Research Paper

Optimization of Cutting Parameter in Edm Using Taguchi Method

Engineering

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ABSTRACT   *In this Project the complexity of electrical discharge machining process which is very difficult to determine optimal cutting parameters for improving cutting performance has been reported. Optimization of operating parameters is an important step in machining, particularly for operating unconventional machining procedure like EDM. The objective of this paper is to investigate the optimum cutting parameters for a work piece (SS-304) & tool material (Copper, Aluminum, Brass) combination on Fuzzy Logic Control based Electrical Discharge Machine. In order to produce any product with desired quality by machining, proper selection of process parameters is essential. This can be accomplished by Taguchi approach. The aim of the present work is to investigate the effect of process parameters on Material remove rate (MRR), Tool wear ratio (TWR), Surface roughness (SR) to obtain the optimal setting of these cutting parameter.*

1.1 Introduction of EDM :

Electric-discharge machining (EDM) is a non-conventional, thermo-electric process in which the material from work piece is eroded by a series of discharge sparks between the work and tool electrode immersed in a liquid dielectric medium. These electrical discharges melt and vaporize minute amounts of work material, which are then ejected and flushed away by the dielectric. This technique has been widely used in modern metal working industry for producing complex cavities in dies and moulds, which are otherwise difficult to create by conventional machining. EDM can provide an effective solution for machining hard conductive materials and reproducing complex shapes. EDM involves the phenomena such as: spark initiation, dielectric breakdown, thermo-mechanical erosion of metals. Metal removal process in EDM is characterized by nonlinear, stochastic and time varying characteristics. Many regression techniques have been used for modeling the EDM process. Unlike milling and drilling operations, operating speeds in EDM are very low. Large electric current discharge can enhance speeds but reduces the dimensional quality of machined surface. Similarly the material removal rate is also affected by other process parameters.

1.2 PRINCIPLE OF EDM

In this process the metal is removing from the work piece due to erosion case by rapidly recurring spark discharge taking place between the tool and work piece. Show the mechanical set up and electrical set up and electrical circuit for electro discharge machining. A thin gap about 0.025mm is maintained between the tool and work piece by a servo system shown in fig 1.1. Both tool and work piece are submerged in a dielectric fluid Kerosene/ EDM oil/ demonized water is very common type of liquid dielectric although gaseous dielectrics are also used in certain cases.

This fig.1.1 is shown the electric setup of the Electric discharge machining. The tool is mead cathode and work piece is anode. When the voltage across the gap becomes sufficiently high it discharges through the gap in the form of the spark in interval of from 10 of micro seconds. And positive ions and electrons are accelerated, producing a discharge channel that becomes conductive. It is just at this point when the spark jumps causing collisions between ions and electrons and creating a channel of plasma. A sudden drop of the electric resistance of the previous channel allows that current density reaches very high values producing an increase of ionization and the creation of a powerful magnetic field. The moment spark occurs sufficiently pressure developed between work and tool as a result of which a very high temperature is reached and at such high pressure and temperature that some metal is melted and eroded.
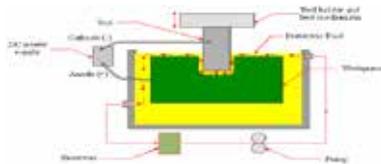

Fig. 1.1Set up of Electric discharge machining

Such localized extreme rise in temperature leads to material removal. Material removal occurs due to instant vaporization of the material as well as due to melting. The molten metal is not removed completely but only partially as the potential difference is withdrawn as the plasma channel is no longer sustained. As the plasma channel collapse, it generates pressure or shock waves, which evacuates the molten material forming a crater of removed material around the site of the spark.

In the present paper the design of experiment (DOE) and Taguchi method is used for optimization of process parameters. The objectives of optimization are (i) maximize the material removal rate (MRR), (ii) minimize the surface roughness value and (iii) maximize the Tool Wear Ratio (TWR). The process parameters considered in experiments include current; gap voltage and Tool material are usually the machining performances to evaluate the machining effect.

2 LITERTURE REVIEW

Kuriakose and Shunmugam (2005) used Genetic Algorithms (GA) for solving a multi objective problem in wire EDM process.

Kansal et al. (2005) adopted the response surface optimization scheme to select the parameters in powder mixed EDM process.

Keskinetal. (2006) used design of experiments (DOE) for the determination of the best machining parameters in EDM.

