Experimental Analysis and Optimization of Electrical Discharge Machining on Titanium GR-2 with FEA

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Abstract – High residual thermal stresses are developed on the surfaces of Electric Discharge Machined parts because of the high temperature gradients generated at the gap during Electrical Discharge Machining (EDM) in a small heat-affected zone. These thermal stresses can lead to micro-cracks, decrease in fatigue life and strength and possibly catastrophic failure. The results of the analysis show high temperature gradient zones and the regions of large stresses where, sometimes, they exceed the material yield strength. A transient thermal analysis assuming a Gaussian distribution heat source with temperature dependent material properties can be used to investigate the temperature distribution. In this project, a series of experiments has to be conducted with copper electrode as a tool and Titanium alloy as work piece to machine small depth on the work piece.The combination of gap voltage, Ampere setting were new line considered for maximum Material Removal Rate (MRR), Surface Roughness (SR), and minimum machining timing. . The main aim was to identify the electrode which could enhance the production of quality of impression and to have a significant contribution for modern industrial requirements. The experiments were carried out as per L9 orthogonal array with each experiment performed under different conditions of such as Ampere rating, sparking voltage while machining. Thermal gradient and Thermal flux also evaluated ANSYS 11.

Index Terms – EDM, ANSYS, Thermal Flux, MRR, SR.

1. INTRODUCTION

1.1 Electric Discharge Machining

Electric discharge machining is a thermo-electric non-traditional machining process. Material is removed from the work piece through localized melting and vaporization of material. Electric sparks are generated between two electrodes when the electrodes are held at a small distance from each other in a dielectric medium and a high potential difference is applied across them. Localized regions of high temperatures are formed due to the sparks occurring between the two electrode surfaces. Work piece material in this localized zone melts and vaporizes. Most of the molten and vaporized material is carried away from the inter-electrode gap by the dielectric flow in the form of debris particles. To prevent excessive heating, electric power is supplied in the form of short pulses. Spark occurs wherever the gap between the tool and the work piece surface is smallest. After material is removed due to a spark, this gap increases and the location of the next spark shifts to a different point on the work piece surface. In this way several sparks occur at various locations over the entire surface of the work piece corresponding to the work piece-tool gap. Because of the material removal due to sparks, after some time a uniform gap distance is formed throughout the gap between the tool and the work piece. Thus, a replica of the tool surface shape is formed on the work piece as shown in Figure 1.1. If the tool is held 3 stationary, machining would stop at this stage. However if the tool is fed continuously towards the work piece then the process is repeated and more material is removed. The tool is fed until the required depth of cut is achieved. Finally, a cavity corresponding to replica of the tool shape is formed on the work piece.

2. LITERATURE REVIEW

Shailesh Dewangan[1] et.al were analyzed Surface integrity remains one of the major areas of concern in electric discharge machining (EDM).During the current study, grey-fuzzy logic-based hybrid optimization technique is utilized to determine the optimal settings of EDM process parameters with an aim to improve surface integrity aspects after EDM of AISI P20 tool steel. The experiment is designed using response surface methodology (RSM) considering discharge current (Ip), pulse-on time (Ton), tool-work time (Tw) and tool-lift time (Tup) asprocess parameters. Various surface integrity characteristics such as white layer thickness (WLT), surfacecrack density (SCD) and surface roughness (SR) are considered during the current research work. Grey relational analysis (GRA) combined with fuzzy-logic is used to determine grey fuzzy reasoning grade (GFRG). The optimal solution based on this analysis is found to be Ip ¼ 1 A, Ton ¼ 10 ms, Tw ¼ 0.2 s, and Tup ¼ 0.0 s. Analysis of variance (ANOVA) results clearly indicate that Ton is the most contributing parameter followed by Ip, for multiple performance characteristics of surface integrity.

Milan Kumar Das[2] were investigated combination of process parameters for optimum surface roughness and material removal rate (MRR) in electro discharge machining (EDM) of EN31 tool steel using artificial bee colony (ABC) algorithm. Forexperimentation, machining parameters viz., pulse on time, pulse off time, discharge current and voltage are varied based on central composite design (CCD). Second order response equations for MRR and surface roughness are found out using response surface methodology (RSM). For optimization, both single and multi-objective responses (MRR and surface roughness: Ra) are considered. From ABC analysis, the optimum combinations of process parameters are obtained and corresponding values of maximum MRR and minimum Ra are found out. Confirmation tests are carried out to validate the analyses and it is seen that the predicated values show good agreement with the experimental results. This study also investigates the influence of the machining parameters on machining performances. It is seen that with an increase in current and pulse on time, MRR and surface roughness increase in the experimental regime. Finally, surface morphology of machined surfaces is studied using scanning electron microscope (SEM) images.

