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Electric Discharge Machining Characteristics of Inconel Alloy

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Abstract.
Harder Inconel alloy was machined using the unconventional technique wire electric discharge machining. The parameters selected for studies are Current, pulse on time voltage and pulse off time. Material Removal Rate and Surface roughness was recorded as responses. The experiments were designed using taguchi orthogonal array. The results obtained were optimized using Grey Relational Analysis (GRA). The results revealed that the current was the most influential factor followed by the pulse on time. The better surface roughness was achieved when machined with lower current intensity and higher pulse ratio. Highest material removal rate was achieved when machined with higher current intensity.

INTRODUCTION:

Electric discharge machining is suitable for machining complex shaped ceramic parts in a most accurate and flexible way compared to other unconventional means of machining. Because of the properties of high hardness and resistance strength, composite materials are difficult to machine using a traditional technique. A difficult-to-machine material can be easily machined in EDM with improved quality characteristics[1]. The relaxation pulses provide a rougher surface, whereas iso-energetic pulses offer relatively smoother surfaces[2].

An increase in the current intensity leads to an increase in the metal removal rate, and electrode wear rate in the case of WEDM but reduces the surface finish[2-4]. The pulse current and pulse-on time were the two significant factors that affect the material removal rate[5-7].

The gap voltage shows the greatest impact on the metal removal rate in WEDM[8]. The material removal rate of composites is lesser than of base metal alloy but the former shows better surface finish[9]. A zinc coated brass wire has a higher cutting speed and offers a smoother surface than a high-speed brass wire[10].

Optimization of surface roughness of high-carbon high-chromium steel on wire cut EDM has been made[11-12]. The value of the surface roughness increases with the pulse-on time and it decreases with applied voltage[13-14]. The better surface finish can be gained when the machining is done at lower level machining features, the pulse-off time has less impact on the material removal rate[15].

The effect of conventional EDM and powder mixed electric discharge machiningon the surface properties of SiCP/Al composites has been analyzed and it was foundthat the latter provides a good surface finish[16]. Silicon powder mixedon a dielectric under conventional EDM conditions provides a better polishing performance[17]. The machining efficiency and surface roughnessare reduced in PMEDM due to the loss of energy in discharge gap[18].PMEDM is applied especially where the productivity and surface quality of the work piece are needed[19].

The EDM is suitable for machining particulate-reinforced metal matrix compositescompared to other unconventional machining; however, the process is extremely slow.EDM results in a crater-like surface, the size of the craters increases with increased discharge energy. Tool wear, tool breaking and recast layer are the main problems in electro discharge machining[20-21]. The present work analyzes the influence of EDM process parameters on the surface roughness and material removal rate.

METHODS

Experimental Procedure

The experimentation were conducted by varying the machine parameters constant as shown in Table 1. The effect of machining parameters on machining of Inconel alloy on the surface roughness and material removal rate was studied. The opted machining time was 5 min for all the experiments. The material removal rate were calculated by weight difference of work piece material before and after the machining by using a digital electronic weighing

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machine of accuracy0.0001 g. The mean values of ten measurements from different areas of the sample were recorded. The surface roughness was measured with an SJ210 surface roughness tester which has an accuracy of 5%. Every part was measured at five different locations distributed along the EDM'ed surface.

RESULTS:

As the output parameter is surface roughness, the investigator is expected to achieve the smaller possible value. So the investigator is chosen the expected signal to noise ratio as smaller is better. This option enables the process to get the smaller value, so the results are used to be nearer to zero. Because, in smaller is better problems, S/N ratio is aimed to converge closer to zero.

Using the signal to noise ratio obtained from the software, the means of the signal to noise ratio corresponding to each machining parameter are analyzed. The effect of each machining parameter on the response and the trend of each parameter can be analyzed using main effects plot for S/N ratio. The effect of each level of the parameter on the response also can be identified. The best suitable level of input parameters is chosen to achieve the desired output parameter.

From the Main effects plot for S/N ratio of Surface roughness, (Fig. 1) it is found that signal to noise ratio is smaller with the combination, peak current - 3A, on-time - 10µs, off- time - 12µs and Voltage- 80V. So A1B1C3D1 is the optimum set of parameters to obtain lowest Surface roughness value. The optimum set of parameters is fed and the confirmation experiments are carried out to ensure the desired output.

Using the signal to noise ratio obtained from the analysis, the means of the signal to noise ratio corresponding to each machining parameter are analyzed. The influence of each machining parameter on the response and the trend of each parameter is analyzed using main effects plot for S/N ratio. The effect of each level of the parameter on the response is also identified. The best suitable level of input parameters is chosen to achieve the desired output parameter.

