# Prediction of Surface Roughness and Material Removal Rate for 7024 AL-Alloy in EDM Process

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## ABSTRACT

This paper studies prediction the values of MRR and surface roughness in Electrical discharge operations. It is a operation in which the material removal rate is machined with elevation spark in the midst work piece and electrode sunken through dielectric solution.Through use Taguchi found that the accuracy of the measured and prediction values that have been is 93% and 99% for each of the MRR and surface roughness respectively. The effect of different Electrical discharge machining factors are (Gap, pulse off time and pulse on time) to predict the (material removal rate) and (roughness). Note that connected pole that was used is copper. From (ANOVA) found that the large parameter effect on MRR is pulse-on 65% and pulse-off 25% while large parameter effect for surface roughness is pulse-on 96% . The least influential parameter for metal removal rate is the gap and the least influential parameter for surface roughness is pulse-off and Gap.

**Keywords:** EDM, MRR, Surface Roughness, Prediction.

## INTRODUCTION

electrical discharge machining (EDM) is a process of nontraditional machining depends on remove material of surface by different of repeat electrical discharges between a work pieces machined and tool called electrode. The high temperature of the spark and electrode cases electrode wears [1]. And Electrical discharge machining is not direct contact between the work piece and the electrode, vibration and chatter problems during machining [2]. The Electrical discharge machining operation is using for machining the cut tool, dies punch and other machining parts to [3].

EDM is the operation which control in erosion of electrically conductive materials by the spark through the tool (cathode) and the work piece (anode) with gap between (0.02 to 0.5) mm, and called as spark-gap [4]. Because it is the cut tool cannot touch the work piece, so it is made of a soft material like graphite, brass and copper. The tool put in a fluid such as kerosene, to work under pressure. The coolant Considered as a dielectric, away to clean particles of eroded material from the tool and the work piece. The tank is put it inside the work piece, the electrode and the dielectric fluid, and end is submerged. An electrode, chosen depending on the profile of the cut and it is position on the top with a small gap [5].

**Ozgedik and Cogun (2006) [6]** detect the variations in dimension tool wear characters namely, front and edge wear and quality of machining outputs, tool wear, material removal rate, surface roughness and relative wear were studying with large machining factors. Experiments were run out use kerosene dielectric fluid, steel as work piece and round copper tools with a under different dielectric flushing conditions (suction, injection and static), pulse durations and discharge currents. The researcher was shown that machining factors and dielectric flushing conditions have a large effect on machining performance outputs and geometric tool wear characteristics.

**Khan (2008) [7]** studied an analysis that use to calculate the wear of electrode along the cross-section of the tool compare to the same through Electrical discharge machining of mild steel and aluminum use brass and copper electrodes, and find that the increase of electrode wear with increase voltage and current, but wear along the cross-section of the tool is more compared to the same along. It was also found that the wear ratio increases with an increase in current, that means, though a higher current causes more removal of work material, the highest wear ratio found during cutting of steel as work piece using a brass as tool.

**Mahendran et al. (2010) [8]** have focused on the principle of micro- EDM, , types of generators, dielectric fluid and Electrical discharge machining process factors as input, the tool wear ratio and the material removal rate as output . Micro- Electrical discharge machining process is depending on the thermoelectric energy between the electrode (tool) and a work piece. Micro- Electrical discharge machining is developed way to produce micro-parts in the range of (50-100) µm. This paper is essential for the development in the paper to fabricate the micro- Electrical discharge machining with micro actuator tool feed mechanism machine.

**Li et al. (2012) [9]** investigated the method by which (flushing parameters and flushing modes) affects machining indices of performance, i.e., tool wear rate and material removal. Depending on a study conduct, compare with mono-hole inner flushing with traditional solid electrode, a bunched electrode with several hole inner flushing Bears higher peak current and results in larger relative tool wear ratio and higher material removal rate because of a more effective flushing process. This result in material removal rate is 3 times larger by about 789.8 $mm^3$/min and in a higher TWR, which exceeds 41% in the Electrical discharge machining with a bunched electrode.

