JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

ANOVA based optimization of process parameters for Electro Discharge Machining of D2 Stainless Steel

Kuldip Kumar Sahu[1],Sapan Kumar Dutta[2]

[1]Assistant Professor,School of Engineering and IT,Arka Jain University Jharkhand

[2]Assistant Professor, Dept. of Mechanical Engineering, GGSESTC Bokaro, Jharkhand

Corresponding Author – Kuldip Kumar Sahu , kuldip.s@arkajainuniversity.ac.in

Abstract: Wire-cut electrical discharge machining is extensively used for machining of difficult to machine materials and intricate profiles when precision is of prime importance. Wire-cut electrical discharge machining allowed success in the production of newer materials, especially for the aerospace and medical industries. Being a complex process, it is very difficult to determine optimal process parameters for improving cutting performance. The objective of this research work is to study the effect of machining parameters of wire-cut electrical discharge machining on D2 Stainless steel. The experimentation has been carried out to investigate the effect of machining process parameters such as pulse on time, pulse off time and feed rate of wire on material removal rate and surface roughness. The thickness of work piece material and diameter of copper wire is kept constant. It is evident from present study that input parameters have significant influence on process performance characteristics. The experimentation was executed as per Taguchi robust design methodology. L9 orthogonal array of experimental design were used to perform the experiments. Analysis of variance (ANOVA) were employed to optimize the material removal rate and surface roughness. Based on analysis it was found that pulse on time, pulse off time are the significant parameters that effect the MRR and surface roughness. The investigation indicated that material removal rate and surface roughness increases with increase in pulse on time and decreases with increase in pulse off time.

***Keywords: Electric Discharge Machining,* L9 Orthogonal array, Signal to Noise ratio, Material removal rate, Surface Roughness, T-on and T-off time, Feed Rate.**

I. INTRODUCTION

Wire-cut electrical discharge machining (WEDM) is a non-traditional manufacturing process based on removing material from a part by means of a series of recurring electrical discharges (created by electric pulse generators at short intervals) between a tool calledelectrode and the work piece in the presence of a dielectric fluid. This fluid makes it possible to flush eroded particles (mainly in the form of hollow spheres) from the gap and it is really important to maintain this flushing continuously.

WEDM has potential applicability in machining industries for achieving good accuracy and surface finish, and contour generation. The drawbacks of EDM processes are overcome in WEDM process by replacing different tools with wire. Due to accuracy andfine surface finishes make WEDM is particularly suitable for manufacture of dies and prototype parts. In WEDM, pulsating direct current power supply between the electrodes (work and tool material) generates an electric sparks, which causes melting, and vaporization of the material. WEDM is being used to machine variety of conductivematerials at miniature levels. It can reduce many hours of manual grinding and polishing in making precision parts.

The main process parameters in WEDM are pulse on-time (T_{on}), pulse off-time (T_{off}), arc gap, dielectric fluid, work piece material and types of electrode wire. Pulse on-time is the duration of time (µs) the current is allowed to flow per cycle. Material removal is directly proportional to the amount of energy applied during this on-time. This energy is really controlled by the peak current and the length of the on-time. Pulse off-time is the duration of time (µs) between the sparks (that is to say, on-time). This time allows the molten material to solidify and to be wash out of the arc gap. This parameter is to affect the speed and the stability of the cut. Thus, if the off-time is too short, it will cause sparks to be unstable. Arc gap is the distance between the electrode and the part during the process of EDM. It may be called as spark gap. The dielectric fluid is a catalyst conductor, coolant and also a flushing medium.

