International Journal of Latest Engineering and Management Research (IJLEMR)
ISSN: 2455-4847
www.ijlemr.com ‖ Volume 1 - Issue 7 ‖ August 2016 ‖ PP. 01-09

Analysis of the influence of EDM process parameters on surface quality, MRR, EWR FOR EN31

N.Rajiv Kumar[1], K.P.Shankar[2], P.Umar Ahamed[3]
[1]*(Department of Mechanical Engineering, SriGuru Institute of Technology, India)*
[2]*(Department of Mechanical Engineering, SriGuru Institute of Technology,India)*
[3]*(Department of Mechatronics Engineering, Coimbatore Institute of Engineering &Technology, India)*

ABSTRACT: This research work deals the performance characteristics in machining of EN31 by Electrical Discharge Machining process. The experiments were carried out as per Taguchi 's L9 orthogonal array with each experiment performed under the various machining parameters, namely pulse- on time(x_1), pulse-off time(x_2), Discharge current(x_3) and Gap control(x_4). They were optimized with considerations of multiple performance characteristics including surface roughness (Ra), electrode wear ratio and material removal rate. The development of regression equation is used to analyse the performance characteristics and the study based on L9 orthogonal array with modified Taguchi method. An orthogonal array and analysis of variance (ANOVA) were employed to study the performance characteristics in EDM process

KEYWORDS: EDM, MRR, EWR, SR, Taguchi, ANOVA, L_9 ORTHOGONAL ARRAY

I. INTRODUCTION

EDM is a controlled material removal technique where by high frequency electric sparks are used to erode the work piece which takes a shape corresponding to that of tool electrode. EDM is an important "non-traditional manufacturing method", developed in the late 1940s and has been accepted worldwide as a standard processing manufacturing of forming tools to produce plastic mouldings, die castings, forging dies, etc. New developments in the field of material science have led to new engineering metallic materials, composite materials, and high tech ceramics having good mechanical properties and thermal characteristics as well as sufficient electrical conductivity so that they can be readily be machined by spark erosion. At the present time, EDM is a widespread technique used in industry for precision machining of all types of conductive materials such as: metals, metallic alloys, graphite or even some ceramic materials of whatever hardness. EDM Technology is increasingly being used in tool, die and mould making industries, for machining of heat treated tool steels and advanced materials requiring high precision, complex shapes and high surface finish.

The complexity EDM and the number of the involved parameters require an accurate analysis for assessing the process performance. The effects of electrode material and flushing, in conjunction with electrode size and depth of cut, upon productivity, electrode wear and surface quality have been evaluated through a complete factorial experiment.

WORK PIECE: EN31

EN-31 is a high carbon alloy steel which achieves a high degree of hardness with compressive strength and abrasion resistance. This type of steel has high resisting nature against wear and can be used for components which are subjected to severe abrasion, wear or high surface loading. Tool steels are generally ingot-cast wrought products, and must be able to withstand high specific loads as well as be stable at elevated temperatures.

COMPOSITION OF EN 31:

Table 1.1 shows the composition of EN31.

Table 1.1 Composition of EN31

ELEMENTS	**% COMPOSITION**
Carbon	1.08
Silicon	0.183
Copper	0.003
Manganese	0.452
Phosphorous	0.023
Sulphur	0.0195
Molybdenum	0.07
Chromium	1.19

Lead	0.005
Titanium	0.002
Vanadium	0.003
Aluminium	0.057
Iron	96.9125

II. EXPERIMENTAL SET-UP

Before run the experiment, the electrode and work piece is cut regarding their dimension. The electrode needs to be cut its dimension same for all material. The lathe machine is used to cut the electrode. For the work piece, the wire cut EDM machine is used for cutting all specimens in same dimension. This picture refers all the material dimension that should cut and shape.

MACHINING PARAMETERS

The process parameters selected are pulse-on-time, pulse-off-time, Discharge current and Gap control. Table 2.1 shows the machining parameters and their levels.