## 2. Taguchi Method:

Taguchi discovers a novel conception for the quality control method named as (Taguchi parameter design). The method stated that the quality of manufactured part must be computed by the deviation amount from the required value. With takes into consideration not only the operation mean, but also the variation magnitude or (noise) created with manipulating the inputs parameters or operation variables. The technique is focus on two major groups; a unique matrix type called orthogonal array (OA), all the columns include number of experiment depending on the level number for the control factor, in addition to (signal to noise ratio) S/N [10].

$$S/N = -10\log\left[\frac{1}{n}\sum_{i=1}^{n}(y_i^{\,2})\right] \quad ; \qquad i = 1,2 \dots\dots n \qquad \dots\dots..(1)$$

The formula is utilized to calculating signal to noise ratio are given by:

$$S/N = -10\log\left[\frac{1}{n}\sum_{i=1}^{n}\left(1/{y_i}^2\right)\right] \quad ; \qquad i = 1,2 \dots\dots n \qquad \dots..(2)$$

Where: $\boldsymbol{n}$ are the measurements of input

$\boldsymbol{yi}$ are the measurements value of output

## Experimental Work:

### EDM machine

CHEMER EDM machine type (CM 323C) used to implement the practical part. The work piece with dimensions (30×40×10 mm) used in the experiment was Aluminum alloy (7024).The percentages of chemical composition are given in **Table (1)** to cut straight line with depth 3 mm.

**Table (1): Chemical composition of Aluminum 7024**

| Cu% | Mg% | Si% | Fe% | Mn% | Cr% | Ni% |
|---|---|---|---|---|---|---|
| 2.14 | 1.55 | 0.163 | 0.422 | 0.216 | 0.090 | 0.012 |
| Ga% | Pb% | Zn% | Ti% | V% | Other% | AL% |
| 0.010 | 0.071 | 4.93 | 0.038 | 0.007 | 0.132 | 90.219 |

The components of the EDM machine are of three main parts: Work holding assembly, upper and lower wire guide assembly and wire transport system.

### Work-Holding Assembly:-

The work-holding assembly consists of work-table with X-Y coordinate base**.** The work piece is fitted on the work-holding assembly with the help of jaws, bolt or special work-holding fixture.

### Cutting Tool:

The electrode must be easily machined, but has higher density, melting point and thermal conductivity. The heat rise has to be less when localized on the surface of the tool. In this paper, the copper is selected as tool electrode material because it possesses the good characteristics efficiently.

### Design of Experiments:-

The cutting work with total number are (nine) with (3) levels and (3) parameters as (27 test) . A partial design was done for studying the effects of parameter on MRR and surface roughness values. The parameters were $T_{on}$, $T_{OFF}$, Gap. as **Table (2).**

**Table (2): Cutting conditions**

| No | Parameter | Symbol | Level $_1$ | Level $_2$ | Level $_3$ | Units |
|---|---|---|---|---|---|---|
| **1** | Pulse-on time | $T_{ON}$ | 50 | 100 | 150 | $\mu$sec |
| **2** | Pulse-off time | $T_{OFF}$ | 25 | 50 | 75 | $\mu sec$ |
| **3** | Gap | Gap | 1 | 3 | 5 | mm |

The other factors were kept constant during machining which are:

- Current = 50 Amp
- Machining time (MT)= 3 min
- voltage (Sv) = 25 Volt

The final distribution of the experiments according to Taguchi orthogonal array for their levels and final result of MRR and surface roughness are shown in **Table (3)**, in addition to the predicted values by the program Minitab16 depending on the Taguchi method.