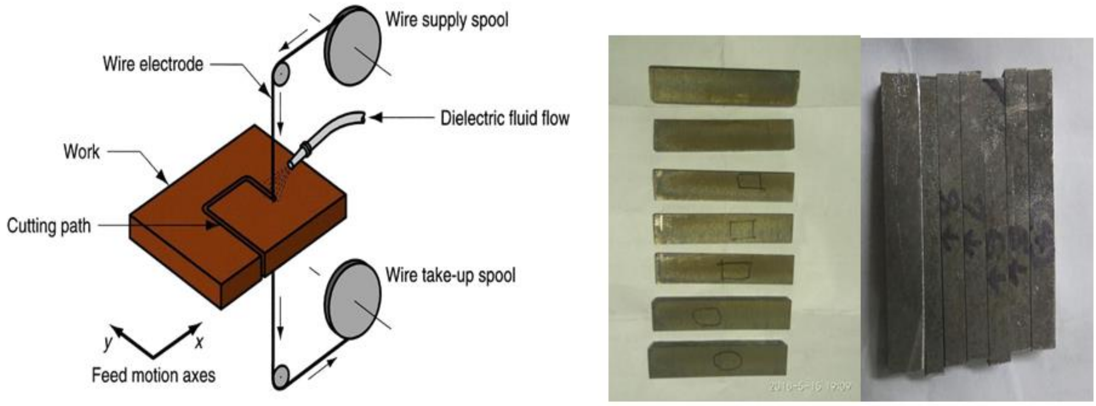


Figure 1 Schematic diagram of WEDM and samples after machining

II. EXPERIMENTAL DETAILS

The experiments were carried out on wire cut EDM machine (EXCETEK). The specifications of WEDM machine tool is given in table-1

Table 1 Specification of WCEDM Machine tool

Design	Fixedcolumn,movingtable
Machineweight	3100kg
Maximumworkpieceheight	750x550x50mm
Maximumworkpieceweight	500kg
Maintabletraverse(x,y)	380x280mm
Auxiliarytabletraverse(u,v)	120x120mm
Wire electrodediameter	0.2mm
Controlledaxes	X,Y,U,Vsimultaneous/independent
Interpolation	linearandcircular
Inputpowersupply	3phase,AC415V,50HZ

The stainless steel plate is mounted on EXCETEKW EDM machine tool and specimen of 60 mm x 60 mm x 10 mm size is cut. The close up view of plate blank used for cutting the specimen is mounted on the WEDM machine.
The experiments were accomplished on EXCETEK WEDM machine. Following steps were followed in the cutting operation:-

1. The reference point on the work piece was set for setting work coordinatesystem. The programing was done with the reference to the work coordinatesystem.
2. The program was made for cutting operation of the work piece up to 40 mm straight line.
3. While performing various experiments, the following precautions were taken
4. To reduce error due to experimental setup, each experiment was repeated 2 times.
5. Each set of experiments was performed at room temperature.
6. Before taking the measurement of surface roughness the work piece was cleaned

Work piece to be machined is mounted on the table which is operated by the controlledunit. A very thin copper wire is passed and operated by wire feed mechanism. Dielectricfluid (deionized water) was passed over the work piece and the wire using pump. Whenthe DC supply is given to the circuit, spark is produced across the gap between the wire and workpiece. When the voltage across the gap become sufficiently large, the high power spark is produced. This sparks occurs in an interval of 5 to 24 micro seconds. So thousands of spark discharge occurs per second across the very small gap between the wire and thework piece, work piece metal is melted, eroded and some of it is vaporized. The metal is thus removes in this way from the workpiece. The removed fine particles are carried away by dielectric fluid circulated around it.

Design of an experiment is an effective tool to design and conduct the experiment with minimum resources. Orthogonal array is a statistical method of defining parameters that converts tests into factors and levels. Test design using orthogonal array creates an efficient and concise test suit with fewer test cases without compromising test coverage. In this work L9 orthogonal array design matrix is used to set the control parameters to evaluate the process performance. The table shows the design matrix used in this work.

Table 2 Experimental design using L9 orthogonal array

ExperimentNo.	Pulseon Time (µs) (A)	Pulseoff Time(µs) (B)	Feed Rate(mm /min) (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

Specimen of 60 mm x 60 mm x 10 mm size is cut by WEDM process with the help of copper wire on stainless steel as work piece material for each combination of parameters considered according to the orthogonal array. To calculate material removal rate standards formulas are used and surface roughness of the specimen machined was evaluated using surface roughness testing machine.

