EFFECT OF TWO DIFFERENT CRYOGENIC TREATED WIRES IN WIRE ELECTRICAL DISCHARGE MACHINING OF AISI D3 DIE STEEL

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Abstract: *In this experimental investigation cryogenically treated zinc coated diffused brass wire and cryogenically treated plain brass wire have been used as cutting tool. In this experimentation AISI D3 die steel has been taken work piece. The input process parameters considered are pulse width, time between two pulses, wire mechanical tension and wire feed rate. Taguchi's L9 orthogonal array has been used for design of experiments. The process performance is measured in terms of optimization of material removal rate. After performing the experiment, results of both wires have been compared. It is found that the cryogenically treated zinc coated diffused brass wire gives good material removal rate as compare to cryogenically treated plain brass wire.*

Keywords*: Cryogenic, WEDM, Process parameters, Material Removal Rate.*

INTRODUCTION

In the present study AISI D3 is used as work piece material. AISI D3 tool steel is a high-carbon, high chromium, oil-hardening tool steel that is characterized by a relatively high attainable hardness. Applications for D3 tool steel include blanking, stamping, and cold forming dies and punches for long runs; lamination dies, bending, forming, and seaming rolls, cold trimmer dies or rolls, burnishing dies or rolls, plug gauges, drawing dies for bars or wire**.** Because all these components are made from hard material and only WEDM is suitable to machine these components. The effect on material removal rate has been evaluated by using two different cryogenically treated wires. Then the results for two wires have been compared.

LITERATURE SURVEY

Singh et al.[1] described a case study on En24 steel turned parts using titanium carbide coated tungsten carbide inserts. After optimization they found a single optimal condition to get near optimal value of all the response characteristics simultaneously. The response characteristics optimizes were MRR, tool wear rate, power consumption and surface finish. Mahapatra et al.[2] described the optimization of WEDM process parameters using Taguchi method. The author's optimized material removal rate (MRR), surface finish and cutting width for a rough cut. Discharge current, pulse duration, pulse frequency, wire speed, wire tension and dielectric flow rate and few selected interactions both for maximizations of MRR and minimization of surface roughness in WEDM process using Taguchi Method. Chattopadhyaya et al.[3] investigated the machining characteristics of EN-8 steel with copper as a tool electrode during rotary electrical discharge machining process. The mathematical models for prediction of output parameters have been developed using linear regression analysis. Three input parameters of the model viz. peak current, pulse on time and rotational speed of tool electrode were chosen as variables for evaluating the output parameters such as metal removal rate (MRR), electrode wear ratio (EWR) and surface roughness (SR). The analysis was done using Taguchi Method and Analysis of Variances. Kapoor et al.[4] proved that zinc coated brass wires are better than composite wires. The outermost layer of the wire has having high mechanical strength, vibration dumping effect, heat transfer effect and resistance to breakage which ultimately increased the machining speed. Kapoor et al.[5] determined effects of cryogenic treated wire electrode on the surface of an EN-31 steel machined by WEDM. Wire, pulse width and wire tension were taken as input parameters. Brass wire electrode was used as a tool in wire electrical discharge machining (WEDM). The process performance was measured in terms of surface roughness. Three levels for each control variables were selected for the full factorial experiment. Surface roughness values were measured with Surf Tester (SJ201)[6]. It was found the Surface roughness increases with increase in pulse width whereas, both shallow and deep cryogenic treated wire exhibit improved surface finish. *Rao et al. [6] investigated* effects of pulse on time, pulse off time, peak current, flushing pressure of dielectric fluid, wire feed rate setting, wire tension setting, spark gap voltage setting and servo feed setting are experimentally investigated in machining of Aluminum BIS-24345 alloy using CNC Wire-cut EDM process. Sharma et al.[7] used the taguchi method to optimize the process parameters of cryogenic treated D-3 machined by WEDM. It was found that the pulse width and time between two pulses has significant effect on SR values. Mukherjee et al.[8] described the different optimization techniques, their advantages and drawbacks. Gill et al.[9] studied machined on the effect of deep cryogenic treatment on surface Roughness of OHNS Die steel machined on WEDM. It was found that the cryogenic treatment had made a significant contribution in improving surface finish. After comparisons 39.8% improvement has been reported. Lahaneet et al.[10] applied a number of approaches to determine the optimal process settings that can optimize multiple performance measures of WEDM operation. The authors used weighted principal component method to optimize the multiple responses of WEDM processes. The results show that the WPC method offers significantly better overall quality as compared to other approaches. Aliasa et al.[11] investigated that the main objective of maximum MRR with minimum kerf width and surface roughness within the desired parameters can be achieved through WEDM technology.

