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OPTIMIZATION OF PROCESS PARAMETERS IN ELECTRICAL DISCHARGE MACHINING PROCESS BY USING TAGUCHI METHOD

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ABSTRACT
The objective of this research study is to investigate the optimal process parameters of Electric Discharge Machining on RENE80 nickel super alloy material with aluminum as a tool electrode. The effect of various process parameters on machining performance is investigated in this study. The input parameters considered are current, pulse on time and pulse off time are used for experimental work and their effect on Material Removal Rate, Tool Wear Rate and Surface Roughness. The Taguchi method is used to formulate the experimental layout, ANOVA method is used to analysis the effect of input process parameters on the machining characteristics and find the optimal process parameters of Electric Discharge Machining. The results of the present work reveal that proper selection of input parameters will play a significant role in Electric Discharge Machining.
KEYWORDS: Electrical Discharge Machining, orthogonal array, metal removal rate, tool wear rate ANOVA.

I. INTRODUCTION
Electric Discharge machining (EDM) is a thermo-electric, non-traditional machining process used to machine precise and intricate shapes on difficult to cut materials and super tough metals such as ceramics, maraging steels, cast-alloys, titanium which are widely used in defence and aerospace industries. Electrical energy is used to generate electrical sparks and material removal mainly occurs due to localized melting and vaporization of material which is carried away by the dielectric fluid flow between the electrodes. The performance of this process is mainly influenced by many electrical parameters like, current, voltage, polarity, and pulse on time, pulse of time, electrode gap and also on non-electrical parameters like work and tool material, dielectric fluid pressure. All these electrical and non electrical parameters have a significant effect on the EDM output parameters like, Metal Removal Rate (MRR), Tool Wear Rate (TWR) and Surface Roughness(SR). The EDM is very complex and stochastic process and is very difficult to determine the optimal machining parameters. In the present study the output responses MRR, TWR and SR are conflicting in nature. MRR reflects the productivity and tool wear reflects the accuracy of the product. So in this work it was proposed to study the effects of different input parameter current, pulse on time and pulse off time on Material removal rate, Tool wear rate and Surface roughness with EDM oil as a dielectric. The experimental design has been done by using Taguchi technique. The response has been analyzed using S/N ratio and analysis of Variance.

II. EXPERIMENTAL DETAILS
The experiments were conducted on V3525 precision die sink electric discharge machine as shown in Fig.1 which consist a work table, a servo control system and a dielectric supply system. The machine has 8 current settings from 3A to 24A, 9 settings of pulse on time, 9 settings of pulse off time and spark gap of 50-75 microns The experiments are conducted on RENE80 Nickel Super alloy(Russian grade -RZ) and the work piece dimensions are 70 mm x 35 mm x 5 mm. Work piece material properties are: Hardness (HRC)= 43-45, density (g/cm 3)=8.16, Ultimate tensile strength (Kg/mm 2) =85, Elongation % =3, Creep strength (0 C) = 975. Thermal conductivity (W/m 0 K)= 11.50. The tool material used is aluminum- density 2.70 gm/cm 3 and thermal conductivity 237 w/m 0 k and the machining is done with straight polarity. EDM oil Grade 30 is used as the dielectric fluid and the experiments were performed for a particular set of input parameters. The number of experiments and, input levels are decided based on the design of experiments and the input parameters and their levels are presented in Table 1. The MRR and TWR are calculated using digital balance of accuracy 1mg and

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the machining time is using digital watch of accuracy 1 microsecond and the surface roughness is measured using Taylor Hobson Talysurf machine for a sampling length of 5mm.

