An Experimental Investigation of Machining Parameters for EDM using Electrode Shape Configuration of AISI P20 Tool Steel

Nikhil Rajan[1] Abhijeetsinh Makwana[2] Dr. Purushottam S. Dange
[1]PG Scholar [2]Assistant Professor
[1,2]Department of Mechanical Engineering
[1]SVBIT, GTU Ahmedabad, Gujarat, India [2]Shree Swaminarayan Institute of Technology, GTU Ahmedabad, Gujarat, India

Abstract— The objective of this research is to study the influence of Process parameters and electrode shape configuration on the Machining characteristics of die sinking EDM. The present work aims to study the effect of different electrode shapes (Circular, rectangular and triangular) With constant cross sectional area of 280 mm2 on material removal rate (MRR), surface roughness (SR) and Electrode wear rate (EWR) for AISI P20 tool steel workpiece material and pure copper As electrode material. The optimization of the parameters of the EDM machining will be carried out by using the taguchi's method for design of experiments (DOE). The objective of the analysis is to identify the Optimum electrode shapes in terms of higher MRR, minimum EWR and excellent surface finish. The different parameters considered while carrying out the experiments on the Die-Sinking EDM will be the current applied, pulse on time and pulse off time required etc.

Key words: EDM, Electrode Shapes, DOE, Parameter Analysis

I. Introduction

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-tomachine 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 b y EDM has to be electrically conductive.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. In EDM, as has been discussed earlier, material removal mainly occurs due to thermal evaporation and melting. As thermal processing is required to be carried out in absence of oxygen so that the process can be controlled and oxidation avoided.

II. Literature review

In this paper few selected research paper related to Die-sinker EDM and the studies carried out in these papers are mainly concerned with the different electrode shape configuration and EDM input parameters such as current, voltage, pulse on time, duty cycle, etc.

M. S. Sohani et al. [1] studied Investigations into the effect of tool shapes with size factor consideration in sink electrical discharge machining (EDM) process. He presents paper with the application of response surface methodology (RSM) for investigating the effect of tool shapes such as triangular, square, rectangular, and circular with size factor consideration along with other process parameters like discharge current, pulse on-time, pulse off-time, and tool area. Also The RSMbased mathematical models of material removal rate (MRR) and tool wear rate (TWR) have been developed using the data obtained through central composite design. He finally concluded that the best tool shape for higher MRR and lower TWR is circular, followed by Triangular, rectangular, and square cross sections. From the parametric analysis, it is also observed that the interaction effect of discharge current and pulse on-time is highly significant on MRR and TWR, whereas the main factors such as pulse off-time and tool area are statistically significant on MRR and TWR.

Rajmohan T et al. [2] conducted Optimization of Machining Parameters in Electrical Discharge Machining (EDM) of 304 Stainless Steel using copper as a tool material. Input and output parameters were Pulse on Time, Pulse off Time, Voltage, Current and Material Removal Rate. Using taguchi"s L9 OA and also using ANOVA technique. They finally concluded that the current and pulse off time are the most significant machining parameter for MRR in EDM of 304 Stainless Steel.

T. Muthuramalingam et al. [3] has studied the Application of Taguchi-grey multi responses optimization on process parameters in electro erosion. This multi response optimization of the electrical discharge machining process has been conducted with AISI 202 stainless steel with different tool electrodes such as copper, brass and tungsten carbide. Gap voltage, discharge current and duty factor have been used as electrical excitation parameters with different process levels. Taguchi L27 orthogonal table has been assigned for conducting experiments with the consideration of interactions among the input electrical process parameters. Material removal rate, electrode wear rate and surface roughness have been selected as output parameters. From the experimental results, it has been found that the electrical conductivity of the tool electrode has the most influencing nature on the machining characteristics in EDM process.

T. M. Chenthil Jegan et al. [4] has studied Determination of Electro Discharge Machining Parameters in AISI 202 Stainless Steel Using Grey Relational Analysis. Input and output parameters were Discharge Current, Pulse on Time, Pulse off Time and Material Removal Rate, Surface Roughness. The result shows that Discharge Current was the main parameter affecting the MRR. Hence by properly adjusting the control factors, work efficiency and product quality can be increased.

