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Machinability Evaluation and Optimization of Heat Treated HCHCR with Various Wires on WEDM

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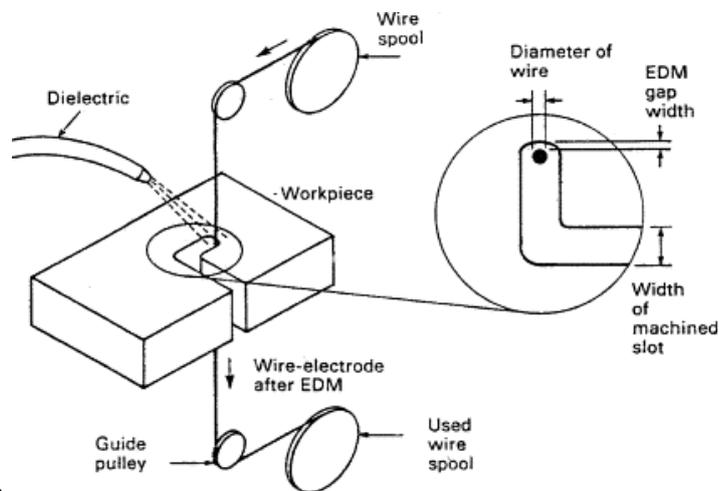
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ABSTRACT: In this experimental work investigation on process parameters is carried out in reusable type wire electrical discharge machining on heat treated high carbon on HCHCR material, using brass and molybdenum wire. This investigation is to be carried out to find best optimal level for higher material removal rate at lower surface roughness for HCHCR material. The experiments were conducted under varying pulse on time, pulse off time and Gap current. In this present study heat treated HCHCR material is used as a work piece, brass wire with 0.25mm diameter used as a tool and IPOL fluid is used as a dielectric fluid for experimentation Taguchi's L9, orthogonal array to be used. For each experiment surface roughness and Machining timing, MRR and cut quality to inspected. By using Taguchi optimization technique optimal value to be found for various output responses. Additionally, the analysis of variance (ANOVA) is too useful to identify the most important factor of the top most performance obtained from the experimentation tool wire.

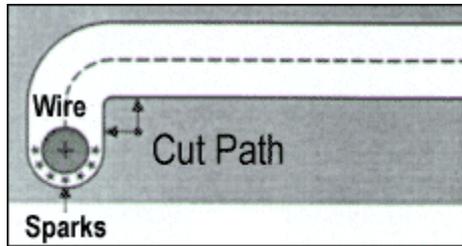
KEYWORDS: WEDM, Optimization, Surface roughness, Material removal rate.

I. INTRODUCTION

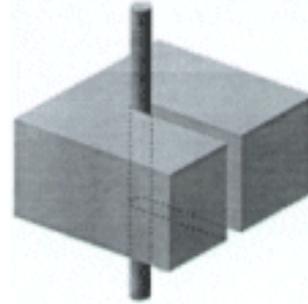
Wire EDM is an electrical discharge machining process with a continuously moving conductive wire as tool electrode. The mechanism of metal removal in wire electrical discharge machining (WEDM) involves the complex erosion effect of electric sparks generated by a pulsating direct current power supply between two closely spaced electrodes in dielectric liquid. The high energy density erodes material from both the wire and work piece by local melting and vaporizing. Because the new wire keeps feeding to the machining area, the material is removed from the work piece with the moving of wire electrode. Eventually, a cutting shape is formed on the work piece by the programmed moving trajectory of wire electrode. The equipment is extensively used in making dies and molds



Schematic layout of WEDM



Cutting path



WCEDM CHARACTERISTICS

- Work material : HCHCR steel (Dia 32*15 Thickness mm)
- Tool material : Molybdenum wire & Brass wire (dia =0.25mm)
- Dielectric fluid : distilled water + kerosene(10:1)
- gap voltage : (60 - 80V)
- Gap current : (1-6 A)

