CHARACTARIZATION AND SURFACE ROUGHNESS STUDY OF HCHCR MATERIAL TO PREPARE PRECISION STAMPING PUNCH

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ABSTRACT

Objective of present work is preparation of punches by characterization study and using 'wire electrical discharge machining process (WEDM). For the proposed study HCHCr material is selected as punch material which Hardening and Tempering at three different temperature viz.,350 ^{0}C, 450 ^{0}C, 550 ^{0}C by conducting mechanical testing like Tensile test, Compression test , Impact test Hardness test. The input parameters chosen for WEDM are Intensity of current, pulse duration time and pulse interval time. To optimize the process parameters response surface method (RSM) is employed for experimentation where in that we using and central composite design (CCD) to create design matrix to conduct the experimentation to prepare & study the surface roughness of precision punches.

Keywords: High Crbon High Cromium Steel (Hchcr), Hardening And Tempering, Wire Cut Electrical Discharge Machining (WEDM) Response Surface Methodology (RSM) Central Composite Design (CCD), And Surface Roughness (SR), Analysis Of Variance (ANOVA)

I. INTRODUCTION

There are many machining process which used now a days, but to machine very hard materials with more accuracy it's better to go non-conventional machining process. For example preparation of punches which used in many industries, the main property requirement for punch is hardness and sum other mechanical properties and also material selection very important. Materials which mainly used for punches is die steels in this paper HCHCr material used and further it hardening and tempering at three different temperature and test are conducted to study the properties like tensile strength, compression strength, Impact strength, and hardness of the material and then based on test results material is selected to prepare punches by using WEDM machining process and also process parameters are optimized based on Surface Roughness study by using ANOVA analysis[1].

II. EXPERIMENTAL WORK

In the present work, HCHCr material is used which Hardening and tempering at 350 0C, 450 0C, 550 0C

Table 1 Chemical Composition HCHCr

Material type	Composition in %
carbon	2.10
Silicon	0.30
chromium	11.50
Magnesium	0.40
Nickel	0.31

2.1 Specimen Preparation as Per ASTM Standard

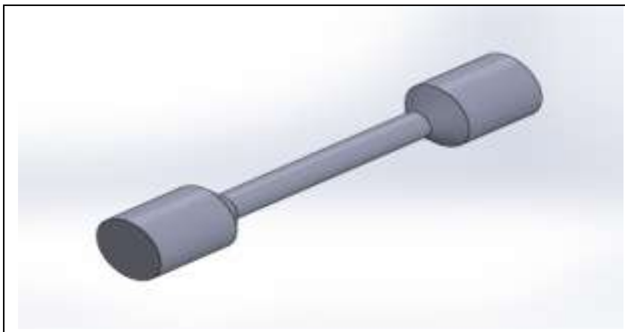

Fig 1 Tensile Test Specimen

Table 2 Specimen Specification

G—Gage length	50.0 ± 60.1 [2.000 ± 60.005]
D—Diameter	12.5± 60.2 [0.500 ± 60.010]
R—Radius of fillet, min	10 -[0.375]
A—Length of reduced section	56 -[2.25]

2.2 Impact Test Specimen: (IZOD) as per ASTM E8M

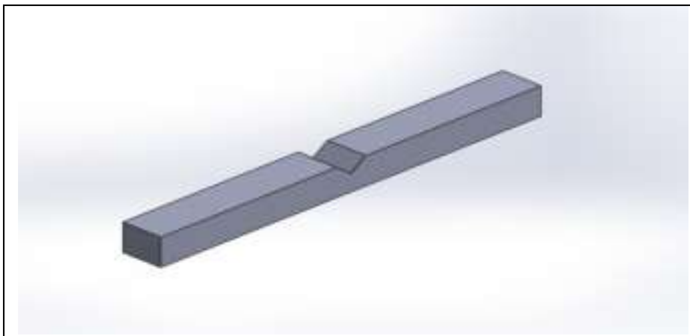

Fig 2 Izod Test Specimen

Table 3 Specimen Specification

For material HCHCr	
Length in mm	75
Width in mm	10
Breath in mm	10
V- notch angle	45

