International Journal of Advanced Research Methodology in Engineering & Technology,
Volume 1, Issue 2, March 2017, ISBN 978-1-63535-889-6

A COMPARATIVE STUDY OF THE EDM CHARACTERISTICS ON VARIOUS PLASTIC MOULD STEELS AS P-20, H-13, STAVAX

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Abstract**—** The present work investigates the machining characteristics of Plastic Mould steel with Copper as a tool electrode in electrical discharge machining process. Comparison of physical mechanical, and thermal properties of steel (P-20, H-13 and STAVAX) which are specifically used in plastic mould. Electrical discharge machining using copper electrode is carried out for all the three materials. A well-designed experimental scheme was used to reduce the total number of Experiments. Parts of the experiment were conducted with the L9 Orthogonal array based on the Taguchi method. Moreover, the signal-to-noise ratios Associated with the observed values in the experiments were determined by which factor is most affected by the Responses of Material Removal Rate (MRR), Surface Roughness (SR).

Our aim is to optimize the control factors Peak current Ip, pulse ON-time Ton, Gap voltage v. for all three materials which are frequently used in tool room for making of Plastic mould. The three different types of material are P-20, H13, and Stavax that are used according to the need. To overcome the problem of which parameters to be kept for these three different type of steels. Firstly we have conducted o-vat for screening of range of Factors by using Taguchi l-9 experimental method optimization has to be carried out.

Keywords**— EDM, Metal removal rate, Surface roughness, Empirical model**

I. INTRODUCTION

Electrical discharge machining (EDM) process has become the workhorse of the tool making industry for the precise machining of work pieces that conduct electricity. It plays a major role in the machining of dies, tools, etc. made of tungsten carbides or hard steels. The material can be machined in the hardened state and distortions resulting from heat treatment processes are eliminated [1]. Although the mechanism of material erosion employed in EDM is still arguable [2], the widely accepted principle is the conversion of electrical energy into thermal energy through a series of discrete electrical discharges occurring between the electrode and Work piece immersed in a dielectric fluid [3]. The insulating effect of the dielectric is important in avoiding electrolysis of the electrodes. Spark is initiated at the point of smallest inter-electrode gap by a high voltage, overcoming the dielectric breakdown strength of the small gap [4]. Erosion of metal from both electrodes takes place there. After each discharge, the capacitor is recharged from the DC source through a resistor, and the spark that follows is transferred to the next narrowest gap. The cumulative effect of a succession of sparks spread over the entire workpiece surface leads to its erosion, or machining to a shape which is approximately complementary to that of the tool [5]. The electrical resistance of the dielectric influences the discharge energy and the time of spark initiation [6]. If the resistance is low, an early discharge will occur. If it is large, the capacitor will attain a higher value of charge before the discharge spark occurs.

The present work investigates the comparative study of machining characteristics of Plastic Mould steel with Copper as a tool electrode in electrical discharge machining process. Comparison of physical and mechanical, thermal properties of steels which are specifically used in plastic mould. Electrical discharge machining using copper electrode is carried out for all the three materials. A well-designed experimental scheme was used to reduce the total number of Experiments. Parts of the experiment were conducted with the L9 Orthogonal array based on the Taguchi method. Moreover, the signal-to-noise ratios Associated with the observed values in the experiments were determined by which factor is most affected by the Responses of Material Removal Rate (MRR), Surface Roughness (SR).

Our aim is to optimize the control factors Peak current Ip, pulse ON-time Ton, duty factor, Gap voltage v.for all three materials which are frequently used in tool room for making of Plastic mould. The three different types of material are P-20, H13, and Stavax that are used L9 orthogonal array of Taguchi experimental design was used to conduct the experiments. Three levels of the three machining parameters, namely; peak current (Ip), pulse on-time (Ton) and gap voltage (volts) constituted the array. Negative polarity of the tool electrode and kerosene dielectric with side flushing was used for all the experiments.