MACHINE MODEL

- Lowest running costs
- Closed loop X, Y with linear scales
- Reciprocating Brass / Molybdenum wire
- Max. cutting speed :60 mm²/ min on Steel (HCHCR/ WPS)
120 mm²/ min on Aluminum
- Surface finish : 1.2 ~ 1.5 μ Ra (with multi-pass)
- Taper : ± 3° / 100 mm
- Inbuilt 2 axes DRO
- KVA-3
- Max Amps: 6

ADVANTAGES OF WCEDM

- Inspection time is reduced.
- High surface finish can be achieved.
- Cycle time for die manufacture is shorter.

DISADVANTAGES OF WCEDM:

- High capital cost.
- Not suitable for large work pieces

II. MATERIALS AND METHOD

WORKING MATERIAL

HCHCR steel is an oil-hardening and non-shrinking cold work tool steel with properties such as good durability, excellent wear resistance and holds a good cutting edge. It is an excellent general purpose tool steel often used where the expense of a high carbon high chromium tool steel would not be justified.

chemical composition of HCHCR

TYPICAL CHEMICAL COMPOSITION				
C	Si	CR	Mn	S
0.90-1.20	0.10-0.35	1.00-1.60	0.30-0.75	0.040 max

APPLICATION



D3 Material is used in tooling applications requiring a high degree of accuracy in hardening, such as draw dies, forming rolls, powder metal tooling and blanking and forming dies and bushes.

MACHINE, ELECTRODE AND DIELECTRIC:

The experiments are carried out using FA103 (MITSUBISHI) wire cut EDM machine. X- Axis 300 mm , Y- Axis 250 mm, Z-Axis 200 mm, U & V -Axis +/- 15 mm, Brass alloy used as wire in the experimental setup. Distilled water with kerosene (dirty oil as 5:1) is used as a dielectric fluid chosen for the experimentation.

SELECTION OF PROCESS PARAMETERS

MACHINING PARAMETER SELECTION

Machining experiments for determining the optimal machining parameters were carried out by setting: gap voltage in the range of 60 to 80V, wire feed in the range of 3.5-13.1 mm/min; a Gap Voltage in the range of 1-3 A, a duty factor in the range of 0.25 to 0.75. To perform the Experimental design, three levels of the machining parameters (Pulse on time, pulse off time & GAP VOLTAGE) were selected.

TAGUCHI APPROACH

The experimental results are then transformed into a signal– to – noise (S/N) ratio to measure the quality characteristics deviating from the desired values. The S/N ratio for each level of process parameter is compared based on the S/N analysis. Regardless of the category of the quality characteristic, a greater S/N ratio corresponds to better quality characteristics. The formulae for signal to noise ratio are designed so that an experimenter can always select the largest factor level setting to optimize the quality characteristic of an experiment. Therefore a method of calculating the Signal-To-Noise ratio we had gone for quality characteristic. They are

1. Smaller-The-Better,
2. Larger-The-Better,
3. Nominal is Best.

III. CALCULATIONS

Machining Parameters and Their Level

Machining parameter	Unit	Level I	Level II	Level III
Pulse on time	Ms	30	31	32
Pulse off time	Ms	5	6	7
Gap Voltage	mm/min	55	60	65

AN ORTHOGONAL ARRAY L₉ FORMATION-FOR BOTH TOOLS

An Orthogonal Array L₉ Formation

TRIAL NO.	DESIGNATION	PULSEON (Micro sec)	PULSEOFF (Micro sec)	Gap Voltage mm/min
1	A ₁ B ₁ C ₁	30	5	55
2	A ₁ B ₂ C ₂	30	6	60
3	A ₁ B ₃ C ₃	30	7	65
4	A ₂ B ₁ C ₂	31	5	60