From the Main effect plots for S/N ratio of Material removal rate (Fig. 2) it is found that signal to noise ratio is larger with the combination of parameters, peak current - 7A, on-time - 30µs, off-time - 8µs and Voltage - 100V. So A3B3C1D3 is the optimum set of parameters to obtain high material removal rate.

Grey Relational Analysis (GRA)

In the GRA method, experimental data are first normalised in the range of zero to one, also known as the grey relational generation. The maximum value attained during the normalization is one. The next stage is to subtract all the normalizing value acquired from that column's peak value. Next, to express the connection between the required and real experimental information, the Grey Relational Coefficient (GRC) is calculated from the standard experimental information. Then, by averaging the GRC corresponding to each process reaction, the grey relational grade is calculated. The general assessment of various process parameters is based on the grey relational grade. As a consequence, optimizing complex various process parameters can be transformed into a single Grey Relational Grade (GRG) optimization. In other words, the GRG for the multi-response method can be regarded as the general assessment of experimental information. The level with the highest GRG is the ideal level of the process parameters.

In this study, a linear data pre-processing method [26] can be expressed as

$$\mathrm{yi(a)} = \frac{\max\ (\mathrm{xi}) - (\mathrm{xi})}{\max\ (\mathrm{xi}) - \min\ (\mathrm{xi})} \qquad \dots (1)$$

$$\mathrm{yi(a)} = \frac{(\mathrm{xi}) - \min\ (\mathrm{xi})}{\max\ (\mathrm{xi}) - \min\ (\mathrm{xi})} \qquad \dots (2)$$

Where yi (a) is the gray relational normalization value. The max (xi) is the largest value of i(x) for that corresponding response and the min (xi) is the smallest value i (x) of for the respective response. The yi (b) is the difference between max (ai) value the corresponding i(a) as shown in equation 3. The max (ai) is the largest normalisation value which is always equal to one.

$$yi(b) = \max(\mathrm{ai}) - (ai) \qquad \dots (3)$$

The sequences after the GRG are shown in Table. An ideal sequence (y0(a) = 1, i = 1, 2, . ., 9) is used for hardness, tensile strength at room and elevated temperature, % elongation at room and elevated temperature. The GRG in the GRA shows the relational degree for the nine sequences (y0 (a) and yi (a), i = 1, 2, . . ., 9; yi(b) = 1,2,…,9. The GRC yi (c) can be calculated as shown in equation 4.

$$yi(c) = \frac{\mathrm{weightage}\ *1}{(\mathrm{bi} + (\mathrm{weightage}\ *1))} \qquad \dots (4)$$

$$yi(d) = Average\ (c^{(row)}) \qquad \dots (5)$$

$$Rank = Rank\ (ui, ui{:}\,uj) \qquad \dots (6)$$

The average of GRC was calculated using the equation 5. A greater GRG value is a greater degree of relationship between the reference sequence y0(a) and the specified sequence yi(d). As mentioned before, the maximum

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reference sequence yi (d) is the best process response in the experimental layout. A higher average value of the GRG means it was given with the higher rank. The rank of the GRC was calculated using the equation 6. The higher rank process parameter is closer to the optimal one.

Using equation 7 and 8, the most influencial factor that affects the response has been calculated. The Pi is the corresponding parameter of the parametric value Li, (i= -1, 0, 1). The yi (e) is the sum of yi(d) for the corresponding parametric value of the level 1. The yi(f) was calculated from the max yi(e) to the min yi(e) interval. The most significant factor influencing the response was the factor that possesses the greater yi(f) value which is recorded as GRA rating.

$$yi(e) = sum\big(yi(d)\big), equalto\ (Pi, Li) \qquad \dots (7)$$

$$yi(f) = \max\big(yi(e)\big) - \min(yi(e)) \qquad \dots (8)$$

GRA has been implemented in this inquiry to select ideal parameter settings. By using either Eqs (1) or (2), all three responses (shown in Table) have been normalized. The objective is to maximize all the measured parameters hence in this study all the responses were normalized for higher the better and is given in the table 4. The next step is conversion of normallized value into a GRG value usin the eq.3. These GRG values are converted into the GRC values using the eq.4. Further these multiple performce characteristics were converted into single GRC using the equation 5.

From the table it was observed that the better output values were obtained when the amp, pulse on time of 30µs, pulse off time of 8 µs and voltage of 100 volts. The most significant factors were calculated by the equation 7 & 8 as shown in table 5. From the values it is observed that the current was the most significant factor followed by the pulse on time.

