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Investigation of surface roughness for EN-31 by REDM with graphite electrode

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Machining of EN-31 is supposed to be very difficult by conventional machining methods. A rotational electrical discharge machine (REDM) has been developed with concentration of abrasive particles in oil. Investigations have been carried out for machining EN-31 material by REDM with graphite electrodes (Ge). Analysis of REDM process parameter has made to carry out on EN-31 for Surface Roughness (R_a) with graphite electrode (G_e). The experiments have been performed with three parameters: Peak current (P_c), tool rotation (T_{rpm}) and abrasive concentration (A_c). The variable concentration of silicon carbide (SiC) has been used to analyse the R_a at various concentration such as 60, 80 & 100 g/L. Optimal results have been obtained for process parameters, Pc – 12 amp, Trpm – 1800 rpm and Ge – 80 g/L.

Keywords: REDM, EN-31, Graphite electrode tool, Surface roughness

1 Introduction

The REDM provides the advantage i.e. the outside layer on the work piece have speedily melt and then detached with arc in place of every charge. The acceptable variety of developed REDM environment be essential condition for obtain interested in deliberation at the bulk of industrialized method and predominantly, during processes associated Rotational Electrical Discharge Machining (REDM). The REDM process mostly functional in the modernization metal manufacturing units for making convoluted and compound shapes. The REDM has accomplished for machining complex and tough material works, as they are specific and hard-to-machine material, such as it is high temperature tool steels materials, which are mostly used in die and mould construction industry like automobile and aerospace industries. The EDM course of action uniqueness are Metal elimination speed, precision, outside terminate and high temperature unnatural region. The EDM process broadly used for the machining of hard materials and complex shapes. The REDM is essential for developed and recondition of compress tool, dies and moulds injection, etc.

2 Literature

Singh *et al*.[1], adding water-based fluid in the EDM as it more eco pleasant for compare to conventional lubricate based. The MRR improved by the use of H_2O. Here a variety of participation parameter like peak current (P_c), pulse-on-time (T_{on}), pulse-off-time (T_{off}), voltage (V) has been used for model configuration to produce arrangement intended for machining. Kahrarnan[2], different type of model was urbanized for calculation and investigation of the association linking the cutting parameters with R_a in spinning method of AISI 4140 harden materials. During the calculation of R_a standards, the typical categorical errors for RSM are established selected as 3.18%. This assessment is satisfactory low to corroborate the higher extrapolative influence of model. Investigational outcome shows that, it can be conditional in the prophecy models be able to functional for conclude the proper cutting setting, within the category to R_a. Ali & Banu[3] explained EDM process is flexible machining procedure which have the ability to produce and meet the conditions for making the geometry in three dimensional (3D) geometry more than ever in mechanized industry, aeronautical and automobile industry, announcement and biotechnology industries. This is identified used for machining solid and weak conductive materials. The tool and the work piece are sufficiently wrapped up dielectric intermediate. Ray[4], RSM is recognized as significant tool in investigational propose in conditions of emergent innovative process in addition to right calculation their performance. The objectives of RSM are used for quality improvement, including increasing of variability with improvement in the process. The purpose of RS Min work of invention are shads welcome up and about innovative avenue of follow a

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line of investigation towards precise forecast of responses in the investigational section. At the current circumstances RSM envisage selected animmobile improved device. Chandramouli & Eswaraiah[5] parameter selected peak-current, pulse-on-time, pulse-off-time and tool lift time for getting the output as MRR and R_a. The Taguchi experimental design (L27 orthogonal array) was use in the direction of layout and experiment was conducted on 17-4 rainfall Hardening Stainless Steel (PH Steel) machined through Cu-W electrode. ANOVA technique was worn with the help of MINITAB-17 software to examination and control of contribution. Smilde *et al*.[6] explained the quantity of datasets consider for input parameter and it becomes the way of fundamental output by using the factors. Presently rejection methods in the output has been existed for examine such data. The method projected in these circumstances for this paper called ANOVA-SCA or ASCA. The facilities are given by the deviation in the entire dataset by their parts and also able to assigned assistance of the unusual factor. Singh *et al*.[7] Modern Electrical Discharge technology is proficient for machining geometrically intricate or solid material machinery, that are accurate and complex-to-contraption, such as high temperature treated tool like steels, composite, super alloys, ceramics, etc. The research paper gives the information in the form of outcomes of an investigational examination accepted out to learning the equipment of machining parameters such seeing that P_c on MRR diameter overcut, electrode wear, and R_a in EDM of EN-31 tool steel. Chow *et al*.[8] adding SiC and Al powder to the kerosene allow an adding together stuck between the electrode and the work piece. The extensive gap increases the rubbish subtraction rate and the material elimination depth. Abridge effect is shaped by the additional powder wandering surrounded by the kerosene. The addition discharge facilitates the dispersal in the discharge into more than a few increments. Wu *et al*.[9] the best allocation result is established when the concentration of the Al powder and surfactant at the dielectric are 0.1 and 0.25 g/L, respectively. The higher practical value of surface roughness is 0.172 μm is achieved under these parameters, which are positive polarity, DC Current 0.3 A, Pulse-on-time 1.5 μs, open circuit power input (OCPl) is 140 V and powder concentration 0.25 (A_c). R_a of work piece has been enhanced equal to 60% as compared with EDM below pure dielectric with elevated R_a of 0.434 μm.