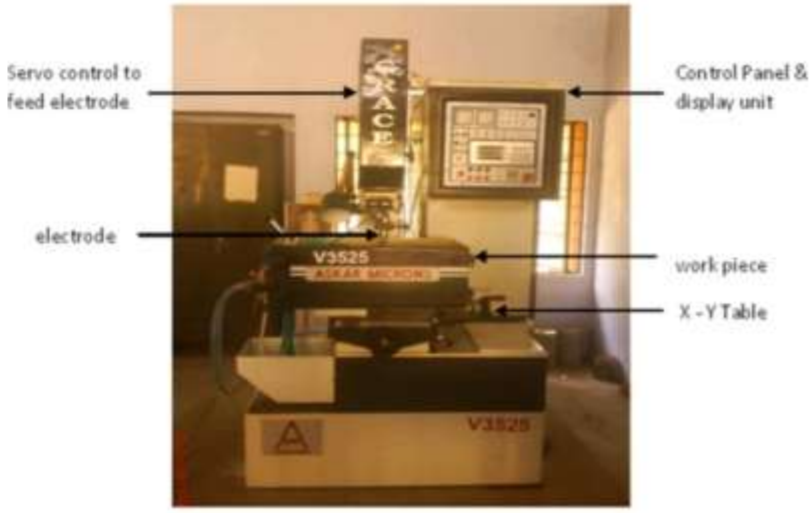

Fig. 1: The Experimental equipment.

The MRR and TWR are calculated using the following expressions.
MRR= 1000×(W b - W a) /t mg/min
TWR= 1000×(T b –T a) /t mg/min
W b : Weight of the work-piece before machining
W a : Weight of the work-piece after machining
T b : Weight of the tool before machining
T a : Weight of the tool after machining
t: Machining time (minutes)

Table 1: Input Parameters Levels.

Input	**Parameters**	**Current**	**(amp)**
Pulse on	Time (µs)	Pulse off Time	(µs)
Symbol A B C	Level1 6 10 10	Level2 15 20 20	Level3 24 30 50
Input	Parameters	Current	(amp)
Pulse on	Time (µs)	Pulse off Time	(µs)

III. OVER VIEW OF TAGUCHI METHOD

Taguchi method involves reducing the variation in a process through robust design of experiments. The overall objective of the method is to produce high quality product at low cost to the manufacturer. Taguchi developed a method for designing experiments to investigate how different parameters affect the mean and variance of a process performance characteristic that defines how well the process is functioning. The experimental design proposed by Taguchi involves using orthogonal arrays to organize the parameters affecting the process and the levels at which they should be varied; it allows for the collection of the necessary data to determine which factors most affect product quality with a minimum amount of experimentation, thus saving time and resources. Taguchi design method is to identify the parameter settings which render the quality of the product or process robust to unavoidable variations in external noise. The relative "quality" of a particular parameter design is evaluated using a generic signal- to-noise (S/N) ratio. Depending on the particular design problem, different S/N ratios are applicable, including "lower is better" (LB), "nominal is best" (NB), or "higher is better" (HB).

As the objective is to obtain the high material removal rate , low tool wear rate, and best surface finish, it is concerned with obtaining larger value for MRR, smaller value of tool wear rate and smaller value of surface roughness .Hence, the required quality characteristic for high MRR is larger the better, which states that the output must be a large as possible, and for tool wear rate and surface roughness is smaller the better, which states that the output must be as low as possible.

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IV. DESIGN OF EXPERIMENTS AND DATA ANALYSIS

Based on L 9 orthogonal array experiments are conducted on RENE80 nickel super alloy with aluminum tool and EDM grade 30 oil as dielectric medium for different experiment levels which are show in Table.2. To achieve validity and accuracy each test is repeated three times. Particular attention was paid to ensure that the operating conditions permitted the effective flushing of machining debris from the working region. The experiments were performed with the bottom surface of the electrode flat and parallel to the work surface.

Table 2: L 9 Orthogonal Array.

Expt. No	A	B	C
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

V. ANALYSIS OF VARIENCE (ANOVA)

The knowledge of the contribution of individual factors is critically important for the control the final response. The analysis of variance (ANOVA) is a common statistical technique to determine the percent contribution of each factor for results of the experiment. It calculates parameters known as sum of squares SS, degree of freedom (DOF), variance and percentage of each factor. Since the procedure of ANOVA is a very complicated and employs a considerable of statistical formula. The Sum of Squares SS(tr) is a measure of the deviation of the experimental data from the mean value of the data[8]. The Fisher's ratio is also called F value. The principle of the F test is that the larger value for a particular parameter, the greater the effect on the performance characteristics due to the change in that parameter. F value is defined as the ratio of Mean square for the term to Mean square for the error term. All these statistical calculations are done in MINI TAB 6.0 software.

