Study of Selective Parameters Influencing Surface Roghness and Metal Removal Rate of Internal Cylinders Produced By ECH

دراسة العوامل المختارة المؤثرة فى جودة الأسطح ومعدل إزالة الرايش على الاسطوانات الداخلية باستخدام طريقة التحضين الكهروكيميائى

N. Radwan* , A. Kohail , S. Abbas***, I. Mousa*****

* Ass. Lecturer, Specialized Studies Academy, Workers University, Egypt.
** Ass. Prof., Specialized Studies Academy, Workers University, Egypt.
*** Prof., Faculty of Engineering., Shoubra, Zagazig University

الملخص

تعتبر عملية التحضين الكهروكيميائى تعديل لعملية التحضين التقليدية. حيث أنه فى عملية التحضين الكهروكيميائى يتم إزالة للرايش بواسطة التحلل الكهربائى بالإضافة الى التآكل الميكانيكى. ولكن أكثر من 80% من الرايش يزال بواسطة التحلل الكهربائى. وتعتبر عملية التحضين الكهروكيميائى واحدة من أهم عمليات التشغيل الغير تقليدية وبالرغم من استخدامها فى بعض العمليات الصناعية خاصة فى تحسين جودة السطوح إلا أنها مازالت غير كاملة التوصيف نتيجة لتنوع العوامل التى تؤثر على عملية التشغيل. حيث يتطلب المزيد من المعلومات عن تأثير شروط التشغيل على جودة السطح.
وقد تم تسجيل النتائج المعملية وتأثير أهم العوامل المؤثرة خاصة: خامة الشغلة- الوقت- التيار المؤثر- الخلوص الابتدائى- سرعة دوران أداة القطع-نوع المحلول الموصل وتركيزه-شكل مقدمة أداة القطع على جودة السطح ومعدل إزالة الرايش. وقد تم إجراء التجارب على أداة تحضين خاصة والتى تم تصميمها وتصنيعها فى المعمل.
وقد أعدت تلك النتائج بهدف إمداد المستخدم بأفضل الأساليب لاختيار شروط قطع مناسبة للحصول على أفضل جودة للسطح.

ABSTRACT

Electrochemical Honing process (ECH) is a modification of conventional honing techniques whereby material is removed from electrically conductive workpieces through a combination of anodic dissolution and mechanical abrasion. Eighty percent, or more, of the material removal occurs through electrolytic action. ECH is one of the non-equilibrium processes and is a technique, which in spite of being used in some industrial plants especially to smothen surfaces, is still not fully described due to the variety of the factors affecting the process. More information about the process is required especially the effects of the working parameters on the produced surface roughness. This paper reports experimental findings on the effect of important process parameters such as workpiece material, time, applied current, initial working gap, rotational speed, electrolyte type and concentration and tool tip shapes on surface quality and metal removal rate (MRR). A special designed honing test rig , which is developed at the laboratory, was used. The surface roughness and (MRR) are measured. The experimental results are a useful guideline for the user for proper selection of conditions for obtaining a good surface quality.

Keywords: Electrochemical machining (ECM); Electrochemical Honing (ECH); surface roughness; metal removal rate (MRR)

Accepted September 24, 2007

1. INTRODUCTION

Increasing demand for high strength, low-weight, metallic and intermetallic alloys has led to an increasing requirements for metal cutting and forming processes able to cope effectively with such materials. Electrochemical machining (ECM) is among the well recognized non-traditional manufacturing processes in industry. Electrochemical machining (ECM) is a non-traditional process used mainly to cut hard or difficult to cut metals, where the application of a more traditional process is not convenient. Those difficult to cut metals demand high energy to form chips, which can result in thermal effects due to the high temperatures inherent to the process in the chip–tool interface **[1&2]**. In traditional processes, the heat generated during the cut is dissipated to the tool, chip, workpiece and environment, affecting the surface integrity of the workpiece, mainly for those hard materials **[3]**. Different from the other machining processes, in ECM there is no contact between tool and workpiece. Electrochemical (electrolyses) reactions are responsible for the chip removal mechanism. The difficulties to cut super alloys and other hard-to-machine materials by conventional process have been largely responsible for the development of the ECM process **[4]**. Several investigations have been achieved to improve ECM accuracy, to improve the electrolyte flow condition in the inter-electrode gap and to reduce the occurrence of cavitations, high electrolyte pressures have been recommended. Pressurized electrolyte purged with gas has also been submitted **[5]**. Improving ECM accuracy has been reported as a result of increased electrolyte turbulence due to the mechanical vibration of one of the electrodes. Fan et al. **[6]** studied the mechanism of improving machining accuracy of ECM by introducing a magnetic field. The integration of an orbital movement of a workpiece to enhance the ECM accuracy was also adopted **[7]** Among the often considered electrolytes, the current efficiency is nearly 100% for NaCl. The current efficiency depends on the current density in use of $NaNO_3$ **[8,9]**. Electrochemical honing (ECH) combines the high removal characteristics of electrolytic dissolution (ECD) and mechanical abrasion (MA) of conventional honing. The process has much higher removal rates than either conventional honing or internal cylindrical grinding. The material removal rate (MRR) for ECH is 3 to 5 times faster than that of conventional honing and 4 times faster than that of internal cylindrical grinding. Tolerances in the range of ± 0.003 mm are achievable, while surface roughness in the range of 0.2 to 0.8 μm R_a are possible **[10]**.

