steel 440C.

Table.1 Shows the Chemical composition of work specimen SS440C.

Chemical composition of SS440C	
Iron (Fe)	79.15%
Chromium (Cr)	18 %
Carbon (C)	1.1%
Manganese (Mn)	1%
Silicon (Si)	1%
Molybdenum (Mn)	0.75%

Table.2 Mechanical Properties of work specimen SS440C

Yield tensile strength	2030 MPa
Density	7.80g/cm^3
Hardness	60 HRC
Modulus of elasticity	200 GPa
Shear modulus	83.9 GPa
Bulk modulus	166 GPa
Elongation	4%
Poisson's Ratio	0.27-0.30

2.2 Wire electrode

Different types of wire electrodes are available. Some are for rough machining while other are only for finishing operations. Wire electrodes are –plain brass wire, zinc coated, molybdenum, composite wires, etc. The size of wires ranging from 0.15 to 0.3 mm are available. Wires with 0.25 mm diameter are preferred. The brass wire is of GF+ AC 500 type & zinc coated wire of falcon ,both having a weight of 3.5 kg.

Fig 2. Brass wire electrode

Fig 3. Zinc coated brass wire electrode

2.3 Machine Specifications

The experimental investigations were performed on Charmilles ROBOFIL 240cc Wire electric discharge machine. The ROBOFIL 240cc has a high speed, maintenance-free wire threading system. The WEDM specifications are described as follows:

- Main table transverse axis(X, Y, Z) : 350,220,220 mm
- Type : Submerged wire cutting
- Auxiliary table transverse (U,V) : (+/- 30°)
- Max part dimensions : 1000 x 550 x 220 mm
- Max weight of Part : 750 kg
- Volume of dielectric tank : 760 liters
- Power supply : 3 phase AC 400 V, 50 Hz
- Compressed air pressure : 6-7 Bar
- Max wire Tension : 5 KgF
- Power consumption : 10 KVA

It can cut very hard materials and is often used in industry for tool and die making. The only requirement is that the material must conduct electricity. EDM power supply has solid state rectifier to convert AC into DC. Power supply system senses the voltage between electrodes which sends signal to servosystem which maintains the required gap between the electrodes. Wire EDM is capable of producing complex and intricate parts. Effective flushing is required to remove the debris formed on the machined surface. With the WEDM process the spool bore hole of EHSV valve body is enlarged from 4.0 mm diameter to 4.480 mm diameter and the corresponding machining time is noted .

Fig.4. Experimental Setup

2.4 Design of Experiments with Levels of Parameters

Experiments were carried out based on Taguchi L9 experimental plan. The experiments were replicated three times to avoid the variations between the input parameter and machining responses. So to avoid any chances of such occurring the experiments are performed in a randomized manner.

The selection of orthogonal array is based on the degree of freedom. Machining voltage, interval between two pulses, wire advance rate, wire tension were taken as process parameters. Current, Flushing pressure is taken as constant. While MRR, Surface Roughness, Cylindricity are responses.

Process variables such as Machining voltage, interval between two pulses, wire advance rate, wire tension were used in this investigation are shown in table 3.

Table 3. Process parameters with their respective levels

Process variables	unit	Levels		
		1	2	3
Machining voltage	Volts	30	40	50
Interval between two pulses	µs	6	7	8
Wire advance rate	m/min	35	45	55
Wire tension	KgF	1	1.25	1.5

Machining voltage also known as the operating voltage is the actual voltage which is applied during the machining process. The ranges of values are selected based on the machine safe working conditions.

Interval between two pulses describes the combinational value of pulse-on time and pulse-off time.

An orthogonal array was prepared for conducting the experiment layout with the machining parameters. The array consists of four process variables with their three levels.

***2.5** Measurement of Output parameters*

Material removal rate (MRR) describes about how much amount of material is removed from a part in a given period of time. The formula for calculation of material removal rate is given below.

MRR= (Volume of the work piece lost during machining)/ (time taken for machining)

Surface Roughness is a good response parameter to present the characteristics of a mechanical component. It is determined by comparing all the peaks and valleys and then taking the average throughout the entire length. TAYLOR HOBSON SURTRONIC 25 is used for measuring .the probe is calibrated to a preset value of 6 microns using a reference plate and then corresponding readings are taken. Cylindricity describes the radial separation of two coaxial cylinders such that the radial difference is at a minimum. Cylindricity values are becoming important in the measurement of component which requires great precision such as fuel injection system, plunger barrel, through cut holes in valve bodies. Cylindricity is measure using TAYLOR HOBSON TALYROND 365.