**Table (3): Experimental design for the work**

| No | T on (µsec ) | T off (µsec) | Gap (mm) | MRR measured (gram/sec) | MRR predicted (gram/sec) | Surface roughness measured(µm) | Surface roughness predicted (µm) |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 0.37 | 0.346 | 2.7133 | 2.595 |
| 2 | 1 | 2 | 2 | 0.21 | 0.235 | 2.3333 | 2.306 |
| 3 | 1 | 3 | 3 | 0.456 | 0.455 | 2.6867 | 2.832 |
| 4 | 2 | 1 | 2 | 0.46 | 0.459 | 4.5333 | 4.678 |
| 5 | 2 | 2 | 3 | 0.496 | 0.472 | 5.2400 | 5.122 |
| 6 | 2 | 3 | 1 | 0.58 | 0.605 | 5.565 | 5.538 |
| 7 | 3 | 1 | 3 | 0.573 | 0.598 | 5.910 | 5.883 |
| 8 | 3 | 2 | 1 | 0.526 | 0.525 | 6.071 | 6.216 |
| 9 | 3 | 3 | 2 | 0.643 | 0.619 | 6.126 | 6.008 |

**Machining Using EDM:**

**Fig (1)** shows nine simple after cutting using of EDM process under machining parameter **Table (3)**.

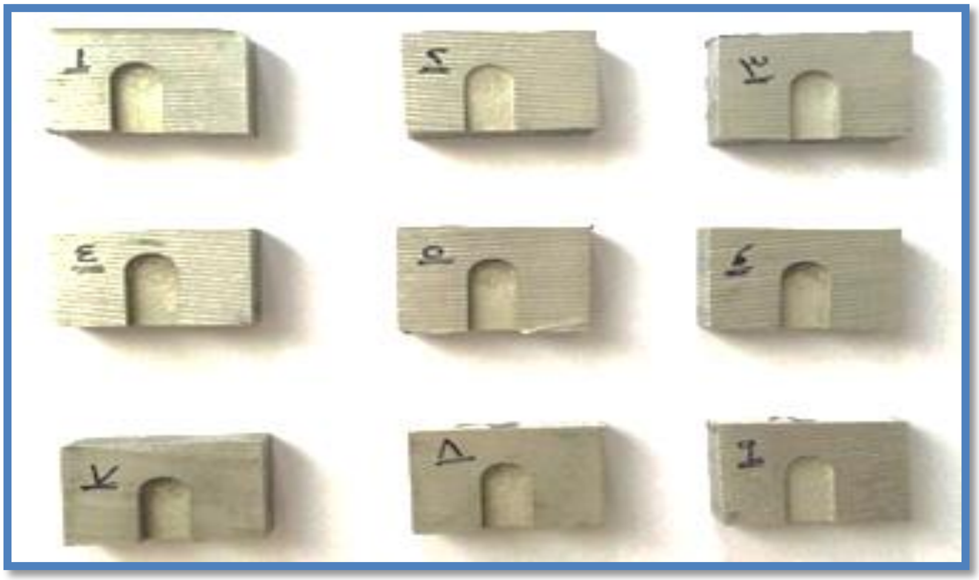

**Figure (1): specimens after machining**

**Surface Roughness Tester:-**

The portable gauge of surface roughness Mahr Federal's is available at measurement lab / production and metallurgy engineering Department/UOT, and shown in **Fig (2).**


**Figure (2): Pocket Surf use in the proposed work for measure surface roughness.**

**Metal Removal Rate (MRR)**

The material removal rate of the work piece will be measured by dividing the weight of work piece before and after machining against the machining time that was achieved [11].

$$MRR = \frac{WPB-WPWA}{MT} \quad \text{……. (3)}$$

Where:
MRR= Material removal rate (g/min)
WPVB= Weight-before cutting (g).
WPWA= Weight-after cutting (g).
MT = time of cutting (min).