OBJECTIVES OF PRESENT INVESTIGATION

On the basis of the literature following objective have been decided for this study:

1. To find the effect of input parameters on material removal rate of machined test pieces.
2. To optimize the process parameters for material removal rate.
3. To compare the results obtained by cryogenically treated plain brass wire and zinc coated diffused brass wire.

EXPERIMENTATION

The Charmilles Model 290 Wire EDM (WEDM) was used to carry out the experiments. The AISI D3 steel was used as work piece materials for the present experiments, as shown in Fig. 1.

Figure 1. Photographic view of workpieces

Two types of wire electrodes were used namely brass wire and zinc coated diffused wire.
The various parameters which were taken for experimental study are: pulse width, time between two pulses, wire mechanical tension and wire feed rate. Three levels of each parameter have been taken. Parameter and levels selected are shown in Table 1.

Table 1. Parameter and their levels

S.No	Level	Units	Symbol	Level 1	Level 2	Level 3
1	Pulse width	µs	A	0.4	0.6	0.8
2	Time b/w two pulses	µs	B	9	11	13
3	Wire mechanical tension	daN	WB	0.70	1.20	1.70
4	Wire feed rate	m/min	WS	8.0	9.0	10.0

An L9 orthogonal array, as shown in Table 2, has been employed, according to the taguchi method based robust design philosophy, to evaluate the main influencing factors that effect the SR and MRR. A set of four WEDM parameter with three levels of control factor, such as factor (pulse width), (time between two pulses), (wire mechanical tension), and (wire feed rate), have been considered as the controlling factor for machining of D3 with cryogenic treated wires.

Table 2. Taguchi L9 orthogonal array

Exp	Pulse width	Time b/w two pulses	Wire mechanical tension	Wire feed rate
1	0.4	9	0.70	8.0
2	0.4	11	1.20	9.0
3	0.4	13	1.70	10.0
4	0.6	9	1.20	10.0
5	0.6	11	1.70	8.0
6	0.6	13	0.70	9.0
7	0.8	9	1.70	9.0
8	0.8	11	0.70	10.0
9	0.8	13	1.20	8.0

RESULTS AND DISCUSSION

S/N Ratio for Material Removal Rate

In this work S/N ratios were calculated with higher the better approach as large value of MRR is required to save the time. The values of S/N ratios for material removal rates for all treatments are given in Table 3 for cryogenically treated PBW and in Table 4 for cryogenically treated ZCDBW.

Table 3. Results for S/N ratio for MRR with PBW

Exp.	**Pulse width (µs)**	**Time b/w two pulses (µs)**	**Wire mechanical tension (daN)**	**Wire feed rate (m/min)**	**MRR (g/min)**	**S/N Ratio(dB)**
1	0.4	9	0.70	8.0	**0.0458**	**-26.782**
2	0.4	11	1.20	9.0	**0.0442**	**-27.091**
3	0.4	13	1.70	10.0	**0.0457**	**-26.801**
4	0.6	9	1.20	10.0	**0.0647**	**-23.781**
5	0.6	11	1.70	8.0	**0.0712**	**-22.950**
6	0.6	13	0.70	9.0	**0.0689**	**-23.235**
7	0.8	9	1.70	9.0	**0.0750**	**-22.498**
8	0.8	11	0.70	10.0	**0.101**	**-19.879**
9	0.8	13	1.20	8.0	**0.0920**	**-20.724**