III. RESULTS AND DISCUSSIONS

After finding all the observation S/N ratio and Means are calculated and variousgraph for analysis is drawn by using Minitab 15 software. The S/N ratio for MRR,surfaceroughnessiscalculated onMinitab15 softwareusingTaguchi method.

Table 3 Input parameters and corresponding output responses

Experiment No.	Pulseon Time (µs) (A)	Pulseoff Time(µs) (B)	Feed Rate(mm/ min) (C)	MRR (mm^3/min)	Surface Roughness(µm)
1	6	0.010	1.8	**0.60**	**2.07885**
2	6	0.025	3.0	**0.66**	**2.23145**
3	6	0.040	4.5	**0.684**	**2.72945**
4	12	0 .010	3.0	**0.72**	**2.71765**
5.	12	0.025	4.5	**0.762**	**2.8024**
6.	12	0.040	1.8	**0.81**	**3.25215**
7.	20	0.010	4.5	**0.852**	**3.2345**
8.	20	0.025	1.8	**0.90**	**3.6334**
9.	20	0.040	3.0	**1.20**	**3.43925**

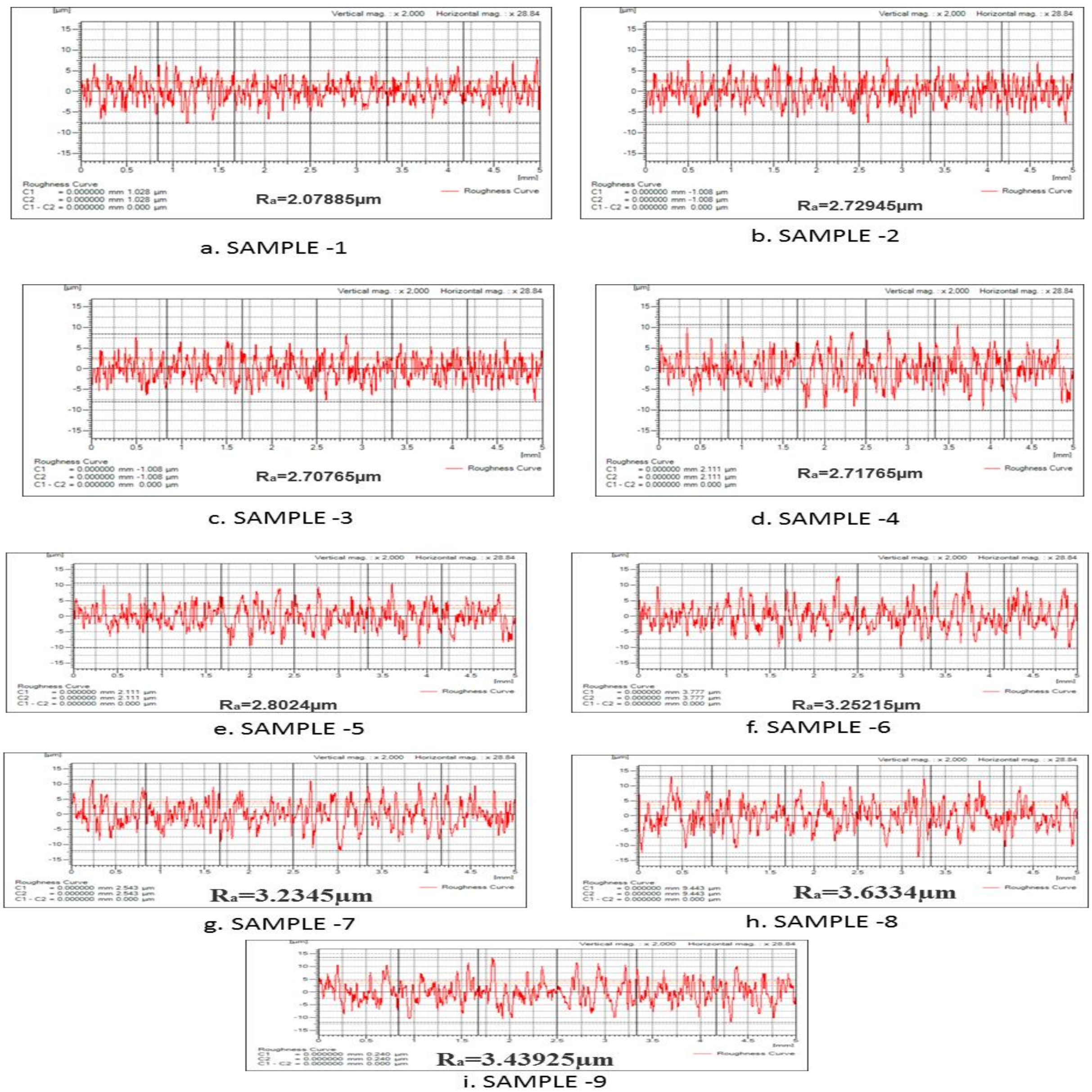


Figure 2 Surface Roughness measurement of Different Samples

Taguchi method stresses the importance of studying the response variation using the signal to noise (S/N) ratio, resulting in minimization of quality characteristic variation due to uncontrollable parameter. The material removal rate was considered as quality characteristic with the concept of "larger is better".

The MRR values measured from the experiment and their corresponding S/N ratiovaluesarelistedinthe table 4.

Table 4 Experimental Result and Corresponding S/N Ratio for MRR

Sr. No.	Pulseon Time(µs)	Pulseoff Time(µs)	Feed Rate(mm/min)	MRR(mm^3/min)	S/N
