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Parametric Optimization of Electro Discharge Machining of 20MnCr5 Alloy Steel Material using Taguchi Technique

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Abstract—*Electric discharge machining is a process which is used to machine very hard material that are difficult to machine, deep & complex shapes by metal erosion for electro conductive materials. The metal is removed through the action of an electric discharge for short duration and high current density between the tool and the work piece. The eroded metal on the surface of both work piece and the tool is flushed away by the dielectric fluid. This paper deals with the optimization of Electric Discharge Machining process parameters based on the Taguchi technique. The aim of this research is to optimize the process parameters of EDM Machine to get maximum MRR and minimum TWR. The process parameters to be optimize are current, T_{on} ,T (Duty Cycle) . Work piece materials are the samples of 20MnCr5.Three Electrode are used which are of Aluminum, Copper, Brass material. The 18 no of experiments are performed by using L18 orthogonal array on a SE-35 Electra Pulse 500x300 EDM machine and MINITAB-17 Software is used . The effect of the variable parameters mentioned above upon machining characteristics such as material removal rate (MRR), tool wear rate (TWR)) is studied and investigated.*

Keywords*: MRR, TWR, ANOVA, 20mncr5 Steel, MINITAB-17Software, EDM, Taguchi Method.*

1. INTRODUCTION

Electrical Discharge Machining (EDM) is a machine that is used as non-traditional manufacturing and this machine is continually developing further technology that would be impossible to produce with faster and conventional. This machine produces tools with complex-shapes and being used extensively in industries. Furthermore EDM can operate as surface finish in last stage of tool production. 20MnCr5 is an important tool mainly because of its high hardness, strength and wear resistance. In an EDM operation, it is need to select right parameters for sparking performance. However, the right and desired parameters that base on the experience, instruction manual or a large number of test of experiment that require a lot of time and materials. This study presents experimental analysis based on Taguchi design. The objective of this research is to study the performance of different electrode of copper ,brass, aluminum materials on 20MnCr5 work piece with EDM process.

2. EXPERIMENTAL MATERIALS AND EQUIPMENTS

2.1 Tool material

The three tools used are of Copper, Brass, Aluminum material. These tools were prepared on lathe machine into cylindrical shape of 15mm diameter .

Fig. 1: Aluminum ,Brass, copper Electrodes of 15mm diameter

2.2 Work material

Work Material : In these experiments, the 20MnCr5 work piece material was selected and its composition is Cr 1.00 - 1.30, Mn -1.10 - 1.40, S- .035, C- .17 - .22, Si- .10 - .35, P- .035 % by weight. Three samples were prepared on which 18 no of experiments are performed and are shown in fig.2.

Fig 2: Samples of 20MnCr5 Alloy Steel

2.3 Machine Used

The 18 no of experiments were performed on a Die Sinking EDM Machine Of Type SE-35 Electra Plus 500 x300 . This machine contain a jet flushing system whose purpose is to flush away the debris produced from EDM process & it controls the sparking produced .In this experiment we used –ve polarity for electrode and +ve polarity for work piece .the dielectric fluid used is EDM Oil-30 which is easily available in the market .

Fig. 3: Electronica SE-35 EDM machine

3. EXPERIMENTAL DETAILS

This paper uses Taguchi Technique which is very effective to deal with responses influenced by multi-variables. Dr. Genichi Taguchi is regarded as the foremost proponent of robust parameter design, which is an engineering method for product or process design that focuses on minimizing variation and/or sensitivity to noise. When used properly, Taguchi designs provide a powerful and efficient method for designing products that operate consistently and optimally over a variety of conditions. Taguchi proposed several approaches to experimental designs that are sometimes called "Taguchi Methods." These methods utilize two, three, four, five, and mixed-level fractional factorial designs. The Taguchi method is devised for process optimization and identification of optimal combinations of factors for given responses. The steps involved are: 1. Identify the response functions and the process parameters to be evaluated. 2. Determine the number of levels for the process parameters and possible interaction between them. 3. Select the appropriate orthogonal array and assign the process parameters to the orthogonal array and conduct the experiments accordingly. 4. Analyze the experimental results and select the optimum level of process parameters. 5. Verify the optimal process parameters through a confirmation experiment. The process parameters chosen for the experiments are: (a) pulse-on time (ton), (b) current (Ip), and (c) duty cycle(T) and three electrode Copper, brass, Aluminum while the response functions are: (a) Metal Removal Rate (MRR) and (b) Tool Wear rate (TWR).According to the capability of the commercial EDM machine available and general recommendations of machining conditions for 20MnCr5 the range and the number of levels of the parameters are selected and are given in table1.

