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Experimental Investigation and Comparative Geometrical Evaluation of WCEDM Process on OHNS by using Various Wires

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Abstract: With the increasing demands of high surface finish and machining of complex shape geometries, conventional machining process are now being replaced by non-traditional machining processes. Wire EDM is one of the non-traditional machining processes. Surface roughness and MRR are of crucial importance in the field of machining processes. This paper summarizes the Taguchi optimization technique, in order to optimize the cutting parameters in Wire EDM for HCHCR. The objective of optimization is to attain the minimum machining timing and the best surface quality simultaneously and separately. In this present study HCHCR is used as a work piece, brass wire of 0.25mm diameter used as a tool and distilled water is used as a dielectric fluid for experimentation Taguchi's L8, orthogonal array was used. The input parameters selected for optimization were wire feed, pulse on time, and pulse off time. Dielectric fluid pressure, wire speed, wire tension, resistance and cutting length are taken as fixed parameters. For each experiment surface roughness and Machining timing, MRR were found optimal control factor and percentage of contribution through ANOVA technique. Finally concluded according to geometrical tolerations brass is better than molybdenum. Minimum surface Roughness and maximum MRR obtained through molybdenum wire and machining timing of brass is very high comparative than molybdenum wire

Keywords: HCHCR, WEDM, Taguchi Analysis, Brass and Molybdenum wires

I. UNCONVENTIONAL MACHINING PROCESS

Since beginning of the human race, people have evolved tools and energy sources to power these tools to meet the requirement for making the life easier and enjoyable. Merchant had displayed the gradual increase in strength of material with year wise development of material in aerospace industry. This manufacturing revolution is now, as it has been in the past, centered on the use of new tools and new forms of energy. The result has been the introduction of new manufacturing processes used for material removal, forming and joining, known today as non-traditional manufacturing processes. In the early stage of mankind, tools were made of stone for the item being made. When iron tools were invented, desirable metals and more sophisticated articles could be produced. In twentieth century products were made from the most durable and consequently, the most unmachinable materials. In an effort to meet the manufacturing challenges created by these materials, tools have now evolved to include materials such as alloy steel, carbide, diamond and ceramics.

II. WIRE ELECTRICAL DISCHARGE MACHINING PROCESS

A. Wire EDM Process

Electrical Discharge Machining, EDM is one of the most accurate manufacturing processes available for creating complex or simple shapes and geometries within parts and assemblies. EDM works by eroding material in the path of electrical discharges that form an arc between an electrode tool and the work piece. EDM manufacturing is quite affordable and a very desirable manufacturing process when low counts or high accuracy is required. Turnaround time can be fast and depends on manufacturer back log. The EDM system consists of a shaped tool or wire electrode, and the part. The part is connected to a power supply. Sometimes to create a potential difference between the work piece and tool, the work piece is immersed in a dielectric (electrically non-conducting) fluid which is circulated to flush away debris. The cutting pattern is usually CNC controlled. Many EDM machine electrodes can rotate about two-three axis allowing for cutting of internal cavities. This makes EDM a highly capable manufacturing process.

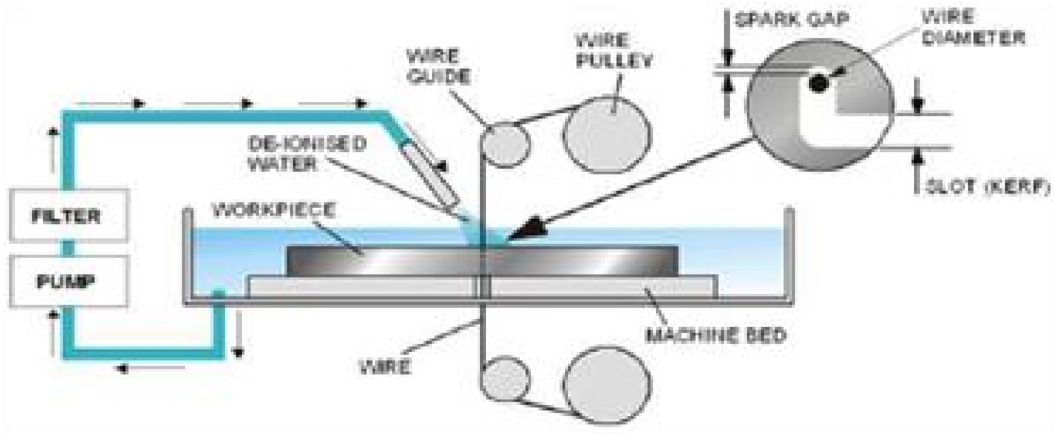

Fig: 1 Schematic Diagram of WEDM System

Electrical discharge wire cutting, more commonly known as wire electrical discharge machining (WEDM), is a spark erosion process used to produce complex two- and three-dimensional shapes through electrically conductive work pieces by using wire electrode.