Table 2.1 Parameter levels

Symbol	Control Factor	Level 1	Level 2	Level 3
A	**Pulse ON time (µs)**	**6**	**8**	**10**
B	**Pulse OFF time (µs)**	**4**	**8**	**10**
C	**Discharge Current (amps)**	**4**	**6**	**8**
D	**Gap Control(µm)**	**4**	**5**	**6**

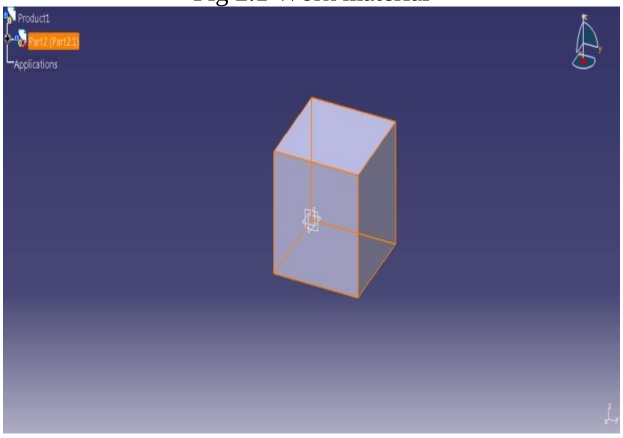
The experimental layout for the four machining parameters using the L_9 orthogonal array is shown in Table 2.2.

Table 2.2 L_9 Orthogonal array

Ex. No.	Control Factor			
	A	**B**	**C**	**D**
1	1	1	1	1
2	2	2	2	2
3	2	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

Typical Work material is shown in figure 2.1.

Fig 2.1 Work material



The Figure 2.2 shows a typical EDM Machine.

Fig 2.2 EDM Machine

III. METHODOLOGY

The process is conducted by the following three phases:

1)PLANNING PHASE

- State the problem or area of concern
- Select the objective of experiments
- Select the quality characteristics & measurement system
- Select the factor that may influence the selected quality characteristics
- Identify control & noise factors
- Select the level of factors
- Select appropriate orthogonal array
- Select the interactions that may influences the selected quality characteristics
- Assign factors for orthogonal array

2)CONDUCTION PHASE

- Conduct test described by trials in orthogonal array

3)ANALYSIS PHASE

- Analysis & interpret result of experimental trials
- Conduct conformation experiment

EXPERIMENTAL OBJECTIVE:

1. Eliminating trials and error method of adjustment
2. Optimizing the process parameters and response
3. Reducing the percentages of rejection

TAGUCHI'S TECHNIQUE

Taguchi quality system:

Quality frequency divides quality system into two parts: quality of design and quality of performance. Taguchi refers to these two parts as off line quality control and on line quality control.

Off line quality control:

The following are the stages in off line quality control

- Correctly identifying customer needs and expectations.
- Design a product, which can be consistently and economically manufactured.
- Designing a product, which can be meet customer expectations.
- Developing clear and adequate specifications, standard procedures and equipment for manufacturing.

On line quality control:

Production quality methods are of three forms and they are

1. Process diagnosis and adjustment
2. Prediction and correction
3. Measurement and action

EXPERIMENTAL DESIGN TECHNIQUES:

Experimental design was used to identify which combination of settings or levels for certain key factors produced the best average value for the product or process characteristics of interest.

Experiment:

Experiment is a series of trials or tests , which produce quantifiable outcomes. An experiment where the outcome and be completely predicted an advance is called a 'deterministic experiment'. Industrial experiments are generally performed to explore, estimate and confirm.

- ❖ Exploration
- ❖ Estimation
- ❖ Confirmation

Exploration:

Gather data to learn more about process or product characteristic.

Confirmation:

Gather data to verify a hypothesis about a relationship among variables.

MATERIAL REMOVAL RATE (MRR)

MRR (mm^3/min) = V/T

Where;

V = Volume of Work Piece removed (mm^3),

T = time (minutes)

Volume of material removal = L*B*H mm^3

Where,

L = Length of removing material on work piece.

B = Breath of removing material on work piece.

H = Height of removing material on work piece.

L = 12mm, B = 12mm H = 1mm

Material Removal Rate = (Density*Volume of material removal)/Time taken

Density of EN31 = 7.8 Kg/m^3

Density of EN31 = $7.8*10^{-6}$Kg/mm^3

Average of Material Removal Rate = (Trial 1 + Trial 2 + Trial 3)/ 3.

The machining time for various trials are shown in table 3.1 and the average MRR is calculated and tabulated as shown in table 3.2.