3 Experimental design and analysis

The experimentation was conducted on conventional EDM with tool rotation taking L27 Orthogonal Array. The design of experiment has three factors connections can be calculated. The main focus is on R_a with the help of REDM (Fig. 1). The powder concentration has to be mixed with the help of a stirrer. The stirrer is getting the rotation with the help of motor. The development of REDM by introducing the step-up motor by fixing the rotation as per the experiment shown in Table 1.

3.1 Measuring along with testing equipment used

R_a investigation was conducted on all machined surface of the EN-31work piece and composition shown in Table 2. R_a of the work piece was measured by using Taylor Hobson Surtronic, Fig. 2.

3.2 Minitab 17 software

Minitab 17 software gives the both motionless and active comeback experiment in a stationary response examination. These have the fixed three levels and their levels main function is to provide the best combination so that they can achieved noise factor. MINITAB 17 has to be calculated the response tables and also generates main effects with the addition of interaction plots such as signal to noise ratios (S/N ratios) Means has static design versus. the main

Fig.1 — Surface roughness tester (Taylor Hobson Surtronic).

Table 1 — Design of experiment.

Machining parameters	Level 1	Level 2	Level 3
Peak Current (P_c) (amp)	8	10	12
Tool Rotation (T_{rpm}) (rpm)	1200	1500	1800
Abrasive Concentration(A_c)(g/L)	60	80	100

Table 2 — Chemical composition of EN-31 material.

Element	C	Mn	Si	S	P	Cr
%age	0.9	2.34	0.35	0.04	0.04	1.0

Fig. 2 — REDM Sparkonix mos -35 A.

Table 3 — Orthogonal array DOE for Ra.

Exp. Run	P_c	T_{rpm}	A_c	$R_{a(\mu m)}$
1	8	1200	60	5.0200
2	8	1200	80	7.0000
3	8	1200	100	7.4800
4	8	1500	60	6.3000
5	8	1500	80	5.0200
6	8	1500	100	6.2500
7	8	1800	60	5.9600
8	8	1800	80	4.8600
9	8	1800	100	1.3800
10	10	1200	60	3.0500
11	10	1200	80	0.0347
12	10	1200	100	4.8000
13	10	1500	60	5.3600
14	10	1500	80	0.0343
15	10	1500	100	0.3450
16	10	1800	60	0.0480
17	10	1800	80	0.0313
18	10	1800	100	0.0325
19	12	1200	60	0.5950
20	12	1200	80	0.0355
21	12	1200	100	0.0330
22	12	1500	60	0.0519
23	12	1500	80	0.0297
24	12	1500	100	0.0335
25	12	1800	60	0.0293
26	12	1800	80	0.0326
27	12	1800	100	0.0318

control factors. The Taguchi design and its orthogonal array technique were used for the designing the investigational course of action by means of different types of proposes like three level. In this learning, a three-factor set of connections is selected with 27 no. of records of experiments, as shown in Table 3. In this work, EN-31 material machined with graphite tool material by using REDM. The fundamental properties of Graphite electrode as (a) elevated thermal conductivity (b) soaring electrical conductivity (c) advanced thickness (d) High melting position (e) with a reduction of expenditure (f) simple to get the results of MRR, varying the P_c, T_{rpm}, and A_c.

