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Optimization of Process Parameters for Deep hole drilling using drill EDM for Maximum machining rate and minimum EWR on Tungsten Carbide

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Abstract – *EDM is a non-traditional concept of machining which uses spark erosion to machine materials and is widely used in machining of tough to machine materials .The objective of the research is to optimise the process parameters to obtain maximum machining rate and minimum EWR while drilling deep holes using Drill EDM on Tungsten Carbide using a tubular copper electrode of 3mm. The study was done by selecting the most prominent parameters i.e. Discharge current, Pulse on time & Pulse off time with L9 orthogonal set of experiments and optimising the responses individually using Taguchi Method and later by Grey relation analysis to obtain a single set of parameters for multi-machining characteristics.*

Key Words: EDM, EDD, WC machining, EDM Drilling, Taguchi, Grey Analysis, EWR

1. Background:

Electro discharge machining is a non-traditional concept of machining which has been widely used to produce dies and moulds. It is also used for finishing parts for aerospace and automotive industry and surgical components. The process is grounded on eliminating material from a part by means of a series of frequent electrical discharges between tool called the electrode and the work piece in the presence of a dielectric fluid. The electrode is advanced in the direction of the work piece until the gap is slight enough so that the impressed voltage is excessive enough to ionize the dielectric. Small duration discharges are created in a liquid dielectric gap, which splits tool and work piece. Material is removed with the erosive effect of the electrical discharges from tool and work piece. EDM does not make through contact between the electrode and the work thus eradicating mechanical stresses and vibration difficulties while machining. Materials of any hardness can be cut as long as the material can conduct electricity

The dielectric fluid helps release energy to concentrate into a channel of very small cross-sectional area. It also acts as coolant and flushes away the particles of machining from the gap. The electrical resistance of the dielectric fluid effects the discharge energy at the time of spark commencement. Early discharge will occur, if the resistance is low. If resistance is large, the capacitor will achieve a higher value of charge before the spark occurs. As the erosion on the workpiece surface takes place the tool has to be advanced through the dielectric towards it. A servo system, which is employed to maintain the gap voltage between the workpiece and electrode with a reference value, is to ensure that the electrode moves at a proper rate towards workpiece, and to retract the electrode if short circuiting occurs. The volume of material removed per discharge is characteristically in the range of 10^{-6}–10^{-4} mm^3 and the metal removal rate (MRR) is generally between 2 and 400 mm^3/min conditional on specific application.

1.1 EDD

Hole drilling EDM uses low cost electrode tube (normally brass or copper material) to drill holes on an electrically conductive material at a very high speed, the hole depth diameter ratio can reach up to 200. The hole diameter is generally from 0.3mm to 3.0mm, this technology is widely used for hole machining in aerospace, energy, cutting tools, automotive, medical, mould and die industries. The specially designed spindle and clamping head allow the use of thin and solid electrodes with diameters ranging from .3mm to 3.0mm with internal or external dielectric finishing. During EDD a reference point is set at the work surface so as to determine the Tool wear periodically. A servo drive maintains a constant gap between the workpiece and electrode. If in any case the electrode truces the workpiece a short circuit occurs. In this case servo drive retracts the electrode and stops or resumes the EDD process.

2. Methodology:

The experiments were conducted on rapid drill EDM with Tungsten Carbide C2 (6% Co,94%WC) on a bar test specimen 43mm*23mm*2mm with a copper electrode as a drilling tool, Outer dia-3mm & inner dia-1.3mm. Following 3 parameters i.e. discharge current(Ip), Pulse on time(Ton), & pulse off time(Toff) were selected and varied on three levels (Table 1) and the responses Machining time, Hole depth and Electrode wear length was noted(Table2)

Table -1: Machining parameters and their levels

Machining Parameter	Symbol	Units	Levels		
			1	2	3
Discharge Current (A)	*I*	A	5	6	7
Pulse On Time (B)	T_{on}	µs	5	6	7
Pulse Off Time (C)	T_{off}	µs	4	5	6

Table -2: Data collection from experiment

S.NO	IP (A)	TON (µs)	TOFF (µs)	Electrode wear (mm)	Depth (mm)	Time (sec)
1	5	5	4	0.630	9.14	582
2	5	6	5	0.222	9.566	565
3	5	7	6	0.500	8.91	569
4	6	5	6	0.305	9.545	509
5	6	6	4	0.215	9.375	389
6	6	7	5	0.200	9.142	420
7	7	5	5	0.840	8.994	345
8	7	6	6	0.555	8.825	277
9	7	7	4	0.240	8.783	358

The machining rate is calculated using (depth/time) and the EWR is calculated using the formula $[\pi/4(d_2^2-d_1^2)*h]$ where d2=external diameter of electrode, d1=internal diameter & h= length of electrode melted during experiment. The results are shown in Table 3

Table -3: Calculation of machining rate & EWR

S.No	MC rate	EWR
1	0.016	3.615
2	0.017	1.274
3	0.016	2.869
4	0.019	1.750
5	0.024	1.234
6	0.022	1.148
7	0.026	4.820
8	0.032	3.185
9	0.025	1.377

For machining rate SN ratio, larger the better and for the EWR SN ratio smaller the better is used and the results are analysed in Minitab software. Taguchi method was used to optimize the responses.