M.Dastagiri[3] were experimentally analyzed pursue the influence of four design factors current (I), voltage (V), pulse on(Ton), and duty factor (η) which are the most connected parameters to be controlled by the EDM process over machining specifications such as material removal rate (MRR) and tool wear rate(TWR) and characteristics of surface integrity such as average surface roughness (Ra) and the hardness (HR) and also to quantify them In this paper the experiments have been conducted by using full factorial design 23 with three central point in the DOE techniques and developed a mathematical model to predict material removal rate, average surface roughness and hardness using input parameters such as current, voltage, pulse on, and duty factor. The predicted results are very close to experimental values. Hence this mathematical model could be used to predict the responses such as material removal rate, and average surface roughness effectively within the input parameters studied.

Vikas[4] were presented an idea about the effect of the various input process parameters like Pulse ON time, Pulse OFF time, Discharge Current and Voltage over the Surface Roughness for an EN41 material. Here, 5 different output parameters concerned with surface roughness like Ra, Rq, Rsk, Rku and Rsm are taken and optimized accordingly, using the Grey-Taguchi method. The Grey-Taguchi method used in the article considers an L27 orthogonal array, which uses a different combination of the 4-input parameters to obtain an optimized value of the surface roughness for EN41 material. The 5 different output values of the surface roughness are calibrated into a single value (i.e. Grade) by calculating their normalized, Δ and ξ values .On the basis of their Grade, the S/N ratio is obtained and accordingly the ANOVA table is generated. It was found that the Current had larger impact over the Surface Roughness value, followed by the Voltage. The experimental results thus, obtained were compared with the theoretical results and they were found very close to one another

M. Durairaj[5] et.al were analyzed Surface roughness and kerf width are of crucial importance in the field of machining processes. This paper summarizes the Grey relational theory and Taguchi optimization technique, in order to optimize the cutting parameters in Wire EDM for SS304. The objective of optimization is to attain the minimum kerf width and the best surface quality simultaneously and separately. In this present study stainless steel 304 is used as a work piece, brass wire of 0.25mm diameter used as a tool anddistilled wtater is used as a dielectric fluid.For experimentation Taguchi's L;16, orthogonal array has been used. The input parameters selected for optimization are gap voltage, wire feed, pulse on time, and pulse off time. For each experiment surface roughness and kerf width was determined by using contact type surf coder and video measuring system respectively. By using multi objective optimization technique grey relational theory, the optimal value is obtained for surface roughness and kerf width and by using Taguchi optimization technique, optimized value is obtained separately. Additionally, the analysis of variance (ANOVA) is toouseful to identify the most important factor.

3. THEORETICAL BACKGROUND

3.1 Effect of input parameters

Based on the discharge phenomena discussed above, the effect of various input parameters on material removal rate (MRR) and surface roughness (Ra) is discussed below.

3.1.1 Discharge Current

The discharge current (Id) is a measure of the power supplied to the discharge gap. A higher current leads to a higher pulse energy and formation of deeper discharge craters. This increases the material removal rate (MRR) and the surface roughness (Ra) value. Similar effect on MRR and Ra is produced when the gap voltage (Vg) is increased.

3.1.2 Pulse-on time

Machining takes place only during the pulse-on time (Ton). When the tool electrode is at negative potential, material removal from the anode (work piece) takes place by bombardment of high energy electrons ejected from the tool surface. At the same time positive ions move towards the cathode. When pulses with small on times are used, material removal by electron bombardment is predominant due to the higher response rate of the less massive electrons. However, when longer pulses are used, energy sharing by the positive ions is predominant and the material removal rate decreases. When the electrode polarities are reversed, longer pulses are found to produce higher MRR.

3.1.3 Pulse-off time

A non-zero pulse off time is a necessary requirement for EDM operation. Discharge between the electrodes leads to ionization of the spark gap. Before another spark can take place, the medium must de-ionize and regain its dielectric strength. This takes some finite time and power must be switched off during this time. Too low values of pulse-off time may lead to short-circuits and arcing. A large value on the other hand increases the overall machining time since no machining can take place during the off-time. The surface roughness is found to depend strongly on the spark frequency. When high frequency sparks are used lower values of Ra are observed.