1.	6	0.010	1.8	0.60	-4.82248
2.	6	0.025	3.0	0.66	-3.45583
3.	6	0.040	4.5	0.684	-3.06667
4.	12	0.010	3.0	0.72	-2.62114
5.	12	0.025	4.5	0.762	-2.74640
6.	12	0.040	1.8	0.81	-1.67701
7.	20	0.010	4.5	0.852	-1.23792
8.	20	0.025	1.8	0.90	-0.68294
9.	20	0.040	3.0	1.20	1.19812

Result and Discussion for MRR

Regardless of the category of the performance characteristics, a greater S/N valuecorrespond to better performance. Therefore the optimal level of the machiningparametersis thelevelwithgreatestvalue.

Pulse on:- Effect of parameter pulse on is shown in the figure 3(a) for S/N ratio and its optimum value is 20µs. For higher value of Ton MRR is higher and better. This is because high pulse-on time (TON) results in faster erosion of the material as longer duration of spark results in higher spark energy release hence increase in MRR is obtained.

Pulse off -The effect of parameter pulse off time on material removal rate is shown in the figure 3(a) for S/N ratio and optimum value is 0.040µs. For higher value of T-off the MRR is higher and better. This is because as the pulse off time decreases, the number of discharges within a given period becomes more which leads to a higher material removal rate.

Feed Rate- The effect of feed rate on material removal rate is shown in the figure 3(a) for S/Nratio.Itsoptimumvalueis3.0mm/min.WirefeedratedoesnotplaysignificantroleforMRR