The main purpose of this work is the experimental study of the different variables in electrochemical Honing. A special honing test rig, which was developed at the laboratory, was used. The metal removal rate (MRR) and surface roughness were measured, which have been used as the response parameters to evaluate the results. Many parameters were changed during the experiments such as: workpiece material, machining time, applied current, gap, electrolyte type, electrolyte concentration, rotational speed (rpm), and tool tip shapes. The electrolytic solutions ; sodium chloride (NaCl) and sodium nitrate ($NaNO_3$) with different concentrations were used. Using electrochemical honing showed good results concerning roughness and metal removal rate.

2. EXPERIMENTAL WORK

A schematic view of the developed ECH machine and its components is presented in Fig. (1). The main parts of the ECH setup are the electrochemical honing unit, drilling machine, the multi-stage centrifugal pump, and the electrolyte tanks with filtering system. The electrochemical honing unit is shown in Fig. (2). The electrochemical honing unit is composed of a tephlon round section frame in which a spindle carrying the tool on its holder is guided and moves rotationally and axially towards the workpiece which is fixed. The electrochemical honing unit is fixed to the drilling machine table as shown in Fig.(3). The electrolyte is pumped from a tank through filtering system to the working gap using a stainless steel multi-stage centrifugal pump of maximum delivery 1.6 m^3/ hr and maximum pressure 5 atm. A large electrolyte tank (70 liter) was used to limit the effect of temperature variations during experiments. Pressure guage is fixed for measuring electrolye pressure during the machining. The electrochemical honing machine also provided with valves for controlling the electrolye pressure and its return to the tanks through elastic pipe. The power supply is connected to the instrument to obtain DC current due to machining, the positive terminal is connected to the tool, while the negative one is connected to the workpiece. After machining, surface roughness measurements were carried out using Surftest SV 402 manufactured by Mitutoyo (Japan). The time taken for finishing the hole was recorded by an electronic timer. An electronic balance (Metler, LC: 0.1 mg) was used to weight the workpiece before and after ECH process to calculate the metal removal rate MRR. The holes of the workpiece surface were produced through drilling and internal turning processes with an average surface roughness of 6 to 7 μm to ensure a common value of roughness for all the specimens before electrochemically machined specimens. The experimental changed parameters for the preliminary tests are illustrated in Table(1). During experiments, the following parameters were fixed, shown in Table(2). In this paper, we will use Steel (St37) as our workpiece material to study the effect of many machining process on surface roughness and metal removal rate.

Process Parameters	Designation	Variation Range
Workpiece material	W_m	St 37 , Aluminum alloy.
Time	t	10 to 120 sec by step 10
Gap	G	0.2-0.5-0.8 mm
Applied current	I	50-100-200 amp
Rotational Speed	S_R	320-850-1200 rpm
Electrolyte Type	E_T	NaCl , $NaNO_3$ with different concentrations.
Tool Tip Shape	T_S	inclined slots, knurled slots , straight slot cutting, Fig.(4)

Table 1 . *The experimental parameters*

Parameter	Value
Electrolyte Temperature	35 ±1 °C
Inlet electrolyte Pressure (atm.)	2-3
Tool material	Brass
Stroke	27 mm/min
Applied Voltage	20 v .