In Fig. 3, the residual plots for SN ratio is shown for probability plot, fits, histogram and order. Figure 4 shows that main effect plots of SN ratio at different factors P_c, T_{rpm} and A_c on R_a. Here we select the options for “Smaller is better (SB)”. The main effects plot for EN-31 material of depth in favor of surface roughness ($R_{a)}$ the rejoinder unpredictable based at S/N ratio. Ra have uppermost SN ratio designed for P_c (8 amp), T_{rpm} (1200 rpm) and A_c (60 g/L).This implies that the effect on one factor is reliant upon an extra factor. This type of arrangement is helpful to decide whether the model which meets the consideration of the examination.

Figure 5 shows the major outcome of the organize factors provisions as P_c, T_{rpm} and A_c on Ra. The main effect plots experimental capitulate of surface roughness is shown for probability plot, fits, histogram and order. Figure 6 special effects plot for EN-31 material that input current has main result at R_a as the response variable placed at rank 1. The optimum level for a factor is the level that gives the highest value of R_a in the investigational area. The increment in value of P_c from 8 amp to12 amp, the surface roughness is also decreased. Increasing the value of T_{rpm} from 1200 to 1800 rpm, the surface roughness is decreased. Besides the ultimate standardized structure with less number of micro cracks and thinner recast layer to the motionless tool EDM have to be noted by increasing the A_c from 60 to 80 g/L, the roughness is also decreased and then from 80 to 100 g/L the roughness is increased. Therefore, the optimum levels of the control factors which has given the better R_a into the EN-31 material. It indicated that when peak current is increased material removable rate was increases due to more amounts of heat generated and deeper crater and wider structure.

It is clearly indicated from Table 4, that the Peak Current make more influencing on R_a comparing with Tool Rotation and Abrasive Concentration parameter. The delta values are Peak Currents, Tool Rotation and Abrasive Concentration parameters are 40.619, 13.769 and 12.859 respectively. The case of R_a, it is “Smaller is better”, so from this table it is clearly defined that peak current is the most important factor then Tool Rotation and Abrasive Concentration. From the Table 3, the surface roughness equation is developed for second order as in Eq. (1).

