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Study of Electric Discharge Machining and Optimization of MRR, SR & TWR

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Abstract : EDM is an non conventional machine which is used in removing metal through thermal energy. The metals which can't be easily machined by drilling, milling, grinding etc. This research paper aims to investigate the set of process parameters such as pulse on time, pulse off time, current in the Electric discharge machining process to achieve results like higher material removal rate, better surface finish and lesser tool wear rate. The experiment is done on the Mild steel AISI20 work piece and the electrode taken is of copper. Taguchi method is used to get the optimized result. Graphs and response table are used to find the optimal levels of the parameters in the Electric discharge machining. The result revealed that the current, pulse off time & pulse on time have a great influence on the MRR,TWR and surface roughness.

Keywords
Electric discharge machining, AISI20 steel work-piece, copper electrode, Current, Pulse off time, Pulse on time, Taguchi L9 orthogonal array, Miinitab-17, S/N ratio, Surface Roughness (Ra), Material Removal Rate(MRR), Tool Wear Rate(TWR).

Introduction
Electro Discharge Machining (EDM) is an electro-thermal non-traditional machining process in which electrical energy is used to generate electrical spark and material removal mainly occurs due to thermal energy of the spark. Electric discharge machining is mainly used to machine those materials which are difficult to machine with other traditional processes. There is no direct contact of the electrode and work piece in the EDM. So the machining problems like the stresses and the vibrations does not arise during the machining processes.

EDM is the thermal erosion process in which metal is removed by a series of recurring electrical discharges between a cutting tool acting as an electrode and a conductive work piece, in the presence of a dielectric fluid. This discharge occurs in a voltage gap between the electrode and work piece. Heat from the discharge vaporizes minute particles of work piece material, which are then washed from the gap by the continuously flushing dielectric fluid.

Materials and Methods

Edm Machine (Press Mach-A25)
A EDM Machine "Press Mach-A25" made by TOOLCRAFT is used to carry out the experimentation.

Selection Of Machining Tool
The cutting tool selected for present work is copper cylindrical electrode of diameter 12.50 mm. Density of copper is 8.96 gm./cm^3 .

Selection Of Work Piece Material
The work piece used for current work is AISI 1020 steel. Density of AISI 1020 Steel is 7.87 gm/cm³.

Selection Of Machining Parameters
The following process parameters, used in this work are shown in table:

Polarity	Positive
Current	6-12 amp
Pulse off time	4-8µs
Pulse on time	15-75µs
Duty factor	0.7

Process Parameters And Levels Used In The Experiment: The machining process is done on the EDM by taking Current, Pulse off time & Pulse on time as process parameters. The parameters and the levels used in the process are shown in table:

Levels	Current	Pulse on time	Pulse off
Level 1	6	15	4
Level 2	9	45	6
Level 3	12	75	8

Design Matrix
According to the present work there are three levels and three factors. So according to Taguchi approach we selected L9 orthogonal array. With the help of minitab-17 following design matrix has been formed.

Experiment	Current	Pulse on time	Pulse off time
1	6	15	4
2	6	45	6
3	6	75	8
4	9	15	6
5	9	45	8

6	9	75	4
7	12	15	8
8	12	45	4
9	12	75	6

Results and Discussions

The design matrix is formed by using minitab 17 software. According to design matrix, experiments are performed. By using the readings of experiments we calculate MRR, Ra & TWR as follows:

Material Removal Rate (MRR)

The material removal rate is generally described as the volume of metal removed per unit time. To calculate MRR following equation is used to calculate the Material Removal Rate (MRR):

$$MRR(mm^3/min.) = \frac{[\text{Initial Weight of workpiece (gm.)} - \text{Final Weight of workpiece (gm.)}]}{\text{Density (gm./mm}^3) \times \text{Machining Time (min.)}}$$

Surface Roughness (R_a)

Roughness measurement has been done using a portable stylus-type profilometer, Mitutoyo- Surftest SJ- 201P/M. The evaluation length of 2.5 mm is used to measure response R_a value in µm.