Table 2 . *Fixed experimental conditions*

3. EXPERIMENTAL RESULTS AND DISCUSSION

3.1. Effect of workpiece material

The effect of workpiece material on surface roughness at different machining time is shown in Figure **(3)**. From results, St37 gives the higher value of the average roughness (R_a) than Aluminum workpieces. It must be noticed that St37 has smaller grain size as compared with AL alloy. So, the material having smallest grain size, the produced average surface roughness will be greater than those having bigger grain size. This fact also was reported in **[11 &12]**.

3.2. Effect of machining time

As illustrated in Figure **(3)** , it is observed that, by increasing the machining time, the average surface roughness decreases. The same results was previously declared by Sembel and Hocheng **[13,14]**. Results show that increasing machining time will remove the higher asperities of initial hole till obtaining a smooth surface and after that surface roughness is kept approximately constant even with increasing machining time. Also, Figure **(4)** shows the effect of machining time on metal removal rate.

3.3. Effect of the electrolyte type and concentration

Figure **(5)** shows that Sodium Nitrate ($NaNO_3$) with concentration 240 gm/lit gives better results than both Sodium Nitrate ($NaNO_3$) with concentration 120 gm/lit and Sodium Chloride ($NaCl$) with concentration 120 gm/lit for the average surface roughness. Also, Figure **(6)** shows the relationship between electrolyte concentration and material removal rate. It can be noted that the increase in electrolyte concentration increases the material removal rate. This can be attributed to at higher concentration, a large number of ions associated in the machining process also increase the machining current and thus enhances the material removal rate.

3.4. Effect of initial working gap

One finds narrower initial gap produces larger amount of material removal and which results in increasing the average roughness **[14]**. Truly, the resistance across the anode and cathode is inversely proportional to the initial gap. More electrical energy is consumed without material removal due to the resistance. The effective electrical field on the anode is decreased with wider electrode gap, thus less material is removed. Figure **(7)** illustrates the relationship between initial working gap and surface roughness. Also, Figure **(8)** shows the relationship between initial working gap and metal removal rate.

3.5. Effect of tool rotational speed

The effect of tool rotational speed on surface roughness by using a cylindrical tool was previously illustrated by Senbel [13] in the case of boring processes, they showed that with the increase in tool rotational speed the roughness improved, up to rotational speeds of 11000 rpm. For ECH process, The same results were obtained but for limited speeds not exceeding 1200 rpm due to the experimental test rig limitations. Figure (9) illustrates the effect of tool rotational speed on surface roughness for different machining time. On the other hand, as shown in Figure **(10)**, metal removal rate is increasing with the increase of the tool rotational speed.

3.6. Effect of applied current

An increase in applied current improves the surface roughness of the machined hole surface. This fact is reached in Figure **(11)**. This is due to that, a further increase in current density breaks up the protective layer that causes deterioration to the surface quality, so that there is a decrease in the percentage of the covered surface areas where the reaction of a non removing effect occurs and a smoother surface is produced. Also, Figure (12) leads to the fact that, any increase in the applied current will increase the metal removal rate.

3.7. Effect of Tool Tip Shape

Figure **(13)** illustrated that, the inclined slots tool shape produces a better surface roughness compared with both knurled and straight slot cutting. Also. Figure **(14)** shows the effect of tool tip shape on metal removal at different machining times. It is found that the smallest amount of metal removal is produced when using the inclined slots tool when compared with both knurled and straight slot cutting. This is accounted by the decrease of the current density for the inclined slots tool.

4. CONCLUSIONS

The present work introduce a special designed honing test rig which developed in the laboratory. This test rig used to study of the selective parameters influencing surface roughness of internal cylinders produced by electrochemical honing process ECH.

These selective parameters are: workpiece material, machining time, initial working gap, applied current tool rotational speed, electrolyte type and electrolyte concentration. the results show that:

1. Steel 37 shows a greater surface roughness compared with Aluminum. This is due to the fact that the material having smallest grain size, the produced average surface roughness will be greater than those having bigger grain size.
2. The produced diameter of hole can be controlled mostly with machining time, while other conditions apply mild effects. Increasing the machining time decreasing the average surface roughness.
3. Increasing the electrolyte concentration improved the average surface roughness.
4. The amount of material removal increases with increasing electrolyte concentration
5. Sodium Nitrate ($NaNO_3$) gives better results than Sodium Chloride (NaCl) for the average surface roughness and metal removal rate
6. Increasing the initial working gap decreases the average surface roughness. This true because the resistance across the anode and cathode is inversely proportional to the initial gap.
7. Increasing the initial working gap decreases the amount of metal removal.
8. Increasing the tool rotational speed improves the average surface roughness.
9. with the increasing of tool rotational speed the metal removal rate will be decreased.

