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Original Research Article

OPTIMIZATION OF EDM PROCESS PARAMETER WITH MULTI-OBJECTIVE TECHNIQUES

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ABSTRACT

This work demonstrates the optimizing process of multiple Responses for Electrical Discharge Machining (EDM) of AISI P20 tool steel parts via the Taguchi method-based Grey analysis. Optimization is one of the practices used in manufacturing sectors to attain for the best manufacturing situations, which is an essential need for industries towards manufacturing of quality products at lower cost. This methodology uses three different tool materials such as Copper, Brass and Graphite and finding the optimum settings of machine parameters and for combining multiple quality characteristics into one integrated numerical value called Grey relational grade. Six machining parameter are design by Taguchi method using L_{27} orthogonal array based on Taguchi design and observed that which factor is most affected by the Responses of Material Removal Rate (MRR), and Tool Wear Rate (TWR).

KEYWORD : Material removal rate; Tool wear rate; Taguchi Design; Grey relation analysis;

INTRODUCTION

The new concept of manufacturing uses non-conventional energy sources like sound, light, mechanical, chemical, electrical, electrons and ions. With the industrial and technological growth, development of harder and difficult to machine materials, which find wide application in aerospace, nuclear engineering and other industries owing to their high strength to weight ratio, hardness and heat resistance qualities has been witnessed. New developments in the field of material science have led to new engineering metallic materials, composite materials and high tech ceramics having good mechanical properties and thermal characteristics as well as sufficient electrical conductivity so that they can readily be machined by spark erosion. Non-traditional machining has grown out of the need to machine these exotic materials. The machining processes are non-traditional in the sense that they do not employ traditional tools for metal removal and instead they directly use other forms of energy. The problems of high complexity in shape, size and higher demand for product accuracy and surface finish can be solved through non-traditional methods. Currently, non-traditional processes possess virtually unlimited capabilities except for volumetric material removal rates, for which great advances have been made in the past few years to increase the material removal rates. As removal rate increases, the cost effectiveness of operations also increase, stimulating ever greater uses of non-traditional process. The Electrical Discharge Machining process is employed widely for making tools, dies and other precision parts. Das et al. [2012] studied the effect of machining parameters on MRR in EDM of EN31 tool steel. The selected control parameters were Ton, Toff, Ip and V with L27 OA based on Taguchi design. Showed that discharge current has the most significant effect on MRR followed by Toff and V. Chen and Lee [2010] had described the optimization of EDM parameters for machining ZrO2 ceramic. They studied machining responses such as, MRR, TWR, and SR. Experimental study according to L27 OA based on the Taguchi design were adopted. Electro Discharge Machining (EDM) is an electro-thermal non-traditional machining Process, where electrical energy is used to generate electrical spark and material removal mainly occurs due to thermal energy of the spark. EDM is mainly used to machine difficult-to-machine materials and high strength temperature resistant alloys. EDM can be used to machine difficult geometries in small batches or even on job-shop basis. Work material to be machined by EDM has to be electrically conductive.

OBJECTIVE OF PRESENT WORK

There should be research endeavor to apply multi-objective optimization techniques in order to achieve reasonably low value of MRR and TWR with different electrode material. The current study, EDM was carried out on AISI P20 tool steel using three different electrode materials. The effect of these materials along with four different EDM parameters was investigated on different aspects of surface integrity like material removal rate and tool wear rate.

- Design the experiment in MINITAB 14
- Perform the experiment in EDM machining and noted the responses.
- Effect of responses has been found with respect to their input parameters.
- Optimize the multi objective responses by Grey Relation method.

EXPERIMENTAL METHODOLOGY

The experimental runs were conducted on Electronica Electraplus PS 50ZNC Die Sinking Machine. Commercial grade EDM oil (specific gravity = 0.763, flash point = 94 ºC) was used as dielectric fluid. The work piece material was AISI P20 tool steel with semi-circular shape (100 mm diameter and 10 mm thickness). Three different cylindrical shaped tool electrodes namely copper, brass and graphite each with 12 mm diameter as shown in Figure 1 were considered during the current studied. The different properties of all the tool materials are provided in Table 1.

Figure 1 Workpiece and Tool (A) Graphite (B) Copper (C) Brass

Table 1 Properties of different electrode material

Material	Copper	Brass	Graphite
Density (g/cm^3)	8.929	8.429	2.20
Melting point (°C)	1085	930	3300
Thermal conductivity (W/m-k)	391	159	80
Electrical resistivity (Ω m)	1.68×10^{-8}	7.1×10^{-8}	60×10^{-5}
Hardness	HB 100	HB 60	HB 10

DESIGN OF EXPERIMENT: In this study, L27 Orthogonal Array (OA) based on Taguchi design are used machining parameters like tool material, pulse on time (Ton), Discharge current

(Ip), Work time (Tw), Lift time (Tup) and Flushing pressure (F), that can be used to assigning the factor and their interaction. For a 6 factor and each are 3 level the total number of experiment to be conduct 27 Minitab software was used to analysis the findings the results. Machining parameter and their levels are presented in Table 2.