Table 3.1 Machining time

Ex. No.	**Control Factor**				**Machining Time(min.)**		
	A	**B**	**C**	**D**	**Trial 1**	**Trial 2**	**Trial 3**
1	1	1	1	1	5.22	5.11	5.50
2	2	2	2	2	3.45	3.42	4.20
3	2	3	3	3	3.30	3.25	3.52
4	2	1	2	3	1.30	1.32	1.28
5	2	2	3	1	2.12	2.00	1.54
6	2	3	1	2	4.14	3.30	3.52
7	3	1	3	2	2.30	2.38	2.22
8	3	2	1	3	4.39	5.04	4.37
9	3	3	2	1	6.01	5.48	5.43

Table 3.2 Material removal Rate

Ex .n o	**Control factors**				**MRR X10^{-4}(g/mm^3)**			**AVG. MRR X10^{-4}(g/mm^3)**
	A	**B**	**C**	**D**	**T1**	**T2**	**T3**	
1	1	1	1	1	2.151	2.198	2.042	2.130
2	2	2	2	2	3.255	3.284	2.674	3.071
3	2	3	3	3	3.403	3.456	3.190	3.349
4	2	1	2	3	8.640	8.500	8.775	8.638
5	2	2	3	1	5.298	5.616	7.293	6.069

6	2	3	1	2	2.713	3.401	3.190	3.101
7	3	1	3	2	4.883	4.719	5.059	4.887
8	3	2	1	3	2.151	2.198	2.042	2.130
9	3	3	2	1	3.255	3.284	2.674	3.071

SURFACE ROUGHNESS

The closed-form solutions of surface roughness parameters for a theoretical profile consisting of elliptical arcs are presented. Parabolic and simplified approximation methods are commonly used to estimate the surface roughness parameters for such machined surface profiles. The closed-form solution presented in this study reveals the range of errors of approximation methods for any elliptical arc size. Using both implicit and parametric methods, the closed-form solutions of three surface roughness parameters, Peak-to-Valley Roughness, Rt, Arithmetic Average Roughness Ra, and Root-Mean-Square Roughness Rq, were derived.In other work surface roughness or surface quality, also known as surface texture are terms used to describe the general quality of machined surface, which is concerned with the geometric irregularities and the quality of a surface. The ideal surface roughness may be specified in various ways, but two common methods are the peak to valley height (h) and the arithmetic average, Ra (μm). The Ra value, also known as centre line average (CLA) and arithmetic average (AA) is obtained by averaging the height of the surface above and below the centre line. The average Ra value is shown in table 3.3.

Table 3.3 Surface Roughness

EXPT. NO.	**Control Factors**				**Surface Roughness(Ra) μm**			**Avg. μm**
	A	**B**	**C**	**D**	**T1**	**T2**	**T3**	
1	1	1	1	1	5.73	5.82	5.67	5.74
2	2	2	2	2	9.62	9.77	9.80	9.73
3	2	3	3	3	11.80	11.76	11.88	11.81
4	2	1	2	3	8.11	8.15	8.21	8.15
5	2	2	3	1	10.57	10.66	10.52	10.58
6	2	3	1	2	10.83	10.78	10.92	10.84
7	3	1	3	2	11.78	11.83	11.92	11.84
8	3	2	1	3	8.65	8.57	8.49	8.57
9	3	3	2	1	9.09	9.12	8.96	9.05

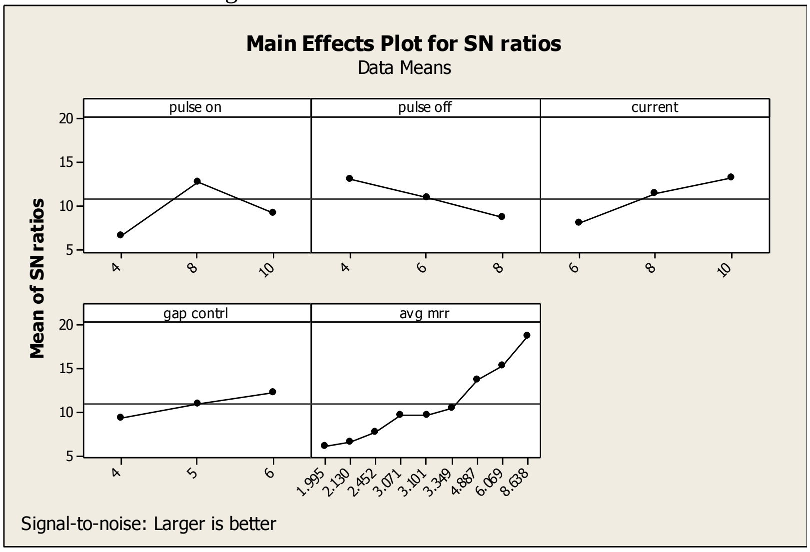
IV. ANALYSIS

ANALYSIS FOR MRR:

There are many factor need to be consider during operating the machine to make sure the results produce are in good condition and increase productivity. The most important factor in making the production run faster is the time taken for machining product. The time taken for machining can be express in term of material removal rate (MRR). Material removal rate (MRR) is a value of time that calculated to determine the rate of production in industries.

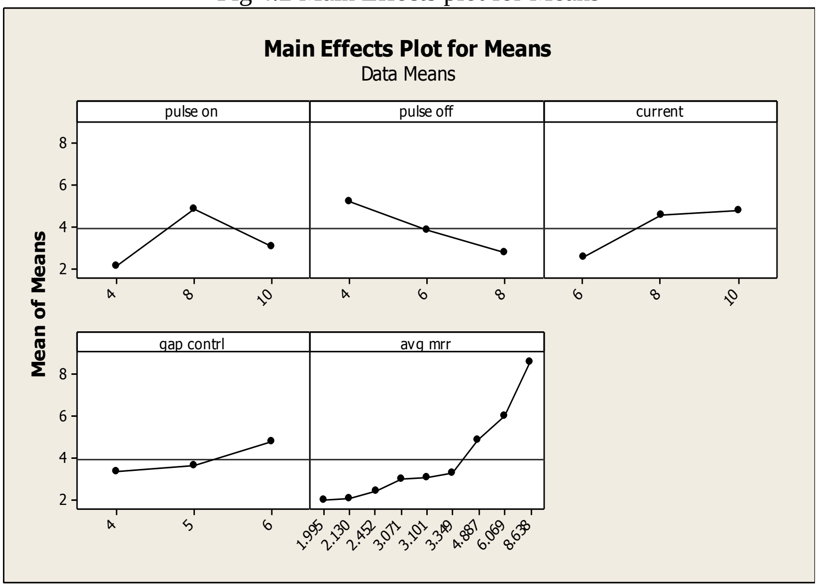
The main effects plot for SN ratio is shown in figure 4.1 (Larger is better) and it indicates the effects of parameters.

Fig 4.1 Main Effects Plot for SN ratio



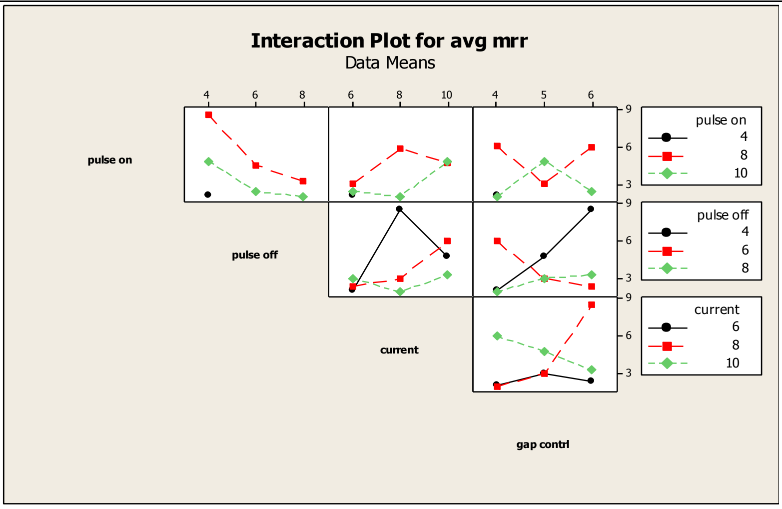
The main effects plot for means is plotted as shown in the figure 4.2

Fig 4.2 Main Effects plot for Means



The interaction plot for average MRR is plotted as shown in the figure 4.3. The present study proposes a material removal rate model based upon a micro-contact model which considers the effects of the various parameters such as pulse-on-time, pulse-off-time, discharge current and gap voltage.