III. HARDENING PROCESS

The use of this treatment will result in an improvement of the mechanical properties, as well as an increase in the level of hardness, producing a tougher, more durable item. Alloys are heated above the critical transformation temperature for the material, then cooled rapidly enough to cause the soft initial material to transform to a much harder, stronger structure. Alloys may be air cooled, or cooled by quenching in oil, water, or another liquid, depending upon the amount of alloying elements in the material. Hardened materials are usually tempered or stress relieved to improve their dimensional stability and toughness. Steel parts often require a heat treatment to obtain improved mechanical properties, such as increasing increase hardness or strength. The hardening process consists of heating the components above the critical (normalizing) temperature, holding at this temperature for one hour per inch of thickness cooling at a rate fast enough to allow the material to transform to a much harder, stronger structure, and then tempering. Steel is essentially an alloy of iron and carbon; other steel alloys have other metal elements in solution. Heating the material above the critical temperature causes carbon and the other elements to go into solid solution. Quenching "freezes" the microstructure, inducing stresses. Parts are subsequently tempered to transform the microstructure, achieve the appropriate hardness and eliminate the stresses.

1) Hardness Verification

Using the “C” Scale

a) Use a Diamond indenter

b) Major load: 150 Kg, Minor load: 10 Kg

c) Use for Case hardened steel HCHCR- steel.

2) Before Heat Treatment

SL.NO	TRAIL-1,2 & 3	AVERAGE HRC
1	27,23,25	25

3) After Heat Treatment

SL.NO	TRAIL-1 & 2	AVERAGE HRC
1	65,63,64	64
2	66,65,65	65
3	63,64,66	64

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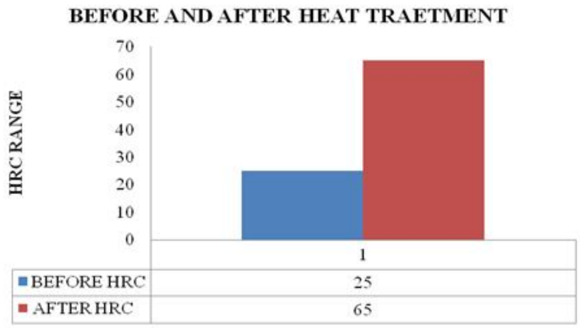
A. Comparison Of Before And After Heat Treatment



IV. WIRE CUT EDM PROCESS

Fig: 2 Electronica Ezee wcedm

A. WCEDM Characteristics

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

B. Machine Model

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

V. WORK PIECE 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.

A. 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.

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VI. MACHINE, ELECTRODE AND DIELECTRIC

The experiments are carried out using RATNA SPARKI wire cut EDM machine. X- Axis 300 mm , Y-Axis 250 mm, Z-Axis 200 mm, U &V -Axis +/ - 15 mm, Brass and Molybdenum wire were 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.

VII. SELECTION OF PROCESS PARAMETERS

A. Machining Parameter Selection

In this study, a Reciprocating Wire-cut EDM machine, Electronic make, RATNA SPARKI-l was used as the experimental machine. Cylindrical molybdenum wire with a diameter of 0.15 mm was used as an electrode to erode a work piece of HCHCR round rod of the thickness of 15mm. The work piece and electrode were separated by a moving dielectric fluid i.e. blend of distilled water and kerosene oil in a ratio of 5:1.

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 theExperimental design, three levels of the machining parameters (Pulse on time, pulse off time & GAP VOLTAGE) were selected.

The effect of various input parameters on material removal rate (MRR) and surface roughness (Ra) & Machining timing is discussed below

1) Pulse on Time
2) Pulse off time
3) Gap Voltage

Table: 1 Machining Parameters and Their Level

MACHINING PARAMETER	UNIT	LEVEL-I	LEVEL-II
Pulse on time	µs	30	32
Pulse off time	µs	5	7
Gap Voltage	V	50	70

B. An Orthogonal Array L_4 Formation-For Both Wires

Table: 2 an Orthogonal Array L_4 Formation

TRIAL NO	DESIGNATION	PULSE ON (Micro sec)	PULSE OFF (Micro sec)	GAP VOLTAGE (V)
1	$A_1B_1C_1$	30	5	50
2	$A_1B_2C_2$	30	7	70
3	$A_1B_3C_3$	32	5	70
4	$A_2B_1C_2$	32	7	50