Table 5.1: Experimental results of different trials.

Exp No	MRR				TWR				SR
	T1	T2	T3	AVG	T1	T2	T3	AVG	AVG
1	21	17	18.5	18.8	6	4.5	4	4.83	3.67
2	10	7	8.5	8.5	4.8	5.6	5.3	5.2	5.25
3	6.5	5.5	16.5	9.5	2.6	3.4	4.3	3.4	3.94
4	121	127	137	128.3	24.5	25.3	29	26.3	4.18
5	76.5	73	113	87.5	13.33	11.5	19.3	14.71	5.15
6	56.5	52	50	52.8	9	9.1	11	9.7	6.46
7	250	255	256	253.6	49.33	50.67	45	48.3	5.99
8	180	150	165	165	37.16	38	31.5	35.5	5.94
9	222	210	205	212.3	34.6	35	32	33.8	6.21

Table.5.2: S/N ratios of different experiments for MRR,TWR and SR.

Expt. No.	. S/N ratio of MRR	S/N ratio of TWR	S/N ratio of SR

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1	25.1199	-13.9271	-11.2933
2	19.4626	-14.6960	-14.4032
3	15.1175	-7.81870	-11.9099
4	41.9729	-28.4649	-12.4235
5	37.9195	-22.6899	-14.2361
6	34.2530	-20.0260	-16.2047
7	48.0610	-33.7844	-15.5485
8	44.2916	-29.7173	-15.4757
9	46.3654	-30.7564	-15.8618

Table.5.3: ANOVA results for MRR

Source	DOF	Seq. SS	Adj. MS	F
Current	2	59569.3	29784.7	1004.49
Pulse on time	2	4249.1	2124.5	71.65
Pulse off time	2	2532.9	1266.5	42.71
Residual Error	2	59.3	29.7	
Total	8	66410.6		
DF- Degree of freedom, SS- Sum of squares, MS- Mean squares(variance), F- Ratio of variance of a source to variance of error				

Table.5.4: ANOVA Results for TWR.

Source	DOF	Seq. SS	Adj. MS	F
Current	2	1744.02	872.01	82.06
Pulse on time	2	229.18	114.59	10.78
Pulse off time	2	90.09	45.04	4.24
Residual Error	2	21.25	10.63	
Total	8	2084.53		

Table 5.5: ANOVA results for SR.

Source	DOF	Seq. SS	Adj. MS	F
Current	2	4.6651	2.33254	1.97
Pulse on time	2	1.5551	0.77754	0.66
Pulse off time	2	0.1643	0.08214	0.07
Residual Error	2	2.3688	1.18441	
Total	8	8.7533		

Table.5.6: Response Table for Means of MRR

Level	Current	Pulse on Time	Pulse off Time
1	11.04	132.16	77.84
2	85.27	84.00	114.33
3	208.32	88.47	112.45
Delta	197.28	48.47	36.49
Rank	1	2	3

Table.5.7: Response Table for Means of TWR

Level	Current	Pulse on Time	Pulse off Time
1	4.287	26.787	15.203
2	16.720	16.557	22.143
3	38.000	15.663	21.660

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Delta	33.713	11.123	6.940
Rank	1	2	3

Table.5.8: Response Table for Means of SR

Level	Current	Pulse on Time	Pulse off Time
1	4.287	4.613	5.357
2	5.263	5.447	5.213
3	6.047	5.537	5.027
Delta	1.760	0.923	0.330
Rank	1	2	3