10. Increasing the applied current increases the average surface roughness. This is due to that, a further increase in current density breaks up the protective layer that causes deterioration to the surface quality.

11. Metal removal rate is increasing with the increase of the applied current.

12 The inclined slots tool shape produces a better surface roughness compared with both knurled and straight slot cutting.

13. The smallest amount of metal removal is produced when using the inclined slots tool when compared with both knurling and straight slot cutting. This is accounted by the decrease of the current density for the inclined slots tool.

References

[1] Tsuneo Kurita_, Mitsuro Hattori, "A study of EDM and ECM/ECM-Lapping Complex Machining Technology", International Journal of Machine Tools & Manufacture 46 (2006), PP: 1804–1810.

[2] M.S. Hewidy, S.J. Ebeid, T.A. El-Taweel , A.H. Youssef, "Modelling the performance of ECM assisted by low frequency vibrations", Journal of Materials Processing Technology 189 (2007), PP: 466–472.

[3] Joao Cirilo da Silva Neto, Evaldo Malaquias da Silva, Marcio Bacci da Silva, Intervening variables in electrochemical machining, Journal of Materials Processing Technology 179 (2006), pp: 92–96.

[4] G.F.Benedict, Nontraditional Manufacturing Processe Electrochemical Machining, Marcel Dekker, New York and Basel, 1987, pp. 125–172.

[5] S.R. Ghabrial, S.J. Ebeid, Beneficial effect of air-electrolyte mixture in stationary ECM, Prec. Eng. 3 (4) (1981) 221–223.

[6] Z. Fan, T.Wang, L. Zhong, The Mechanism of improving machining accuracy of ECM by magnetic Field, J. Mater. Process. Technol. 149 (2004) 409–413.

[7] M.S. Hewidy, S.J. Ebeid, K.P. Rajurkar, M.F. El-Safti, Electrochemical machining under orbital motion conditions, J. Mater. Process. Technol. 109 (2001) 339–346.

[8] H. Hocheng., Y.H. Sun, S.C. Lin, P.S. Kao, A material removal analysis of electrochemical machining using flat-end cathode, Journal of Materials Processing Technology 140 (2003) 264–268.

[9] Mohan Sen, H.S. Shan, Analysis of hole quality characteristics in the electro jet drilling process, International Journal of Machine Tools & Manufacture 45 (2005) 1706–1716.

[10] Hassan El-Hofy, "Advanced Machining Processes-Non-traditional and Hybrid Machining Processes', The McGraw-Hill Companies, 2005.

[11] K.P. Rajurkar and M.S. Hewidy "Effect of Grain Size on ECM Performance", Journal of Mechanical Working Technology, 17, pp.315-324, 1988.

[12] L.Kops and V.B. Quack, "Investigation of the Role of Workpiece Grain Size in Electrochemical Machining Process", ASME Journal of Engineering for Industry, vol. 98, pp.360-368, 1976.

[13] H. A. Senbel, "Factors Affecting Electrochemical Honing", Scientific Bulletin, pp.705-717, 1999.

[14] H. Hocheng, Y.H. Sun, S.C. Lin, P.S. Kao, "A material removal analysis of electrochemical machining using flat-end cathode, Journal of Materials Processing Technology 140 (2003).