Tzeng and Chen (2007) employed a Taguchi fuzzy-based approach for solving the multi-objective optimization problems in high-speed EDM process.

Mandal et al. (2007) have shown the modeling procedure of EDM using neural networks and solution methodology using GA. More recently Yuan et al. (2008) illustrated the optimization process of highspeed wire EDM process using regression methods. In all the above cases multi-objective formulations are solved for online selection of design variables.

Lin et al. employed relational analysis for solving the complicated interrelationships between process parameters and the multiple performance measures of the EDM process.

Et al. used a user friendly fuzzy based system for the selection of electro discharge machining process parameters. Effect of other important parameters like current, voltage and machining time on TWR, SR, over cut and hardness is not considered.

3. Problem Formulation

3.1 Design Variables

The formulation of an optimization problem begins with identifying the underlying design variables, which are primarily varied during the optimization process. In this paper Tool Material, current, Gap Voltage , Ton and Toff are considered as design variables.

be maximized. In this paper, minimization of total machining time is considered as objective function.

3.2 Experimental equipment and design
An EDM machine, developed by SPARKONIX (I) LTD. was used as the experimental machine. The work material, electrode and the other machining conditions were as follows (1) Workpiece (anode) : SS-340;

☐ LENTH: 50 mm
☐ WIDTH: 50 mm
☐ THICKNESS:5mm

TABLE 1 Chemical Composition of Work Piece

Element	Weight %
C.	0.095%
Si	0.251%
Mn	0.490%
Fe	98.977%
Cr	0.047%
P	0.011%

(2)Electrode (cathode) : Aluminum , Brass , Copper

LENGTH: 40 mm
DIAMETER: 19 mm

TABLE 2 Properties of electrodes

Material	Thermal conductivity(W/m-K)	Boiling point (K)	Melting point (K)
Copper	401	2835.15	1357.77
Aluminum	237	2792.15	933.47
Brass	109	2624	900

(3) Dielectric fluid
A total of Five machining parameters (Tool material, Current, Gap Voltage , Ton & Toff) were chosen for the controlling factors and each parameters have levels as shown in Table 3.

Table 3 Process pa1rameters and their levels

Factor	LEVELS		
	Level 1	Level 2	Level 3
Tool Material	ALUMINIUM	BRASS	COPPER
Current (amp)	10	15	20
Spark Gap Voltage	30	40	50
Ton (µs)	6	8	10
Toff (µs)	5	7	9

Orthogonal Array :
A three-level L27(3**5) is selected for conducting the experiment, because in our consideration we have each 3 level for five factors Tool Material ,Current , Gap Voltage and Ton & Toff .

Table -4 Calculation Table of MRR, TWR and Surface Roughness

SR NO.	TOOL MATERIAL	CURRENT (Amp)	Gap VOLTAGE	Ton (µs)	Toff (µs)	MRR (mm3/min)	TWR	SR (µm)
1	ALUMINIUM	10	30	6	5	10.369	3.303	9.238
2	ALUMINIUM	10	30	6	7	11.086	1.561	9.259
3	ALUMINIUM	10	30	6	9	12.160	4.263	9.614
4	ALUMINIUM	15	40	8	5	20.355	4.110	7.514
5	ALUMINIUM	15	40	8	5	24.616	4.747	10.802
6	ALUMINIUM	15	40	8	9	46.941	11.536	10.435
7	ALUMINIUM	20	50	10	5	8.184	2.315	7.030
8	ALUMINIUM	20	50	10	7	35.294	14.663	4.733
9	ALUMINIUM	20	50	10	9	41.211	14.443	6.443
10	BRASS	10	40	10	5	7.576	1.738	7.574
11	BRASS	10	40	10	7	8.528	2.110	8.220
12	BRASS	10	40	10	9	8.993	2.331	10.149
13.	BRASS	15	50	6	5	8.135	0.466	6.806
14	BRASS	15	50	6	7	8.222	0.524	4.970
15	BRASS	15	50	6	9	11.973	4.951	10.036
16	BRASS	20	30	8	5	6.904	1.051	4.676
17	BRASS	20	30	8	7	6.988	0.978	6.034
18	BRASS	20	30	8	9	8.577	0.767	4.628
19	COPPER	10	50	8	5	21.766	32.948	9.175
20	COPPER	10	50	8	7	20.054	51.462	7.934
21	COPPER	10	50	8	9	14.824	54.434	7.459
22	COPPER	15	30	10	5	9.350	17.832	4.100
23	COPPER	15	30	10	7	1.270	5.748	8.001
24	COPPER	15	30	10	9	4.077	12.983	6.578
25	COPPER	20	40	6	5	54.370	35.175	9.700
26	COPPER	20	40	6	7	60.319	7.324	10.156
27	COPPER	20	40	6	9	28.249	7.031	11.053