SN RATIO=-10LOG$_{10}$(S*(1/Yi^2) /n) (LARGER THE BETTER)

SN RATIO=-10LOG$_{10}$(S*Yi^2/n)(SMALLER THE BETTER)

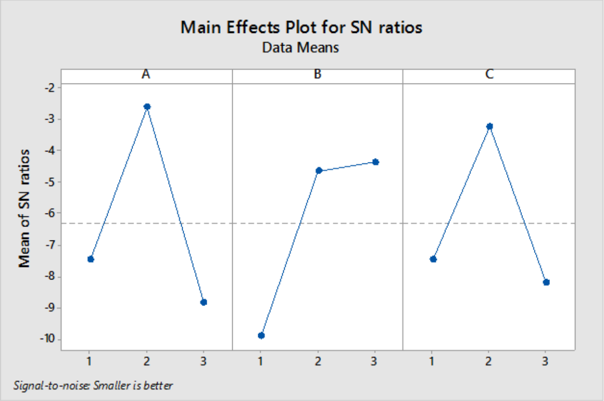

Fig -1: SN Ratio Plot for EWR

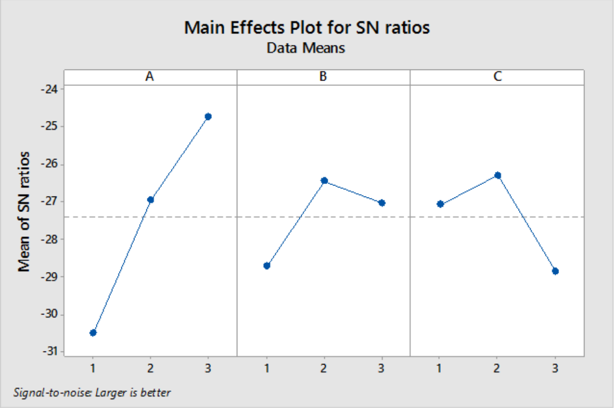

Fig -2: SN Ratio Plot for MC rate

Grey relation study is used to obtain a single set of optimised parameters for both MC rate and EWR A linear data pre-processing formula for the S/N ratio is as follows

$$x_i^*(k) = \frac{x_i^0(k) - \min x_i^0(k)}{\max x_i^0(k) - \min x_i^0(k)}$$

where $x_i^*(k)$ is the order after the data processing; $x_i^0(k)$ is the novel sequence of S/N ratio, i = 1, 2, 3…., m and k =1, 2… n with m=9 and n=2; max $x_i^0(k)$ is the principal value of $x_i^0(k)$; min is the least value of $x_i^0(k)$.

the grey relational coefficient is calculated to get a relationship between the reference and the normalized S/N ratio. The grey relational coefficient is expressed as follows:

$$\gamma(x_0^*(k).x_i^*(k)) = \frac{\Delta\min + \zeta.\Delta max}{\Delta_{oi}(k)+\zeta.\Delta max}$$

$$0 \leq \gamma(x_0^*(k).x_i^*(k)) \leq 1$$

Where $\Delta_{0i}(k)$ is the deviation sequence of the reference sequence $x_0^*(k)$ and comparability sequence $x_i^*(k)$, i.e. $\Delta_{0i}(k) = |x_0^*(k) - x_i^*(k)|$ is the absolute value of the difference between $x_0^*(k)$ and $x_i^*(k)$.

$\Delta_{min} =$ min.min $\Delta_{0i}(k)$,

Table -4: Grey Relation grade calculations

	Normalized Sequence		Deviation Sequence		Grey Relation Coefficient		
S. No	MC rate	EWR	Mc rate	EWR	MC rate	EWR	Mean
1	0.004	0.200	0.996	0.800	0.334	0.385	0.359
2	0.110	0.927	0.890	0.073	0.360	0.873	0.616
3	0.000	0.362	1.000	0.638	0.333	0.439	0.386
4	0.254	0.706	0.746	0.294	0.401	0.630	0.515
5	0.607	0.950	0.393	0.050	0.560	0.908	0.734
6	0.464	1.000	0.536	0.000	0.482	1.000	0.741
7	0.718	0.000	0.282	1.000	0.639	0.333	0.486
8	1.000	0.289	0.000	0.711	1.000	0.413	0.706
9	0.632	0.873	0.368	0.127	0.576	0.797	0.687

After this Taguchi design for larger the better is applied on the mean grey coefficient to obtain single set of parameters for Machining rate and EWR.

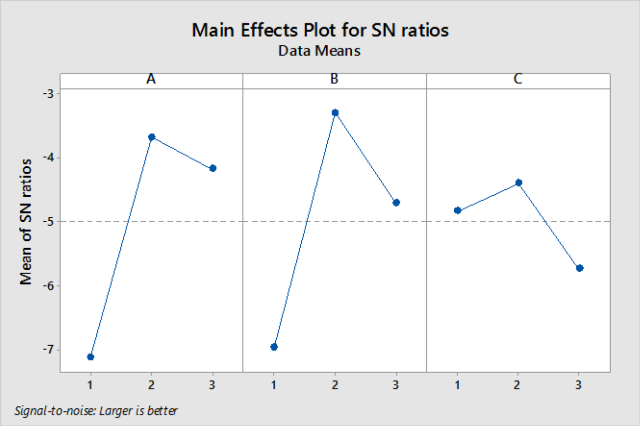

Fig -3: SN Ratio Plot for grey relation grade

3. CONCLUSIONS

Taguchi method was used to optimize 2 machining characteristics i.e. Machining rate and EWR individually for tubular copper electrode size of 3mm.
Grey relation analysis is used for simultaneous optimization of parameters.

For electrode size of 3mm the following observations are made.

Optimal combination of process parameters for Machining Rate is A3(7A), B2(6µs), C2(5µs) and for EWR optimal combination is A2(6A), B3(7µs), C2(5µs)
Single set of parameters maximizing the machining rate and minimizing EWR is A2(6A), B2(6µs), C2(5µs)

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