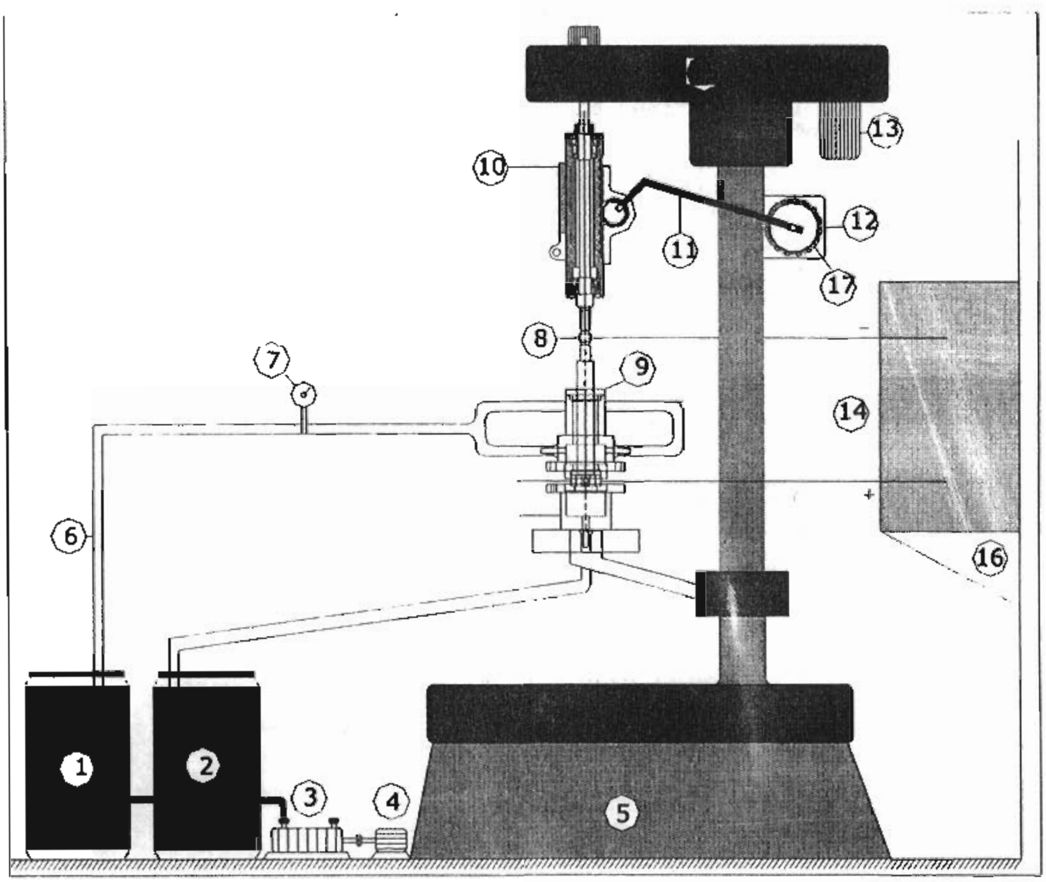

Fig.1 Schematic view of the developed ECH machine and its components.

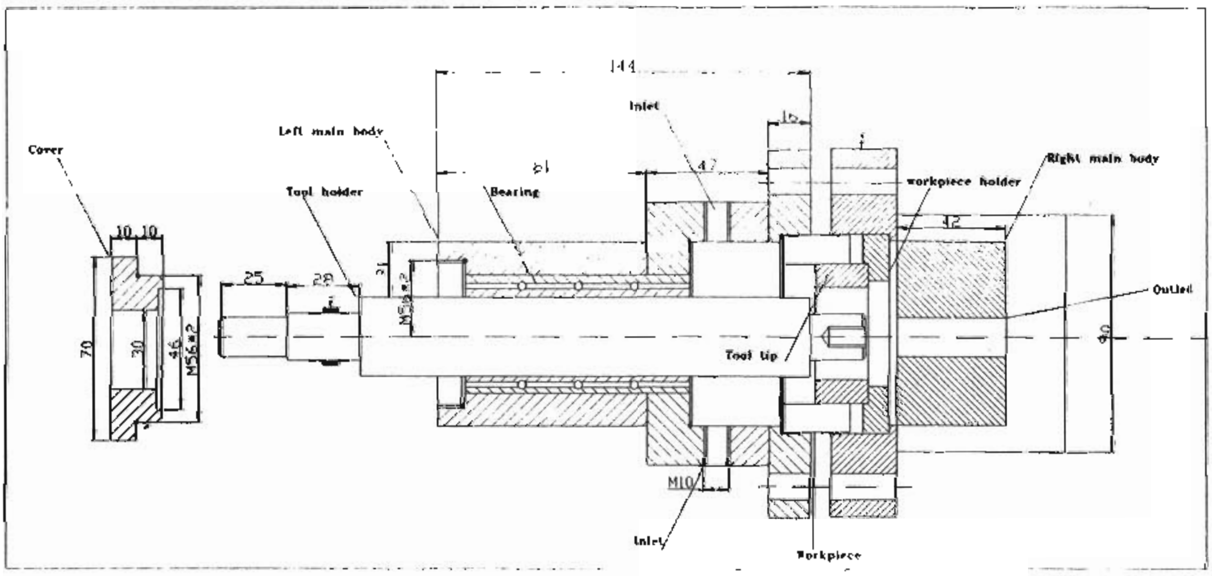

Fig. 2 Electrochemical Honing Cell.