Fig 4.3 Interaction plot for Average MRR



ANALYSIS OF SURFACE ROUGHNESS:

The main effects plot for SN ratio (smaller is better) is shown in figure 4.4 and the figure 4.5 shows the main effects plot for means of the same.

Fig 4.4 Main Effects plot for SN Ratio

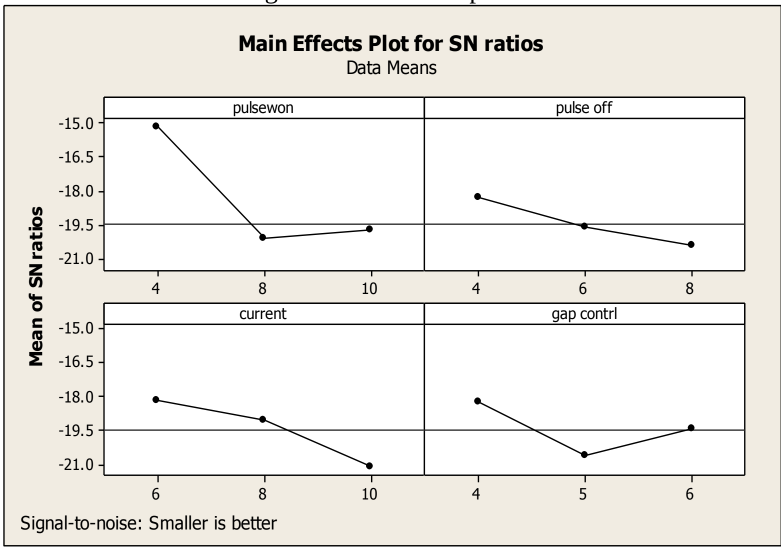
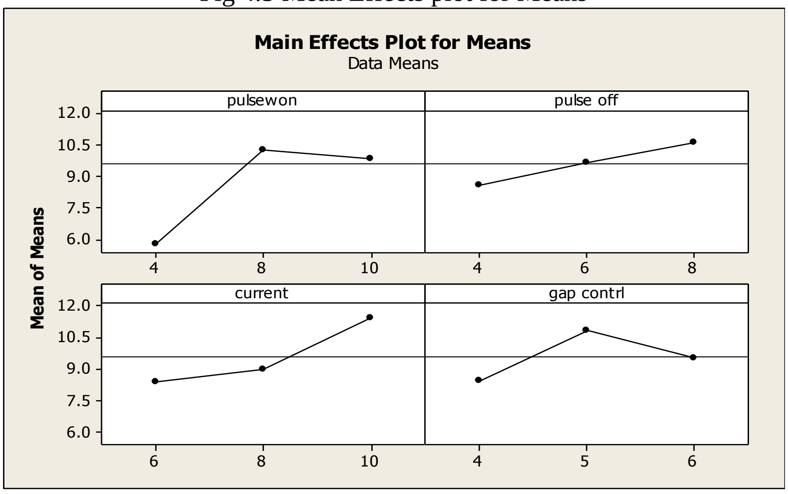


Fig 4.5 Mean Effects plot for Means



The interaction plot for average roughness value is also being plotted as shown in figure 4.6.

Fig 4.6 Interaction plot for Average Surface Roughness

REGRESSION ANALYSIS:

The regression equation is avg. Ra = - 2.13 + 0.237 pulse on time + 0.418 pulse off time + 0.678 Discharge current + 0.368 gap control. Table 4.1 illustrates the Response table for SN Ratio.

Table 4.1 Response table for SN Ratio

LEVEL	CURRENT	PULSE ON	PULSE OFF	GAP CONTROL
1	-15.18	-18.29	-18.18	-18.27
2	-19.96	-19.37	-18.77	-20.37
3	-19.76	-20.43	-21.14	-19.45
DELTA	**4.79**	**2.14**	**2.96**	**2.10**
RANK	**1**	**3**	**2**	**4**

V. CONCLUSION

As conclusion, the experiments of this paper conclude that the machining characteristics in machining process of electric discharge machine (EDM) influence the machining performance.

The higher material removal rate (MRR) will result in better machining performance rate. In this experiment, the higher material removal rate (MRR) obtained is come from electrode copper is 8.638 g/mm^3.

Surface roughness of the EN31 material during electric discharge machining increases with increase in current, pulse on time, voltage and Gap control. And the better surface roughness is 5.74 µm.