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II. BACKGROUND

Most of the research works has been carried out on individual material focus on improving the process parameters such as material removal rate (MRR), and surface roughness (SR). The study of the impact of such machining on making of plastic mould dies

In Oct-09, Narcis Pellicer et al worked on the Tool electrode geometry and process parameters influence on different feature geometry and surface quality in electrical discharge machining of AISI H13 steel. a) Obtained ANOVA tables reveal most clear interactions among input and output parameters in EDM sinking process. MRR & surface roughness increase with discharge current .pulse off variation affects MRR, but its behaviour is not linear due to the interactions with other process parameters which must be deeply analyzed in further studies. b) Tool geometry is a critical choice when different features are machined square and rectangle electrodes present better radial and axial wear ratios. Therefore theses geometries are likely to be the best option for flexible tool electrode .the input factors considered in this experiment were Ton, Vg, Ip, Toff, Tg.

In 2012, S. B. Nipanikar worked on Parameter Optimization of AISI D-3 STEEL Material by using Taguchi method. 1) The material removal rate (MRR) mainly affected by peak current (Ip). Duty cycle (t) has least effect on it. The electrode wear rate (EWR) is mainly influenced by peak current (Ip). The effect of gap voltage (Vg) is less on EWR &least effect. Peak current (Ip) have the maximum effect on the radial overcut (ROC). The gap voltage (Vg) has least effect on it.

2) Optimum parameters of input factors are as follows; Ton: 75 µs Ip:8 Amp t:12 Vg:55volt.

In Oct-09, Anderson Molinett et al, worked on the Surface modification of AISI H13 tool steel with silicon or manganese powders mixed to the dielectric in electrical discharge machining process the input factors considered in this experiment were Ton, Vg, Ip, Toff, Tg.

In 2013, S. B. Chikalthankar , worked on Experimental Investigations of EDM parameters for the material AISI D2 and found that 1) In case of the MRR the current is most influential, followed by pulse ON time, pulse off time and gap voltage. Use high values of current and gap voltage for higher MRR. 2) In case of the surface roughness the current is most influential, followed by pulse ON time, gap voltage and pulse off time. Use low values of current and gap voltage for lower surface roughness.

In 2011, Sanjeev Kumara and Uma Batra worked on Surface modification of die steel materials by EDM Method using tungsten powder mixed dielectric using materials like ohns, aisi D-2, H-13. Experiments were conducted on three die steel materials by electrical discharge machining a) it was possible to achieve a max amount of 3.25% tungsten in the machined surface of H13 die steel. It can be concluded that surface modification is possible by the EDM method b) The presence of suspended powder particles can react with carbon from breakdown of hydrocarbon dielectric at high temperatures of tungsten carbide and increase in the percentage of carbon on the machined surface indicate that of the plasma channel to form carbides c) Favourable machining conditions for material transfer by EDM are found to be low discharge current less than 5A shorter pulse on time less than 10 µs , longer pulse off time more than 50 µs and negative polarity of tool electrode peak current is found to be the most significant factor for surface modification.

III. EXPERIMENTATION

Experiments to investigate the Optimum Condition of the Material Removal Rate (MRR) and Surface Roughness (SR) were conducted on three die steel plastic moulds which are frequently used in making plastic moulds.

The work pieces of three die steel (moulds) materials – Pre-Hardened Steel-P20, Hot Die Steel-H-13 and Corrosion resistant mould steels-Stavax. The samples of these steels were prepared using standard procedure. To understand the realistic influencing parameters of EDM under operating conditions, it is required to conduct a different experimental trial that gives relationship of material removal rate, surface roughness. By studying this, the life of plastic mould steel can be evaluated. The main interest of this study is to understand the maximum material removal rate, surface roughness.