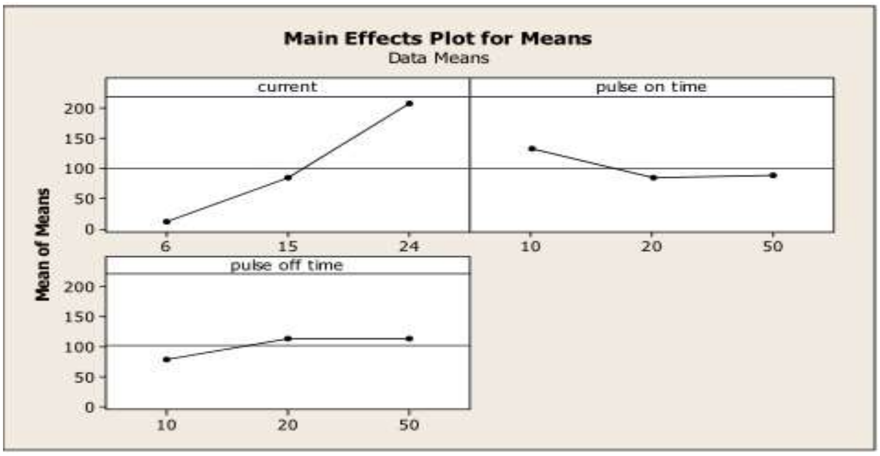

Fig. 5.1: Main effect plot of mean value for MRR.

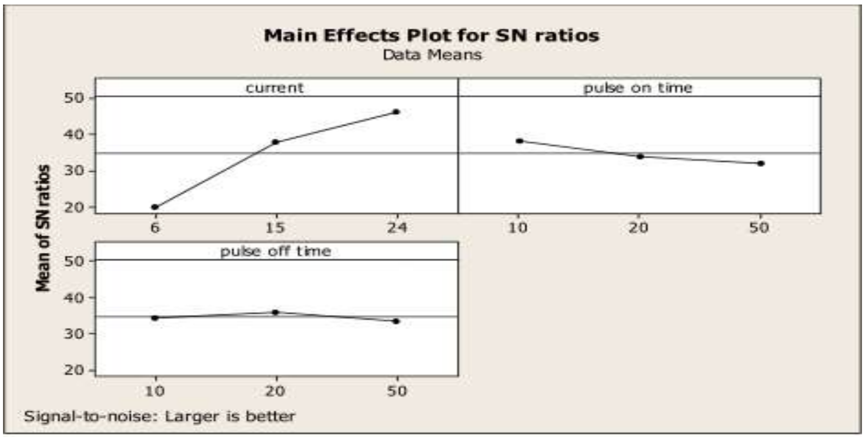

Fig. 5.2: Main effect plot of S/N ratio for MRR.

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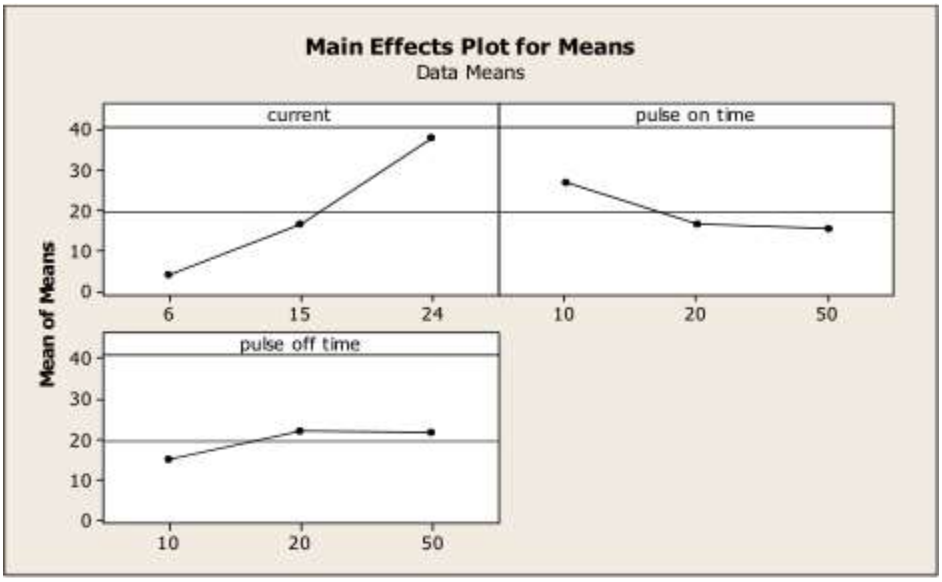

Fig. 5.3: Main effect plot of mean value for TWR.