Table 2 Parameter and Their levels

Control Parameter					
Parameter	Symbol	Level			Unit
		1	2	3	
Tool Material		C	B	G	
Pulse on Time	Ton	100	300	500	µs
Discharge current	Ip	1	4	7	A
Lift Time	Tup	0	0.7	1.4	Sec.
Work time	Tw	0.2	0.6	1.0	Sec.
Flashing Pressure	F	0.2	0.3	0.4	Kgf/cm^2
Fixed Parameter					
Duty Cycle	(ζ)	90			%
Voltage	V	45			V
Sensitivity	SEN	6			
Anti-arc sensitivity	ASEN	3			

A selected work piece material AISI P20 Tool steel there are grooving rang of application plastic molds, frames for plastic pressure dies, hydro forming tools, etc. three different material of tool electrode (Cu, Brass, Graphite), with 30mm diameter. Commercial grade EDM oil (specific gravity = 0.763, freezing point= 94˚C) was used as dielectric fluid. To attain a more accurate result, using L_{27} OA based on Taguchi design, and total number of experiment to be conduct is 27 is presented in Table 3. And every test runs for 90 min.

Table 3 Response table

S. N.	Tool Material	Ton	Ip	Tup	Tw	Fp	MRR (mm^3/min)	Tool wear (mm^3/min)
1	1	1	1	1	1	1	0.4119	0.0156
2	1	1	1	1	2	2	0.4119	0.0156
3	1	1	1	1	3	3	0.4728	0.0137
4	1	2	2	2	1	1	1.8386	0.0246
5	1	2	2	2	2	2	2.3977	0.0237
6	1	2	2	2	3	3	3.0020	0.0165
7	1	3	3	3	1	1	4.4056	0.0087
8	1	3	3	3	2	2	4.5563	0.0635
9	1	3	3	3	3	3	5.1450	0.0212
10	2	1	2	3	1	2	0.6285	0.9380

11	2	1	2	3	2	3	0.6242	1.0055
12	2	1	2	3	3	1	0.6058	1.0610
13	2	2	3	1	1	2	1.6943	2.2080
14	2	2	3	1	2	3	1.3355	2.3420
15	2	2	3	1	3	1	1.6065	2.3010
16	2	3	1	2	1	2	0.0665	0.1320
17	2	3	1	2	2	3	0.0963	0.1161
18	2	3	1	2	3	1	0.0966	0.1610
19	3	1	3	2	1	3	8.1050	0.4290
20	3	1	3	2	2	1	8.0896	0.4950
21	3	1	3	2	3	2	8.8811	0.4930
22	3	2	1	3	1	3	0.0308	0.1180
23	3	2	1	3	2	1	0.0265	0.0530
24	3	2	1	3	3	2	0.0446	0.0720
25	3	3	2	1	1	3	0.4926	0.0909
26	3	3	2	1	2	1	0.5633	0.0101
27	3	3	2	1	3	2	0.5662	0.0253

RESULT ANALYSIS

During the process of Electric discharge machining, the influence of various machining parameter like Ip, Ton, Tw, Tup and Fp has significant effect of MRR are shown in Figure 2. In This figure which indicates the Graphite tool electrode is gives the highest MRR followed by copper and Brass. And Brass tool has given low MRR. And the discharge current (Ip) is directly proportional to MRR. This is expected because an increase in pulse current produces strong spark, which produces the higher temperature, causing more material to melt and erode from the work piece. Besides, it is clearly evident that the other factor does not influence much as compared to Ip. When the pulse on time is increasing the MRR is decreasing, this is due to the fact that with higher Ton, the plasma formed between the Inter electrode gap (IEG) actually hinders the energy transfer and thus reduces MRR. MRR usually increases with Tup (Tool lift time) up to a maximum value after that Tup is gradually decreasing. Because Higher the Tup, higher the flashing results in high MRR. Since increase in Tup on much higher value, decrease in MRR, Likewise the tool spark temperature is decreases the result is decrease in MRR. The Tw and Fp has no significant effect on MRR. The interaction plot of MRR is shown in Figure 2, where each plot exhibits the interaction between three different machining parameters like Ip, Tup and Tw. This implies that the effect of one factor is dependent upon another factor. It is also confirmed by the ANOVA table (Table 4).