Table 4. Results for S/N ratio for MRR with ZCDBW

Exp.	**Pulse width (µs)**	**Time b/w two pulses (µs)**	**Wire mechanical tension (daN)**	**Wire feed rate (m/min)**	**MRR (g/min)**	**S/N Ratio(dB)**
1	0.4	9	0.70	8.0	**0.0555**	**-25.114**
2	0.4	11	1.20	9.0	**0.0548**	**-25.224**
3	0.4	13	1.70	10.0	**0.0458**	**-26.782**
4	0.6	9	1.20	10.0	**0.1017**	**-19.853**
5	0.6	11	1.70	8.0	**0.0948**	**-20.463**
6	0.6	13	0.70	9.0	**0.0764**	**-22.338**
7	0.8	9	1.70	9.0	**0.0988**	**-19.164**
8	0.8	11	0.70	10.0	**0.1020**	**-19.760**
9	0.8	13	1.20	8.0	**0.1160**	**-19.046**

Analysis of S/N Ratio of MRR

The response table for signal-to-noise ratio for all the variables is given in Table 5 and Table 6 In the last row of tables ranks have been assigned to various factors. Higher is the rank, higher is the significance. In the Table 5 and Table 6 pulse width is having rank 1 and is the most significant factor followed by time between two pulses. The wire mechanical tension is having rank 3 and wire feed rate with its lowest rank is least in affecting the material removal rate.

Table 5. Response table for S/N ratio for MRR with PBW

Level	**Pulse width**	**Time b/w two pulses**	**Wire mechanical tension**	**Wire feed rate**
1	-26.891	-24.354	-23.291*	-23.485*
2	-23.322	-23.306*	-23.866	-24.274
3	-21.033*	-23.586	-24.089	-23.487
Delta	5.858	1.048	0.798	0.789
Rank	1	2	3	4

Table 6. Response table for S/N ratio for MRR with ZCDBW

Level	**Pulse width**	**Time b/w two pulses**	**Wire mechanical tension**	**Wire feed rate**
1	-25.706	-21.377*	-22.404	-21.541*
2	-20.884	-21.815	-21.374*	-22.242
3	-19.323*	-22.722	-22.136	-22.131
Delta	6.383	1.345	1.030	0.701
Rank	1	2	3	4

Effect of Input Parameters on Material Removal Rate

Main effect plot and interaction for material removal rate are shown in following figures. Main effect plot shows the variation of material removal rate with each of variable i.e. pulse width, time between two pulses, wire mechanical tension and wire feed rate. X-axis represents the change in level of variable and Y-axis represents the mean S/N ratio of the level or represents the change in resultant response.

Effect of pulse width on MRR

The effect of cryogenically treated electrodes on material removal rate is shown in Fig. 2.

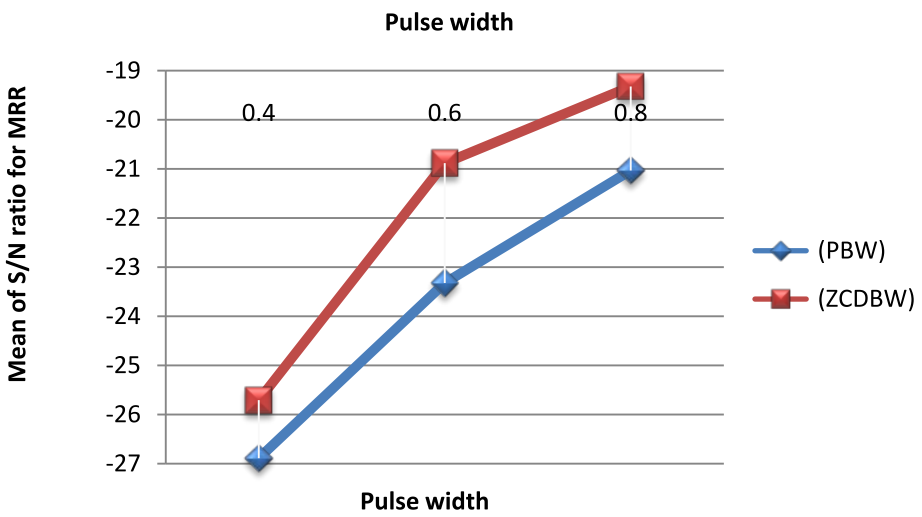

Figure 2. Effect of pulse width on MRR

It shows that MRR increases continuously. When pulse width increases, the MRR also increases. The discharge energy increases with the pulse width and larger discharge energy produces a larger crater. Then larger crater leads to increase in MRR.