**Results and Discussion:**

The regarding between predicted and measured for material removal rate as shown in **Fig( 3**), it is indicate there is an agreement in more values between two bar charts , in **Fig(6),** the comparison of the experimental data and the prediction value for surface roughness. Surface roughness for all experiment is measured using portable surface roughness tester; this shows the efficiency Taguchi method to predict the variables. The independent of the independent values able to predict the dependent values coefficient prediction $R^2$ (which are taken from the program and are considered as an indication of the viability of the program on prediction) pieces are 93.9% and 99.6% for mean material removal rate and surface roughness respectively. The mean of S/N ratio and these characteristics are shown for each characteristic. To study the designed parameter and to indicate the conditions are the main purpose of used the analysis of variance (ANOVA), which significantly affects the quality characteristic. This analysis use to find out the contribution of parameter in controlling the output of the EDM process. The "P%" value in **Table (4)** and **Table (5)** shows the effectiveness for all condition toward affecting the related response characteristics within the limited range. From **Table (4),** it is contain the pulse time on (Ton) is the more significant parameter for maximum MRR, and the pulse time off (Toff) is the next significant parameter for maximum MRR. **Fig (4 and 5**) shows the plot of the means of the material removal rate and the means of S/N ratio. In the Figures it is concluded that the optimum parameter combination for maximum material removal rate is level (3) level (3) level (3), i.e., at 150 µsec pulse time on, 75 µsec pulse time off and 5 mm gap. From **Table (5),** it is concluded that the pulse time on is the most significant factor for minimum surface roughness, gap is the next significant parameter for minimum Ra then pulse time off. **Fig (7 and 8)** shows the plot of the means of the surface roughness and the means of S/N ratio. The optimum parameter for minimum surface roughness is level (1) level (1) level (2), i.e., at 50 µsec pulse time on, 25 µsec pulse time off and 3 mm gap.

**Table (4): ANOVA for Means (MRR)**

| Variance used | DOF | Sum of squares | V | F -ratio | P (%) |
|---|---|---|---|---|---|
| **Pulse on time, $T_{on}$** | 2 | 0.08787 | 0.043935 | 24.47632 | 65.79 |
| **Pulse off time, $T_{off}$** | 2 | 0.0339 | 0.01695 | 9.442897 | 25.38 |
| **Gap, mm** | 2 | 0.0082 | 0.0041 | 2.284123 | 6.13 |
| **Error ,e** | 2 | 0.00359 | 0.001795 | -- | 2.68 |
| **Total** | 8 | 0.13356 | -- | -- | 100 |

**Table (5): ANOVA for Means (Ra)**

| Variance used | DOF | Sum of squares | V | F- ratio | P (%) |
|---|---|---|---|---|---|
| **Pulse on time, $T_{on}$** | **2** | **19.235** | **9.6175** | **171.7411** | **96.62** |
| **Pulse off time, $T_{off}$** | **2** | **0.25** | **0.125** | **2.232143** | **1.25** |
| **Gap, mm** | **2** | **0.31** | **0.155** | **2.767857** | **1.55** |
| **Error ,e** | **2** | **0.112** | **0.056** | **--** | **0.56** |
| **Total** | **8** | **19.907** | **--** | **--** | **100** |