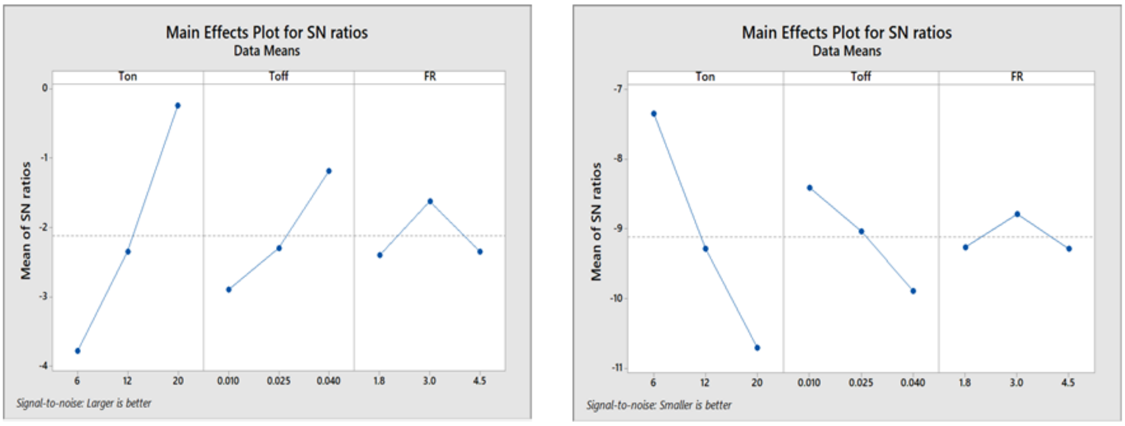
Optimization for Surface Roughness- Surface roughness is also a quality parameter, it should be as low as possible. So we have chosen the smaller is better signal to noise ratio.

Regardlessofthecategoryofperformancecharacteristics,asmallerS/Nvalue correspondstoabetterperformance.Thereforetheoptimallevelofmachining Parametersarethelevelwithsmallestvalue.

PulseonTime - The effect of parameter pulse on Time on the surface roughness values is shown infigure 3(b) for S/N ratio and its optimum value is 20 µs.This is because high pulse-ontime(TON)resultsinfastererosionofthematerialaslongerdurationofsparkresultsin higher spark energy release that leads to increase in size of craters formed henceincreaseinSRis obtained.

PulseoffTime - The effect of parameter pulse off time on the surface roughness values is shown infigure 3(b)forS/Nratio.Sotheoptimumpulseofftimeis0.040 µs.

FeedRate - The effect of parameter feed rate on the surface roughness value is shown in figure 3(b)forS/Nratio.Sotheoptimumfeedrate is 4.5 mm/min.



a. Effect of WEDM Parameters on MRR for S/N Ratio

b. Effect of WEDM Parameters on Surface Roughness for S/N Ratio

Figure 3 Main effect plots for MRR and Surface Roughness

Table 5 Experimental Result and Corresponding S/N Ratio for Surface Roughness

Sr.No.	Pulseon Time(μs)	Pulseoff Time(μs)	Feed Rate(mm/min)	Surface Roughness(μm)	S/Nratio
1.	6	0.010	1.8	2.07885	-6.7954
2.	6	0.025	3.0	2.23145	-6.9523
3.	6	0.040	4.5	2.72945	-8.3020
4.	12	0.010	3.0	2.71765	-8.2644
5.	12	0.025	4.5	2.8024	-9.3895
6.	12	0.040	1.8	3.25215	-10.2240
7.	20	0.010	4.5	3.2345	-10.1767
8.	20	0.025	1.8	3.6334	-10.7867
9.	20	0.040	3.0	3.43925	-11.1682

IV. Conclusions

In the earlier chapters, the effects of process variables on response characteristics(material removal rate, surface roughness) of wire electrical discharge machiningprocess have been discussed. An optimal set of process variables that yields theoptimum quality features to machined parts produced by WEDM process has alsobeenobtained.

- . The analysis of graphs and S/N ratios shows that MRR proportionately increaseswith increase in pulse on time and decreases with increase in pulse off time. Wirefeedrate does notplaysignificantroleforMRR.
- TheanalysisofgraphsandS/NratiosshowsthatSRproportionatelyincreaseswithincreaseinpulseontimeanddecrease swithincreaseinpulseofftimeandwirefeedrate.