By comparing the results of the Material Removal Rate and Surface Roughness it is found that the better machining parameter is fourth level of parameter. The optimum results were been illustrated in table 5.1.

Table 5.1 Optimum Results

PROCESS PARAMETERS	DISCHARGE CURRENT (amps)	PULSE ON TIME (µs)	PULSE OFF TIME (µs)	GAP CONTROL (µm)
MRR AND Ra.	8	4	6	6

REFERENCES

Journal Papers:

[1] **Raghuraman S, Thiruppathi K, Panneerselvam T, Santosh S.**, "Optimization of EDM parameters Using Taguchi Method and grey Relational analysis for mild Steel is 2026", International Journal of Innovative Research in Science, Engineering and Technology, Vol. 2, Issue 7, July 2013.

[2] **G Krishna Mohana Rao1, S. Satyanarayana, M Praveen.**, "Influence of Machining Parameters on Electric Discharge Machining of Maraging Steels – An Experimental Investigation", Proceedings of the World Congress on Engineering 2008 Vol II WCE 2008, July 2 - 4, 2008, London, U.K.

[3] **S.H.Tomadi, M.A.Hassan, Z.Hamedon, R.Daud, A.G.Khalid.**, "Analysis of the Influence of EDM Parameters on Surface Quality, Material Removal Rate and Electrode Wear of Tungsten Carbide", Proceedings of the International MultiConference of Engineers and Computer Scientists 2009 Vol II IMECS 2009, March 18 - 20, 2009, Hong Kong.

[4] **Ruben Phipon and B.B. Pradhan.,** " Process Parameters Optimization Of Micro Electric Discharge Machining Process Using Genetic Algorithm", Ruben Phipon, B.B.Pradhan, International Journal of Engineering Research and Applications (IJERA), Vol. 2, Issue 5, September- October 2012, pp.1986-1993.

[5] **S. Dhanabalan, K. Sivakumar, C. Sathiya Narayanan.,** "Optimization of EDM Process Parameters with Multiple Performance Characteristics for Titanium Grades", European Journal of Scientific Research ISSN 1450-216X Vol.68 No.3 (2012), pp. 297-305.

[6] **Pushpendra, S.Bharti1, S.Maheshwari, C.Sharma.,** "Multi-objective optimization of electric-discharge machining process using controlled elitist NSGA-II", Journal of Mechanical Science and Technology 26 (6) (2012) 1875~1883.

[7] **N.Arunkumar, H.Shareef Abdur Rawoof, R.Vivek.,** "Investigation on the Effect Of Process Parameters For Machining Of EN31 (Air Hardened Steel) By EDM", International Journal of Engineering Research and Applications (IJERA), Vol. 2, Issue4, July-August 2012, pp.1111-1121.

[8] **Singaram Lakshmanan, Mahesh Kumar, Al Mussanah.,** " Optimization of EDM parameters using Response Surface Methodology for EN31 Tool Steel Machining", International Journal of Engineering Science and Innovative Technology (IJESIT) Volume 2, Issue 5, September 2013.

[9] **Lin, J.L., Lin, C.L.,** The use of the orthogonal array with grey relational analysis to optimize the electrical discharge machining process with multiple performance characteristics, International Journal of Machine Tools & Manufacture, Vol. 44, pp.237-244 2002.

[10] **S. Prabhu, B.K. Vinayagam.**, " Analysis of surface characteristics of AISI D2 tool steel material using Electric Discharge Machining process with Single wall carbon nano tubes", IACSIT International Journal of Engineering and Technology Vol. 2, No.1, February, 2010.

[11] **Norfadzlan Yusup, Azlan Mohd Zain, Siti Zaiton Mohd Hashim.,** "Evolutionary techniques in optimizing machining parameters: Review and recent applications (2007–2011)", Expert Systems with Applications 39 (2012) 9909–9927.

[12] **M. Durairaja, D. Sudharsunb, N. Swamynathanb.,** "Analysis 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.

[13] **C.Velmurugan, R.Subramanian, S.Thirugnanam, B.Ananadavel**., "Experimental investigations on machining characteristics of Al 6061 hybrid metal matrix composites processed by electrical discharge machining", International Journal of Engineering, Science and Technology Vol. 3, No. 8, 2011, pp. 87-101.