Effect of time between two pulse on MRR

The effect of varying time between two pulse material removal rates is shown in Fig. 3. It shows that MRR decreases with increases in time between two pulses. The number of discharges within a given period becomes smaller because the time between two pulses increases which leads to a decrease in material removal rate. The results are inline with Rao et al.[7] who conducted an experiment for Prediction of material removal rate for aluminium BIS-24345 alloy in Wire-Cut EDM and found that material removal rate decreases with increase in time between two pulses.

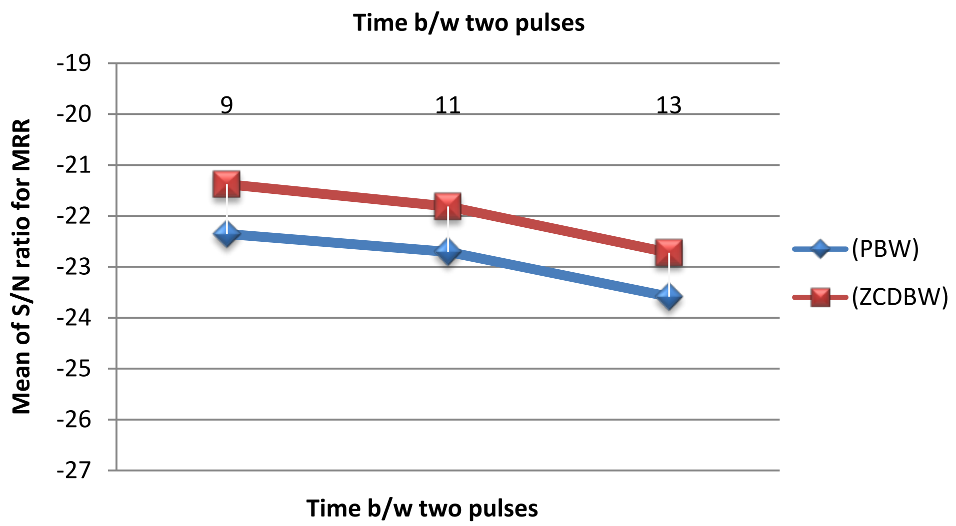

Figure 3. Effect of time between two pulse on MRR

Effect of wire mechanical tension on MRR

The effect of varying wire tension on material removal rate is shown in Fig. 4. It shows that the material removal rate first increases with increase in wire mechanical tension and then decreases. This could be because of transversal wire vibration leading to a limitation in geometric precision, although this vibration could improve machine efficiency through homogeneous spark erosion. Similar results have been reported by Rao et al.[7].