3.1.4 Flushing Pressure

Apart from the electrical parameters, pressure of the dielectric media may have an effect on the process performance during die sinking EDM. Velocity of the dielectric media jet is directly proportional to the inlet flushing pressure. A high velocity flushing jet would lead to better flushing of debris from the discharge gap thus improving the MRR and Ra values. Forced flow of media also helps in reducing the time required for recovery of dielectric strength of the medium since fresh and previously non-ionized medium is continuously supplied to the gap. This leads to higher process stability. Also, it is found that the dielectric strength of air is dependent on the pressure and increases with an increase in the pressure. This favors an increase in the MRR of the process.

3.1.5 Tool rotation

Tool electrode rotation is commonly used in small-hole EDM drilling operations. Tool rotation improves flushing and leads to a more uniform electrode wear. The effects of improved flushing are an increased MRR and lower Ra value. At the same time, process stability increases because tool rotation makes it easier to introduce fresh dielectric into discharge gap as the used up dielectric is thrown out due to the centrifugal force. Thus, even with low pulse off times and poor flushing conditions good machining performance is obtained.

4. GENERAL EXPERIMENTAL SETUP

4.1. EXPERIMENTAL SETUP

Electrodes were machined to a cylindrical shape of 20 mm diameter and 25mm length. Cylindrical piece of 32 mm diameter and thickness 15 mm of HDS has to be planned.

Figure 4.1: General Experimental Setup

4.2. ELECTRODE MATERIALS

Graphite Electrode

Graphite is the most commonly used material for electrode. Graphite was introduced in EDM industry around 50 years ago. General Electric was the first, well known manufacturer to introduce graphite in EDM industry.It was known by its trade name “Gentrode”. Unlike other metal based electrode material, graphite has certain unique properties which keep it above others as a suitable material for EDM electrode. Its heat resistivity is thousands of degrees higher than other materials. It does not melt like other materials; instead it turns straight into gas from solid state. This is also a disadvantage because, instead of creating chips and staying under the di-electric, it causes a dusty cloud to form in work place. This is hazardous if not followed precaution. Vacuuming the dust is a good idea to prevent from breathing graphite in while at work place.Graphite, despite being the best option as an electrode material, has some limitations in molecular level. It is porous so when immerged in di-electric fluid it can cause problematic impurities. Due to this problem, it is better to use denser graphite which shows little penetration even after long hours of soaking. One other way of using graphite without facing problem is to heat the electrode in oven for an hour at 121°C.

4.3. WORK MATERIAL

Table 4.1. Properties of Graphite electrode

Property	Unit	Material
Density	g/cc	1.86
Electrical resistivity	(µ.ohm. cm)	850
Average particle size	Micron(µm)	20
Hardness	HB	95
Fluxural strength	Mpa	76

4.3.1 WORK MATERIAL DETAILS

Work material –Titanium steel

Work material size–25 x 25 x6 mm thickness

4.3.2 CHEMICAL PROPERTIES

Table 4.2 Chemical properties

s.no	ELEMENT	COMPOSITION IN WEIGHT %I MAX
1	Titanium	99.2
2	Carbon, C	0.08
3	ferrous Fe	0.25
4	N	0.03
5	O	0.20
6	H	0.015

5. FINITE ELEMENT ANALYSIS

5.1 INTRODUCTION TO ANSYS

To obtain the relationship between pulse conditions and material removal rate, many attempts have been made to calculate temperature distribution in the electrodes caused by a single pulse discharge by solving time-dependent heat transfer equations assuming various heat source models. Based on the mathematical models, the temperature profile due to the passage of an individual pulse can be created. However the scope of such analysis is limited; a more comprehensive approach is needed. Joshi and Pande's Model [3] considers more realistic assumptions for thermal analysis in EDM process. So it can be considered as best available, realistic and reliable thermal model for the further work of development in EDM process.