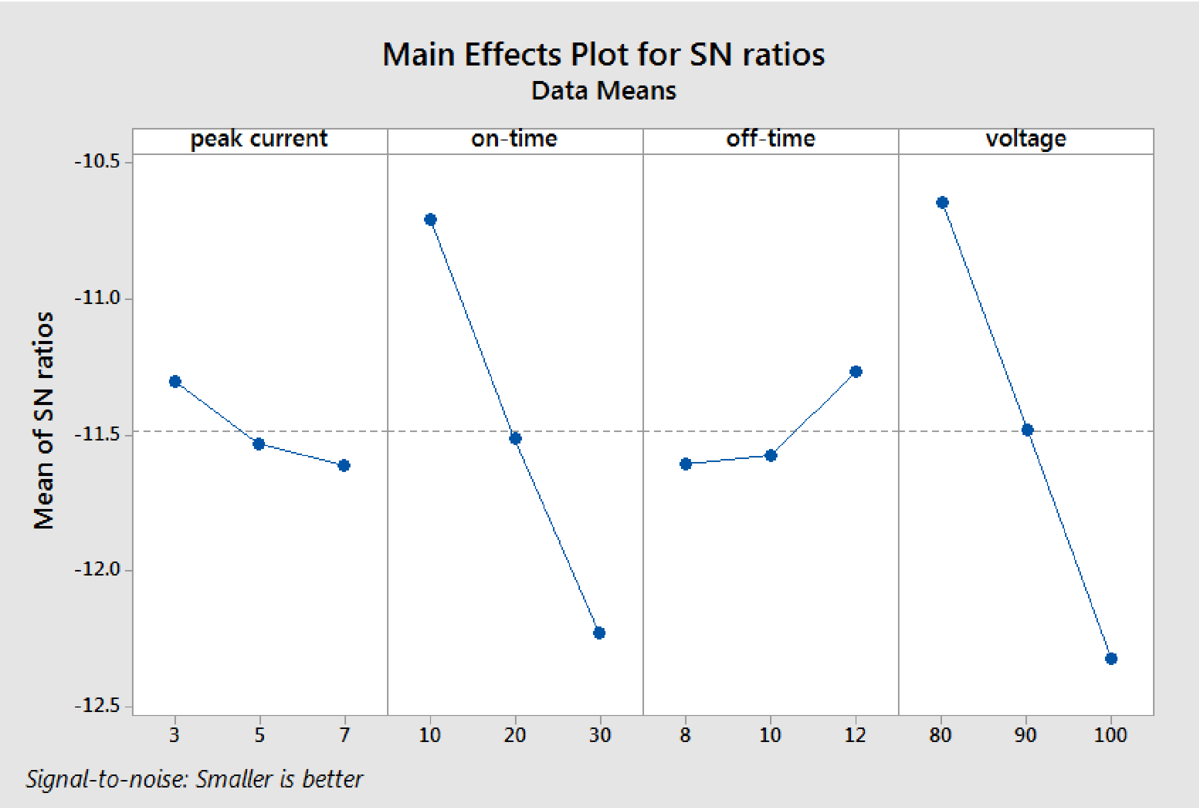

Fig 1: Main effect plot of Surface Roughness

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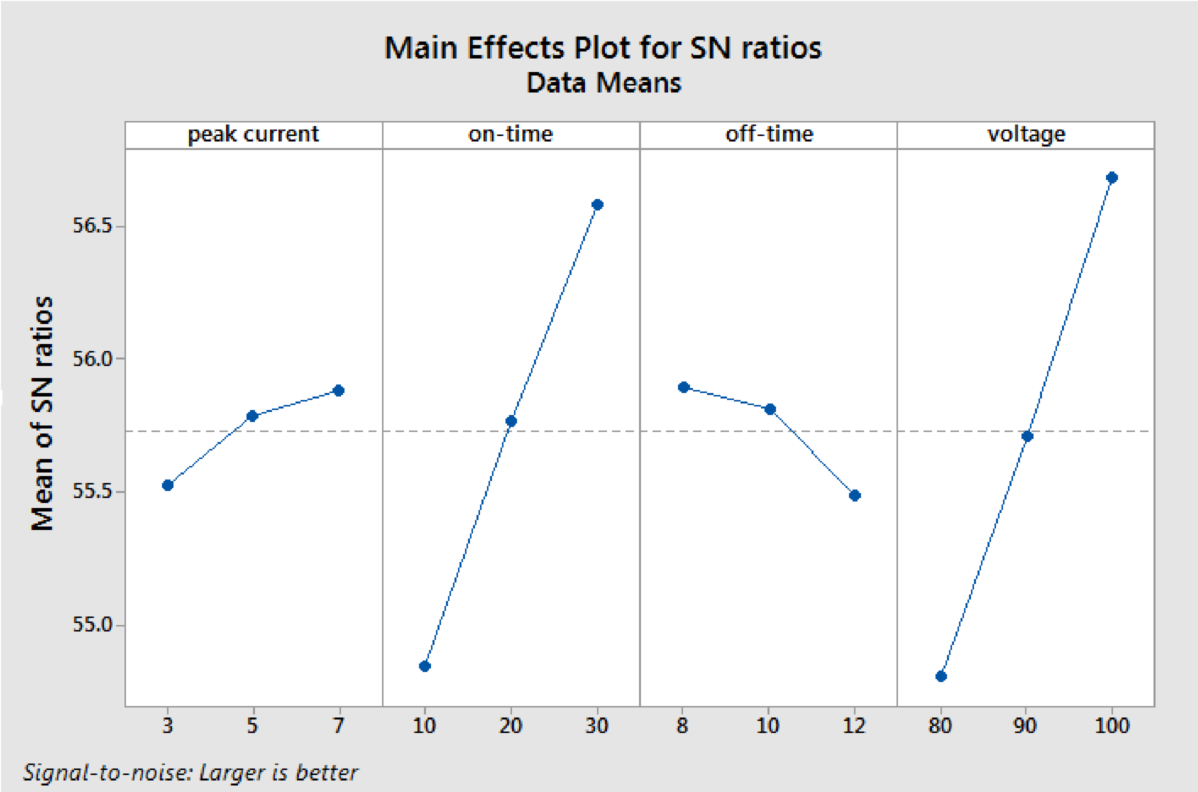