Table 2: Level values of input Factors

control factors	1	2	3
Peak Current(Ip),amp	5	10	15
Electrode	Cupper	Brass	Aluminum
Pulse on time (Ton)µsec.	200	500	1000
Duty cycle(T)	9	10	11

In Taguchi design experimental procedure is done on the basis of different design formed for various level such as two, three, four ,five and mixed levels . . In this study, a 4 factor mixed level setup was chosen with a total no of eighteen experiments to be conducted and that is why OA L18 was choosed.

4. EXPERIMENTAL PROCEDURE

Experiments were performed, randomly on three samples of 20MnCr5 according to the L18 orthogonal array as designed by Taguchi, . For each experiment a separate electrode is used. The machining is done for 15 minutes for each experiment The machining time is calculated by a stop watch . The Metal removal rate and tool wear rate is calculated by weight difference of the electrodes using automatic weighing machine with 300 g capacity with a precision of 0.0001g and then dividing by time for machining .The experimental results for electrode wear rate, MRR based on L18 orthogonal array is shown in table 3.

Table 3: MRR AND TWR

EXP.NO	MRR(gm/m)	TWR(gm/m)
1	0.05700	0.01100
2	0.03830	0.18000
3	0.18980	0.00420
4	0.04900	0.03200
5	0.19890	0.00630
6	0.03730	0.00740
7	0.03660	0.00150
8	0.04400	0.00720
9	0.06930	0.08300
10	0.07660	0.09200
11	0.01590	0.00320
12	0.06533	0.00740
13	0.08260	0.00680
14	0.03100	0.02700
15	0.05460	0.00920
16	0.05660	0.00580
17	0.19798	0.00700
18	0.01660	0.01983

5. RESULTS AND DISCUSSION

After the experimental procedure, different response factors like MRR, TWR calculated from the observed data. Then a statistical analysis were performed on the calculated values and the signal to noise ratio values of three response factors are tabulated in table 4.

Table 4: S/N Ration for MRR and TWR

Sr. No	S/N Ratio for MRR	S/N Ratio for TWR
1	-24.8825	39.1721
2	-28.3360	14.8945
3	-14.4341	47.5350
4	-26.1961	29.8970
5	-14.0273	44.0132
6	-28.5658	42.6154
7	-28.7304	56.4782
8	-27.1309	42.8534
9	-23.1853	21.6184
10	-22.3154	20.7242
11	-35.9721	49.8970
12	-23.6977	42.6154
13	-21.6604	43.3498
14	-30.1728	31.3727
15	-25.2561	40.7242
16	-24.9437	44.7314
17	-14.0676	43.0980
18	-35.5978	34.0535

5.1 Effect of input factors on MRR

The response table for signal to noise ratio for MRR is shown in table 5 and corresponding analysis variances (ANOVA) table is shown in table 6 for MRR, the calculation of S/N ratio follows "Larger the better model".

Table 5: Response table for signal-to- noise ratio for MRR

Level	Current	Material	Ton	T
1	-30.65	-23.89	-23.48	-24.87
2	-25.93	-27.63	-24.55	-27.11
3	-18.28	-27.33	-26.83	-22.83
Delta	12.37	4.30	3.35	4.23
Rank	1	2	4	3