Experiment were performed based on the L9 Orthogonal array and the calculated readings are shown below –

Table 4. Observation table with plain brass wire electrode

Machining voltage (volts)	Interval between two pulses (microsec)	Wire advance rate (m/min)	Wire tension (kgf)	MRR	Surface Roughness (µm)	Roundness (µm)	Cylindricity (µm)	Spark gap (mm)
30	6	35	1	0.09500	0.62	4.128	6.20	0.11675
30	7	55	1.25	0.09299	0.64	3.729	6.61	0.11575
30	8	75	1.5	0.09493	0.58	3.607	5.48	0.11500
40	6	55	1.5	0.09999	0.66	3.958	6.43	0.11675
40	7	75	1	0.09049	0.70	4.937	7.07	0.11625
40	8	35	1.25	0.11081	0.68	5.088	8.15	0.11525
50	6	75	1.25	0.10031	0.72	4.923	6.83	0.11350
50	7	35	1.5	0.10579	0.80	4.975	7.68	0.11750
50	8	55	1	0.10050	0.86	4.760	7.31	0.11450

Table 5 Observation table with Zinc Coated brass wire electrode

Machining voltage (volts)	Interval between two pulses (microsec)	Wire advance rate (m/min)	Wire tension (kgf)	MRR	Surface Roughness (µm)	Roundness (µm)	Cylindricity (µm)	Spark gap (mm)
30	6	35	1	0.09500	0.62	4.128	6.20	0.11675
30	7	55	1.25	0.09299	0.64	3.729	6.61	0.11575
30	8	75	1.5	0.09493	0.58	3.607	5.48	0.11500
40	6	55	1.5	0.09999	0.66	3.958	6.43	0.11675
40	7	75	1	0.09049	0.70	4.937	7.07	0.11625
40	8	35	1.25	0.11081	0.68	5.088	8.15	0.11525
50	6	75	1.25	0.10031	0.72	4.923	6.83	0.11350
50	7	35	1.5	0.10579	0.80	4.975	7.68	0.11750
50	8	55	1	0.10050	0.86	4.760	7.31	0.11450

3. Results and Discussion

The WEDM experiments were performed in order to study the effect of process parameters on the output response characteristics with the process parameters as given in Table 4 and 5.The experimental results are collected for responses like Material removal rate and surface roughness. 9 experiments were conducted using Taguchi experimental design method and obtain S/N values. In this study all the designs, plots and analysis were carried out using Minitab 17 statistical software.

In Taguchi method, the loss function is transformed into signal-to-noise (S/N) ratio. Signal to Noise Ratio are categorized as Lower the better (LB), Higher the best (HB) and Nominal the best (NB).When we consider material removal rate as the performance criterion then Higher value is suited while for Surface Roughness then Lower the best is considered.

a b

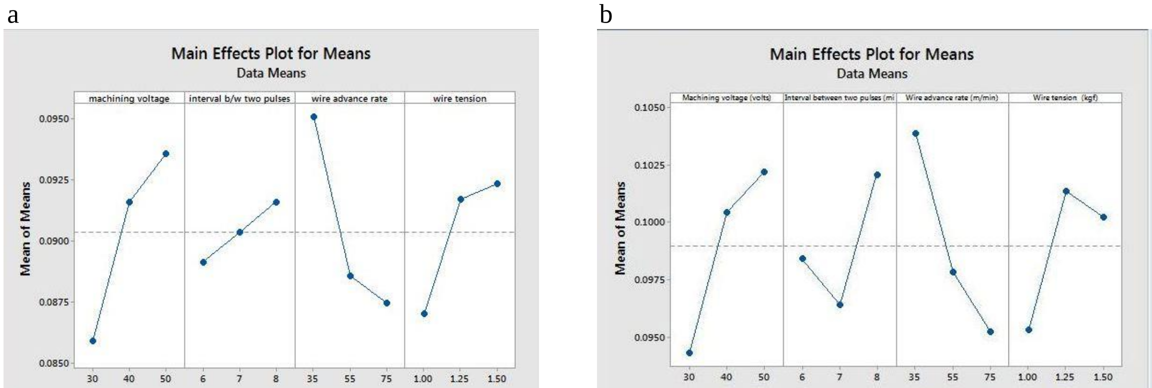

Fig.5. Effects of process parameters on MRR with: **(a)** plain brass wire and **(b)** Zinc coated brass wire

From Fig.5 we can conclude that with an increase in machining voltage the material removal rate also increases with both type of wire electrodes, but the Zinc coated wire electrode gives higher amount of material removal. Also when there is an increase in the value of Wire advance rate, the material removal rate is decreased. The parameter which has the largest contribution is analyzed from Response table.