The following steps are recommended, as a precautionary measure: EDM of hardened and tempered material (a) Conventional machining (b) Hardening and tempering(c) Initial EDM, avoiding “arcing” and excessive Stock removal rates. Finish with “fine sparking”,i.e. low current, high frequency (e) Grind or polish EDM surface (f) Temper the tool at 15–25°C (30–50°F) Lower than the highest previous tempering Temperature. EDM of annealed material

(g) Conventional machining (h) Initial EDM, as C above

(i) Grind or polish EDM surface. This reduces the risk of crack formation during heating and quenching. Slow preheating, in stages, to the hardening temperature is recommended.

To overcome the problem of which parameters to be kept for these three different type of steels. Firstly we have conducted o-vat for screening of range of factors by using Taguchi l-9 experimental method optimization has to be carried out.

Table 1 Original Chemical Composition of the Plastic Mould Work Materials.

Composition wt %	*Pre-hardened Steel AISI-P20*	Hot Die Steel AISI H-13	Corrosion resistant tool steel Stavax AISI-420
Carbon	0.40	0.44	0.38
Silicon	0.30	1.04	0.9
Manganese	1.5	0.28	0.5
Chromium	1.80	5.39	13.6
Vanadium	0.19	1.13	0.3
Molybdenum	0.20	0.93	-
Nickel	-	0.19	-
Iron	Balance	Balance	Balance

Table 2 Specification of Materials used

Raw Material (conventional)	AISI	DIN	DIN NO	HRC	Hardening Temperature Degree celsius	Strength Mpa	Electrical Resistivity
P-20	P-20	40CrMnMoS8-6	1.2311	32-35	830-880	1000-1068	0.19 Ὠ-mm2/m
H-13	H	X40Cr	1.2	43-	1020-	162	0.638

	-13	MoV5-0	344	45	1060	0	Ώmm2/m
STAVAX	420		1.2083	52-54	1020-1060	1200	0.52 Ώ mm2/m

Table 3

Coefficient of Thermal Expansion µm/m°K						
Raw Material	100° C	200° C	300° C	425° C	540° C	650° C
P-20	_	_	_	12.8	11.7	14.2
H-13	10.4	11.5		12.2	12.4	13.1
STAVAX	10.3	10.8			11.7	

Table 4

Thermal Conductivity W/m°K						
Raw Material	95°C	260° C	400° C	540° C	675° C	815° C
P-20	29					
H-13		28.6	28.4	28.4	28.7	
STAVAX	22.5	25.7				

Table 5

Specific Heat J/kg° K						
Raw Material	50-100°C	260° C	400° C	540° C	675° C	815° C
P-20	460					
H-13	460		550		590	
STAVAX	225	257				

Above tables give information about thermal properties of materials which affect the rate of material removal and very important surface roughness.

Table 6 Machining parameters used for the experimentation

Machining parameters used for the experimentation.	
Sparking voltage	50, 55, 60 Volts
Peak current	8, 12, 16 A
Pulse on-time	100, 150, 200µs
Servo control	Electro-mechanical
Polarity	Reverse (electrode negative)
Dielectric	Commercial grade kerosene
Machining time	1mm deep for each cut
Electrode	Electrolytic copper

And average values were noted. Machining of the work pieces was then carried out on Electrical Discharge Machine with conventional copper tool electrode. Time for each machining cut was fixed at 1 mm depth. The input machining parameters and their levels used for experimentation are given in Table 2.

Fig.1 P-20 work piece Fig.2 H-13 work piece

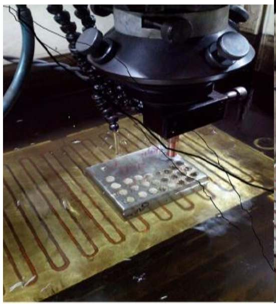


Fig3 Stavax workpiece Fig4 ZNC machine

The experiments were conducted as per the layout shown in Table 5. A EDM die sinking machine with Electronica ZNC was employed for conducting the EDM experiments. Each experiment was conducted for a depth of 1mm. prior to machining; the work pieces and electrode were cleaned and polished. The workpiece was firmly clamped in the vice and immersed in the electrol EDM oil. The positive polarity was used during the experiments. The schematic diagram of die sinking EDM machine. For Surface Roughness Measurement Taylor-Hobson surface tester was used.