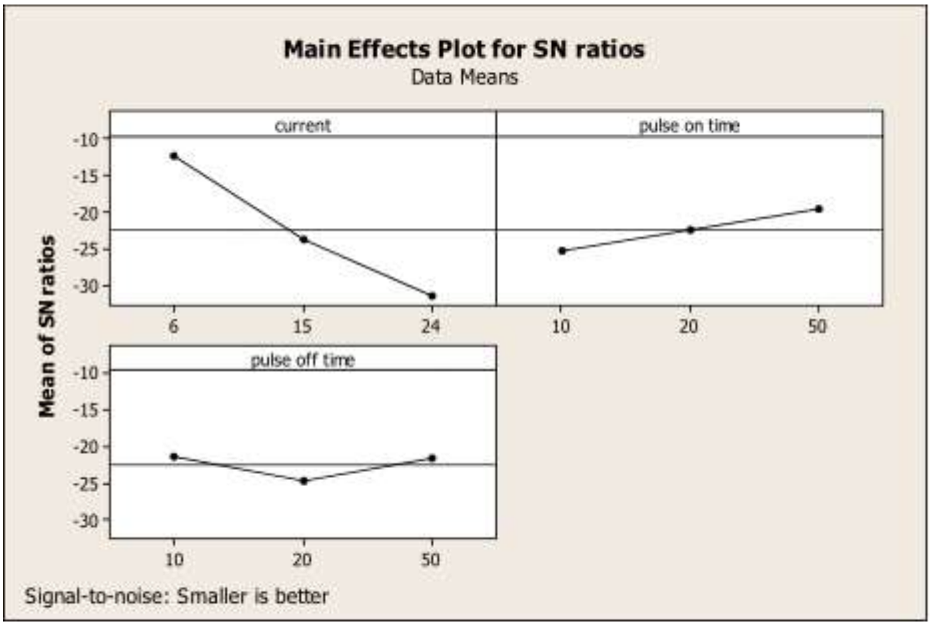

Fig. 5.4: Main effects plot of S/N ratio for TWR

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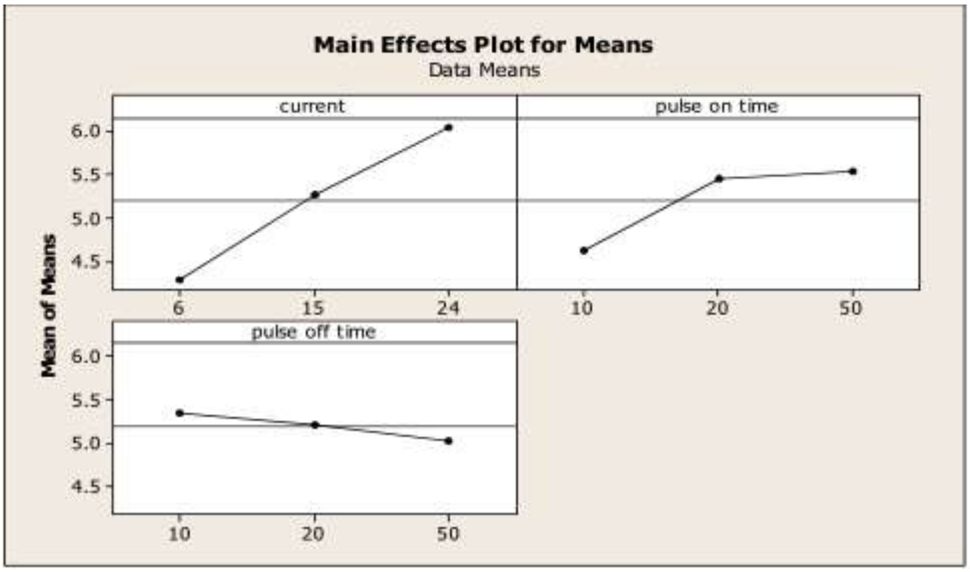