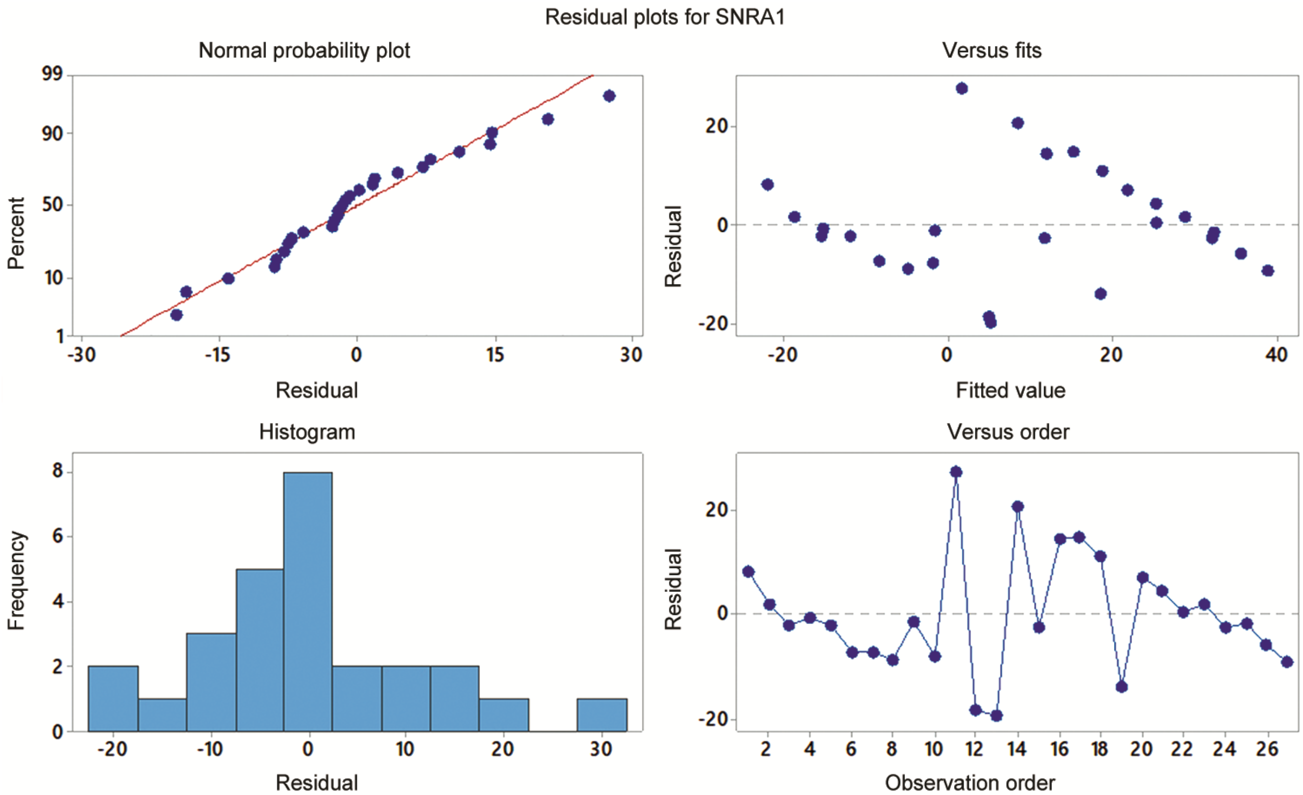

Fig. 3 — Residual plots for SN ratios (Ra).

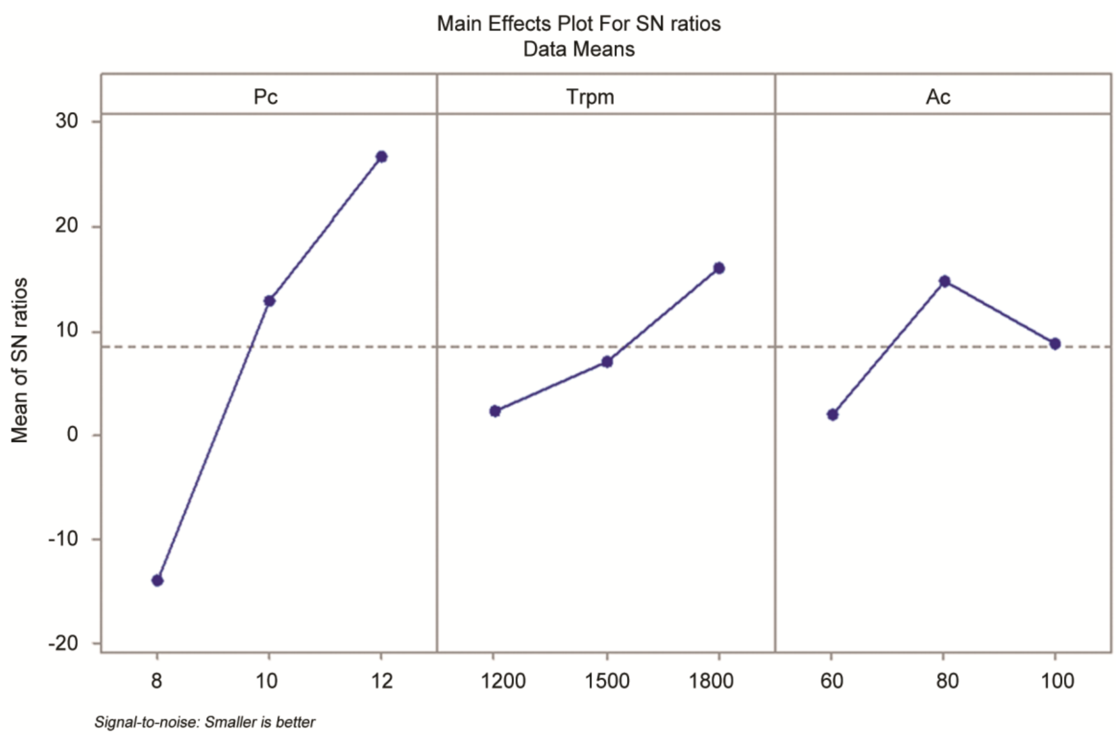

Fig. 4 — Main effects plots for SN ratios (R_a).