Fig 2: Main effect plot of MRR

Table 1: Experimental results of EDM of Inconel alloy

Sl.No	Peak current	Pulse on time	Pulse off time	Voltage	Surface roughness	MRR	Normalization		Grey Relation Co-efficient (GRC)		Grey Relation Grade (GRG)		Average GRG	Rank
1	3	10	8	80	3.04	86	00	00	00	00	00	33	67	1
2	3	10	10	90	3.39	42	77	20	23	80	69	38	54	3
3	3	10	12	00	3.71	01	57	40	43	60	54	46	50	3
4	3	20	8	90	3.75	11	54	44	46	56	52	47	50	2
5	3	20	10	00	4.03	64	36	62	64	38	44	57	50	5
6	3	20	12	80	3.29	30	84	15	16	85	76	37	56	9
7	3	30	8	00	4.38	31	14	86	86	14	37	78	57	6
8	3	30	12	80	3.67	92	59	37	41	63	55	44	50	0
9	3	30	10	90	4.01	59	37	60	63	40	44	56	50	8
0	5	10	8	80	3.26	25	86	14	14	86	78	37	57	5

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11	5	10	10	90	3.39	43	77	20	23	80	69	38	54	12
12	5	10	12	00	4.01	15	37	45	63	55	44	48	46	27
13	5	20	8	90	3.89	35	45	52	55	48	48	51	49	25
14	5	20	10	00	4.29	08	19	78	81	22	38	69	54	11
15	5	20	12	80	3.25	23	86	13	14	87	79	36	58	4
16	5	30	8	00	4.53	63	04	97	96	03	34	94	64	3
17	5	30	12	80	3.75	10	54	43	46	57	52	47	50	24
18	5	30	10	90	4.03	64	36	62	64	38	44	57	50	15
19	7	10	8	80	3.27	26	85	14	15	86	77	37	57	7
20	7	10	10	90	3.46	59	73	26	27	74	65	40	53	14
21	7	10	12	00	3.65	88	61	36	39	64	56	44	50	19
22	7	20	8	90	3.89	35	45	52	55	48	48	51	49	25
23	7	20	10	00	4.37	28	14	85	86	15	37	76	57	8
24	7	20	12	80	3.31	34	83	17	17	83	74	38	56	10
25	7	30	8	00	4.59	72	00	00	00	00	33	00	67	1
26	7	30	12	80	3.92	43	43	55	57	45	47	53	50	21
27	7	30	10	90	4.02	62	37	62	63	38	44	57	50	17

CONCLUSION

The findings showed that the most critical element was the current and then the pulse. As machined with lower current strength and higher pulse ratio, the better surface roughness was obtained. As machined with higher current strength, the maximum content removal rates were reached.

As voltage is applied, different particles that occupy the void become energised that contribute to a lower strength of the current. These energised particles allow a better surface finishing by growing the spark gaps and dissipating heat. The rate of material removal decreases with increased reinforcement due to the poor thermal conductivity and high melting point. Due to the increasing difference in sparks, the tool wear rate decreases.

CONFLICTS OF INTEREST:

The author have declared no conflicts of interest

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