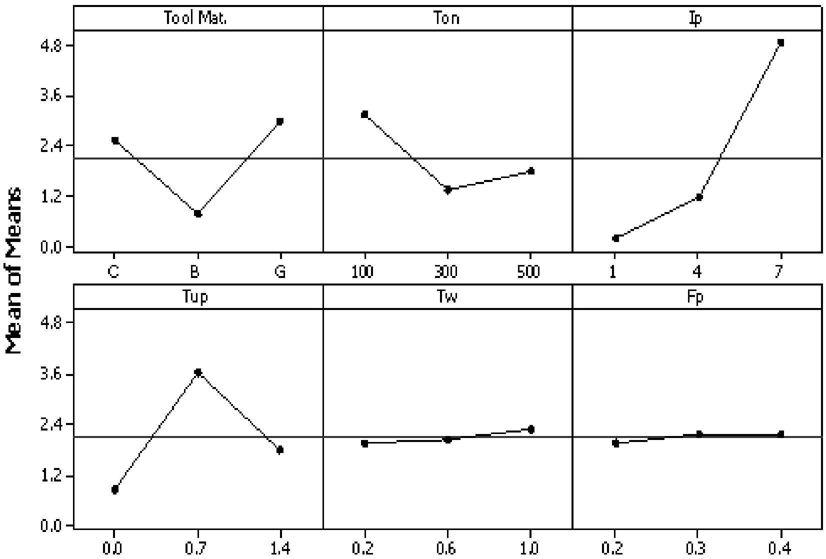

Figure 2 Main Effect Plot for MRR

The analysis of variances for MRR is shown in Table 5.1. Which is clearly indicates that the Fp, interaction IpxTw and TwxTup is not important for influencing MRR, and Ip ,Ton, Tup and Tw are the most influencing factors for MRR and other factors are not significant. This Table is definite that Ip is the most important factor then followed by Tup, Ton,Tw and Fp according to the percentage contribution .

Table 4 Analysis of Variance for MRR

Source	DF	Seq SS	MS	F	% contribution	P
Tool Mat.	2	24.872	12.4358	221.39	13.25	0.000
Ton	2	15.932	7.9661	141.82	8.48	0.000
Ip	2	109.454	54.7269	974.29	58.31	0.000
Tup	2	35.957	17.9786	320.07	19.15	0.000
Tw	2	0.485	0.2427	4.32	0.24	0.035
Fp	2	0.197	0.0986	1.76	0.10	0.209
IpxTw	4	0.297	0.0744	2.65	0.16	0.138
TupxTw	4	0.321	0.0802	2.86	0.17	0.121
Residual Error	6	0.168	0.0281		0.09	
Total	26	187.684			100	

In Grey relational analysis of the experimental result of material removal rate and tool wear rate can be simplified into the optimization of a single response that is Grey relational grade (GRG).

This methodology for optimizing the process parameters of EDM of P20 tool steel considering 6 input parameters and 2 output parameters. Two output responses MRR and TWR finding GRG for each experiment using L_{27} OA based on Taguchi design are shown in Fig 3. This Figure indicate the experiment no 21(parameter setting Tool mat 3,Ton 1,Ip 3,Tup 2,Tw 3,Fp 2) is optimum parameter for MRR and TWR.

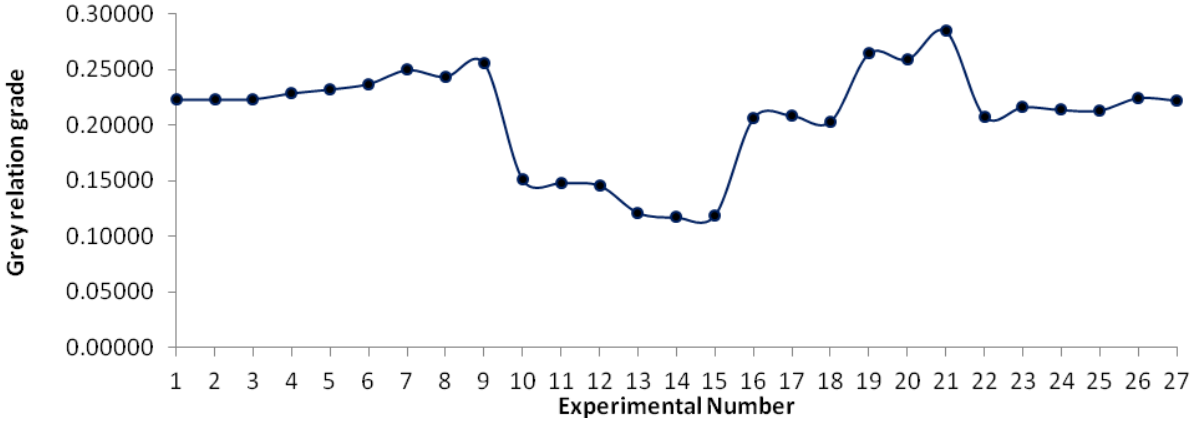

Figure 3 Grey Relation Grade

CONCLUSIONS

Optimize the machine performances on EDM of AISI P20 tool steel and to these performance characteristics with maximum MRR and minimum TWR. MRR increases with T_{up} to a maximum value after that it gradually decreases. And T_w is slightly increasing with MRR, and F_p has no significant effect on MRR and TWR. Tool lift time is increasing the wear rate up to an optimum level and then starts to increase slightly. T_w is no significant effect on TWR. The grey relation analysis convert multiple optimization characteristics into an optimization of single performances characteristics that is called GRG in this paper reported the EDM parameter setting (Tool material: Graphite, Ton = 100 µm, Ip =7 A, Tup = 0.7 s, Tw =1s,Fp =0.3 kgf/cm^2) is optimum setting.

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