2.3 Impact Test Specimen: (Charpy) as per ASTM A370 Standard

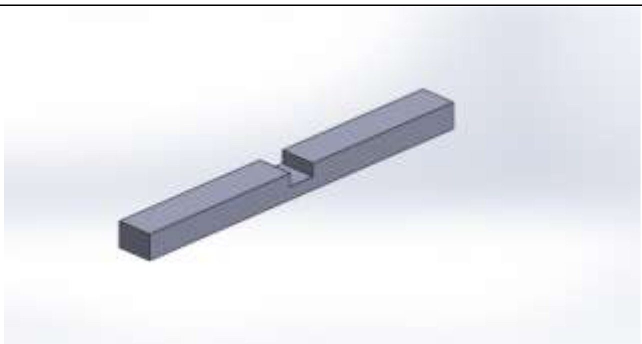

Fig 3 Charpy Test Specimen

Table 4 Specimen Specification

For material HCHCr	
Length in mm	55
Width in mm	10
Breath in mm	10
Square depth	5

2.4 Compression Test Specimen: as Per ASTM E8M Standard

Fig 4 Compression Test Specimen

Table 5 Specimen Specification

For material HCHCr	
Diameter in mm	12.7
Length in mm	25.4

2.5 Hardening Process

To change the hardness of the material or to produce surface that gives the progress is subsequent manufacturing operation to produce a structure, the general purpose heat treatment is done. The main purpose of hardening done to develop less than greater hardness when first stage of cooling is done 1000 F within 1 second with skill full where further cooling is done at sum interval of time at slower rate. Composition of material is specific the rate of quenching alloy steel where slower quench is done for steel hardening compare to mail carbon steel hardening there are many quenching methods but over project work we used water quenching method where of water quenching temperature of water bath must be not rise 80 F therefore 70F is best for quenching generally for plain carbon steel water or brine quenching media is used because brine consist less tendency to produce steam pockets to form these pockets are coursed soft or uneven stress next agitation of steel remove the bubbles which forms on surface material as quenching temperature is reached to 200 F to 25 F the material is dried carefully without too match sizzle[2].

Fig 5 Hardening Equipment

2.6 Tempering Process

To reduce brittleness most of alloy after hardening process material tempered and relive sum of high internal stress which developed during hardening process where tempering is done slowly from its tempering temperature by cooling in still air usually tempering is done before the material is cooled from its hardening process where according to thickness of the material holding temperature and time is varies, but minimum time is one hour. For over work we take the holding time as 60, 90,120 minutes for different temperature due to more thickness holding time is increased to one hour for each specimen.

Fig 6 Tempering Equipment

2.7 Tensile Test

For metallic materials universal testing machine designed for the testing. Machine applied hydraulically operated load and microprocessor controlled for accurate measurement. A variety of grips or holders are used which make this machine very useful for tensile testing, compression, elongation etc. The digital controls and readout permit accurate measurement of all applicable data[3].

2.8 Compression test

Compression test gives the material status when it subjected to compressive load from low to high uniformly until material get fail or fracture. This test gives the standard method to obtain dada for research work. Compressive test carried out on universal testing machine with very high capacity of compression. Where test specimen is prepaid as per ASTM standard then suitable testing machine will chosen for get more accurate dada within time, VERTEX 60HVL universal testing machine is used for testing.

2.9 Hardness Test

Rockwell hardness tester most popular hardness test method, since there is some other methods also used. In Rockwell hardness test it consist number of different indenter and load equivalent to scale, steel indenter made very hard which used to make a contact with material where hardness value are obtained directly on machine dialer. Other test machine is microscope hardness tester which used for thin material[4]l.

2.10 Impact Test

Impact test where material striker by pendulum or drop hammer as supported to static load. Where costume scientific instrument the impact test is a dynamic test where striking of a specimen falling draft is used for impact testing, where specimen is made either V notch Or U notch for Izod and Charpy test as per ASTM standard[5].

2.11 Design of Experiments (DOE)

Design of experiments (DOE) is an engineering tool for analysis where it is systematic technique to engineering problem solving where it applies different technique and principals at collection of dada for accurate generation of dada or valued, supportable and defensible engineering conclusion. It also helps to all of above carried under the constrained or minimum spending of engineering runs time and money[6].

2.12 Full Factorial Design with 3 Factors

A full factorial design indicates all probable combinations of a set of factors. This is the most take in proof design approach" also it is the most costly in experimental resources compeer to other design approach. It supports both categorical factors and incessant factors with up to nine levels. In full factorial designs, we perform an experimental run at every possible combination of the factor levels. The sample size is the product of the numbers of levels of the factors". For example a factorial experiment with a two-level factor, a three-level factor, and a four-level factor has 2 x 3 x 4 = 24 runs[7].