Futurescope

Although the WEDM machining has been thoroughly investigated foe D2 stainlesssteel work material, still there is scope for further investigation. The followingsuggestionsmayproveusefulforfuturework:

1. L9 orthogonal array does not provide interaction between parameters. Therefore higher order orthogonal array can be used to optimize the material removal rate and surface roughness.
2. The effect of process parameters such as flushing pressure, conductivity of dielectric, wire diameter, electric flow rate, work-piece height etc. may also be investigated.

REFERENCES

[1] Reddy Sidda B., Rao PS, Kumar JS and Reddy KVK, "Parametric study ofelectric dischargemachining of AISI 304 stainless steel", Internationaljournalofengineeringscienceand technology,2(8)(2010):pp.3535-3550

[2] Rahman M.M., Khan M.A.R., Kadirgama K., Noor M.M. and Bakar R.A., Experimental In- "vestigation into Electrical Discharge Machining of Stainless Steel 304", Journal of Applied Sciences, 11(3) (2011): pp. 549-554.

[3] Dewangan S.K., "Experimental Investigation of Machining parameters for EDM using U-shaped Electrode of AISI P20 tool steel", M-Tech Thesis (2010).

[4] Tomadi S.H., Hassan M.A. and Hamedon Z., "Analysis of the influence of EDM parameters on surface quality", material removal rate and electrode wear of tungsten carbide, Proceedings of the International Multi Conference of Engineers and Computer Scientists, Vol II (2009).

[5] Iqbal AKM A. and Khan A.A., "Optimization of process parameters on EDM milling of stain-less steel AISI 304", Advanced Materials Research, 264-265 (2011): pp. 979-984.

[5] M. Chenthil Jegan, Dev Anand M. and Ravindran D., "Determination of electro discharge machining parameters in AISI202 stainless steel using grey relational analysis". International Conference on Modeling, Optimization and Computing, Procedia Engineering, 38 (2012): pp. 4005- 4012.

[6] Rajmohan T., Prabhu R., Subba Rao G. and Palanikumar K., "Optimization of machining pa- rameters in electrical discharge machining (EDM) of 304 stainless steel", International Conference on Modeling, Optimization and Computing, Procedia Engineering, 38 (2012): pp. 1030-1036.

[7] Kiyak M. and Cakir O., "Examination of machining parameters on surface roughness in EDM of tool steel", Journal of Materials Processing Technology, 191 (2007): pp. 141-144.

[8] Reza M. S., Hamdi M., Tomadi S. H., Ismail A. R., "Optimization of control parameters for EWR in injection flushing type of EDM on stainless steel 403 work-piece", World Academy of Science, Engineering and Technology, 72 (2010)

[9] Ghosh A. and Mallik A.K., Manufacturing Science, New Delhi, East-West Press Private Limited, 2009

[10] Rao P. N., Manufacturing Technology, Volume-2, Second Edition, New Delhi, Tata McGraw Hill Education Private Limited, 2009

[11] S. Datta and S. S. Mahapatra, "Modeling, Simulation and Parametric Optimization of Wire EDM Process Using Response Surface Methodology Coupled with Grey-Taguchi Technique", International Journal of Engineering, Science and Technology,162-183 (2010).

[12] LokeshGoyat, Rajesh Dudi and NeerajSharma , “Investigation of Process Parameters Contribution and their Modeling in WEDM for D-2 Tool Steel Using ANOVA”, Global Journal of Engineering,Design andTechnology,2(3),41-46(2013)

[13] C.D. Shah, J.R.Mevada and B.C.Khatri , “Optimization of Process Parameter of Wire Electrical Discharge Machine by Response Surface Methodology on Inconel-600”, International Journal of Emerging Technology and Advanced Engineering, 3(4), 2250- 2459(2013).

[14] C.D. Shah, J.R.Mevada and B.C.Khatri , “Optimization of Process Parameter of Wire Electrical Discharge Machine by Response Surface Methodology on Inconel-600”, International Journal of Emerging Technology and Advanced Engineering, 3(4), 2250- 2459(2013).