Tool Wear Rate (Twr)

The Tool Wear Rate is generally described as the volume of metal removed per unit time. To calculate TWR, following equation is used:

$$TWR(mm^3/min.) = \frac{[\text{Initial Weight of Tool (gm.)} - \text{Final Weight of Tool (gm.)}]}{\text{Density (gm./mm}^3) \times \text{Machining Time (min.)}}$$

Response Table : Response table for the experimental design matrix is shown in table

S.N.	Current	Pulse on time	Pulse off time	Change in Wt.	M/C time	MRR	Surface Roughness	Change in wt.	Tool Wear Rate
1	6	15	4	0.7111	6	15.097	3.4897	0.00399	0.08471
2	6	45	6	0.728	6	15.456	3.8476	0.00412	0.08747
3	6	75	8	0.7284	6	15.464	3.8564	0.00434	0.09214
4	9	15	6	0.7124	6	15.125	3.5185	0.00423	0.08980
5	9	45	8	0.7319	6	15.539	3.9354	0.00464	0.09851
6	9	75	4	0.7389	6	15.687	4.0525	0.00471	0.1
7	12	15	8	0.7284	6	15.464	3.8447	0.00451	0.09575
8	12	45	4	0.7399	6	15.709	4.1111	0.00494	0.10488
9	12	75	6	0.7488	6	15.898	4.2858	0.00521	0.1106

Analysis Of Single Response Table

The optimal settings and the optimal values for MRR, Ra & TWR are determined individually by Taguchi's approach. Table shows these individual optimal values and its corresponding settings of the process parameters for the specified performance characteristics.

Table: Means Of Mrr, Twr & Surface Roughness At Different Levels

SINGLE RESPONSE								
MRR			Ra			TWR		
CURRENT	PULSE	PULSE	CURRENT	PULSE	PULSE	CURRENT	PULSE	PULSE
15.339	15.229	15.498	3.731	3.617	3.8844	0.088	0.090	0.096
15.4508	15.568	15.493	3.835	3.964	3.8839	0.096	0.096	0.095
15.690	15.683	15.489	4.080	4.064	3.8788	0.103	0.100	0.0954

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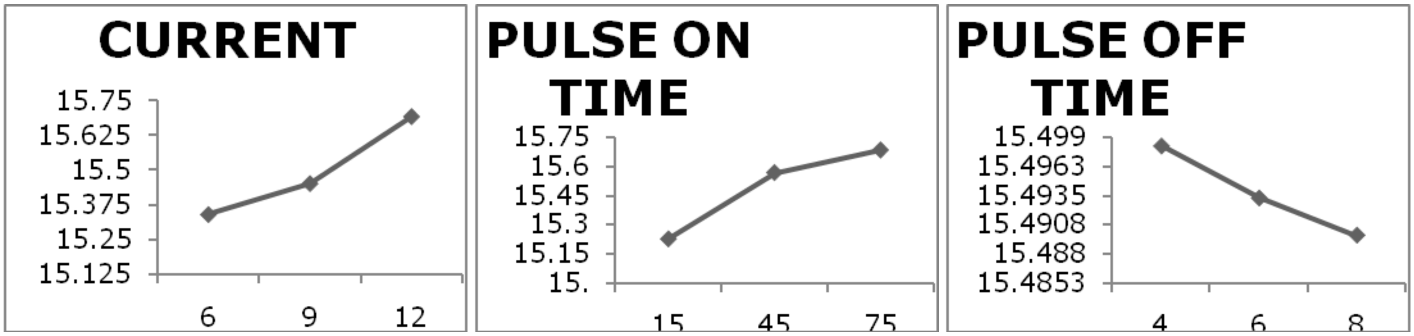

Fig. 1: Response Graph For Mrr

Interpretation Of Plots For Mrr:

BASED ON CURRENT: Initially at 6amp the MRR is low but as the value of current increases, MRR also increases.
BASED ON PULSE ON TIME: With the increase in pulse on time, the value of MRR also increases.
BASED ON PULSE OFF TIME: From the graph it is clear that with the increase in pulse off time, MRR decrases.

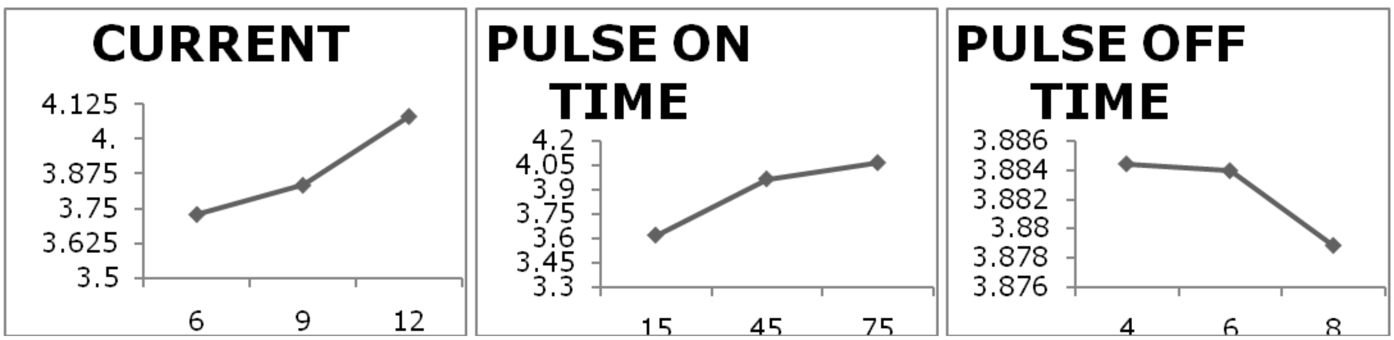

Fig. 2: Response Graph For Surface Roughness

Interpretation Of Plots For Surface Roughness :