The three inputs (factors) that are considered important to the operation are Intensity of current ($\boldsymbol{X_1}$), Pulse Duration ($\boldsymbol{X_2}$), and Pulse interval ($\boldsymbol{X_3}$**)**.

Intensity of current, Pulse Duration and Pulse interval can all be varied continuously along their own scales, from a low to a high setting. Surface Roughness to vary good when progressive changes is made to the inputs

Table 6 High (+1) Low (-1) and Mid Value (0) Settings for a Cutting Operation

Factors	Low- (-1)	Standard- (0)	High-(+1)	Unit
Intensity of Current (X_1)	3	4	5	Amp
Pulse Duration (X_2)	30	45	60	µs
Pulse Interval (X_3)	3	4	5	µs

III. RESULTS AND DISCUSSION

3.1 Tensile Test Results

Table 7 For Green Material

L_Y	69.56 kN
E_Y	15.720 mm
Y_s	600.942 N/mm2
L_p	79.380 kN
E_P	20.140 mm
T_S	685.779 N/mm2
L_B	78.220 kN
E_B	21.090 mm
% A_R	13.82%
% E	8.44%

Table 8 For 350 ^{0}C Tempering Material

L_Y	110.80 kN
E_Y	14.120 mm
Y_s	949.437 N/mm2
L_p	130.420 kN
E_P	16.470 mm
T_S	1142.119 N/mm2
L_B	132.420 kN
E_B	16.450 mm
% A_R	1.97%
% E	0.40%

Table 9 For 450 ^{0}C Tempering Material

L_Y	106.52 kN
E_Y	14.700 mm
Y_s	896.461 N/mm2
L_p	135.600 kN
E_P	23.970 mm
T_S	1141.195 N/mm2
L_B	135.600 kN
E_B	16.240 mm
% A_R	…..
% E	0.08%

Table 10 For 550 ^{0}C Tempering Material

L_Y	117.32 kN
E_Y	14.560 mm
Y_s	959.077 N/mm2
L_p	147.360kN
E_P	24.870 mm
T_S	1204.650 N/mm2
L_B	147.360 kN
E_B	16.130 mm
% A_R	0.32
% E	0.12%

3.2 Hardness Test Results

Table 11 Hardness Values

Green material	54 HRC
350 ^{0}C Tempering material	60 HRC
450 ^{0}C Tempering material	58 HRC
550 ^{0}C Tempering material	56 HRC

3.3 Impact Test Results

Table 12 Charpy Test

Green material	19 Joules
350 ^{0}C Tempering material	16 Joules
450 ^{0}C Tempering material	18 Joules
550 ^{0}C Tempering material	20 Joules

Table 13 Izod Test

Green material	2.9 Joules
350 ^{0}C Tempering material	1 Joules
450 ^{0}C Tempering material	2 Joules
550 ^{0}C Tempering material	3 Joules

3.4 Effect of Tempering Temperature on Ultimate Tensile Strength

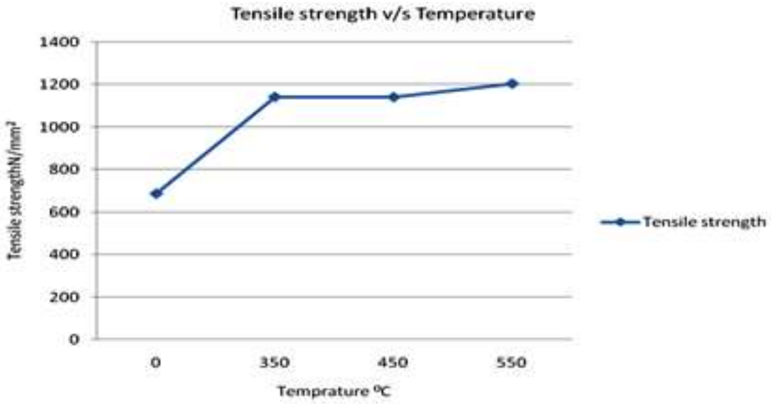

Fig 7 Tensile Strength v/s Temperature

In Fig 7 shows the tensile test v/s tempering temperature where single material tempered at three different temperature which caused to increase in hardness or other mechanical properties of the materials, in this graph we can seen that tensile that tensile strength of the material increase as material is tempered where we get higher value of tensile for specimen which tempered at 550 0c as shown in graph.