Table 6. Response table for means for MRR

Level	Machining voltage	interval between two pulses	Wire advance rate	Wire tension
1	21.32	21.00	20.46	21.21
2	20.78	20.91	21.06	20.77
3	20.59	20.91	21.17	20.71
Delta	0.73	0.22	0.71	0.50
Rank	1	4	2	3

The response table shows the relative importance of input parameters which affects the response. From the table it is clear that process parameter which has the highest value for delta will gets the highest rank. Rank 1 signifies the most influencing parameter .Machining Voltage gets the rank 1 followed by Wire advance rate. and least influencing parameter is time interval between two pulses.

a b

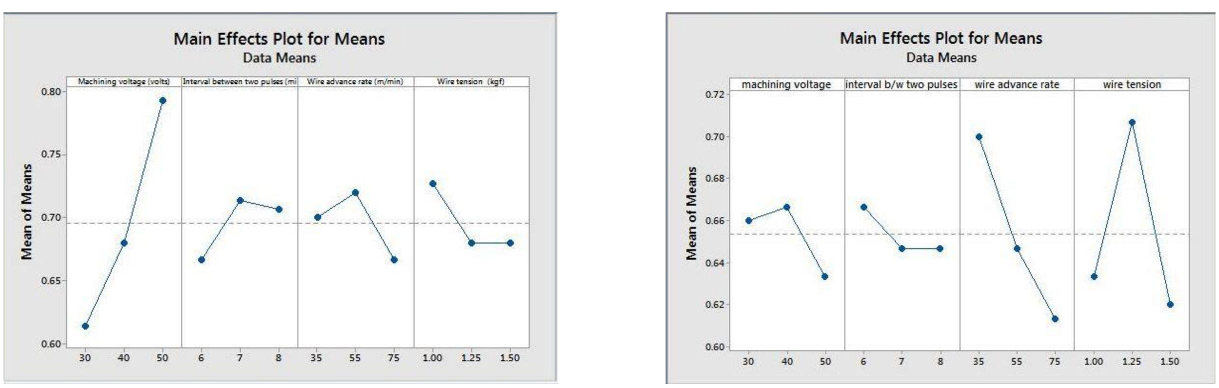

Fig.6. Effects of process parameters on Surface Roughness with: **(a)** plain brass wire and **(b)** Zinc coated brass wire

From the graphs it is clear that as the wire advance rate increases there is decrease in the value of Ra followed by wire tension. The wire tension of about 1.25 KgF is the optimum condition when surface roughness value is least. The Response table for means shown in table 7 shows the most influencing factors.

Table 7. Response table for means for Surface Roughness

level	Machining voltage	interval between two pulses	Wire advance rate	Wire tension
1	18.72	18.74	18.67	18.72
2	18.70	18.67	18.74	18.80
3	18.77	18.79	18.79	18.68
Delta	0.07	0.12	0.12	0.12
Rank	4	3	1	2

3.1Analysis of Variance (ANOVA) technique is generally employed to analyze the influence of parameters. In this the F value determines most important process parameters. F stands for Fisher's test statistic .The parameter whose having P value is less than 0.05 will be most effective factor.

Table 8 Anova table for MRR

Source	DF	Seq SS	Contribution	Adj MS	F-Value	P-Value
Machining voltage	2	0.000094	36.98%	0.000047	10.59	0.086
Wire advance rate	2	0.000101	39.72%	0.000051	11.37	0.081
Wire tension	2	0.000050	19.81%	0.000025	5.67	0.150
Error	2	0.000009	3.94%	0.000004		
Total	8	0.000255	100.00%			

Table 9 Anova table for Surface Roughness

Source	DF	Seq SS	Contribution	Adj MS	F-Value	P-Value
Machining voltage	2	0.001867	6.86%	0.000933	2.33	0.300
Wire advance rate	2	0.011467	42.16%	0.005733	14.33	0.065
Wire tension	2	0.013067	48.04%	0.006533	16.33	0.058
Error	2	0.000800	2.94%	0.000400		
Total	8	0.027200	100.00%			

4. Conclusion

In this research zinc coated wire, it gives more material removal rate (MRR) as compare to the brass wire and also analyzing S/N and mean value for optimal conditions for material removal rate. Higher pulse on time, lower current and higher wire speed are favorable parameters to attain higher material removal rate The material removal rate increases with an increase in the machining voltage .An optimum combination of parameter for maximizing MRR and minimum Surface roughness was obtained from the analysis. For most of the precise machining operations and complex shapes it is best suited to go with zinc coated wire electrodes.

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