Based On Current: As the value of current increases, surface roughness also increases.
Based On Pulse On Time: With the increase in pulse on time, the value of Surface roughness increases.
Based On Pulse Off Time: Surface roughness decreases with the increase in pulse off time.

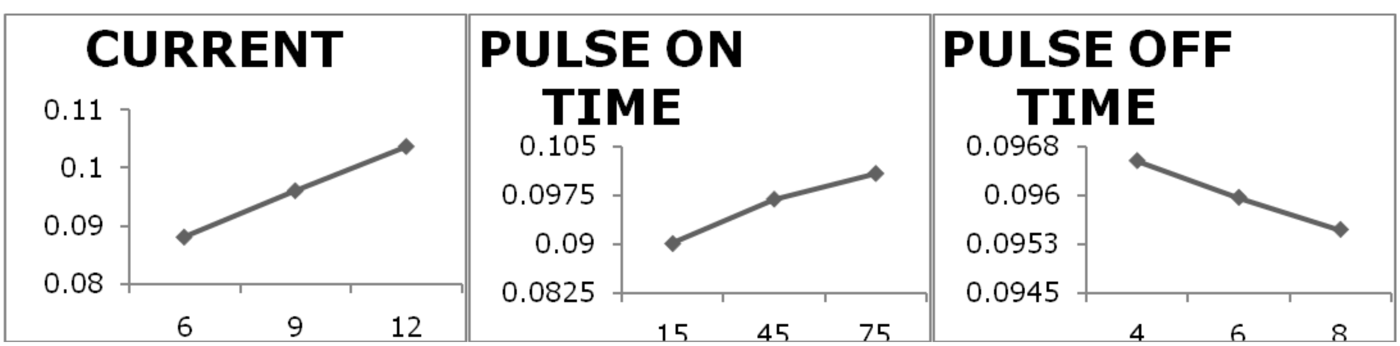

Fig. 3: Response Graph For Tool Wear Rate

Interpretation Of Plots For Tool Wear Rate:

Based On Current: As the value of current increases, Tool wear rate also increases.
Based On Pulse On Time: Tool wear rate increases with the increase in pulse on time.

Based On Pulse Off Time: As the value of pulse off time increases, Tool wear rate decreases.

Analysis Of Multi-Response Stage

The S/N ratio considers both the mean and the variability. In the present work, a multi- response methodology based on Taguchi technique and Utility concept is used for optimizing MRR, Ra & TWR. Taguchi proposed many different possible S/N ratios to obtain the optimal process efficiency. Two of them are selected for the present work. Those are,

- **Larger the better S/N ratio for MRR**

$$\eta_1 = -10\log_{10}[\frac{1}{MRR^2}]$$

- **Smaller the better type S/N ratio for R_a**

$$\eta_2 = -10\log_{10} \mathrm{Ra}^2$$

- **Smaller the better type S/N ratio for TWR**

$$\eta_3 = -10\log_{10} TWR^2$$

From the utility concept, the multi-response S/N ratio of the overall utility value is given by

$$\eta_{obs} = W_1\eta_1 + W_2\eta_2 + W_3\eta_3$$

Where W_1, W_2& W_3 are the weights assigned to the MRR, R_a& TWR. Weights are defined according to the importance and choice of the operator, customer's requirements. Weights values taken for W_1, W_2& W_3 are as follows:

W_1 for MRR = 0.40, W_2 for Ra = 0.40
W_3 for TWR = 0.20

The best combination for process parameters for simultaneous optimization of Material removal rate (MRR), Surface roughness (R_a), &Tool Wear Rate (TWR) is obtained by the mean values of the multi-response S/N ratio shown in Table.