Fig. 5.5: Main effects plot of mean value for SR

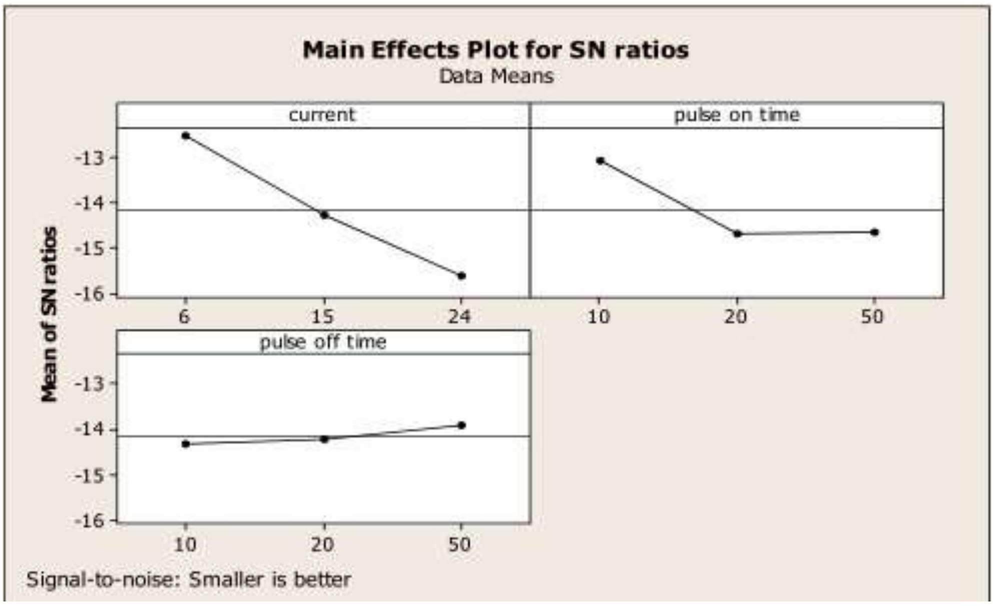

Fig. 5.6: Main effects plot of S/N ratio for SR.

VI. EXPERIMENTAL RESULTS AND ANALYSIS

After the collection of experimental data the calculated S/N ratio value for MRR,TWR and SR is shown in the table no.4 The ANOVA results for MRR ,TWR and SR is shown in table no.5.3, 5.4and 5.5 respectively and Response Table for Means of MRR,TWR and SR is shown in table no.5.6, 5.7and 5.8 respectively. Current , pulse on time and pulse of time is assigned as rank 1, 2, and 3 respectively according to their larger value of delta. Rank 1 means highest contribution factor for the MRR,TWR and SR and 3 means lowest contribution

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factor for MRR,TWR and SR. Pulse off time is the least contribution parameter. From the figure no. 5.1, it is observes that MRR goes on increasing with higher values of current. MRR has highest value at current 24A. From the figure no. 5.3, TWR has lowest value at current 6A, pulse-on time 50µs and pulse off time value at 10µs. For current 6A, pulse-on time 6µs and pulse off time value at 50µs the surface finish is better than other values which shown in the figure no. 5.5.

6.1 Optimum design for MRR, TWR and SR

In the experimental analysis, main effect plot of S/N ratio for MRR, TWR and SR is used for estimating the S/N ratio of MRR with optimal design condition. As shown in the figure no.5.2, MRR has highest value at level 3 for current, level 1 for pulse on time and level 3 for pulse off time.

As shown in the figure no.5.4, TWR has lowest value at level 1 for current, level 3 for pulse on time and level 1 for pulse off time.

SR has lowest value at level 1 for current, level 1 for pulse on time and level 3 for pulse off time which shown in the figure no.5.6.

VII. CONCLUSIONS

The result shows that current, pulse on time and pulse off time have significant effect on MRR,TWR and SR. The results of the present work reveal that proper selection of input parameters will play a significant role in Electric Discharge Machining.

- The MRR is increasing with increase in current.
- MRR is decreasing initially with increase in the pulse on time and increasing later with an increase in pulse on time.
- MRR is increasing with increase in the pulse off time but the increase is less as compared to pulse on time.
- TWR is increasing linearly with increase in the current.
- The TWR is decreasing with increase in pulse on time, when increase in pulse off time the TWR is increasing.
- The SR is increasing with increase in current and pulse on time but decreasing with increase in pulse off time.
- For optimum MRR, A3B1C3 levels must be selected and for optimum TWR, A1B3C1 levels and for optimum SR, A1 B1 C3 must be selected.

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