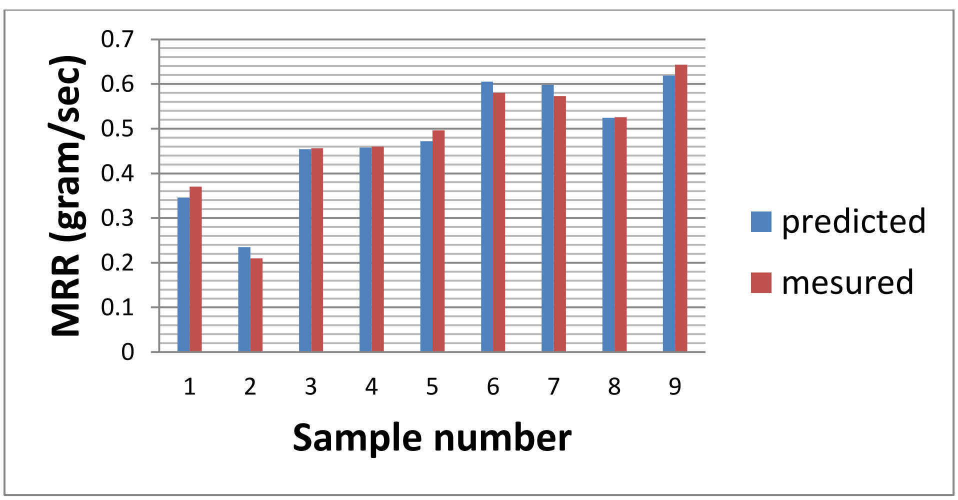


**Figure (3): The diagram of the measured and predicted material removal rate for the experimental data.**

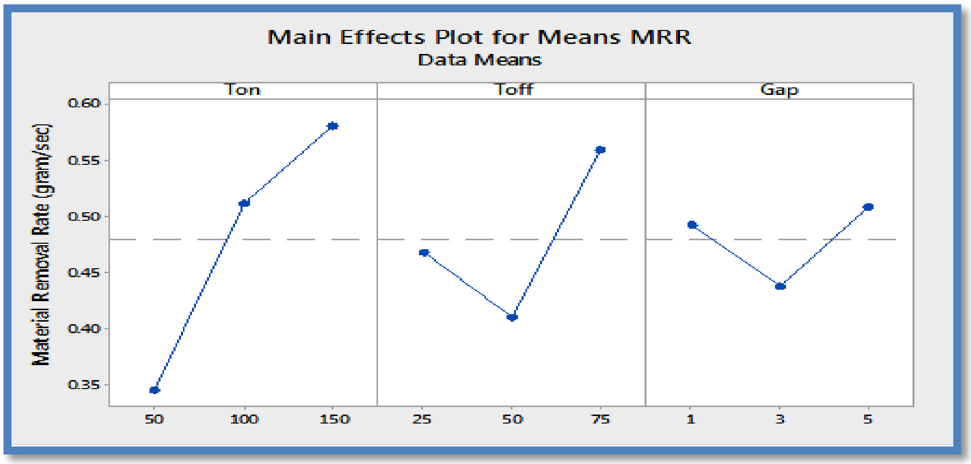


**Figure (4): Main effects Plot for means (MRR)**

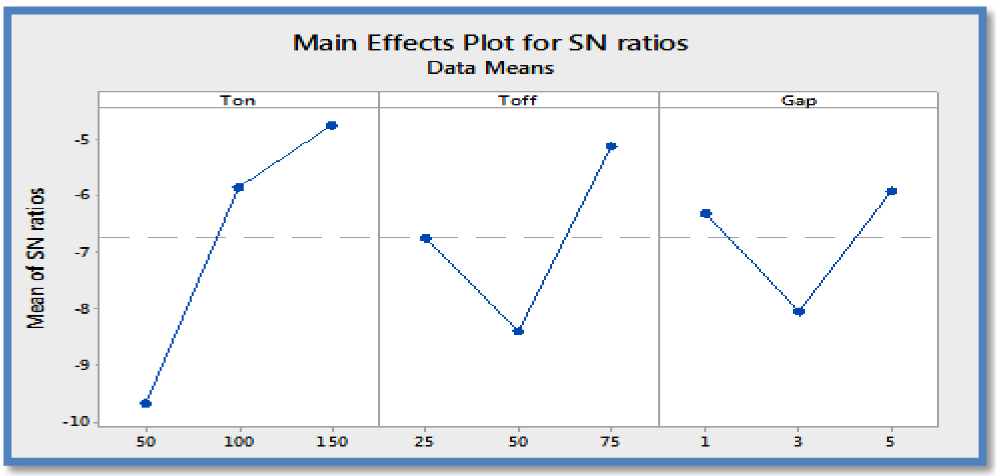


**Figure (5): The mean S/N ratio plot for (MRR)**

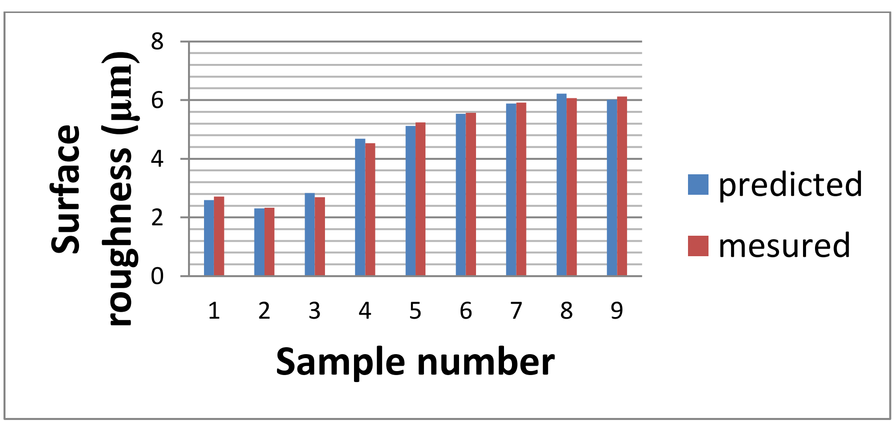


**Figure (6): The compare between of the measured and predicted surface roughness for the experimental value.**

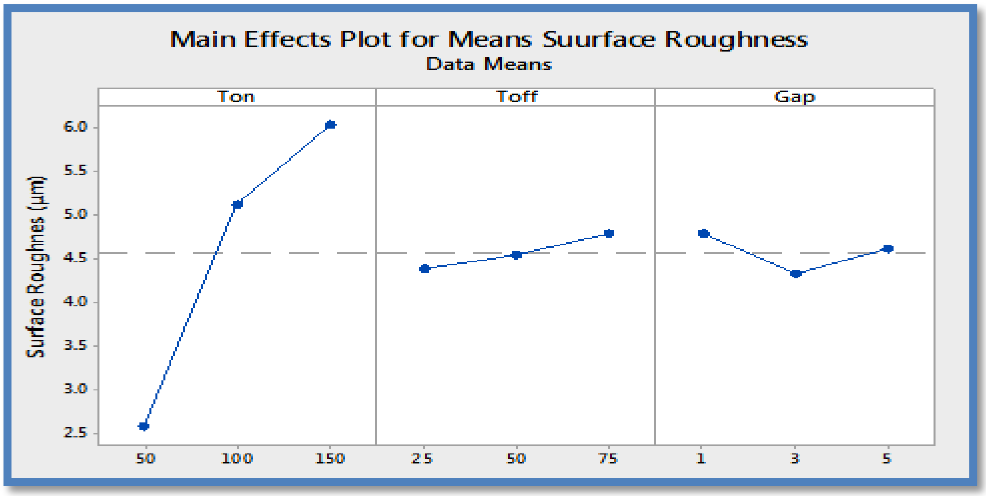


**Figure (7): Main effects Plot for means (Ra)**

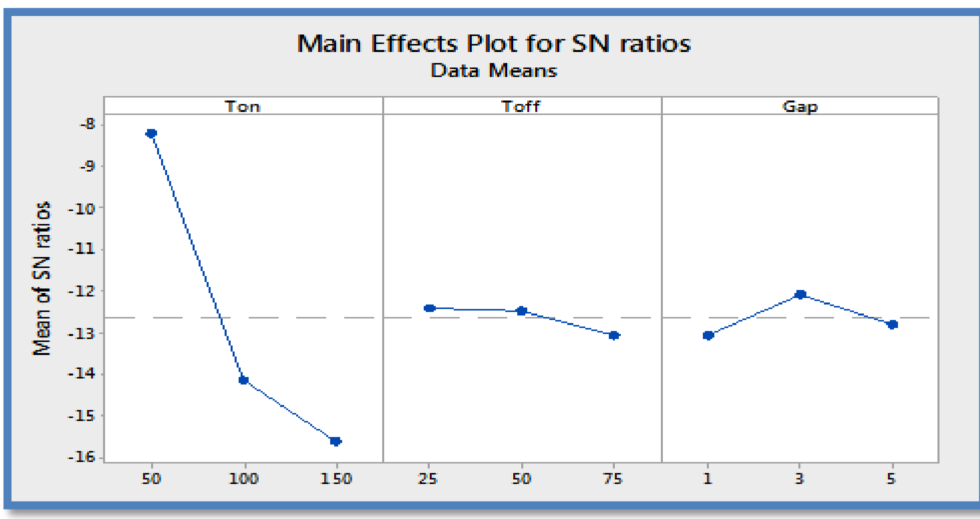


**Figure (8): The mean S/N ratio plot for (Ra)**

## CONCLUSIONS

The conclusions of this paper can be summarized as: At low pulse on time supplied (50µsec) it get more accurate machining but max MRR using copper electrode and work piece of 10 mm thickness, the MRR is less, while this process gives best surface roughness. The accuracy between the predicted and experimental values at the optimum combination of variables characteristics for MRR, and surface roughness lies within 93% and 99% respectively.