Table: Design Matrix With Multi-Response S/N Ratio

S. N.	Current	Pulse On Time	Pulse Off Time	Mrr	η_1 For Ra	Surface Roughness	η_2 For Mrr	Tool Wear Rate	η_3 For Twr	η_{obs}
1	6	150	4	15.097	-10.855	3.4897	23.578	0.0847	21.440	9.377
2	6	45	6	15.546	-11.703	3.8476	23.782	0.0874	21.162	9.063
3	6	75	8	15.464	-11.723	3.8564	23.786	0.0921	20.710	8.967
4	9	15	6	15.125	-10.97	3.5185	23.594	0.0898	20.933	9.253
5	9	45	8	15.539	-11.899	3.9354	23.828	0.0985	20.130	8.797
6	9	75	4	15.687	-12.154	4.0525	23.911	0.1	20	8.7027
7	12	15	8	15.464	-11.697	3.8447	23.786	0.095	20.376	8.911
8	12	45	4	15.709	-12.279	4.1111	23.923	0.1048	19.585	8.574
9	12	75	6	15.898	-12.640	4.2858	24.026	0.11061	19.1236	8.379

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Table: Mean Values Ofη_{obs}at Different Levels

Levels	Mean Value of η_{obs} for Process Parameters		
	Current	**Pulse On Time**	**Pulse Off Time**
Level 1	9.136	9.180	8.884
Level 2	8.917	8.812	8.8988
Level 3	8.621	8.683	8.892

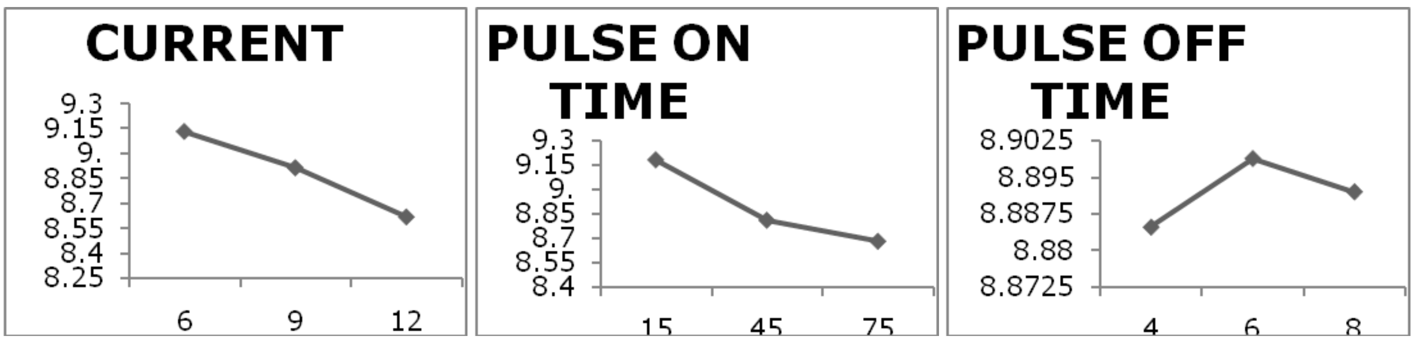

Fig. 4: Multi-Response S/N Ratio Graph

Interpretation of Plots

Based On The Current: From the graph the max. value of multi response is at current value of 6 Amp. So we get the optimum values of MRR, Ra & TWR, at lower value of current.

Based On Pulse On Time: This graph also gives the combined result for MRR, Surface Roughness and TWR. With the increase in pulse on time the value obtained from multi response reduces. So we get the best optimum values for MRR, Ra & TWR at lower value of pulse on time i.e. 15µs.

Based On Pulse Off Time: This graph gives the combined result for MRR, Surface Roughness and TWR. As the pulse off time is increased from its initial value 4µs the multi response value for MRR, Ra & TWR also increases. But with the further increase from 6µs, the multi response value for MRR, Ra & TWR decreases. We get the best optimum value for MRR, Ra & TWR at value of pulse off time 6µs.

Conclusion

A set of experiments are performed on AISI20 mild steel work pieces with the use of copper electrode in Electric discharge machining. The experimental studies are conducted by varying the parameters like Current, Pulse off time and Pulse on time.The result shows that current, pulse on time and pulse off time have significant effect on MRR,TWR and SR. The results of the present work reveal that proper selection of input parameters will play a significant role in Electric Discharge Machining:

1. Individually MRR increases with increasing current, pulse on time and decreases with increasing pulse off time.
2. With the increase in Pulse on time or current, Surface roughness increases and with increasing pulse off time, the value of Ra decreases.
3. With the increase in pulse on time or current, Tool Wear Rate increases.Tool Wear Rate decreases with increase in pulse off time.
4. At lower value of current, lower value of pulse on time and medium value of pulse off time, we get the best optimal values of MRR, Ra & TWR. So the machining parameters should be set as lower pulse on time, lower current and medium pulse off time.

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