Determination of the working range of the process parameters a large number of trials were conducted by varying one of the process parameters and keeping the other parameters constant. The working range of discharge current, pulse on time, and pulse off time was explored by inspecting the cavity produced in the work piece by the electrode. The working range of the process parameters selected under the present study is indicated in Table 3.

Table 7: Taguchi L-9 Orthogonal Array

TRIAL.NO	Ton µs	Ip Amperes	Vg volts
1	100	8	50
2	100	12	55
3	100	16	60
4	150	8	60
5	150	12	50
6	150	16	55
7	200	8	55

8	200	12	60
9	200	16	50

Table 8 Responses MRR and Input Factors

TRIAL.NO	Ton	Ip	Vg	MRR P-20-3	MRR H-13 OS	MRR STAVAX
1	100	8	50	12.102	12.547	12.116
2	100	12	55	27.798	22.260	21.966
3	100	16	60	34.739	30.532	28.144
4	150	8	60	14.369	18.730	14.241
5	150	12	50	32.760	26.200	26.383
6	150	16	55	38.144	34.720	30.608
7	200	8	55	15.813	19.620	14.149
8	200	12	60	31.945	31.915	24.086
9	200	16	50	36.968	34.880	30.900

Table 9 : Responses SR and Input Factors

TRIAL.NO	Ton	Ip	Vg	SR p-20	SR-H13	SR-STAVAX
1	100	8	50	4.3	5.3	6.2
2	100	12	55	6.8	5.8	7.2
3	100	16	60	7.42	7.3	7.8
4	150	8	60	5.3	5.9	6.4
5	150	12	50	7.8	7.2	8.3
6	150	16	55	8.4	8.31	8.9
7	200	8	55	6.1	6.8	7.7
8	200	12	60	8.6	7.68	9.43

IV. RESULTS AND DISCUSSIONS

Table 10: For MRR of P-20 Material

Ton	Ip	Vg	MRR P-20	SNRA1
100	8	50	12.102	21.65714
100	12	55	27.798	28.88027
100	16	60	34.739	30.81635
150	8	55	14.369	23.14883
150	12	60	32.760	30.30688
150	16	50	38.144	31.62852
200	8	60	15.813	23.98029
200	12	50	31.945	30.08806
200	16	55	36.968	31.35652

Fig 5.Main effect plot for MRR-P20

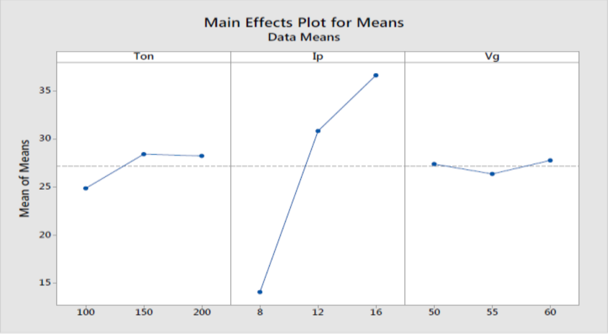


Table 11: Analysis of Variance For MRR P-20

Source	DF	Adj.SS	Adj.MS	F-Value	P-Value
Ton	2	23.904	11.952	195.46	0.005
Ip	2	820.898	410.449	6712.4	0.00
Vg	2	3.115	1.558	0.038	
error	2	0.122	0.061		
Total	8	848.04			

Model Summary
S 0.247286 R-sq-99.99% R-sq(adj)99.94%
R-sq(pred) 99.71%
Regression Equation
MRR P-20 = -13.7 + 0.0336 Ton + 2.815 Ip + 0.037 Vg