3.3 CALCULATION OF MRR
The method used for the calculating the MRR is the weight difference of the work piece Initial and Final machining. The formula used for the ECM is given below.

$$MRR = \frac{W_I - W_f}{\rho * t}$$

Where, Wi =Weight before machining (in gm.)
Wf = Weight after machining (in gm.)
= density of work piece material. (In gm/mm3)
t = time consumed for machining. (In minutes)

The weight of the work piece and tool is taken on the very high precise weighing machine. Least count of the weighing machine is 0.001 gm. The density of wore piece is 0.00792 gm/mm3 .

3.4 CALCULATION OF TOOL WEAR RATIO :
First we calculate tool wear this formula is give below ,

$$TW = \frac{T_I - T_f}{\rho * t}$$

Where, Ti =Weight of tool before machining (in gm.)
Tf = Weight of tool after machining (in gm.)
= density of work piece material. (In gm/mm3)
(Al- 0.00256 ,Br – 0.00821, Cu- 0.00865 in gm/mm3)
t = time consumed for machining. (In minutes)

Tool wear ratio is defined as the volume of metal removed from the work piece to the volume of the material loss from the tool

$$TWR = \frac{MRR}{TW}$$

Where, TW =Tool wear rate.
MRR = Material Remove Rate.

3.5 MEASURMENT OF SURFACE ROUGHNESS :
Surface roughness is measured on a MITUTOYO MAKE PORT-ABLE DIGITAL SURFACE FINISH TESTER (MODEL: surf test set no: 178-923E). This equipment is very accurate and gives digital reading of the surface finish.

3.6 Solution Methodology :
Design of experiments (DOE) was introduced by R.A.Fisher in England in 1920's to study the effect of multiple variables si-multaneously. Design of Experiment is an engineering method-ology for obtaining product and process conditions, which are minimally sensitive to the various causes of variation, to pro-duce high-quality products with low development and manu-facturing costs. Arrangement or patterns for collection of data in a structured manner from the system by imposing treatments for each pattern is called design of experiments (DOE).To infer upon the behavior of a system or process using the experimen-tal data, we must concern ourselves with how to conduct exper-iments for data collection. This means that the project should be designed such that the affecting parameters can be quickly rec-ognized & their effect on system can be expressed analytically & precisely. For this purpose we need to determine the values of input parameters for the process which will give us the results.

Taguchi Method is a new engineering design optimization meth-odology that improves the quality of existing products and pro-cesses and simultaneously reduces their costs very rapidly, with minimum engineering resources and development man-hours. The Taguchi Method achieves this by making the product or process performance "insensitive" to variations in factors such as materials, manufacturing equipment, workmanship and op-erating conditions.

3.7 Analysis :
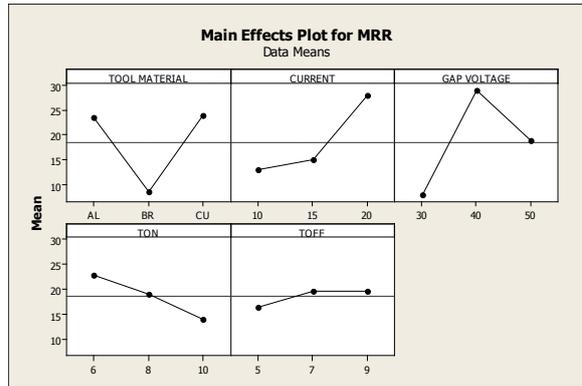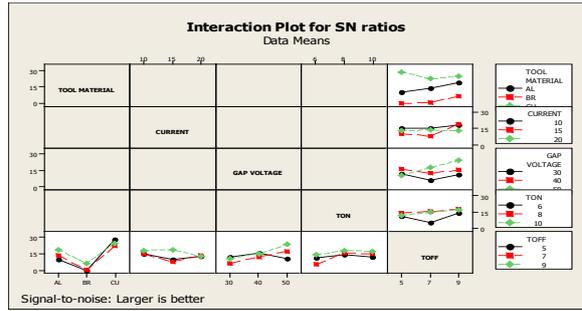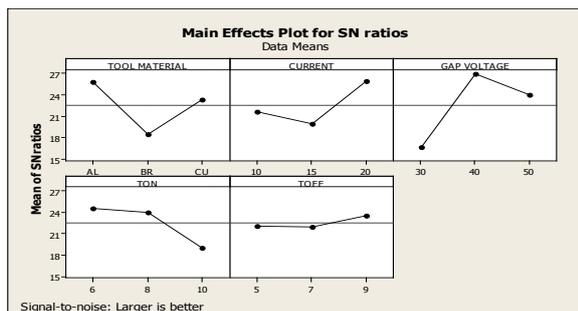Taguchi Orthogonal Array Design
L27(3**5)
Factors: 5
Runs: 27
Columns of L27(3**13) Array
1 2 3 4 5