D. Gurguí et al. [5] investigated Influence of the Process Parameters to Manufacture Micro-cavities by Electro Discharge Machining (EDM). In this research the application of the conventional EDM process to manufacture micro cavities with the objective to obtain how the process parameters could effects on the result. As a result the dimensions and shape of the microcavities were analyzed. Finally the results provide recommendations of operating conditions for better micro-cavities manufacturing in stainless steel 316L.

III. MATERIALS AND METHODS

The pure copper with 99.96 % is used as a tool material because of its higher MRR and less TWR and yields a better surface finish. The pure copper tools with constant cross sectional area of 280mm2 and different shapes like triangular, rectangular, and circular are used to erode a AISI P20 workpiece. The tool material is a pure electrolytic copper (99.9% Cu).

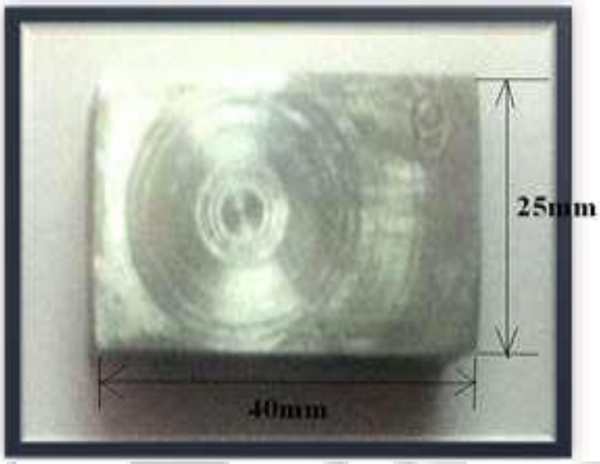

Fig. 1: Raw material SS 316 plates as per required dimensions

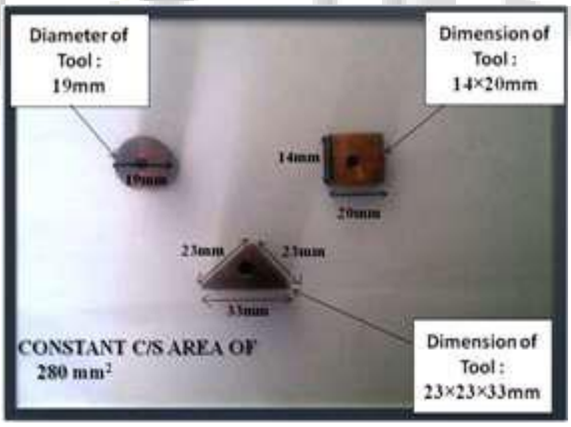

Fig. 2: Raw material pure copper (electrode shapes) as per required dimensions

IV. EXPERIMENT DETAILS

In the present investigation, the experiments were performed in an "S25 Sparkonix" EDM machine. The impulse flushing of kerosene (dielectric fluid) was employed throughout the experimental investigations. The schematic diagram of the experimental setup is shown in Fig. 3.

Fig. 3: Experimental Setup (S25 Sparkonix EDM)

V. DESIGN OF EXPERIMENTS

FACTORS	LEVEL 1	LEVEL 2	LEVEL 3
Current	10	15	20
Pulse on Time	6	8	7
Pulse off Time	5	7	6

Table 1: Factors & Their Levels

SR NO.	CURRENT (Amp.)	PULSE ON TIME (µs)	PULSE OFF TIME(µs)
1	10	6	5
2	10	8	7
3	10	7	6
4	15	6	7
5	15	8	6
6	15	7	5
7	20	6	6
8	20	8	5
9	20	7	7