4.1 Effect of parameters on EDM performance measures Based on the S/N ratio and ANOVA analysis of the result, various conclusions are drawn. As shown in Table 10 and Fig. 5, factors at level A2 (pulse on time, 150 µs), B3 (discharge current, 16 A), and C3 (Gap Voltage, 60 Volts) gives maximum MRR. Factor C is having least significant effect on improving MRR. The contribution order of machining parameters for mrr is discharge current, then pulse on time, and then Gap Voltage as shown in table 11. The heat energy supplied to remove the workpiece material is controlled by the discharge current. Hence, the contribution and significance of discharge current is largest. The pulse on time controls the duration of time for which the current is allowed to flow per cycle. The material removed from the workpiece is directly proportional to the amount of energy supplied during this period. Thus, it is the second factor as far as contribution and significance is concern. During the Gap Voltage, no material is removed from the workpiece as there is no discharge current supplied. This results in lowest significant effect and lowest contribution for MRR.

From Table 12 and Fig. 6, A1 (pulse on time), factor B1 (discharge current), is the most significant factor among all factors where as factors C (Gap Voltage) have insignificant effect on SR. The Table 13 indicates that the contribution of factor B is very high for SR as compared to factors A and C.The optimum level of factors for SR is A1 (Pulse On Time,100 µs), B1 (Peak Current, 8A), and C2 (Gap Voltage,55 volts). The time duration of heat energy available for material removal depends on pulse on time. This energy is shared by a larger number of sparks results in reduction the size of the crater. This improves surface finish. Hence, contribution and significance of peak current and pulse on time is largest for SR.

Table 12:For SR of P-20 Material

Ton	Ip	Vg	SR

100	8	50	4.3
100	12	55	6.8
100	16	60	7.42
150	8	55	5.3
150	12	60	7.8
150	16	50	8.4
200	8	60	6.1
200	12	50	8.6
200	16	55	9.1

Fig 6. Main effect plot for SR-P20

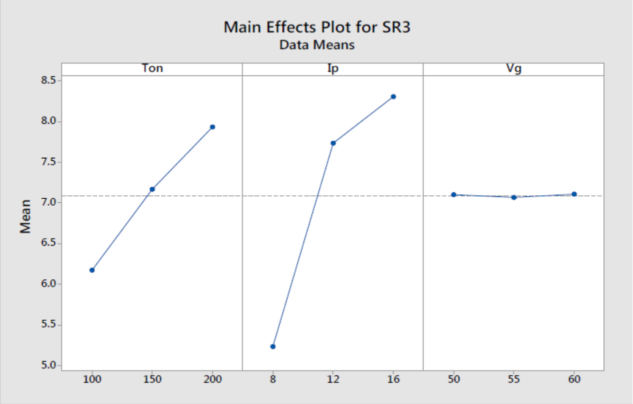


Table 13 Analysis of Variance For SR P-20

Source	DF	Adj.SS	Adj.MS	F-Value	P-Value
Ton	2	1.8156	11.952	195.46	0.005
Ip	2	15.268	410.449	6712.4	0.00
Vg	2	0.0156	1.558	0.038	
error	2	0.0156	0.061		
Total	8	17.1156			

Model Summary of SR of P-20

S 0.247286 R-sq-99.99% R-sq(adj) 99.94% R-sq(pred) 99.71%

Regression Eqn for SRP20=-0.2+0.01760Ton+0.3842 Ip+.0007Vg

Table 14. For MRR of H-13 Material

Ton	Ip	Vg	MRRH-13	SNR
100	8	50	12.547	21.9708
100	12	55	29.260	29.32549
100	16	60	30.532	29.69511
150	8	55	20.730	26.33199
150	12	60	36.200	31.17417
150	16	50	31.720	30.02666
200	8	60	19.620	25.85398
200	12	50	31.915	30.0799
200	16	55	34.880	30.85153