Taguchi Analysis: MRR versus TOOL MATERIAL, CURRENT, GAP VOLTAGE, TON, TOFF
Response Table for Signal to Noise Ratios Larger is better :
10*log10 (sum(1/y**2)/n)

Level	TOOL MATERIAL	CURRENT	GAP VOLTAGE	TON	TOFF
1	25.76	21.60	16.55	24.48	22.02
2	18.41	19.91	26.89	24.00	21.91
3	23.25	25.91	23.98	18.94	23.49
Delta	7.35	6.00	10.34	5.54	1.58
Rank	2	3	1	4	5

Main Effects Plot for SN ratios
Data Means
Signal-to-noise: Larger is better

Interaction Plot for SN ratios
Data Means
Signal-to-noise: Larger is better

Main Effects Plot for MRR
Data Means

Taguchi Analysis: TWR versus TOOL MATERIAL, CURRENT, GAP VOLTAGE, TON, TOFF
Response Table for Signal to Noise Ratios Larger is better
10*log10 (sum(1/y**2)/n)

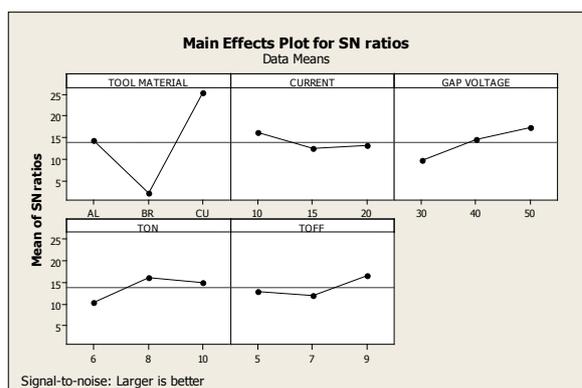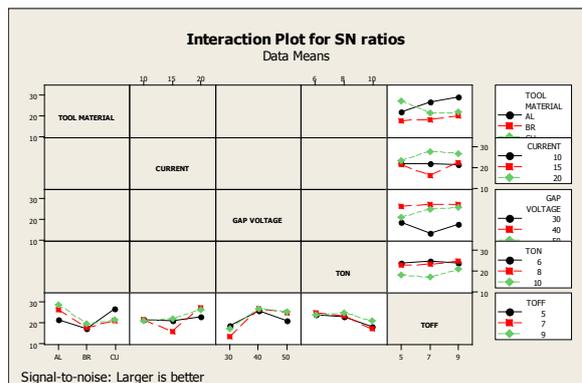| Level	TOOL MATERIAL	CURRENT	GAP VOLTAGE	TON	TOFF
1	14.188	16.086	9.695	10.405	12.761
2	2.024	12.353	14.538	16.032	12.013
3	25.216	12.989	17.195	14.992	16.655
Delta	23.192	3.734	7.500	5.627	4.642
Rank	1	5	2	3	4

Interaction Plot for SN ratios
Data Means
Signal-to-noise: Larger is better

Main Effects Plot for SN ratios
Data Means
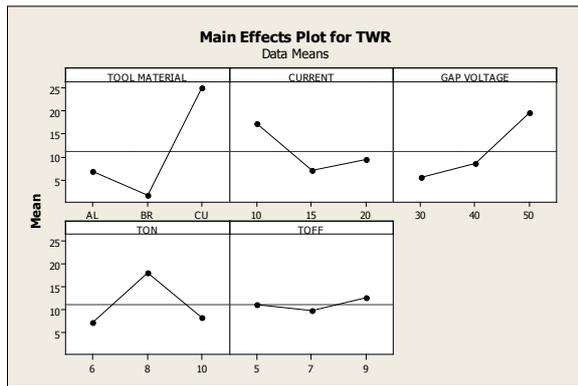Signal-to-noise: Larger is better