Table 2: Taguchi's L9 Orthogonal Array

VI. FINAL EXPERIMENTS AS PER DOE TABLE

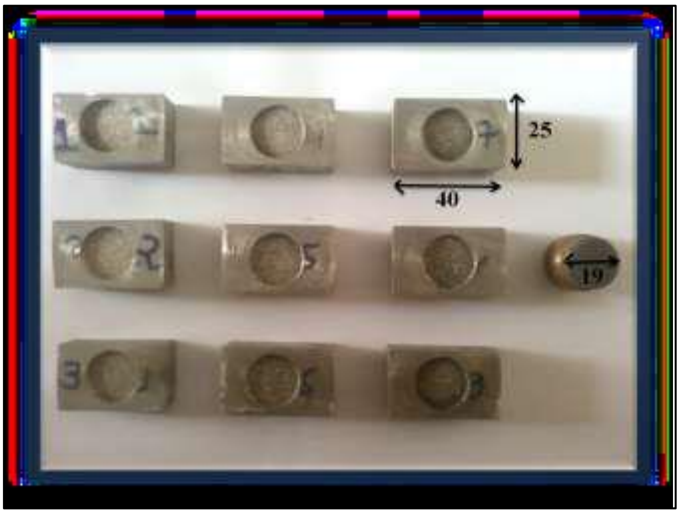

Fig. 4: with Circular Tool

Fig. 5: with Triangular Tool

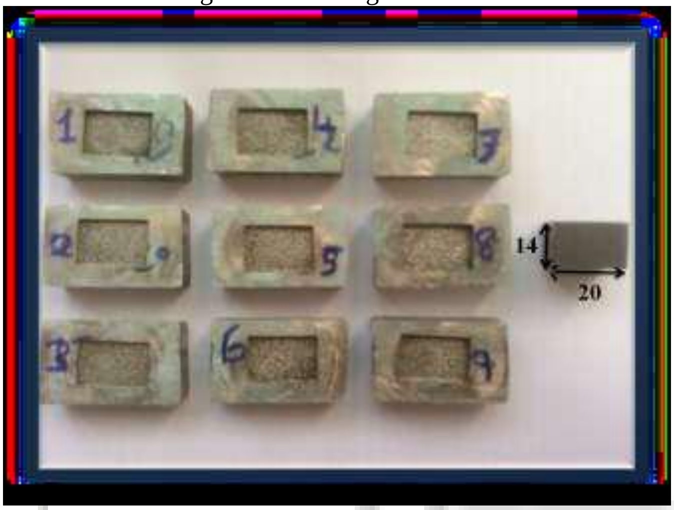

Fig. 6: with Rectangular Tool

VII. RESPONSE MEASURES

S R N O.	SH AP E	I	T ON	T OF F	MRR (mm^3/min)	EWR (gm/min)	SR (µm)
1		10	6	5	44.826	0.001505	10.9022
2		**10**	**8**	**7**	48.532	**0.000804**	19.2010
3		**10**	**7**	**6**	31.398	0.001164	**9.8011**
4		15	6	7	51.612	0.004197	12.2055
5		15	8	6	71.592	0.004155	17.0260
6		15	7	5	72.769	0.002857	23.7787
7		20	6	6	75.926	0.006925	16.3809
8		**20**	**8**	**5**	**91.615**	0.006125	18.6624
9		20	7	7	85.368	0.007463	21.4050
10		10	6	5	29.991	0.003263	11.4422
11		10	8	7	30.594	0.001975	19.2414
12		10	7	6	37.051	0.002867	10.1080
13		15	6	7	54.891	0.005771	13.0221
14		15	8	6	49.601	0.003840	17.7259
15		15	7	5	56.105	0.003537	23.7922
16		20	6	6	66.168	0.004780	16.8874
17		20	8	5	68.513	0.008403	18.7841
18		20	7	7	59.513	0.005343	21.5472
19		10	6	5	34.672	0.001843	11.4351
20		10	8	7	29.076	0.001549	19.2241
21		10	7	6	38.305	0.003273	10.0102
22		15	6	7	52.830	0.005769	12.9151
23		15	8	6	66.129	0.007092	17.5571
24		15	7	5	70.236	0.004944	23.6810
25		20	6	6	87.590	0.009331	16.8705
26		20	8	5	77.446	0.006711	18.6921
27		20	7	7	73.734	0.004178	21.4420

VIII. RESULT & DISCUSSION

In this chapter, the optimization of the parameters of the EDM machining will be carried out by using the taguchi"s method for design of experiments (DOE). The objective of the analysis is to identify the Optimum electrode shapes in terms of higher MRR, minimum EWR and excellent surface finish.