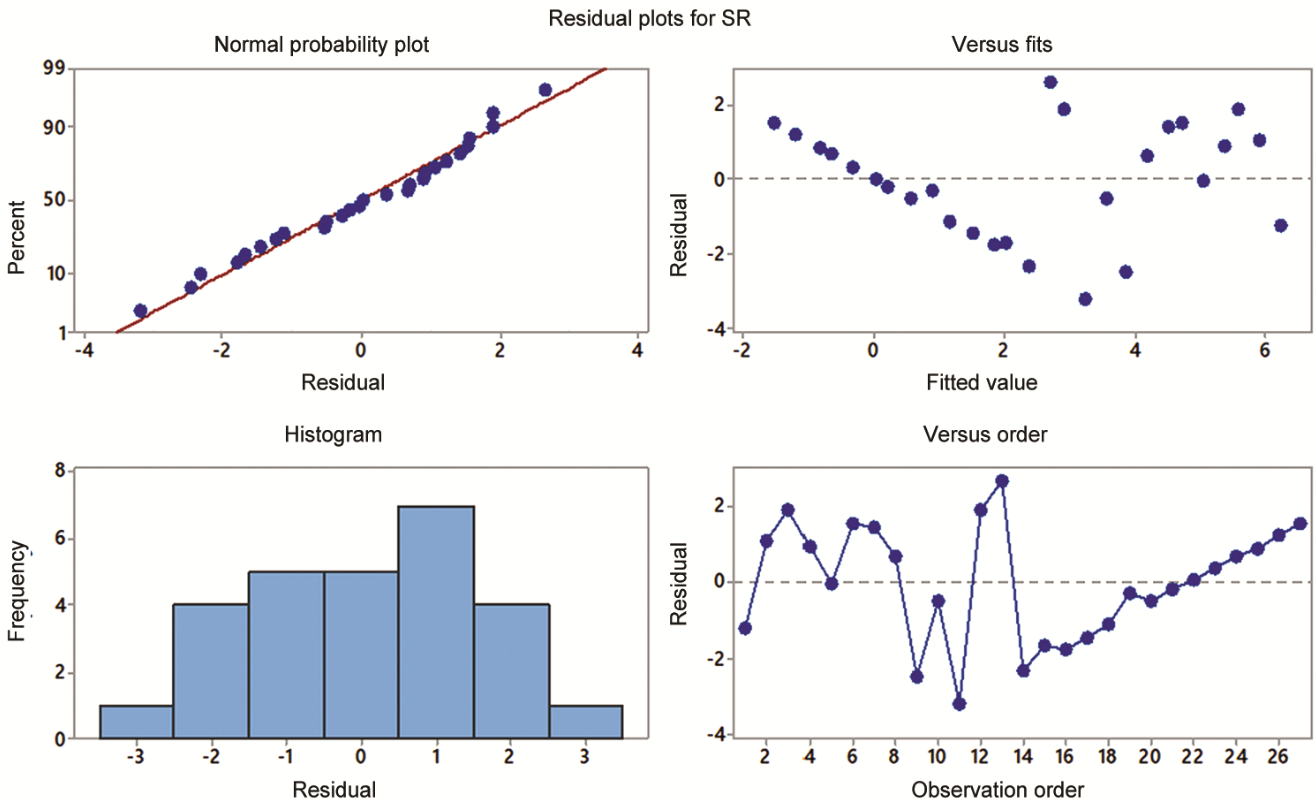

Fig. 5 — Residual plots for surface roughness.