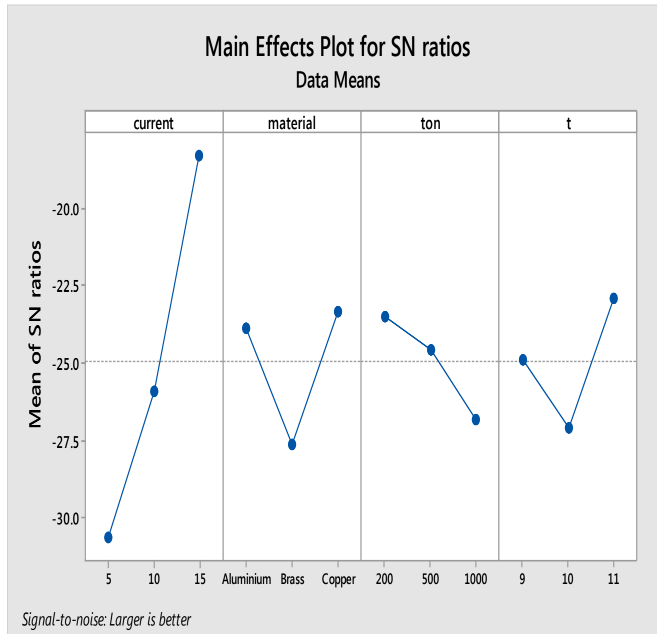


Fig. 4: Shows main effect plot for MRR

Table 6: Analysis of Variance for MRR

Source	DF	Seq SS	F	P	% contribution
Current	**2**	**467.1**	**37.54**	**0.000**	**68.87**
Material	**2**	**65.58**	**5.26**	**0.031**	**9.670**
TON	**2**	**35.11**	**2.82**	**0.112**	**5.177**
T	**2**	**53.68**	**4.31**	**0.049**	**0.079**
Residual Error	**9**	**56.06**	**-----**	**-------**	**8.266**
Total	**17**	**678.14**	**-----**	**------**	**--------**

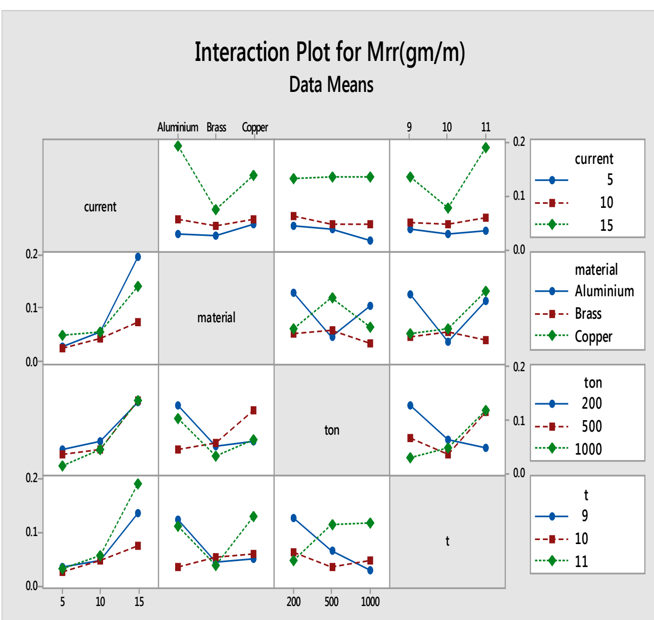
Referring table 6 it is noticed that factor current (Ip) has largest contribution to the total sum of squares i.e. 68.87%. The factor pulse-on time (Ton) and material also have the considerable contribution in total sum of the squares which is 5.177% and 9.670 respectively. The factor duty cycle (T) has much less contribution of 0.079 %. The larger the contribution of any factor to the total sum of squares, the larger is the ability of that factor to influence material removal rate (MRR). So peak current (Ip) has maximum effect on material removal rate, Pulse on time (Ton) and material have less considerable effect on material removal rate whereas duty cycle (t) has very less effect on MRR .

5.2 Model Analysis of MRR

The coefficients of model for S/N ratios for MRR are shown in Table -7. The parameter R2 describes the amount of variation observed in MRR is explained by the input factors. R2 = 94.2% indicate that the model is able to predict the response with high accuracy. Adjusted R2 is a modified R2 that has been adjusted for the number of terms in the model. If unnecessary terms are included in the model, R2 can be artificially high, but adjusted R2 (=89.1 %.) may get smaller. The standard deviation of errors in the modeling, S=2.492. Comparing the p-value to a commonly used α-level = 0.05, it is found that if the p-value is less than or equal to α, it can be concluded that the effect is significant (shown in bold), otherwise it is not significant

Table 7: Estimated Model Coefficients for MRR

Term	Coef	SE Coef	T	P
Constant	-24.954	0.5883	-42.418	0.000
Current 5	-5.6996	0.8320	-6.851	0.000
Current 10	0.9728	0.8320	-1.169	0.272
Material aluminum	1.0601	0.8320	1.274	0.235
Material Brass	-2.6799	0.8320	-3.221	0.010
ton 200	1.4691	0.8320	1.766	0.111
ton 500	0.4088	0.8320	0.491	0.635
t 9	.0856	0.8320	.103	0.920
t 10	-2.1565	0.8320	2.592	0.029
S = 2.496	R-Sq = 91.7	R-Sq(adj) = 84.4%	--------	-------