A. For MRR

Level	Electrode shape	Current	Pulse on time	Pulse off time
1	35.64	31.01	34.42	35.14
2	33.66	35.56	34.84	34.81
3	34.83	37.56	34.87	34.19
Delta	1.98	6.56	0.46	0.95
Rank	**2**	**1**	**4**	**3**

Table 3: Response Table for Signal to Noise Ratios for MRR, Larger is better

From Response table 5 for Signal to noise ratio larger is better for MRR, it is seen that 1 rank is given to current so current is most significant for MRR, followed by electrode shapes and pulse on time, pulse off time are less significant. In 1 Rank having 37.56 is larger S/N ratio for level 3 so, I.e. 20 A is more significant.

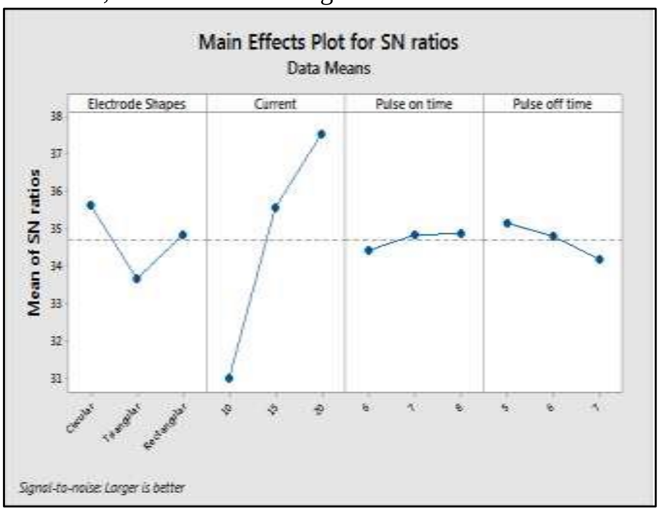

Fig. 7: Main Effects Plot for SN Ratio for MRR

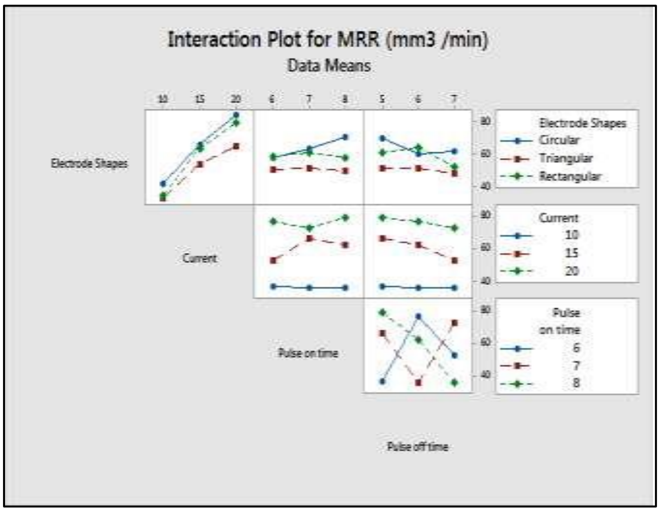

Fig. 8: Interaction Plot for MRR

B. *For EWR*

Level	Electrode shape	Current	Pulse on time	Pulse off time
1	50.34	54.70	47.57	48.46
2	47.79	46.89	48.98	47.60
3	47.35	43.89	48.93	49.43
Delta	2.99	10.81	1.41	1.83
Rank	2	1	4	3

Table 4: Response Table for Signal to Noise Ratios for EWR, Smaller is better

From Response table 6 for Signal to noise ratio Smaller is better for EWR, it is seen that 1 rank is given to current so current is Most significant for EWR, followed by electrode shapes and pulse on time, pulse off time are less significant. In 1 Rank having 43.89 is Smaller S/N ratio for level 3 so, I.e. 20 A is more significant.