VIII. EXPERIMENTAL DATA & OPTIMIZATION

A. Experimental Data Of Machining Character For Both Wires

Table: 3 Experimental Data of the WEDM process

EXP	BRASS			MOLYBDENUM		
	RA (µm)	MT (mins)	MRR (gm/min)	RA (µm)	MT (mins)	MRR (gm/min)
1	4.004	56.10	0.026	4.106	24.10	0.071
2	4.809	68.38	0.024	4.677	30.00	0.059
3	4.599	61.00	0.033	3.547	22.00	0.077
4	3.989	52.05	0.040	4.002	28.40	0.063
Avg	4.350	59.38	0.030	4.083	26.12	0.067

From the above experimental data we observe that RA and MT of Molybdenum wire is better than the brass wire. Where the MRR of molybdenum wire is slightly more than brass.

Comparision of Surface Roughness B/W Brass and Molybdenum Wire

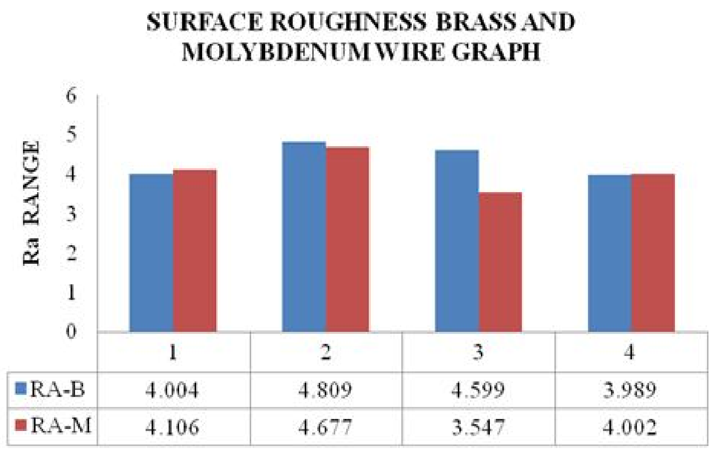

Fig: 3 comparison surface roughness brass and molybdenum wire

Comparision of MT B/W Brass and Molybdenum Wire

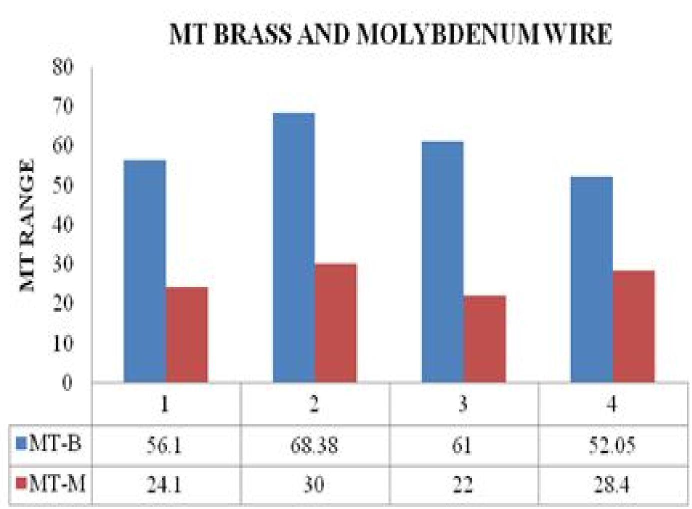

Fig: 4 comparison MT brass and molybdenum wire

Comparision of MRR B/W Brass and Molybdenum Wire

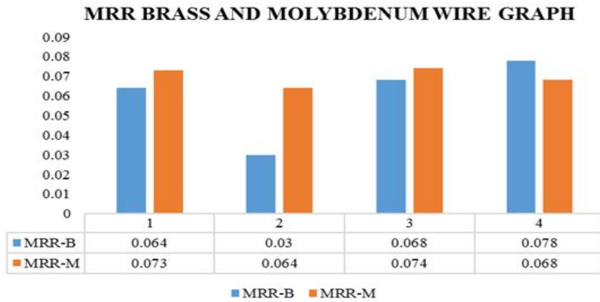

Fig: 5 comparison MRR brass and molybdenum wire

B. Surface Roughnesses (Analysis of Result) - Using Brass Wire

Table: 4 Surface Roughness and S/N Ratios Values for the Experiments

S.NO	DESIGNATION	T ON (µs)	T OFF (µs)	GV (V)	RA (µm)	SNRA1
1	$A_1B_1C_1$	30	5	50	4.004	-12.0499
2	$A_1B_2C_2$	30	7	70	4.809	-13.6411
3	$A_1B_3C_3$	32	5	70	4.599	-13.2533
4	$A_2B_1C_2$	32	7	50	3.989	-12.0173