Fig 6. Main effect plot for MRR-H13

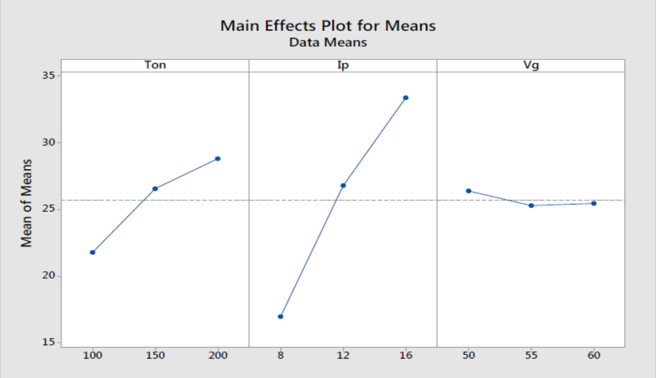


Table 15: Analysis of Variance for MRR of H-13

Source	DF	Adj.SS	Adj.MS	F-Value	P-Value
Ton	2	52.131	26.065	29.31	0.033
Ip	2	437.232	218.616	245.85	0.004
Vg	2	20.123	10.061	11.31	0.081
error	2	1.778	0.889		
Total	8	511.264			

Model Summary

S 0.9429 R-sq-99.65% R-sq(adj)98.61% R-sq(pred) 92.96%

Regression eqn for MRR H-13 =

MRR H13 = -4.26 + 0.0703 Ton + 2.051 Ip - 0.094 Vg

4.2 Effect of parameters on EDM performance measures Based on the S/N ratio and ANOVA analysis of the result, various conclusions are drawn. As shown in Table 14 and Fig. 6, factors at level A2 (pulse on time, 150 µs), B3 (discharge current, 16 A), and C3 (Gap Voltage, 60 Volts) gives maximum MRR. Factor C is having least significant effect on improving MRR. The contribution order of machining parameters for mrr is discharge current, then pulse on time, and then Gap Voltage as shown in table 15. The heat energy supplied to remove the workpiece material is controlled by the discharge current. Hence, the contribution contribution and significance of discharge current is largest. The pulse on time controls the duration of time for which the current is allowed to flow per cycle. The material removed from the workpiece is directly proportional to the amount of energy supplied during this period. Thus, it is the second factor as far as contribution and significance is concern. During the Gap Voltage, no material is removed from the work piece as there is no discharge current supplied. This results in lowest significant effect and lowest contribution for MRR.

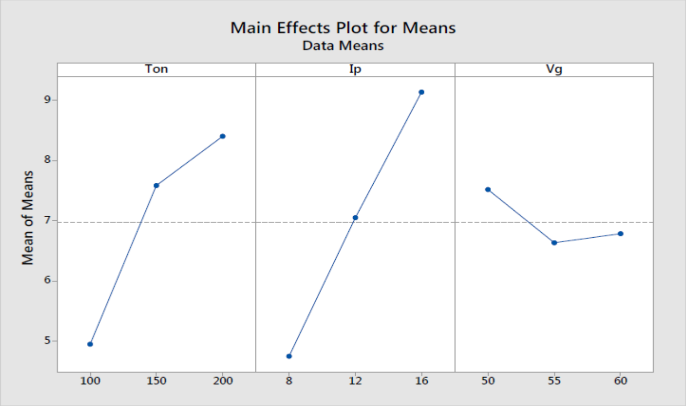
From Table 16 and Fig. 7, A1 (pulse on time), factor B1 (discharge current), is the most significant factor among all factors where as factors C (Gap Voltage) have insignificant effect on SR. The Table 17 indicates that the contribution of factor B is very high for SR as compared to factors A and C.The optimum level of factors for SR is A1 (Pulse On Time,100 µs), B1 (Peak Current, 8A), and C2 (Gap Voltage,55 volts). Contribution and significance of peak current and pulse on time is largest for SR.