5.2 THERMAL FLUX AND THERMAL GRADIENT RESULT

Table:5.1 thermal flux and Thermal gradient result

NO	T ON	T OFF	AMPS	TF W/m2	TG K/m
1	7	8	10	$0.105*10^{-08}$	$0.147*10^{-09}$
2	7	9	12	$0.130*10^{-08}$	$0.184*10^{-09}$
3	7	10	14	$0.169*10^{-08}$	$0.238*10^{-09}$
4	8	8	12	$0.151*10^{-08}$	$0.213*10^{-09}$
5	8	9	14	$0.144*10^{-08}$	$0.202*10^{-09}$
6	8	10	10	$0.144*10^{-08}$	$0.202*10^{-09}$
7	9	8	14	$0170*10^{-08}$	$0.240*10^{-09}$
8	9	9	10	$0.154*10^{-08}$	$0.216*10^{-09}$
9	9	10	12	$0.152*10^{-08}$	$0.215*10^{-09}$

5.3 CURRENT VS THERMAL FLUX

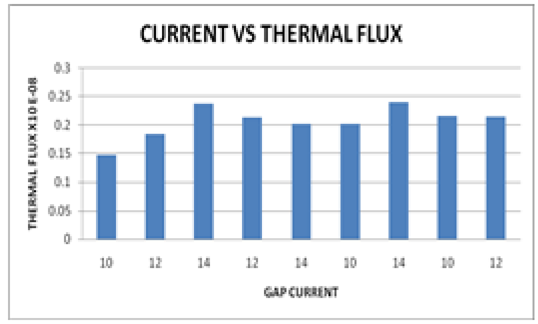
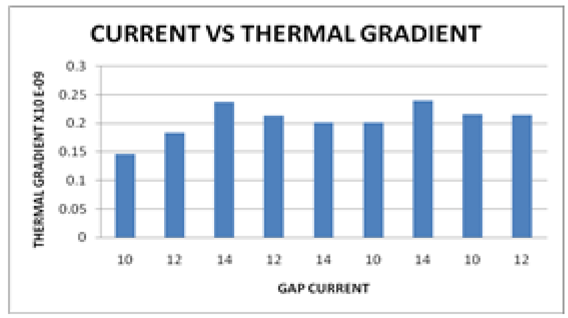


Figure:5.1 Current Vs Thermal Flux

5.4 CURRENT VS THERMAL FLUX



5.2 figure: Current Vs Thermal Gradient

5.5 ANSYS CONCLUSION

If current increased Thermal flux gets increased both are directly proportional with each other. If in the current maximum Thermal gradient also increased both are directly proportional with each other. Compared with thermal flux value the Thermal gradient mostly affected by discharge current. In this analysis Sample No 7 has more affected by the discharge current.

6. DESIGN OF ORTHOGONAL ARRAY

TABLE:6.1 Process parameters and their levels

s.no	T ON	TOFF	AMPS
1	7	8	10
2	8	9	12
3	9	10	14

6.2 AN ORTHOGONAL ARRAY L_9 FORMATION

Table:6.2 An Orthogonal Array L9 Formation

NO	Designation	T ON	TOFF	AMPS
1	$A_1B_1C_1$	7	8	10
2	$A_1B_2C_2$	7	9	12

3	$A_1B_3C_3$	7	10	14
4	$A_2B_1C_2$	8	8	12
5	$A_2B_2C_3$	8	9	14
6	$A_2B_3C_1$	8	10	10
7	$A_3B_1C_3$	9	8	14
8	$A_3B_2C_1$	9	9	10
9	$A_3B_3C_2$	9	10	12

6.3 EXPERIMENTAL OUT PUT RESPONSE & OPTIMIZATION

Table: 6.3 Experimental data

No	Desig Nation	T On	T Off	Amps	RA µS	MT Min	MRR g/min
1	$A_1B_1C_1$	4	5	8	3.654	28	0.0031
2	$A_1B_2C_2$	4	6	10	2.506	23	0.0035
3	$A_1B_3C_3$	4	7	12	3.346	18	0.0049
4	$A_2B_1C_2$	5	5	10	1.913	19	0.0046
5	$A_2B_2C_3$	5	6	12	3.558	15	0.0052
6	$A_2B_3C_1$	5	7	8	1.735	20	0.0043
7	$A_3B_1C_3$	6	5	12	0.920	13	0.0049
8	$A_3B_2C_1$	6	6	8	2.868	16	0.0052
9	$A_3B_3C_2$	6	7	10	2.457	18	0.0042