The response table is obtained using the Minitab 17 software. The experimental results are now transformed into a signal-to-noise (S/N) ratio. The input parameter signifies the impact of Surface roughness value. From the table, it can be easily seen that the RA using brass wire is less when pulse on time is 32 µ.sec and pulse off time is 7 µ.sec, where gap voltage is 50 V.

1) Roughness Response for Each Level of The Process Parameter - BRASS

Table: 5 Response Table for Signal to Noise Ratios-Smaller is better

LEVEL	T ON	T OFF	GV
1	-12.85	-12.65	-12.03
2	-12.64	-12.83	-13.45
Delta	0.21	0.18	1.41
Rank	2	3	1

Table: 6 Analysis of Variance for RA

SOURCE	DF	SEQ SS	ADJ MS	F	P	% OF CONTRIBUTION
T ON	1	0.012656	0.012656	-	-	3
T OFF	1	0.009506	0.009506	-	-	2
GV	1	0.500556	0.500556	-	-	95
Error	0	-	-			0
Total	3	0.522719				100

Now, the Analysis of Variance, also called the ANOVA table (Table 6) was generated to obtain the percentage Contribution of the different parameters individually and along with their interaction over the Surface Roughness value. The variance ratio was obtained from the Minitab 19 software. It was found out that the Input Gap Voltage had a larger contribution to the Surface roughness value using brass wire

2) Regression Equation: RA = 4.350 + 0.05625 T ON_30 - 0.05625 T ON_32 - 0.04875 T OFF_5 + 0.04875 T OFF_7 - 0.3538 GV_50 + 0.3538 GV_70

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C. Surface Roughnesses (Analysis Of Result) - Using Molybdenum Wire

Table: 7 Surface Roughness and S/N Ratios Values for the Experiments

S.NO	DESIGNATION	T ON (µs)	T OFF (µs)	GV (V)	RA (µm)	SNRA1
1	$A_1B_1C_1$	30	5	50	4.106	-12.2684
2	$A_1B_2C_2$	30	7	70	4.677	-13.3993
3	$A_1B_3C_3$	32	5	70	3.547	-10.9972
4	$A_2B_1C_2$	32	7	50	4.002	-12.0455

Table 7 is obtained using the Minitab 17 software. The experimental results are now transformed into a signal-to-noise (S/N) ratio. The input parameter signifies the impact of Surface roughness value. From the table, it can be easily seen that the RA using molybdenum wire is less when pulse on time is 32 µ.sec and pulse off time is 7 µ.sec, where gap voltage is 50 V.

1) Roughness Response For Each Level Of The Process Parameter - Molybdenum

Table: 8 Response Table for Signal to Noise Ratios-Smaller is better

LEVEL	T ON	T OFF	GV
1	-12.83	-11.63	-12.16
2	-11.52	-12.72	-12.20
Delta	1.31	1.09	0.04
Rank	1	2	3

Table: 9 Analysis of Variance for RA

SOURCE	DF	SEQ SS	ADJ MS	F	P	% OF CONTRIBUTION
T ON	1	0.380689	0.380689	-	-	58
T OFF	1	0.263169	0.263169	-	-	41
GV	1	0.003364	0.003364	-	-	1
Error	0	-	-			0
Total	3	0.647222				100

Now, the Analysis of Variance, also called the ANOVA table (Table 9) was generated to obtain the percentage Contribution of the different parameters individually and along with their interaction over the Surface Roughness value. The variance ratio was obtained from the Minitab 19 software. It was found out that the Input Pulse ON time had a larger Contribution to the Surface roughness value while using molybdenum wire.