Table 16 for SR of H-13 Material

Ton	Ip	Vg	SR-H13	SNR H-13

100	8	50	3.65	11.2459
100	12	55	4.5	13.0643
100	16	60	6.7	16.5215
150	8	55	4.8	13.6248
150	12	60	7.85	17.8974
150	16	50	10.1	20.0864
200	8	60	5.8	15.2686
200	12	50	8.8	18.8897
200	16	55	10.6	20.5061

Fig 7. Main effect plots for SR H-13



Ton	2	19.5039	9.7519	28.59	0.034
Ip	2	28.8439	14.4219	42.28	0.023
Vg	2	1.3406	0.6703	1.96	0.337
error	2	0.6822	0.3441		
Total	8	50.3706			

Model Summary
S 0.584047 R-sq-98.65% R-sq (adj) 94.58%
R-sq (pred) 72.57%
Regression eqn =1.06+0.01733Ton+0.2804Ip+0.0003 Vg.

Table 18: For MRR of Stavax Material

Ton	Ip	Vg	MRR STAVAX
100	8	50	12.116
100	12	55	23.966
100	16	60	30.144
150	8	55	16.241
150	12	60	28.683
150	16	50	32.608
200	8	60	16.149
200	12	50	26.086
200	16	55	34.979

Fig.8 Main effect plots for MRR Stavax

Table 19: Analysis of Variance for MRR (Material Removal Rate) of STAVAX

Source	DF	Adj.SS	Adj.MS	F-Value	P-Value
Ton	2	27.627	13.814	12.23	0.076
Ip	2	485.046	242.523	214.67	0.005
Vg	2	4.061	2.030	1.80	0.357
error	2	2.259	1.130		
Total	8	518.993			

Model Summary
S 1.06289 R-sq-99.56% R-sq (adj) 98.26%
R-sq (pred) 91.18%
MRR STAVAX = -8.94 + 0.0230 Ton + 2.048 Ip + 0.062 Vg

4.3 Effect of parameters on EDM performance measures
Based on the S/N ratio and ANOVA analysis of the result, various conclusions are drawn. As shown in Table 18 and Fig. 8, factors at level A2 (pulse on time, 150 µs), B3 (discharge current, 16 A), and C3 (Gap Voltage, 60 Volts) gives maximum MRR. Factor C is having least significant effect on improving MRR. The contribution order of machining parameters for mrr is discharge current, then pulse on time, and then Gap Voltage as shown in table 19. The heat energy supplied to remove the workpiece material is controlled by the discharge current. Hence, the contribution and significance of discharge current is largest. The pulse on time controls the duration of time for which the current is allowed to flow per cycle. The material removed from the workpiece is directly proportional to the amount of energy supplied during this period. Thus, it is the second factor as far as contribution and significance is concern. This results in lowest significant effect and lowest contribution for MRR.

From Table-20 and Fig.9, A1 (pulse on time), factor B1 (discharge current), is the most significant factor among all factors where as factors C (Gap Voltage) have insignificant effect on SR. The Table 14 indicates that the contribution of factor B is very high for SR as compared to factors A and C. The optimum level of factors for SR is A1 (Pulse on Time, 100 µs), B1 (Peak Current, 8A), and C2 (Gap Voltage, 55 volts). The time duration of heat energy available for material removal depends on pulse on time. This energy is shared by a larger number of sparks results in reduction the size of the crater. This improves surface finish. Hence, contribution and significance of peak current and pulse on time is largest for SR.

Table 20: For MRR of STAVAX Material

Ton	Ip	Vg	SR-STAVAX	SNR
100	8	50	5.2	14.3201

100	12	55	6.2	15.8478
100	16	60	7.65	17.6732
150	8	55	5.36	14.5833
150	12	60	7.26	17.2187
150	16	50	7.86	17.9085
200	8	60	6.67	16.4825
200	12	50	8.43	18.5166
200	16	55	8.89	-18.978

Fig 9.main effect plot for SR-Stavax

error	2	0.0996	0.0996		
Total	8	13.4952			

Model Summary

S 0.223184 R-sq-99.26% R-sq (adj) 97.05% R-sq (pred) 85.05%

SR-STAVAX = 3.26 + 0.01940 Ton + 0.2621 Ip - 0.0243 Vg

5.1. Optimum machining parameters

The optimum machining parameters for the three work materials and the relative contribution of the factors have been summarized in Table 5. It is found that the combination of input