6.4 SURFACE ROUGHNESSES (ANALYSIS OF RESULT)

Table:6.4 Surface Roughness And S/N Ratios Values For The Experiments

NO	Desig nation	T ON	T OFF	AMPS	RA	S/N
1	A1B1C1	7	8	10	3.654	-11.2554
2	A1B2C2	7	9	12	2.506	-7.9796
3	A1B3C3	7	10	14	3.346	-10.4905
4	A2B1C2	8	8	12	1.913	-5.6343
5	A2B2C3	8	9	14	3.558	-11.0241
6	A2B3C1	8	10	10	1.735	-4.7860
7	A3B1C3	9	8	14	0.920	0.7242
8	A3B2C1	9	9	10	2.868	-9.1516
9	A3B3C2	9	10	12	2.457	-7.8081

6.5 ROUGHNESS RESPONSE FOR EACH LEVEL OF THE PROCESS PARAMETER

TABLE:6.5 Response Table for Signal to Noise Ratios- Smaller is better

Level	A	B	C
Pulse on	-9.909	-5.388	-8.398
Pulse off	-7.148	-9.385	-7.141
Current	-5.412	-7.695	-6.930
Delta	4.497	3.997	1.468
Rank	1	2	3

TABLE:6.6 Analysis of Variance

Source	DF	SS	MS	F	P	% of contribution
T on	2	1.8720	0.9360	0.53	0.652	28
T off	2	1.0029	0.5014	0.29	0.777	14
Amps	2	0.3326	0.1663	0.10	0.913	6
Error	2	3.4997	1.7498			52
Total	8	6.7071				100

Model Summary

S R-sq R-sq(adj) R-sq(pred) 1.32281 47.82% 0.00% 0.00%

6.6 MACHINING TIME (ANALYSIS OF RESULT)

Table:6.7 Machining Time And S/N Ratios Values For The Experiments

NO	Desig Nation	T ON	T OFF	AMPS	MT Min	S/N Ratio
1	$A_1B_1C_1$	7	8	10	28	-28.9432
2	$A_1B_2C_2$	7	9	12	23	-27.2346
3	$A_1B_3C_3$	7	10	14	18	-25.1055
4	$A_2B_1C_2$	8	8	12	19	-25.5751
5	$A_2B_2C_3$	8	9	14	15	-23.5218
6	$A_2B_3C_1$	8	10	10	20	-26.0206
7	$A_3B_1C_3$	9	8	14	13	-22.2789
8	$A_3B_2C_1$	9	9	10	16	-24.0824
9	$A_3B_3C_2$	9	10	12	18	-25.1055

6.7 MACHINING TIME FOR EACH LEVEL OF THE PROCESS PARAMETER

Table:6.8 Response Table for Signal to Noise Ratios- Smaller is better

Level	A	B	C
1	-27.09	-25.60	-26.35
2	-25.04	-24.95	-25.97
3	-23.82	-25.41	-23.64
Delta	3.27	0.65	2.71
Rank	1	3	2

6.8 ANALYSIS OF VARIANCE (ANOVA)

TABLE:6.9 Analysis of Variance (ANOVA)

Source	DF	SS	MS	F	P	% of contribution
Ton	2	84.222	42.11	7.73	0.114	52
Toff	2	6.222	3.111	0.57	0.636	4
Amps	2	59.556	29.778	5.47	0.155	37
Error	2	10.889	5.444			7
Total	8	160.889				100

S = 0.333333 R-Sq = 99.81% R-Sq(adj) = 99.22%

6.9MRR (ANALYSIS OF RESULT)

Table:8.10 MRR And S/N Ratios Values For The Experiments

NO	Designation	TON	T OFF	AMPS	MRR g/min	S/N Ratio
1	$A_1B_1C_1$	7	8	10	0.0031	-50.1728
2	$A_1B_2C_2$	7	9	12	0.0035	-49.1186
3	$A_1B_3C_3$	7	10	14	0.0049	-46.1961
4	$A_2B_1C_2$	8	8	12	0.0046	-46.7448
5	$A_2B_2C_3$	8	9	14	0.0052	-45.6799
6	$A_2B_3C_1$	8	10	10	0.0043	-47.3306
7	$A_3B_1C_3$	9	8	14	0.0049	-46.1961
8	$A_3B_2C_1$	9	9	10	0.0052	-45.6799
9	$A_3B_3C_2$	9	10	12	0.0042	-47.5350

6.10 MRR FOR EACH LEVEL OF THE PROCESS PARAMETER

TABLE:8.11 Response Table for Signal to Noise Ratios-Larger is better

Level	T ON	TOFF	AMPS
1	-48.50	-47.70	-47.73
2	-46.59	-46.83	-47.80
3	-46.47	-47.02	-46.02
Delta	2.03	0.88	1.78
Rank	1	3	2