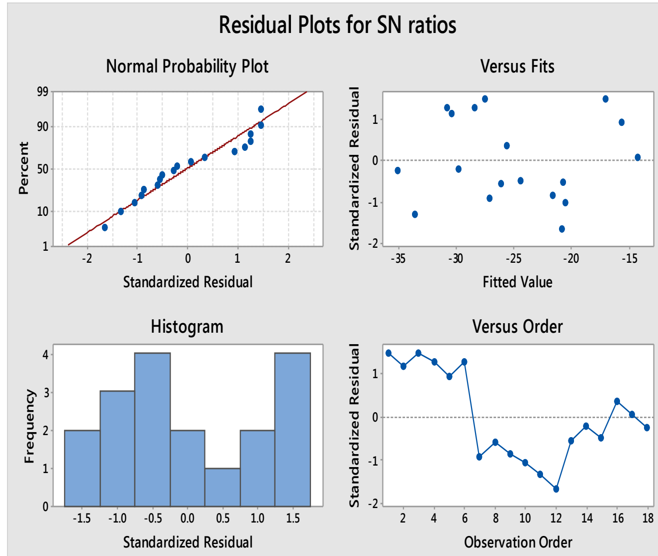


Fig. 5: Shows interaction and residual plot for MRR

5.3 Effect of input factors on TWR

The response table for signal to noise ratio for MRR is shown in table 4 and corresponding analysis variances (ANOVA) table is shown in table -8 for MRR, the calculation of S/N ratio follows "SMALLER the better model"

Table 8: Response table for signal-to- noise ratio for TWR

Level	Current	Material	Ton	T
1	42.26	47.23	37.25	36.92
2	35.95	25.43	36.42	36.18
3	36.72	42.28	41.26	41.83
Delta	6.31	21.80	4.84	5.65
Rank	2	1	4	3

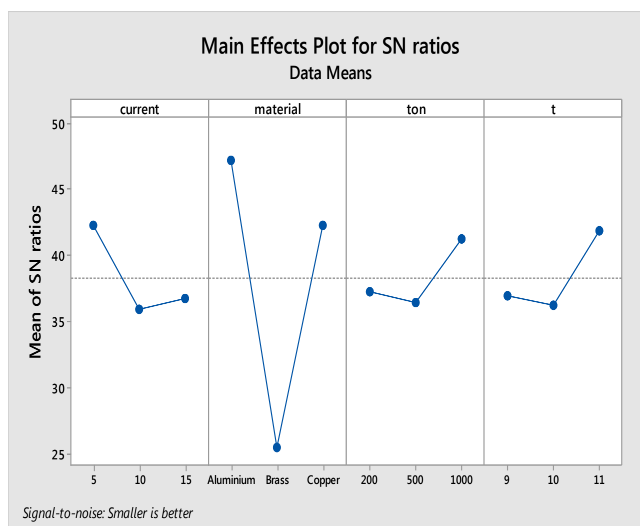


Fig. 6: Shows main effect plot for TWR

Table 9: Analysis of Variance for TWR

Source	Seq SS	F	P	% contribution
Current	142.30	6.09	0.021	7.083
Material	1568.01	67.11	0.000	78.049
T ON	80.44	3.44	0.078	4.004
T	113.10	4.84	0.037	5.629
Residual Error	105.15	-----	-------	
Total	2008.99	-----	------	--------

Referring table-9 it is noticed that material has largest contribution to the total sum of squares i.e. 78.049%. The factor current and duty cycle also have the considerable contribution in total sum of the squares which is 7.083% and 5.629% respectively. The factor pulse on time (Ton) has much less contribution of 4.004%. The larger the contribution of any factor to the total sum of squares, the larger is the ability of that factor to influence tool wear rate (TWR). So material has maximum effect on tool wear rate, duty cycle and current have considerable effect on tool rate whereas pulse on time (ton) has very less effect on TWR .

5.4 Model Analysis of TWR

The coefficients of model for S/N ratios for TWR are shown in Table-10. The parameter R2 describes the amount of variation observed in TWR is explained by the input factors. R2 = 94.8% indicate that the model is able to predict the response with high accuracy. Adjusted R2 is a modified R2 that has been adjusted for the number of terms in the model. If unnecessary terms are included in the model, R2 can be artificially high, but adjusted R2 =90.1 % may get smaller. The standard deviation of errors in the modeling, S=3.189.Comparing the p-value to a commonly used α-level = 0.05, it is found that if the p-value is less than or equal to α, it can be concluded that the effect is significant (shown in bold), otherwise it is not significant .