3.5 Effect of Tempering Temperature on Impact Strength

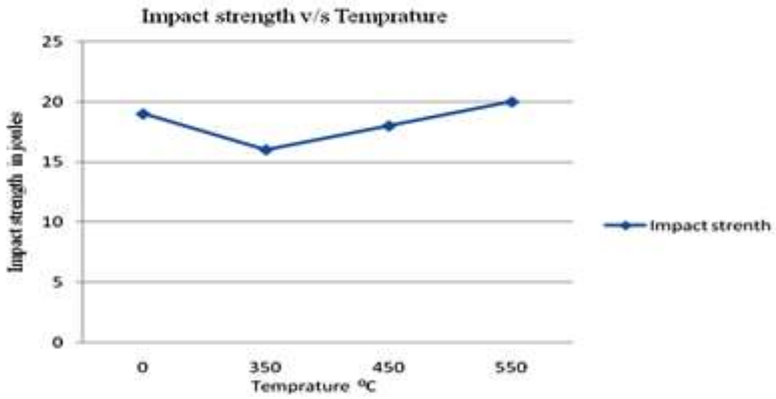

Fig 8 Impact Strength v/s Temperature

In Fig 8 shows the effect of tempering temperature on impact strength of the material, where graph is between the impact strength v/s tempering temperatures in graph we can be seen that impact strength of material is changed as material undergoes tempering process, where higher value of impact strength is obtained at 550 0c tempered specimen which nearly at 1200 n/mm2. Where from graph we can seen that the value of impact in decreases at 350 0c temperature which is mainly at this temperature makes material very brittle and have low strength.

3.6 Effect of Tempering Temperature on Hardness

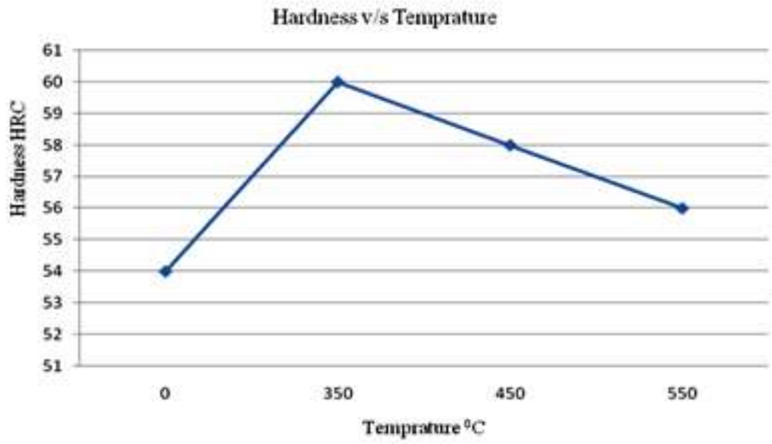

Fig 9 Hardness v/s Temperature

The variation is hardness of material HCHCr due to hardening and tempering process as shown in above graph which plotted as hardness v/s temperature, graph shows all three tempering temperature and respective hardness. Where hardness is varies frequently with temperature this variation is based on quenching time at materials quenching during hardening and tempering process, by considering the experimental results and graphs we can observed that material having higher value of hardness at 350 0c tempering material. But due to high hardness makes material brittle in nature.

3.7 Final Selection of Punch Material

HCHCr Tempered at 550 ^{0}C

Tensile Strength	1204.650 N/mm^2
Hardness	56 HRC
Impact Strength	20 Joules

By considering the all above test results like tensile test results, Impact test results, Hardness test, microstructure etc. where we get maximum tensile strength of material out of all four readings at 550 0c tempered material, where in impact test the higher value of impact strength also we get for same tempered material (at 550 0c), since hardness of material we get higher at 350 0c tempered material but for this value of hardness makes material brittle in nature which not suitable for preparation of punch. Therefore we select material which tempered at 550 0c where hardness is nearly around 56HRC which is higher than green materials hardness 56HRC. Therefore material selected for punch is HCHCr material tempered at 550 0c with tensile strength 1200 n/mm2, Impact strength 20 joules, and hardness is 58HRC.