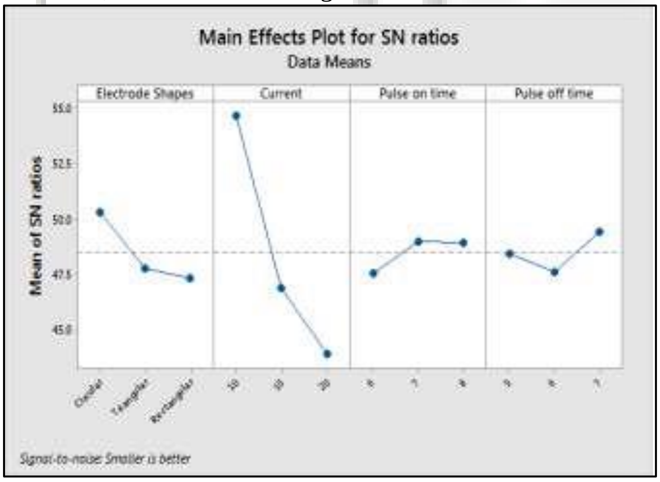

Fig. 9: Main Effects Plot for SN Ratio for EWR

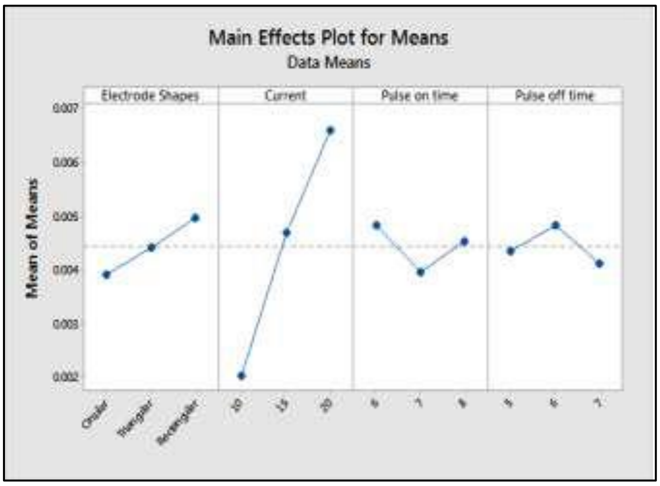

Fig. 10: Main Effects Plot for Means for EWR

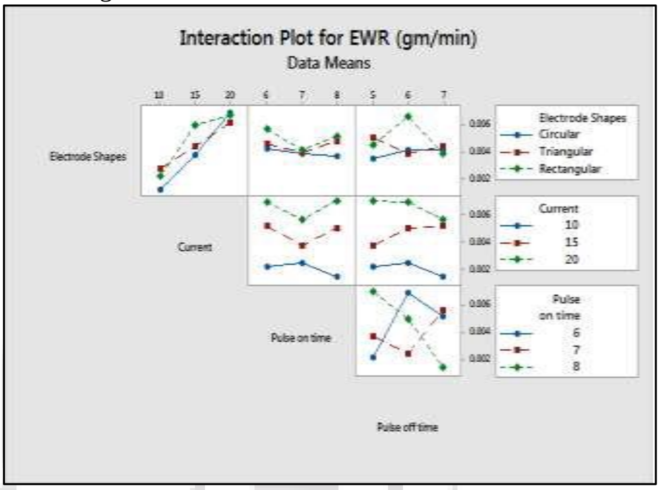

Fig. 11: Interaction Plot for EWR

C. *For SR*

Table 5 Response Table for Signal to Noise Ratios for SR, Smaller is better

Level	Electrode shape	Current	Pulse on time	Pulse off time
1	-24.05	-22.23	-22.52	-24.66
2	-24.27	-24.81	-24.71	-23.09
3	-24.23	-25.51	-25.32	-24.80
Delta	0.22	3.29	2.79	1.71
Rank	4	1	2	3

From Response table for Signal to noise ratio Smaller is better for SR, it is seen that 1 rank is given to current so current is significant for SR, followed by pulse on time And electrode shapes, pulse off time are less significant. In 1 Rank having -25.51 is Smaller S/N ratio for level 3 so, i.e. 20 A is more significant.