2) Regression Equation: RA = 4.083 + 0.3085 T ON_30 - 0.3085 T ON_32 - 0.2565 T OFF_5 + 0.2565 T OFF_7 - 0.02900 GV_50 + 0.02900 GV_70

D. Machining Time (Analysis Of Result) - Using Brass Wire

Table: 10 Machining Time and S/N Ratios Values for MT

S.NO	DESIGNATION	T ON (μs)	T OFF (μs)	GV (V)	MT (mins)	SNRA1
1	$A_1B_1C_1$	30	5	50	56.10	-34.9793
2	$A_1B_2C_2$	30	7	70	68.38	-36.6986
3	$A_1B_3C_3$	32	5	70	61.00	-35.7066
4	$A_2B_1C_2$	32	7	50	52.05	-34.3284

The response table is obtained using the Minitab 17 software. The experimental results are now transformed into a signal-to-noise (S/N) ratio. The input parameter signifies the impact of machining time value. From table, it can be found that the MT is less when pulse on time is 32 µ.sec and pulse off time is 7 µ.sec, where gap voltage is 50 V.

1) Machining Time For Each Level Of The Process Parameter - BRASS

Table: 11 Response Table for Signal to Noise Ratios - MT Smaller is better

LEVEL	T ON	T OFF	GV
1	-35.84	-35.34	-34.65
2	-35.02	-35.51	-36.20
DELTA	0.82	0.17	1.55
RANK	2	3	1

Table: 12 Analysis of Variance of MT

SOURCE	DF	SEQ SS	ADJ MS	F	P	% OF CONTRIBUTION
T ON	1	32.661	32.661	-	-	22
T OFF	1	2.772	2.772	-	-	2
GV	1	112.678	112.678	-	-	76
Error	0	-	-			0
Total	3	148.112				100

Now, the Analysis of Variance, also called the ANOVA table (Table 12) was generated to obtain the percentage Contribution of the different parameters individually and along with their interaction over the machining timing value. The variance ratio was obtained from the Minitab 19 software. It was found out that the Input Gap Voltage had a larger Contribution to the machining timing value while using brass wire.

2) Regression Equation: MT = 59.38 + 2.857 T ON_30 - 2.857 T ON_32 - 0.8325 T OFF_5 + 0.8325 T OFF_7 - 5.307 GV_50 + 5.307 GV_70

E. *Machining Time (Analysis of Result) - Using Molybdenum Wire*

Table: 13 Machining Time and S/N Ratios Values for MT

S.NO	DESIGNATION	T ON (µs)	T OFF (µs)	GV (V)	MT (mins)	SNRA1
1	$A_1B_1C_1$	30	5	50	24.1	-27.6403
2	$A_1B_2C_2$	30	7	70	30.0	-29.5424
3	$A_1B_3C_3$	32	5	70	22.0	-26.8485
4	$A_2B_1C_2$	32	7	50	28.4	-29.0664

The response table is obtained using the Minitab 17 software. The experimental results are now transformed into a signal-to-noise (S/N) ratio. The input parameter signifies the impact of machining time value. From the table, it can be found that the machining time is less when pulse on time is 32 µ.sec and pulse off time is 5 µ.sec, where gap voltage is 70 V.

1) *Machining Time For Each Level Of The Process Parameter - Molybdenum*

Table: 14 Response Table for Signal to Noise Ratios-MT Smaller is better

LEVEL	T ON	T OFF	GV
1	-28.59	-27.24	-28.35
2	-27.96	-29.30	-28.20
DELTA	0.63	2.06	0.16
RANK	2	1	3

Table: 15 Analysis of Variance of MT

SOURCE	DF	SEQ SS	ADJ MS	F	P	% OF CONTRIBUTION
T ON	1	3.4225	3.4225	-	-	8
T OFF	1	37.8225	37.8225	-	-	92
GV	1	0.0625	0.0625	-	-	0
ERROR	0	-	-			0
TOTAL	3	41.3075				100

Now, the Analysis of Variance, also called the ANOVA table (Table 15) was generated to obtain the percentage Contribution of the different parameters individually and along with their interaction over the machining timing value. The variance ratio was obtained from the Minitab 19 software. It was found out that the Input Pulse OFF time had a larger Contribution to the machining timing value using molybdenum wire.

2) *Regression Equation:* MT = 26.13 + 0.9250 T ON_30 - 0.9250 T ON_32 - 3.075 T OFF_5 + 3.075 T OFF_7 + 0.1250 GV_50 - 0.1250 GV_70

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F. Material Removal Rate (Analysis Of Result) - Using Brass Wire

Table: 16 S/N Ratios Values for the MRR

S.NO	DESIGNATION	T ON (µs)	T OFF (µs)	GV (V)	MRR (gm/min)	SNRA1
1	$A_1B_1C_1$	30	5	50	0.026	-31.7005
2	$A_1B_2C_2$	30	7	70	0.024	-32.3958
3	$A_1B_3C_3$	32	5	70	0.033	-29.6297
4	$A_2B_1C_2$	32	7	50	0.040	-27.9588

Gap voltage, pulses on time and pulses off time are significant parameter for MRR. The response table is obtained using the Minitab 17 software. The experimental results are now transformed into a signal-to-noise (S/N) ratio. The input parameter signifies the impact of material removal rate value. From the table, it can be found that the material removal rate is more when pulse on time is 32 µ.sec and pulse off time is 7 µ.sec, where gap voltage is 50 V using brass wire.