3.8 Wire Electrical Discharge Marching Results

Run	Intensity of current X1 Amps	Pulse duration X2 Micro-second	Pulse interval X3 Micro-second	Surface roughness Ra Micro-meter
1	5	30	3	4.70
2	3	60	5	3
3	5	60	3	3.30
4	4	45	4	3.90
5	3	30	3	4.20
6	5	45	4	3.50
7	4	30	4	3.20
8	4	45	5	4.20
9	4	45	4	3.60
10	4	45	4	4.20
11	4	45	4	4.40
12	5	60	5	3.90
13	3	60	3	3.40
14	3	45	4	3.20
15	3	30	5	5
16	4	45	4	5.90

17	4	60	4	3.50
18	5	30	5	3.52
19	4	45	4	3.8
20	4	45	3	3

Fig 4.10 Punch Made by WEDM

Table 13 Estimated Regression Coefficients for Surface Roughness

Term	Coef	SE Coef	T	P
Constant	6.22909	2.73822	2.275	0.046*
Intensity of current	-2.30773	1.20971	-1.908	0.086*
Pulse Duration	-0.00430	0.06496	-0.066	0.948
Pulse Interval	0.89227	1.20971	0.738	0.478
Intensity of current* Intensity of current	0.30909	0.14171	2.181	0.054*
Pulse Duration*Pulse Duration	-0.00018	0.00063	-0.289	0.779
Pulse Interval*Pulse Interval	-0.04091	0.14171	-0.289	0.779
Intensity of current*Pulse Duration	0.00833	0.00554	1.504	0.163*
Intensity of current*Pulse Interval	-0.02500	0.08309	-0.301	0.770
Pulse Duration*Pulse Interval	-0.00833	0.00554	-1.504	0.163*

S = 0.235005 PRESS = 3.95253
R-Sq = 86.65% R-Sq(pred) = 4.48% R-Sq(adj) = 74.64%

In above table 10 shown the Estimated Regression Coefficients for Surface Roughness where we set 85% of accuracy at this percentage we only get affect Intensity of current on surface roughness. Star mark indicates these effects.

Table 11 Analysis of Variance for Surface Roughness

Source	DF	Seq SS	Adj SS	Adj MS
Regression	9	3.58573	3.58573	0.398414
Linear	3	2.97800	0.21717	0.072391
Intensity of current	1	1.93600	0.21717	0.072391
Pulse Duration	1	0.96100	0.00024	0.000242
Pulse Interval	1	0.08100	0.03005	0.030046
Intensity of current*Intensity of current	1	0.33800	0.26273	0.262727
Pulse Duration*Pulse Duration	1	0.01013	0.00460	0.004602
Pulse Interval*Pulse Interval	1	0.00460	0.00460	0.004602
Interaction	3	0.25500	0.25500	0.085000
Intensity of current*Pulse Duration	1	0.12500	0.12500	0.125000
Intensity of current*Pulse Interval	1	0.00500	0.00500	0.005000
Residual Error	10	0.55227	0.55227	0.055227
Lack-of-Fit	5	0.39227	0.39227	0.078455
Pure Error	5	0.16000	0.16000	0.032000
Total	19 4.13800			

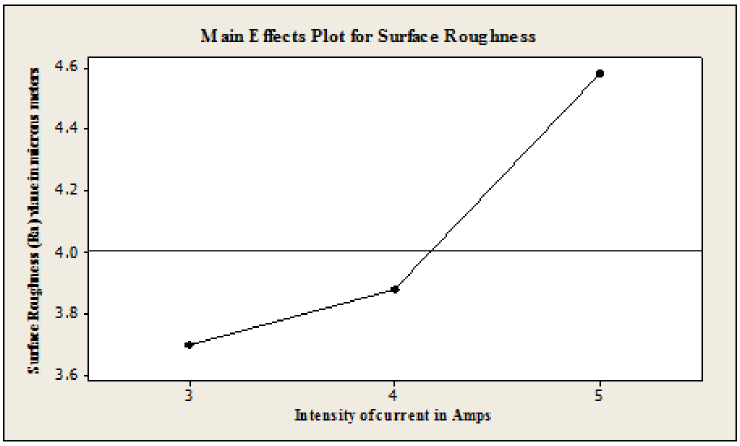

Fig 11 Intensity of Current v/s Surface Roughness

Fig 11 shown the effect of Intensity of current on surface roughness where we can seen when current increased between 3 to 4 amps Surface- roughness value Ra also increased slightly around 3.7 to 3.9 where current at 4 to 5 Ra value increased rapidly up to 4.5 as shown in graph. This is because the crater size generated by a single pulse becomes larger with an increase in single pulse energy. Single pulse energy increases with increasing discharge current; therefore the SR also increases.