5	A ₂ B ₂ C ₃	31	6	65
6	A ₂ B ₃ C ₁	31	7	55
7	A ₃ B ₁ C ₃	32	5	65
8	A ₃ B ₂ C ₁	32	6	55
9	A ₃ B ₃ C ₂	32	7	60

EXPERIMENTAL DATA & OPTIMIZATION

EXPERIMENTAL DATA OF THE EDM PROCESS

Experimental Data of the EDM process

EXP	BRASS		MOLYBDENUM	
	RA	MT	RA	MT
1	7.321	52.18	5.288	28.18
2	4.590	55.10	5.764	35.40
3	7.865	50.32	5.918	40.20
4	7.011	52.32	5.110	37.18
5	4.834	54.12	5.987	40.25
6	3.851	52.18	5.217	36.54
7	12.829	50.56	4.967	41.45
8	3.808	52.12	5.055	35.23
9	8.861	54.14	6.077	40.32

SURFACE ROUGHNESSES (ANALYSIS OF RESULT)-BRASS

Surface Roughness and S/N Ratios Values for the Experiments

S.NO	Designation	T ON	T OFF	GV	RA μm	SNRA1
1	A ₁ B ₁ C ₁	30	5	55	7.321	17.2914
2	A ₁ B ₂ C ₂	30	6	60	4.590	13.2363
3	A ₁ B ₃ C ₃	30	7	65	7.865	17.9140
4	A ₂ B ₁ C ₂	31	5	60	7.011	16.9156
5	A ₂ B ₂ C ₃	31	6	65	4.834	13.6861
6	A ₂ B ₃ C ₁	31	7	55	3.851	11.7115
7	A ₃ B ₁ C ₃	32	5	65	12.829	22.1639
8	A ₃ B ₂ C ₁	32	6	55	3.808	11.6139
9	A ₃ B ₃ C ₂	32	7	60	8.861	18.9497

ROUGHNESS RESPONSE FOR EACH LEVEL OF THE PROCESS PARAMETER-BRASS

Response Table for Signal to Noise Ratios-Smaller is better

LEVEL	T ON	T OFF	GV
1	-16.15	-18.79	-13.54
2	-14.10	-12.85	-16.37
3	-17.58	-16.19	-17.92
DELTA	3.47	5.94	4.38
RANK	3	1	2



Response Table for Means

LEVEL	T ON	T OFF	GV
1	6.592	9.054	4.993
2	5.232	4.411	6.821
3	8.499	6.859	8.509
DELTA	3.267	4.643	3.516
RANK	3	1	2

Factor Information

FACTOR	TYPE	LEVELS	VALUES
T ON	FIXED	3	30,31,32
T OFF	FIXED	3	5,6,7
GV	FIXED	3	55,60,65

Analysis of Variance for RA

SOURCE	DF	SEQ SS	ADJ MS	F	P	% OF CONTRIBUTION
T ON	2	16.163	8.0815	11.93	0.077	24
T OFF	2	32.368	16.1842	23.90	0.040	47
GV	2	18.553	9.2765	13.70	0.068	27
ERROR	2	1.354	0.6772			2
TOTAL	8	68.439				100

SURFACE ROUGHNESSES (ANALYSIS OF RESULT) – MOLYBDENUM

Surface Roughness and S/N Ratios Values for the Experiments

S.NO	Designation	T ON	T OFF	GV	RA μm	SNRA1
1	A ₁ B ₁ C ₁	30	5	55	5.288	-14.4658
2	A ₁ B ₂ C ₂	30	6	60	5.764	-15.2145
3	A ₁ B ₃ C ₃	30	7	65	5.918	-15.4435
4	A ₂ B ₁ C ₂	31	5	60	5.110	-14.1684
5	A ₂ B ₂ C ₃	31	6	65	5.987	-15.5442
6	A ₂ B ₃ C ₁	31	7	55	5.217	-14.3484
7	A ₃ B ₁ C ₃	32	5	65	4.967	-13.9219
8	A ₃ B ₂ C ₁	32	6	55	5.055	-14.0744
9	A ₃ B ₃ C ₂	32	7	60	6.077	-15.6738