TABLE:8.12 Analysis of Variance

Source	DF	SS	MS	F	P	% of contribution
T ON	2	0.000002	0.000001	1.65	0.378	50
TOFF	2	0.000000	0.000000	0.29	0.775	-
Amps	2	0.000001	0.000001	1.48	0.403	25
Error	2	0.000001	0.000000			25
Total	8	0.000004				100

Model Summary

S R-sq R-sq(adj) R-sq(pred) 0.0007024 77.37% 9.48% 0.00%

7. CONCLUSION AND RESULT

In this study, the Taugchi technique and ANOVA were used to obtain optimal EDM parameters in the machining of Titanium with graphite electrode. The experimental results were evaluated using Taguchi technique.

The following conclusion can be drawn.

7.1 OPTIMAL CONTROL FACTOR

1.Surface Roughness-A1(T-ON – 7 µs)B2(T-OFF – 9 µs)C3(Amps-14)

2.Machining Timing- A1(T-ON – 7 µs)B3(T-OFF – 10 µs)C2(Amps-12)

3.Material Removal Rate- A1(T-ON – 7 µs)B3(T-OFF – 10 µs)C2(Amps-12)

7.1.1 PERCENTAGE OF CONTRIBUTION OF PROCESS PARAMETER

1.Surface Roughness-Pulse on time- 28%

2.Machining Timing- Pulse on time52%

3. Material Removal Rate-Pulse on time50%

7.1.2 ANSYS CONCLUSION

If current increased Thermal flux gets increased both are directly proportional with each other. If in the current maximum Thermal gradient also increased both are directly proportional with each other. Compared with thermal flux value the Thermal gradient mostly affected by discharge current. In this analysis Sample No 7 has more affected by the discharge current.

REFERENCES

[1] Shailesh Dewangan, Soumya Gangopadhyay*, Chandan Kumar Biswas Multi-response optimization of surface integrity characteristicsof EDM process using grey-fuzzy logic-based hybrid approach. Engineering Science and Technology, an International Journal 18 (2015) 361e368

[2] Milan Kumar Dasa, Kaushik Kumarb, Tapan Kr. Barmana*and Prasanta Sahooa Application of Artificial bee Colony Algorithm for Optimization ofMRR and Surface Roughness in EDM of EN31 tool steel 3rd International Conference on Materials Processing and Characterisation (ICMPC 2014)

[3] M.Dastagiri,, A.Hemantha Kumar Experimental Investigation of EDM Parameters on StainlessSteel&En41b 12th GLOBAL CONGRESS ON MANUFACTURING AND MANAGEMENT, GCMM 2014

[4] Vikasa, Apurba Kumar Royb, Kaushik Kumarb* Effect and ptimization of various Machine Process Parameters on the Surface Roughness in EDM for an EN41 Material using Grey-Taguchi 3rd International Conference on Materials Processing and Characterisation (ICMPC 2014)

[5] M. Durairaja, D. Sudharsunb,*, N. SwamynathanbAnalysis of Process Parameters in Wire EDM with Stainless Steel using Single Objective Taguchi Method and Multi Objective Grey Relational Grade ,International Conference On DESIGN AND MANUFACTURING, IConDM 2013

[6] Y.H. Guu* AFM surface imaging of AISI D2 tool steel machinedby the EDM process Applied Surface Science 242 (2005) 245–250

[7] M. Azadi Moghaddam *, F. Kolahan Modeling and Optimization of Surface Roughness of AISI2312 Hot Worked Steel inEDM based on Mathematical Modeling and Genetic Algorithm IJE TRANSACTIONS C: Aspects Vol. 27, No. 3, (March 2014) 417-424

[8] P. Balasubramaniana, T. Senthilvelan Optimization of Machining Parameters in EDM process using Cast and Sintered Copper Electrodes Procedia Materials Science 6 (2014) 1292 – 1302

[9] Vikasa, Apurba Kumar Royb, Kaushik Kumar Effect and Optimization of various Machine Process Parameters on the Surface Roughness in EDM for an EN41 Material using Grey-Taguchi Procedia Materials Science 6 (2014) 383 – 390

[10] P.B Wagh,Dr.R.R Deshmukh,R.D Gurav- Mathematical Modeling and Process Parameters Optimization for Surface Roughness in Edm for En31Material by Response Surface Methodology, Volume : 3 | Issue : 10 | Oct 2013 | ISSN - 2249-555X .