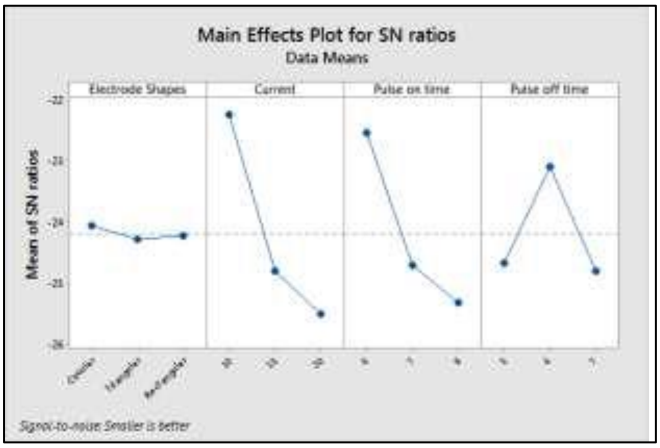

Fig. 12: Main Effects Plot for SN Ratio for SR

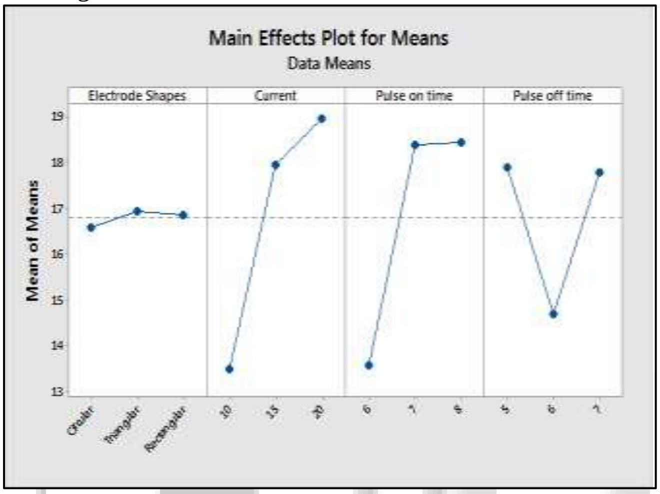

Fig. 13: Main Effects Plot for Means for SR

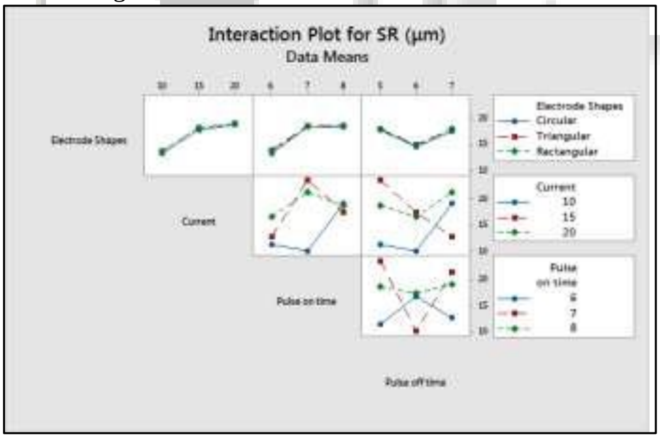

Fig. 14: Interaction Plot for SR

IX. CONCLUSION

In this research the influence of electrode shape, discharge current, pulse on time and pulse off time on MRR, EWR and SR are investigated. Electrodes of Three different shapes of constant crosssectional area of 280mm2 are used for Experiment. The MRR, EWR and surface roughness are measured and analyzed.