ROUGHNESS RESPONSE FOR EACH LEVEL OF THE PROCESS PARAMETER- MOLYBDENUM

Response Table for Signal to Noise Ratios-Smaller is better

LEVEL	T ON	T OFF	GV
1	-15.04	-14.19	-14.30
2	-14.69	-14.94	-15.02
3	-14.56	-15.16	-14.97
DELTA	0.48	0.97	0.72
RANK	3	1	2



Response Table for Means

LEVEL	T ON	T OFF	GV
1	5.657	5.122	5.187
2	5.438	5.602	5.650
3	5.366	5.737	5.624
DELTA	0.290	0.616	0.464
RANK	3	1	2

Factor Information

FACTOR	TYPE	LEVELS	VALUES
T ON	FIXED	3	30,31,32
T OFF	FIXED	3	5,6,7
GV	FIXED	3	55,60,65

Analysis of Variance for RA

SOURCE	DF	SEQ SS	ADJ MS	F	P	% OF CONTRIBUTION
T ON	2	0.1372	0.06862	0.34	0.745	9
T OFF	2	0.6281	0.31404	1.57	0.389	40
GV	2	0.4069	0.20347	1.02	0.496	26
ERROR	2	0.4000	0.19999			25
TOTAL	8	1.5722				100

MACHINING TIME (ANALYSIS OF RESULT)-BRASS

Machining Time and S/N Ratios Values for MT

S.NO	Desig	T ON	T OFF	GV	MT	SNRA1
1	A ₁ B ₁ C ₁	30	5	55	52.18	-34.3501
2	A ₁ B ₂ C ₂	30	6	60	55.10	-34.8230
3	A ₁ B ₃ C ₃	30	7	65	50.32	-34.0348
4	A ₂ B ₁ C ₂	31	5	60	52.32	-34.3734
5	A ₂ B ₂ C ₃	31	6	65	54.12	-34.6672
6	A ₂ B ₃ C ₁	31	7	55	52.18	-34.3501
7	A ₃ B ₁ C ₃	32	5	65	50.56	-34.0761
8	A ₃ B ₂ C ₁	32	6	55	52.12	-34.3401
9	A ₃ B ₃ C ₂	32	7	60	54.14	-34.6704



MACHINING TIME FOR EACH LEVEL OF THE PROCESS PARAMETER –BRASS Response Table for Signal to Noise Ratios-MT Smaller is better

LEVEL	T ON	T OFF	GV
1	-34.40	-34.27	-34.35
2	-34.46	-34.61	-34.62
3	-34.36	-34.35	-34.26
DELTA	0.10	0.34	0.36
RANK	3	2	1

Means Table for Signal to Noise Ratios-MT

LEVEL	T ON	T OFF	GV
1	52.53	51.69	52.16
2	52.87	53.78	53.85
3	52.27	52.21	51.67
DELTA	0.60	2.09	2.19
RANK	3	2	1

General Linear Model: MT versus T-ON, T-OFF, GV

Factor Information

FACTOR	TYPE	LEVELS	VALUES
T ON	FIXED	3	30,31,32
T OFF	FIXED	3	5,6,7
GV	FIXED	3	55,60,65

Analysis of Variance of MT

SOURCE	DF	SEQ SS	ADJ MS	F	P	% OF CONTRIBUTION
T ON	2	0.5432	0.2716	0.10	0.908	3
T OFF	2	7.1139	3.5569	1.32	0.431	34
GV	2	7.8923	3.9461	1.46	0.406	38
ERROR	2	5.3899	2.6949			25
TOTAL	8	20.9392				100