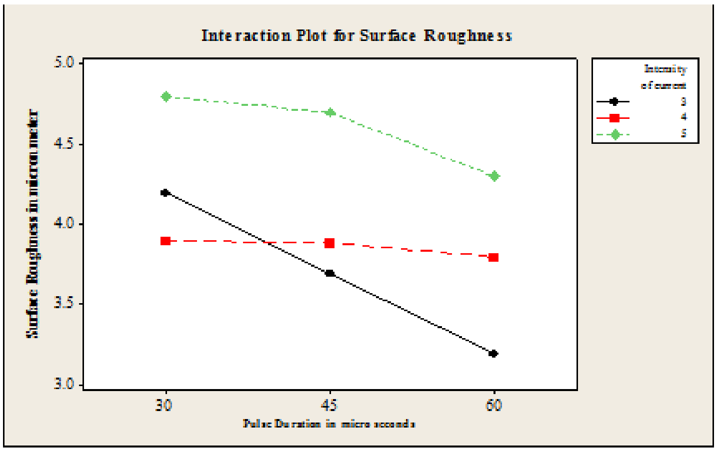

Fig 12 Interaction Plot For Surface Roughness Vs Intensity of Current And Pulse Duration Time

Fig 12 shows the interaction plot for pulse duration and intensity of current With Surface Roughness. Where at the current intensity 3 to 4 roughness of the material is interact at pulse duration of 40 micro seconds as shown in above graph.

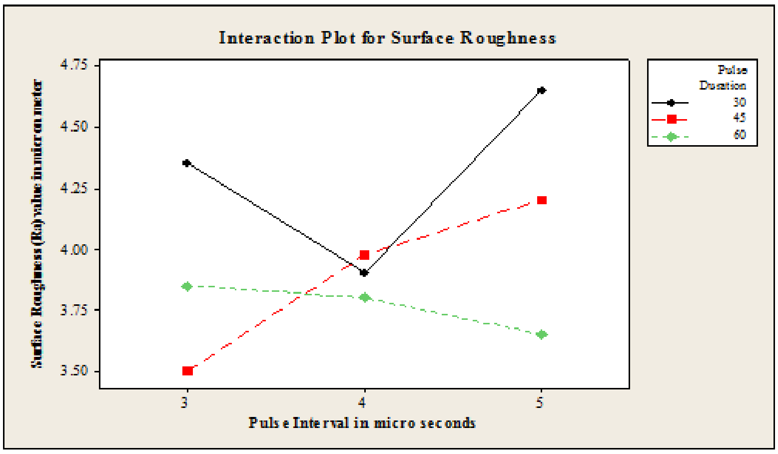

Fig 12 Interaction Plot for Surface Roughness Vs Pulse Duration and Pulse Interval Time

Fig 12 shows the interaction plot between pulse duration and pulse interval with surface-roughness. Where at the pulse duration 30 to 45 micro seconds at the pulse interval of 4 micro seconds surface roughness value achieved as 3.9.and at pulse duration 30 to 45 micro second at interval of 3.7 surface roughness shows as3.75

IV. CONCLUSION

In the present work characterization and experimental study was performed on HCHCr material to manufacture stamping punch, which hardened and tempered at three different temperature for characterization study. DOE technics is applied to consider machining characteristics in wire EDM.

1. Mechanical property test results shows good tensile strength of 1204.65 N/mm^2, Impact strength 20 Joules, hardness 56 HRC of material which hardened and tempered at 550 ^{0}C
2. Punch results and ANOVA analysis presents shows two set of optimal process parameters.
3. To manufacture punch wire cut EDM process was adopted.
4. Intensity of current found to be the most important parameter affecting the surface roughness value.

5. Interaction affects of intensity of pulse duration and pulse interval has the significant effect on Ra value.
6. Lower Ra value has been achieved by optimizing the parameters significantly such as current, pulse duration and pulse interval set at 3 amps, 60 micro seconds and 3 micro seconds.
7. The individual effect and interaction affects of process parameters on Ra value is better understand by plots.
8. For the research and theoretical work data base of results provides useful reference.

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