The Following conclusions can be made from this experimental research.

- The main effects of current, pulse on time, pulse off time are significant in MRR, SR and EWR, also higher-order effect of pulse on time and current have significant contribution in MRR and EWR.
- The Optimum tool shape for higher material removal rate, lower electrode wear rate and lower surface roughness is circular, followed by Triangular and rectangular cross sections of tools.
- Main effects plots for MRR shows that, the MRR increases linearly with applied current, also MRR increases with pulse on-time duration and then starts decreasing with increase in pulse off time duration.
- Main effects plots for EWR shows that, the EWR increases linearly with applied current, and the EWR decreases with pulse on-time and then increase with pulse off duration.
- Main effects plots for SR shows that, the SR increases linearly with applied current, and the pulse on-time and then decrease with pulse off duration and then starts increasing with increase in pulse off time duration.
- The influence of the shape of electrodes on surface roughness is found to be insignificant. However, a round shape electrode produces a smoother surface followed by the triangular and rectangular shaped electrodes.
- When current is increased, the crack length, crack widths are also increased due to the high temperature generation at high currents. Formation of micro cracks increases during EDM with a higher current and higher pulse-on time.

- **Optimum Values For MRR :**

SR NO	SHAPE	I (A)	T_{ON} (µs)	T_{OFF} (µs)	MRR (mm^3/min)
1	Circular	20	8	5	91.615

- **Optimum Values For EWR :**

SR NO	SHAPE	I (A)	T_{ON} (µs)	T_{OFF} (µs)	EWR (gm/min)
1	Circular	10	8	7	0.000804

- **Optimum Values For SR :**

SR NO	SHAPE	I (A)	T_{ON} (µs)	T_{OFF} (µs)	SR (µm)
1	Circular	10	7	6	9.8011

REFERENCES

[1] Gurguí D, Vázquez E, Ferrer I; Influence of the process parameters to manufacture micro-cavities by Electro Discharge Machining (EDM). Procedia Engineering, 2013; 63:499-505.

[2] Muthuramalingam T, Mohan B; Application of Taguchi-grey multi responses optimization on process parameters in electro erosion. Measurement, 2014; 58:495-502.

[3] Manohar M, Selvaraj T, Sivakumar D, Gopinath S, George KM; Experimental Study to Assess the Effect of Electrode Bottom Profiles while Machining Inconel 718 through EDM Process. Procedia Materials Science, 2014; 6: 92-104.

[4] Mhatre MS, Sapkal SU, Pawade RS; Electro discharge machining characteristics of Ti-6Al-4V alloy: A grey relational optimization. Procedia Materials Science, 2014; 5.
[5] Torres A, Puertas I, Luis CJ; Modelling of surface finish, electrode wear and material removal rate in electrical discharge machining of hard-to-machine alloys. Precision Engineering, 2015;40:33-45.
[6] Shabgard M, Oliaei SNB, Seyedzavvar M, Najadebrahimi A; Experimental investigation and 3D finite element prediction of the white layer thickness, heat affected zone, and surface roughness in EDM process. Journal of mechanical science and technology, 2011; 25(12):3173-3183.
[7] Das MK, Kumar K, Barman TK, Sahoo P; Optimization of surface roughness and MRR in EDM using WPCA. Procedia Engineering,2013; 64:446-455.
[8] Chen DC, Jhang JJ, Guo MW; Application of Taguchi design method to optimize the electrical discharge machining. Journal of Achievements in Materials and Manufacturing Engineering, 2013;57(2):76-82.
[9] Rajmohan T, Prabhu R, Rao GS, Palanikumar K; Optimization of Machining Parameters in Electrical Discharge Machining (EDM) of 304 Stainless Steel. Procedia Engineering,2012; 38:1030-1036.
[10] Jegan TC, Anand MD, Ravindran D; Determination of electro discharge machining parameters in AISI202 stainless steel using grey relational analysis. Procedia Engineering, 2012; 38:4005-4012.