Main Effects Plot for TWR
Data Means

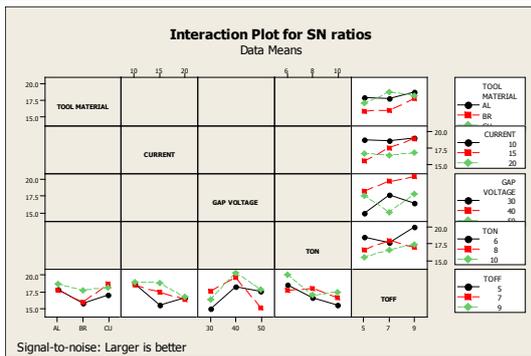**Taguchi Analysis: SR versus TOOL MATERIAL, CURRENT, GAP VOLTAGE, TON, TOFF**

Response Table for Signal to Noise Ratios Larger is better
10*log10 (sum(1/y**2)/n)

Level	TOOL MATERIAL	CURRENT	GAP VOLTAGE	TON	TOFF
1	18.16	18.78	16.37	18.85	16.96
2	16.55	17.32	19.48	17.29	17.50
3	18.01	16.63	16.88	16.59	18.26
Delta	1.62	2.15	3.11	2.26	1.30
Rank	4	3	1	2	5

Interaction Plot for SN ratios
Data Means

Signal-to-noise: Larger is better

Main Effects Plot for SN ratios
Data Means

Signal-to-noise: Larger is better

Main Effects Plot for SR
Data Means

General Linear Model: MRR versus TOOL MATERIAL, CURRENT, ...

Factor	Type	Levels	Values
TOOL MATERIAL	fixed	3	AL, BR, CU
CURRENT	fixed	3	10, 15, 20
GAP VOLTAGE	fixed	3	30, 40, 50
TON	fixed	3	6, 8, 10
TOFF	fixed	3	5, 7, 9

Analysis of Variance for MRR, using Adjusted SS for Tests

Source	DF Seq SS	Adj SS	Adj MS	F	P
TOOL MATERIAL	2 1378.1	1378.1	689	6.81	0.007
CURRENT	2 1177.8	1177.8	588.9	5.82	0.013
GAP VOLTAGE	2 1989.3	1989.3	994.7	9.83	0.002
TON	2 362.1	362.1	181.1	1.79	0.199
TOFF	2 65.3	65.3	32.6	0.32	0.729
Error	16 1618.6 1618.6	101.2			
Total	26 6591.2				

S = 10.0581 R-Sq = 75.44% R-Sq(adj) = 60.09%

General Linear Model: TWR versus TOOL MATERIAL, CURRENT, GAP VOLTAGE, T_{on} & T_{off}

Factor	Type	Levels	Values
TOOL MATERIAL	fixed	3	AL, BR, CU
CURRENT	fixed	3	10, 15, 20
GAP VOLTAGE	fixed	3	30, 40, 50
TON	fixed	3	6, 8, 10
TOFF	fixed	3	5, 7, 9

Analysis of Variance for TWR, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
TOOL MATERIAL	2	2708.21	2708.21	1354.10	21.94	0.000
CURRENT	2	508.08	508.08	254.04	4.12	0.036
GAP VOLTAGE	2	1003.55	1003.55	501.78	8.13	0.004
TON	2	640.98	640.98	320.49	5.19	0.018
TOFF	2	31.29	31.29	15.65	0.25	0.779
Error	16	987.35	987.35	61.71		
Total	26	5879.46				

S = 7.85553   R-Sq = 83.21%   R-Sq(adj) = 72.71%
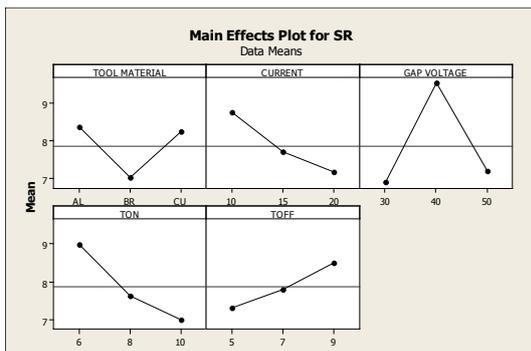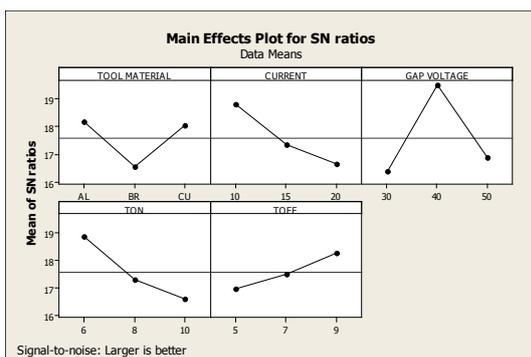
General Linear Model: SR versus TOOL MATERIAL, CURRENT ,GAP VOLTAGE, Ton & Toff