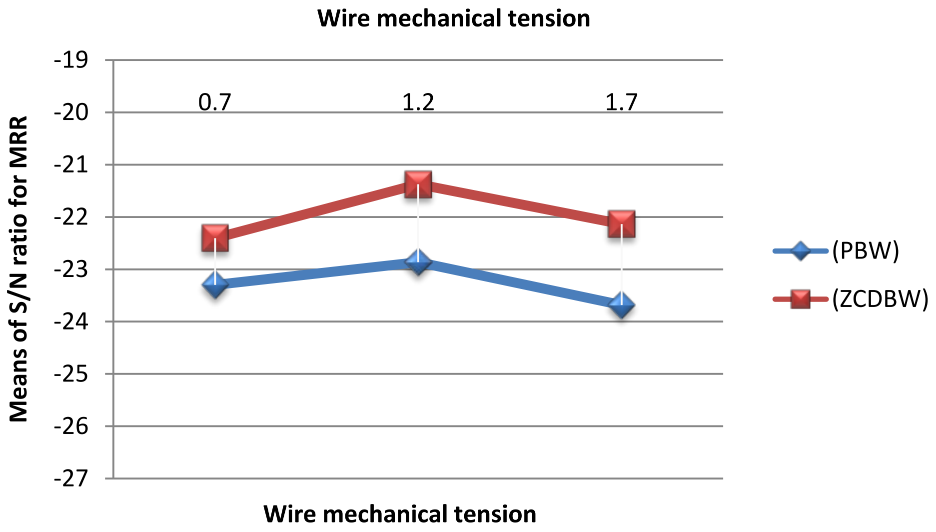

Figure 4. Effect of wire mechanical tension on MRR

Effect of wire feed rate on MRR

The effect of varying wire feed rate on MRR is shown in Fig. 5. The material removal rate first decreases and then slightly increases. However the effect of wire feed rate is very less and insignificant. Similar results have been shown by Rao et al.[7]

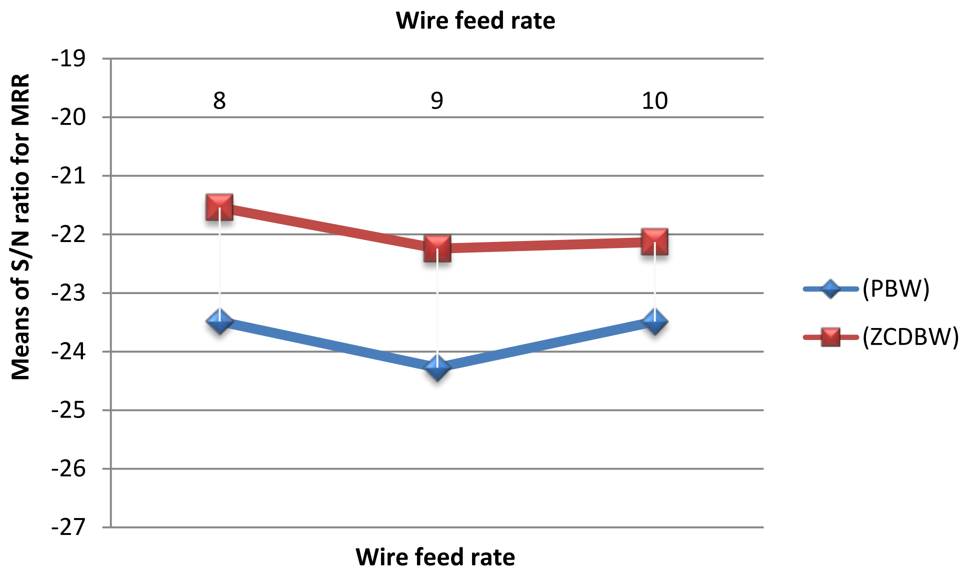

Figure 5. Effect of wire feed rate on MRR

COMPARSION OF PERFORMANCE OF WIRES FOR MRR

In Fig. 6 the comparison of cryogenically treated plain brass wire and cryogenically treated zinc coated diffused brass wire is done on the basis of response factor i.e. material removal rate. The observed values show that the cryogenically treated zinc coated diffused brass wire is good in MRR as compared to plain brass wire.