MACHINING TIME (ANALYSIS OF RESULT) - MOLYBDENUM

Machining Time and S/N Ratios Values for MT

S.NO	Desig	T ON	T OFF	GV	MT	SNRA1
1	A ₁ B ₁ C ₁	30	5	55	28.18	-28.9988
2	A ₁ B ₂ C ₂	30	6	60	35.40	-30.9801
3	A ₁ B ₃ C ₃	30	7	65	40.20	-32.0845
4	A ₂ B ₁ C ₂	31	5	60	37.18	-31.4062
5	A ₂ B ₂ C ₃	31	6	65	40.25	-32.0953
6	A ₂ B ₃ C ₁	31	7	55	36.54	-31.2554
7	A ₃ B ₁ C ₃	32	5	65	41.45	-32.3505
8	A ₃ B ₂ C ₁	32	6	55	35.23	-30.9383
9	A ₃ B ₃ C ₂	32	7	60	40.32	-32.1104

MACHINING TIME FOR EACH LEVEL OF THE PROCESS PARAMETER – MOLYBDENUM

Response Table for Signal to Noise Ratios-MT Smaller is better

LEVEL	T ON	T OFF	GV
1	-30.69	-30.92	-30.40
2	-31.59	-31.34	-31.50
3	-31.80	-31.82	-32.18
DELTA	1.11	0.90	1.78
RANK	2	3	1

Means Table for Signal to Noise Ratios-MT

LEVEL	T ON	T OFF	GV
1	34.59	35.60	33.32
2	37.99	36.96	37.63
3	39.00	39.02	40.63
DELTA	4.41	3.42	7.32
RANK	2	3	1

Factor Information

FACTOR	TYPE	LEVELS	VALUES
T ON	FIXED	3	30,31,32
T OFF	FIXED	3	5,6,7
GV	FIXED	3	55,60,65



Analysis of Variance of MT

SOURCE	DF	SEQ SS	ADJ MS	F	P	% OF CONTRIBUTION
T ON	2	31.976	15.988	7.77	0.114	24
T OFF	2	17.758	8.879	4.32	0.188	13
GV	2	81.167	40.584	19.72	0.048	60
ERROR	2	4.115	2.058			3
TOTAL	8	135.016				100

IV. RESULTS

The aim of the research work was to investigate the machinability of HCHCR WCEDM. In this study three process parameters are varied viz. Pulse on time, Pulse off time and gap voltage rating constant dielectric fluid pressure wire tension and feed rate in the influence on the responses MRR, Machining timing and Ra. Based on the experimental results the following conclusions are drawn:

OPTIMAL CONTROL FACTOR-BRASS

1. Surface Roughness-A3 (T ON – 32 μs) B1 (T OFF – 5 μs) C2 (Volt-60)
2. Machining Timing- A3 (T ON – 32 μs) B1 (T OFF – 5 μs) C2 (Volt-60)

OPTIMAL CONTROL FACTOR-MOLYBDNEUM

1. Surface Roughness- A3 (T ON – 32 μs) B1 (T OFF – 5 μs) C2 (Volt-60)
2. Machining Timing- A2 (T ON – 31 μs) B3 (T OFF – 7 μs) C1 (Volt -55)

PERCENTAGE OF CONTRIBUTION OF PROCESS PARAMETER-BRASS

1. Surface Roughness –T Off-51%
2. Machining Timing-T-Off-40%

PERCENTAGE OF CONTRIBUTION OF PROCESS PARAMETER- MOLYBDNEUM

1. Surface Roughness Gap voltage-38%
2. Machining Timing- Gap voltage -60%

V. CONCLUSION

Minimum Surface Roughness and machining time finish was obtained at through higher level pulse on, lower level pulse off time and medium gap voltage were obtained through brass electrode

Minimum Surface Roughness finish was obtained at through lower level pulse on voltage, medium level pulse off time were obtained through molybdenum wire electrode

Comparative both wire during the machining time Surface finish almost same but machining timing has to be taken very low time during the molybdenum wire. Over cut character also very minimum compared than brass wire .Maximum machining and geometrical character obtained through molybdenum wire for HCHCR during the machining time.



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