## REFERENCES

[1] Pravin R. Kubade and V. S. Jadhav, "An Experimental Investigation of Electrode Wear Rate (EWR), Material Removal Rate (MRR) and Radial Overcut (ROC) in EDM of High Carbon-High Chromium Steel (AISI D3)", International Journal of Engineering and Advanced Technology, Volume-1, Issue-5, June,2012.

[2] Ho K. H., and Newman S. T., "State of the art electrical discharge machining (EDM)", International Journal of Machine Tools and Manufacture, Vol. 43, No. pp. 1287-1300, 2003.

[3] Tsai, K. M. and Wang, P. J., "Predictions on surface finish in Electrical Discharge Machining based upon neural network models", International Journal of Machine Tools & Manufacture, Vol.41, pp.1385-1403, 2001.

[4] Datta, R. N., "Machine tools", New Central Book Agency Ltd , London, Vol.2, pp. 282-286, 2010.

[5] Puertas, I. and Luis, C. J., "Optimization of EDM conditions in the manufacturing process of B4C and WC-Co conductive ceramics", Int. J. Adv. Manuf. Technol., 2011.

[6] Ozgedik Ali, Cogun Can, "An experimental investigation of tool wear in electric discharge machining", Int J Adv Manuf Technol, Vol. 27, pp. 488-500, 2006.

[7] Khan A. A., "Electrode wear and material removal rate during EDM of aluminum and mild steel using copper and brass electrodes", Int J Adv Manuf Technol, Vol. 39, pp. 482-487, 2008.

[8] Mahendran S., Devarajan R., Nagarajan T., Majdi A., "A Review of Micro-EDM", Proceedings of the International Multiconference of Engineers and Computer Scientists, Vol.2, 2010.

[9] Lei Li, Lin Gu, Xuecheng Xi, Wansheng Zhao, "Influence of flushing on performance of EDM with bunched electrode", Int J Adv Manuf Technol , Vol.58, pp.187-194, 2012.

[10] W.K.Hamdan, "Feasibility Development of Incremental Sheet Metal Forming Process Based on CNC Milling Machine", PhD. thesis, 2009.

[11] Maan A. Tawfiq, Shukry H. Aghdeab and Ahmed B. Abdulwahhab, " Studying The affect of Current on (MRR) and (EW) in Electrical Discharge Machining (EDM) ", Eng. & Tech. Journal, Vol. 31, Part (A), No. 17, 2013.