MRR Formula: Before m/c weight - After m/c weight / Time taken X Density

EXP	BRASS				MOLYBDENUM			
B.Weight	135.19	131.53	139.91	138.97	136.80	137.51	136.29	137.78
A.Weight	123.74	125.43	124.02	122.57	123.56	123.56	122.92	123.74

Density of HCHCR-7.8 gm/cc

1) MRR for Each Level of the Process Parameter - BRASS

Table: 17 Response Table for MRR-Larger is better

LEVEL	T ON	T OFF	GV
1	-32.05	-30.67	-29.83
2	-28.79	-30.18	-31.01
Delta	3.25	0.49	1.18
Rank	1	3	2

Table: 18 Analysis of Variance-MRR

SOURCE	DF	SEQ SS	ADJ MS	F	P	% OF CONTRIBUTION
T ON	1	0.000132	0.000132	-	-	83
T OFF	1	0.000006	0.000006	-	-	4
GV	1	0.000020	0.000020	-	-	13
Error	0	-	-			0
Total	3	0.000159				100

Now, the Analysis of Variance, also called the ANOVA table (Table 18) was generated to obtain the percentage Contribution of the different parameters individually and along with their interaction over the material removal rate value. The variance ratio was obtained from the Minitab 19 software. It was found out that the Input Pulse ON time had a larger Contribution to the material removal rate value using brass wire.

2) *Regression Equation:* MRR = 0.06000 - 0.01300 T ON_30 + 0.01300 T ON_32 + 0.006000 T OFF_5 - 0.006000 T OFF_7 + 0.01100 GV_50 - 0.01100 GV_70

G. Material Removal Rate (Analysis Of Result) - Using Molybdenum Wire

Table: 19 S/N Ratios Values for the MRR

S.NO	DESIGNATION	T ON (µs)	T OFF (µs)	GV (V)	MRR (gm/min)	SNRA1
1	$A_1B_1C_1$	30	5	50	0.071	-22.9748
2	$A_1B_2C_2$	30	7	70	0.059	-24.5830
3	$A_1B_3C_3$	32	5	70	0.077	-22.2702
4	$A_2B_1C_2$	32	7	50	0.063	-24.0132

Gap voltage, pulses on time and pulses off time are significant parameter for MRR. The response table is obtained using the Minitab 17 software. The experimental results are now transformed into a signal-to-noise (S/N) ratio. The input parameter signifies the impact of material removal rate value. From the table, it can be found that the material removal rate is more when pulse on time is 32 µ.sec and pulse off time is 5 µ.sec, where gap voltage is 70 V using molybdenum wire.

1) MRR for Each Level of the Process Parameter - Molybdenum

Table: 20 Response Table for MRR-Larger is better

LEVEL	T ON	T OFF	GV
1	-23.78	-22.62	-23.49
2	-23.14	-24.30	-23.43
Delta	0.64	1.68	0.07
Rank	2	1	3

Table: 21 Analysis of Variance-MRR

SOURCE	DF	SEQ SS	ADJ MS	F	P	% OF CONTRIBUTION
T ON	1	0.000025	0.000025	-	-	13
T OFF	1	0.000169	0.000169	-	-	87
GV	1	0.000001	0.000001	-	-	0
Error	0	-	-			0
Total	3	0.000195				100

Now, the Analysis of Variance, also called the ANOVA table (Table 21) was generated to obtain the percentage Contribution of the different parameters individually and along with their interaction over the material removal rate value. The variance ratio was obtained from the Minitab 17 software. It was found out that the Input Pulse OFF time had a larger Contribution to the material removal rate value using molybdenum wire.