Factor	Type	Levels	Values
TOOL MATERIAL	fixed	3	AL, BR, CU
CURRENT	fixed	3	10, 15, 20
GAP VOLTAGE	fixed	3	30, 40, 50
TON	fixed	3	6, 8, 10
TOFF	fixed	3	5, 7,

Analysis of Variance for SR, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
TOOL MATERIAL	2	9.875	9.875	4.937	2.51	0.113
CURRENT	2	11.543	11.543	5.772	2.93	0.082
GAP VOLTAGE	2	36.997	36.997	18.499	9.41	0.002
TON	2	18.755	18.755	9.378	4.77	0.024
TOFF	2	6.294	6.294	3.147	1.60	0.233
Error	16	31.466	31.466	1.967		
Total	26	114.930				

S = 1.40235 R-Sq = 72.62% R-Sq(adj) = 55.51%

General Regression Analysis: MRR versus CURRENT, GAP VOLTAGE, TON, TOFF.
Regression Equation
TOOL
MATERIAL
AL   MRR = -9.03817 + 1.49713 CURRENT + 0.549327 GAP
      VOLTAGE - 2.23335 TON + 0.833183 TOFF
BR   MRR = -23.9627 + 1.49713 CURRENT + 0.549327 GAP
      VOLTAGE - 2.23335 TON + 0.833183 TOFF
CU   MRR = -8.58673 + 1.49713 CURRENT + 0.549327 GAP
      VOLTAGE - 2.23335 TON + 0.833183 TOFF

General Regression Analysis: TWR versus CURRENT, GAP VOLTAGE, TON, TOFF.
Regression Equation
TOOL
MATERIAL
AL   TWR = -14.6873 - 0.782242 CURRENT + 0.709557 GAP
      VOLTAGE + 0.26575 TON + 0.3834 TOFF
BR   TWR = -19.8012 - 0.782242 CURRENT + 0.709557 GAP
      VOLTAGE + 0.26575 TON + 0.3834 TOFF
CU   TWR = 3.53445 - 0.782242 CURRENT + 0.709557 GAP
      VOLTAGE + 0.26575 TON + 0.3834 TOFF

General Regression Analysis: SR versus CURRENT, GAP VOLTAGE, TON, TOFF.
Regression Equation
TOOL
MATERIAL
AL   SR = 12.0993 - 0.157428 CURRENT + 0.0136556 GAP
      VOLTAGE - 0.500125 TON + 0.293931 TOFF
BR   SR = 10.7687 - 0.157428 CURRENT + 0.0136556 GAP
      VOLTAGE - 0.50012 TON + 0.293931 TOFF
CU   SR = 11.9978 - 0.157428 CURRENT + 0.0136556 GAP
      VOLTAGE - 0.500125 TON + 0.293931 TOFF

4.Conclusion :
After the Taguchi analysis we give a larger is better for the Signal to ratio form equation $10*log10 (sum(1/y^{**}2)/n)$ and we get result Gap Voltage is more significant for MRR and SR and Toll Material is more significant for TWR. This may be noted on graph and analysis result to first rank.
Taguchi designs traditionally focus on main effects, but it is important to test suspected interactions. Use the interactions plots to determine whether the effect of one factor on a response characteristic depends on the level of another factor. If the lines are parallel to each other, then there is no interaction between the two factors. If the lines are not parallel to each other, then there is an interaction between the two factors.
In general liner model we analyses that the value of "P " is less than 0.005 then this factor is more significant from MRR,TWR & SR General Linear Model analysis for MRR GAP VOLTAGE P value is 0.002 ,TWR TOOL MATERIAL P value is 0.000 and for SR GAP VOLTAGE P value is 0.002 then we conclude GAP Voltage is more significant for MRR & SR AND Tool Material is more significant for TWR.

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