Machining parameters for the best value of micro-hardness is the same for all the three work materials. Even the relative contribution of the factors is almost identical. Hence, it can be conclusively inferred from this data that the input process parameters are independent of the work material and the same values will hold good for any work material. Peak current emerges as the most significant factor with more than 70% contribution in all cases. Another important observation is that the contribution of pulse on-time is more than gap voltage

Table 22. **Optimum condition**

Parameters	Work-Material		
	P-20	H-13	STAVAX
Optimum MRR Condition	**A2B3C3**	**A2B3C1**	**A2B3C3**
Peak Current Contribution	95.79%	85.51%	93.45%
Pulse-On-Time Contribution	2.81%	10.19%	5.32%
Voltage Contribution	0.36%	3.93%	1.78%
Optimum SR Condition	**A1B1C2**	**A1B1C2**	**A1B1C2**
PeakCurrent Contribution	88.51%	57.28%	65.39%
Pulse-On-Time Contribution	10.60%	38.72%	31.91%
Voltage Contribution	0.9%	2.66%	1.94%

Factor A represents peak current and level A1 = 100 µs, A2 = 150 µs, A3 = 200µs.

Factor B represents pulse on-time and level B1 = 8A, B2 = 12A, B3 = 16A.

Factor C represents pulse off-time and level C1 = 50v, C2 = 55v, C3 = 60v.

5.2 Conduct the confirmation test

The Confirmation experiments for Optimum levels obtained were conducted and readings noted for Material Removal Rate and Surface Roughness for three materials total two readings each for MRR and SR were conducted.

For Validation purpose Regression analysis for each material for MRR and SR has been obtained using Minitab-17

. It is observed that experimental values are closer to the optimum values are shown in table below.

Table 23: Validation of Optimum Results

Performance Measure	**Optimum Condition**	**Optimum Value**	**Predicted Value**
MRR P-20(mm3/min)	A2B3C3	38.600	38.24
MRR for H-13 (mm3/min)	A2B3C1	34.401	34.72
MRR stavax (mm3/min)	A2B3C3	30.998	30.48
SR P-20 (µ)	A1B1C2	4.6721	4.630
SR H-13 (µ)	A1B1C2	5.053	4.99
SR Stavax (µ)	A1B1C2	5.9603	6.01

6. Conclusions

In this study, The influence of the Process Parameters and optimization of P-20,H-13,Stavax Materials in the die sinking EDM was studied by using Taguchi Method, From the Results, it was found that discharge current, pulse-on-time and gap voltage have been found to play significant role in EDM operations. Also, it was found that the optimal level of the factors for SR and MRR are different from each other. from ANOVA, discharge current is more significant than pulse on time for MRR. Whereas for SR peak current is significant also pulse on time is equally significant.

(1) The Values of MRR obtained for optimum P-20 Material is highest of 38.6(mm3/min), for H-13 Material it is in medium range 34.401(mm3/min) and for stavax it is 30.998

(mm3/min), found to be lowest. Which depends upon thermal properties like coeff of thermal expansion, thermal conductivity, specific heat hardness as well as electrical conductivity.

(2)The values of SR surface roughness obtained shows that for stavax material 5.96(µ) it is highest, for H-13 Material it is in medium range of 5.05(µ) and for P-20 it is 4.67(µ) which is lowest .lower SR is required for mould dies for no sticking of polymer material into the die cavity.

(3) It is recommended for large size moulds and having simple shape and less sticking polymers inserts material should be P-20. And for complicated moulded parts also for which polymers are sticky hot die steel H-13 should be used.

For critical shape moulds whose moulded part material polymer is sticky for those corrosion resistant wear resistant stavax material should be used.

Acknowledgments: The authors would like to thank the authorities of M/s Indo German Tool Room, Aurangabad, India for providing the facilities to carry out this work.

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