2) *Regression Equation:* MRR = 0.06975 - 0.001250 T ON_30 + 0.001250 T ON_32 + 0.003750 T OFF_5 - 0.003750 T OFF_7 + 0.000750 GV_50 - 0.000750 GV_70

H. Experimental Data Of Machining Character For Both Wires

Table: 22 Experimental Data of the WEDM process

EXP	BRASS			MOLYBDENUM		
	CIRCLE	ROUNDNESS	CYLINDRICITY	CIRCLE	ROUNDNESS	CYLINDRICITY
1	0.1553	0.0028	0.0229	-0.0500	0.0316	0.0313
2	0.2033	0.0199	0.0381	-0.0597	0.0216	0.0226
3	0.1462	0.0322	0.0325	-0.0336	0.0404	0.0387
4	0.1669	0.0186	0.0201	-0.0526	0.0301	0.0333

Comparision of Circle Error Brass And Molybdenum Wire

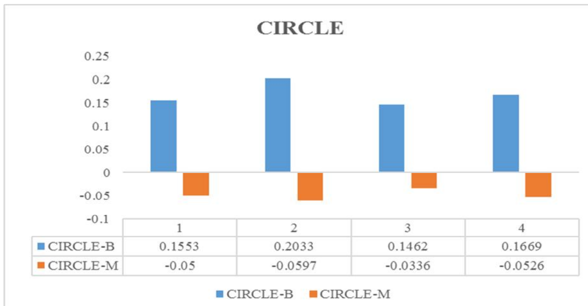

Fig: 6 comparison circle error brass and molybdenum wire

Comparision of Roundness Error Brass And Molybdenum Wire

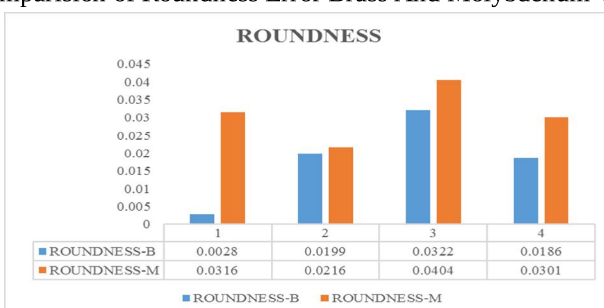

Fig: 7 comparison roundness error brass and molybdenum wire

Comparision Of Cylindricity Error Brass And Molybdenum Wire

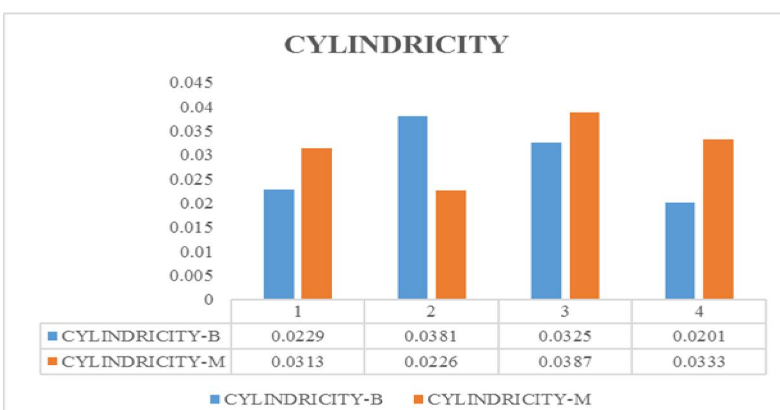

Fig: 8 comparison cylindricity error brass and molybdenum wire

I. Conclusion Of Machining Character And Geometrical Character

1) *Machining Character:* Through experimentally evaluated roughness average, machining time & material removal rate molybdenum wire is suitable for particular heat treated HCHCR the minimum Ra, MT and maximum MRR obtained at through molybdenum wire.
2) *Geometrical Evaluation:* Based on the geometrical evaluation through CMM molybdenum wire shows diameter accuracy is negative and roundness, cylindricity evaluation slightly higher than brass wire. Finally concluded according to geometrical tolerations brass is better than molybdenum.

IX. RESULT & CONCLUSION

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

A. Optimal Control Factor-Brass

- Surface Roughness - A_2 (T ON - 32 µs) B_3 (T OFF - 7 µs) C_1 (Volt - 50)
- Machining Timing - A_2 (T ON - 32 µs) B_3 (T OFF - 7 µs) C_1 (Volt - 50)
- Material Removal Rate - A_1 (T ON - 30 µs) B_3 (T OFF - 7 µs) C_2 (Volt - 70)

1) Percentage Of Contribution Of Process Parameter-Brass

a) Surface Roughness Gap voltage - 95%
b) Machining Timing- Gap voltage - 76%
c) Material Removal Rate- Pulse on time - 83%

B. Optimal Control Factor-Molybdneum

- Surface Roughness - A_1 (T ON - 32µs) B_2 (T OFF - 7 µs) C_3 (Volt - 70)
- Machining Timing - A_2 (T ON - 32µs) B_1 (T OFF - 5 µs) C_3 (volt - 70)
- Material Removal Rate - A_2 (T ON - 32µs) B_1 (T OFF - 5 µs) C_3 (volt - 70)

1) Percentage Of Contribution Of Process Parameter- Molybdneum

a) Surface Roughness Gap voltage - 58%
b) Machining Timing- Gap voltage - 92%
c) Material Removal Rate- Pulse on time - 87%

Finally concluded according to geometrical tolerations brass is better than molybdenum. Minimum surface Roughness and maximum MRR obtained through molybdenum wire and machining timing of brass is very high comparative than molybdenum wire.