Table 10: Estimated Model Coefficients for SN ratios

Term	Coef	SE Coef	T	P
Constant	38.314	0.8056	47.556	0.000
Current 5	3.951	1.1394	3.468	0.007
Current 10	-2.361	1.1394	-2.072	0.068
Material aluminum	8.916	1.1394	7.826	0.000
Material Brass	-12.887	1.1394	-11.311	0.000
ton 200	-1.060	1.1394	-0.930	0.377
ton 500	-1.891	1.1394	-1.660	0.131
t 9	-1.390	1.1394	-1.220	0.253
t 10	-2.129	1.1394	-1.869	0.094
S =3.418	R-Sq = 94.8 %	R-Sq(adj) = 90.1%	--------	-------

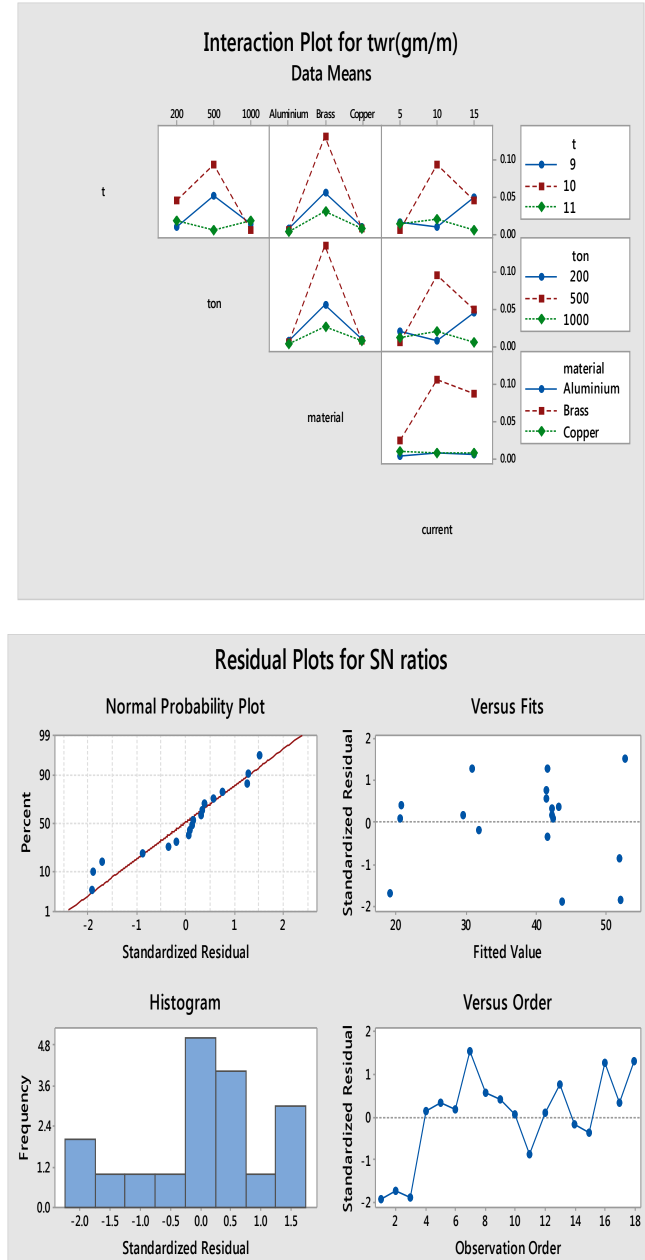


Fig. 7: Shows interaction and residual plot for TWR

6. CONCLUSION

The present work shows the use of taguchi method to find out optimal machining parameter. The S/N ratio for the test results were found out using the taguchi method. Machining parameters namely material, peak current (Ip), duty cycle (t) and pulse on time (Ton) is optimized to meet the objective. As a result of the study the following conclusions are drawn

1. The results reveal that the primary factor affecting the MRR is current subsequently followed by material, pulse on time and duty cycle and in case of TWR the primary factor

affecting TWR is material then peak current then duty cycle and at last pulse on time .

2. The optimized factor are the MRR is cupper, duty cycle (t) =11, pulse on time=200µsecond, peak current=5 amp and for TWR the optimized factors are brass, peak current=10 amp, pulse on time (ton) =500µsecond, duty cycle (t) =10

So by this research optimized parameter has been find out for which there will be maximum MRR and min TWR by using Taguchi Technique.

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