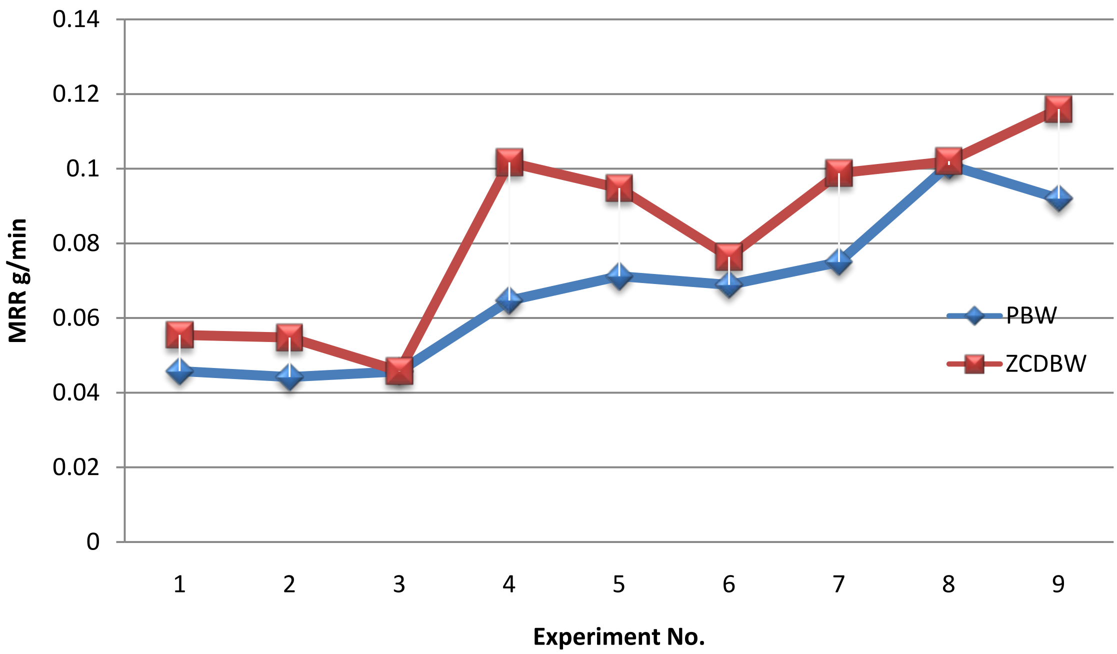

Figure 6. Comparison of wires for MRR.

The graph shows that higher value of material removal rate is achieved by using the cryogenically treated zinc coated diffused brass wire as compared to plain brass wire. Hence cryogenically treated zinc coated diffused brass wire is good for MRR as compared to cryogenically treated plain brass wire.

OPTIMUM SET OF PARAMETERS

A Confirmation of the experimental design was necessary in order to verify the optimum cutting conditions. It was the final step in verifying the results drawn, based on Taguchi's design approach. In this study a confirmation experiment was conducted by setting the levels of the optimal process parameters for surface roughness and material removal rate. For calculating predicted optimum conditions, two most significant parameters (rank 1, rank 2) has been selected. If the optimum condition is A_1, B_2, C_3, D_2, and the most significant factors are A_1, and B_2, then their predicted optimum response would be given by

$$\text{Optimum Response} = \bar{Y} + (\bar{A}_1 - \bar{Y}) + (\bar{B}_1 - \bar{Y}) = (\bar{A}_1 + \bar{B}_1) - \bar{Y}$$

where,

$\bar{Y}$ = overall mean response,

$\bar{A}_1$, $\bar{B}_1$ = average response at Level 1 of these factors.

The optimum values of machine parameters settings were formed from the experiments and their levels are shown in Table 7.

Table 7. Optimal Set of Parameters for MRR

S.No	Parameter	Cryogenically Treated PWB		Cryogenically Treated ZCDBW	
		Level	Values	Level	Values
1	**Pulse width (µs)**	3	0.8	3	0.8
2	**Time b/w two pulses (µs)**	2	11	1	9
3	**Wire mechanical tension (daN)**	1	0.70	2	1.20
4	**Wire feed rate (m/min)**	1	8	1	8

CONCLUSIONS

The effect of four independent variables (pulse width, time b/w two pulses, wire mechanical tension, and wire feed rate) have been studied for material removal rate by using two different wires as electrodes in a WEDM machine. The effects of input parameters were evaluated using ANOVA for S/N ratios. In addition, main effects plots for S/N ratios has been developed and analyzed. The conclusions are:

- The material removal rate was found to be more with cryogenically treated zinc coated diffused brass wire as compare to cryogenically treated plain brass wire.

- With increase in the pulse width the material removal rate also increases.
- With increase in time between two pulses, the material removal rate decreases.
- There is no significant effect of wire mechanical tension and wire feed rate on MRR.
- It is found that cryogenically treated zinc coated diffused brass wire produces 22.55% more material removal rate as compared to plain brass wire.

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