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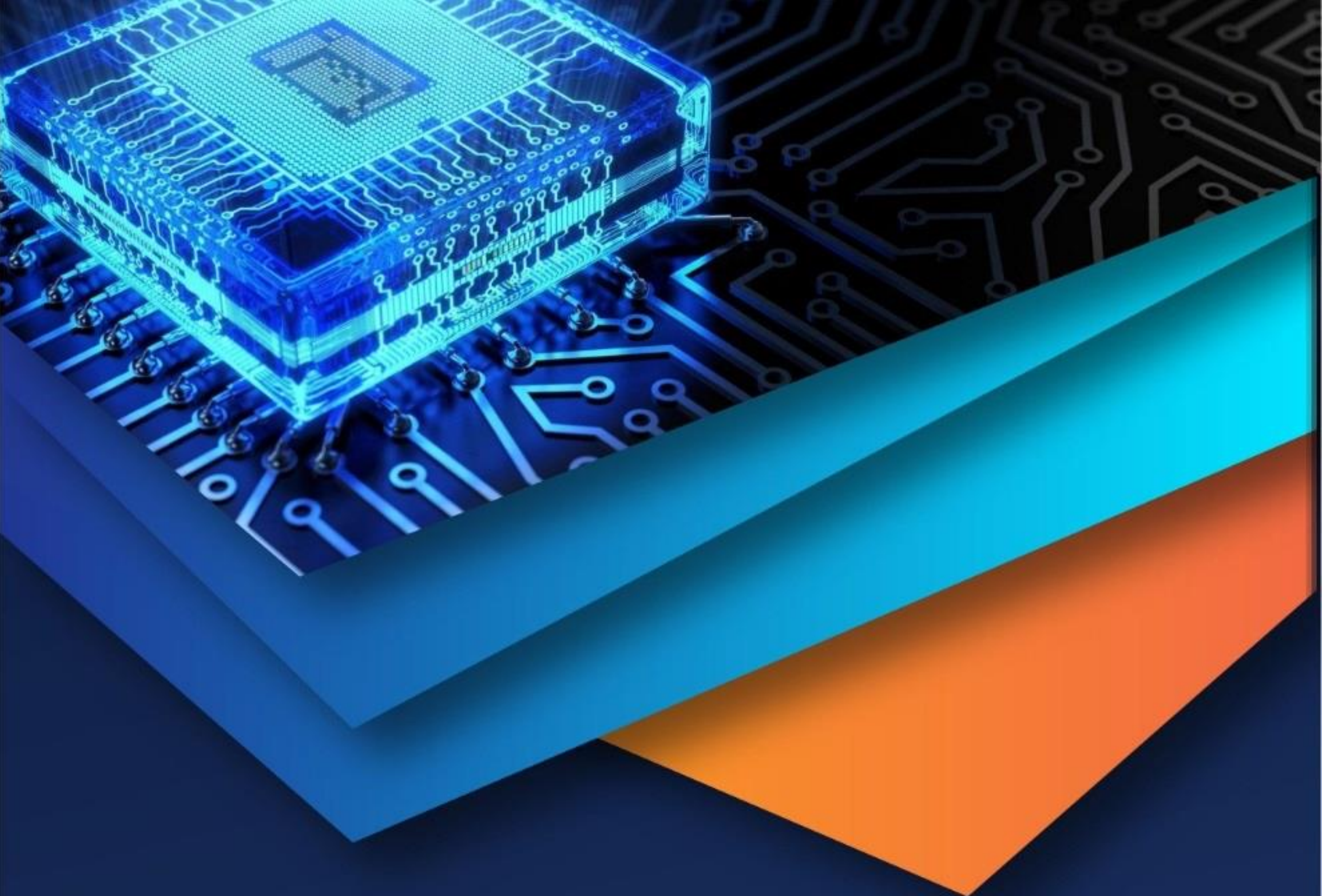

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