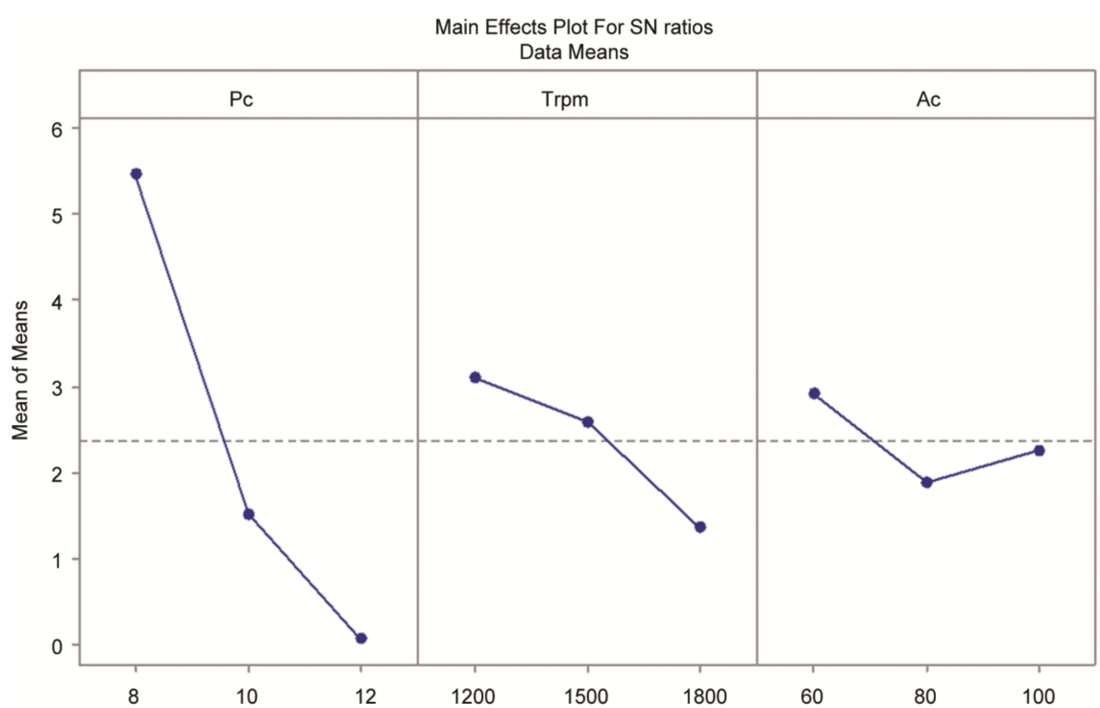

Fig. 6 — Main effects plots for means (R_a).

Table 4 — Response table for means.

Level	Pc	T_{rpm}	A_c
1	-14.039	2.291	1.941
2	12.896	7.086	14.800
3	26.581	16.060	8.696
Delta	40.619	13.769	12.859
Rank	1	2	3

Table 5 — Analysis of variance for means.

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	9	168.624	18.7360	8.62	0.000
P_c	1	17.213	17.2130	7.92	0.012
T_{rpm}	1	0.343	0.3426	0.16	0.696
A_c	1	0.681	0.6809	0.31	0.583
$P_c * P_c$	1	9.518	9.5178	4.38	0.052
$T_{rpm} * T_{rpm}$	1	0.757	0.7574	0.35	0.563
$A_c * A_c$	1	2.960	2.9605	1.36	0.259
$P_c * T_{rpm}$	1	3.775	3.7746	1.74	0.205
$P_c * A_c$	1	0.211	0.2112	0.10	0.759
$T_{rpm} * A_c$	1	5.660	5.6595	2.60	0.125
Error	17	36.961	2.1742		
Total	26	205.585			

$$Ra = 57.2 - 9.31Pc + 0.0088Trpm - 0.159Ac + 0.315Pc * Pc - 0.000004Trpm * Trpm + 0.00176Ac * Ac + 0.000935Pc * Trpm + 0.0033Pc * Ac - 0.000114Trpm * Ac \quad \ldots (1)$$

The second order equation for surface roughness is developed with the help of MINITAB 17 and interaction between parameters are shown in the equation and analysis of variance for mean is shown in Table 5. The values of S = 1.47451, R-Sq = 82.02%, R-Sq (adj) = 72.50%, R-Sq (pred) = 53.96% is obtained by the software.

4 Conclusions

Mathematical models for R_a was developed to associate leading machining parameters, together with the pulse-on-time, pulse-off-time, duty factor, and open discharge voltage, etc. The REDM has development for learning of machining of the material (EN-31) with graphite electrode and abrasive particles. The outcome for the changing the parameters for the performance of individuality in the REDM of material (EN-31) were investigate and urbanized numerical replica to give way the subsequent conclusions of surface roughness (R_a) as:

(i) The tool rotation considerably increases the regular outside finally in the outer surface.

(ii) With the development of REDM the ultimate exterior is extra standardized in organization with less quantity of micro cracks also small recast layer the same as compared with in on rotary tool EDM.

(iii) Value of Surface Roughness (R_a) decreasing when peak current (P_c) increases from 8 to 12 amp.

(iv) Value of Surface Roughness (R_a) decreasing when tool rotation (T_{rpm}) increases from 1200 to 1800 rpm.

(v) When the Abrasive Concentration (A_c) increase from 60 to 80 g/L, then Surface Roughness value decreases and R_a value increasing further increasing the value of A_c from 80 to 100 g/L.

(vi) The effect of P_c, T_{rpm} and A_c placed in the rank 1,2, and 3 respectively on the surface roughness (R_a).

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