[15] Gaurav Sachdeva, Ravinder Khanna, Parveen Yadav, Amit Nara and Narender Singh, “Experimental study of H-21 punching dies on wire-cut electric discharge machine using Taguchi’s method”, International Journal of Scientific & Engineering Research, 4(5), 559- 567(2013).

[16] Ahmed Raza Khan, AdeelIkram, Nadeem Ahmad Mufti, Muhammad QaiserSaleem, “Parametric optimization for surface roughness, kerf and MRR in wire electrical discharge machining (WEDM) using Taguchi design of experiment”, Journal of Mechanical Science.

[17] K.P.Rajurkar, FarnazNourbakhsh, A.P.Malshe, Jian Cao,“Wire electro- discharge machining of titanium alloy”, The Authors. Published by Elsevier B.V., 2212-8271,(2013).

[18] C.Bhaskar Reddy, “Experimental Investigations on MRR And Surface Roughness of EN 19 & SS 420 Steels in Wire EDM Using Taguchi Method” International Journal of Engineering Science and Technology (IJEST), ISSN: 0975-5462, Vol. 4 No.11 (2012).

[19] S.Balasubramanian, Dr.S.Ganapathy, “Grey Relational Analysis to determine optimum process parameters for Wire Electro Discharge Machining (WEDM)” International Journal of Engineering Science and Technology ,ISSN: 0975-5462 Vol. 3 No. 1(2011).

[20] K. Pasam, S. B. Battula, P. M. Valli and M. Swapna, “Optimizing Surface Finish in WEDM Using the Taguchi Parameter Design Method”, Journal of the Brazilian Society of Mechanical Science & Engineering, 32 (2), 107- 113(2010).

[21] Kuo-Wei Lin, Che-Chung Wang, “Optimizing Multiple Quality Characteristics of Wire Electrical Discharge Machining via Taguchi method- based Gray analysis for Magnesium Alloy” Journal of C.C.I.T., VOL.39, NO.1, May 2010

[22] Jangra Kamal, Jain Ajai, Grover Sandeep, “Optimization of multiple machining characteristics in wire electrical discharge machining ofpunching die using grey relational analysis”, Journal of Scientific and Industrial Research, Vol.69,pp. 606-612 (2010).

[23] B. C. Routara, B.K. Nanda, D.R.Patra, “Parametric Optimization Of CNC Wire Cut Edm Using Grey Relational Analysis”, International Conference on Mechanical Engineering, ICME09-RT-24(2009).

[24] Kanlayasiri K., BoonmungS.,“Effects of wire-EDM machining variables on surface roughness of newly developed DC 53 die steel: design of experiments and regression model”, Journal of Materials Processing Technology, Vol. 192-193, pp: 459–464(2007) .

[25] S. Mahapatra, A. Patnaik, “Optimization of Wire Electrical Discharge Machining (WEDM) Process Parameters Using Taguchi Methods”, International Journal of Advance Manufacturing Technology, 34, 911- 925(2006)

[26] Chiang, K.T., Chang, F.P, “Optimization of the WEDM process of particle- reinforced material with multiple performance characteristics using grey relational analysis”, Journal of Materials Processing Technology, 180, 96- 101.(2006).

[27] M.S.Hewidy, T.A. El-Taweel, M.F.El-Safty., “Modeling the machining parameters of wire electrical discharge machining of Inconel 601 using RSM”, Journal of Materials Processing Technology, 169, 328–336. (2005)

[28] Can Cogun, Gul Tosun, NihatTosun “A Study On Kerf And Material Removal Rate In Wire Cut Electrical Discharge machining based on Taguchi method”, Journal Of Materials.

[29] S.B. Prajapati and N. S. Patel, “Effect of Process Parameters on Performance Measures of Wire EDM for AISI A2 Tool Steel”, International Journal of Computational Engineering Research,03,274-278 (2013).