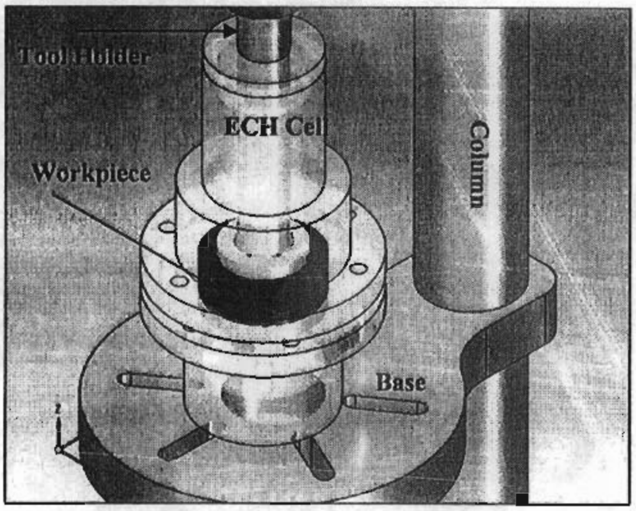

Fig. 3 Fixation of ECH Cell on Drilling Machine.

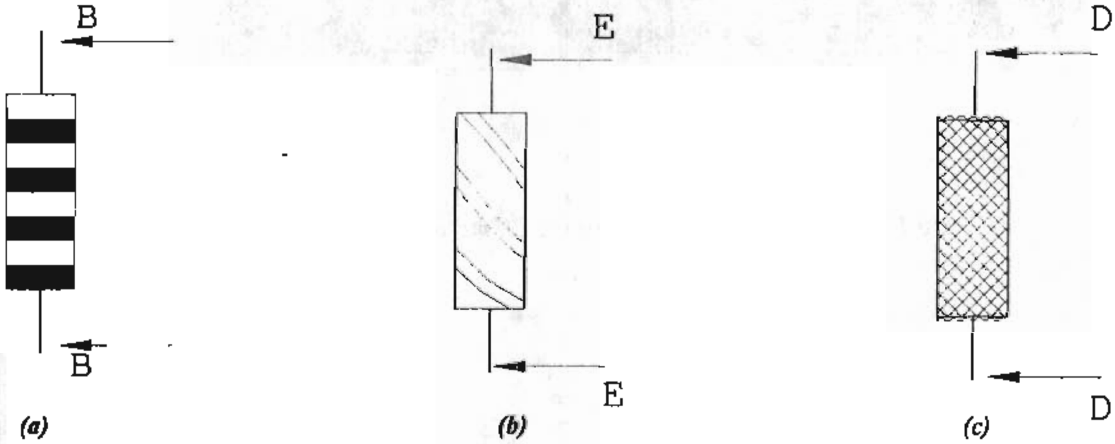

Fig. 4 Tool Tip Shapes.

(a) inclined slots cutting *(b)* straight slots cutting *(c)* knurled slots cutting

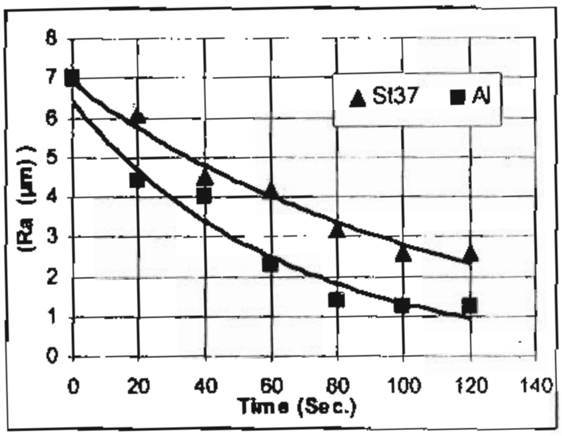

Fig.3 . Effect of workpiece material and machining time on surface roughness.

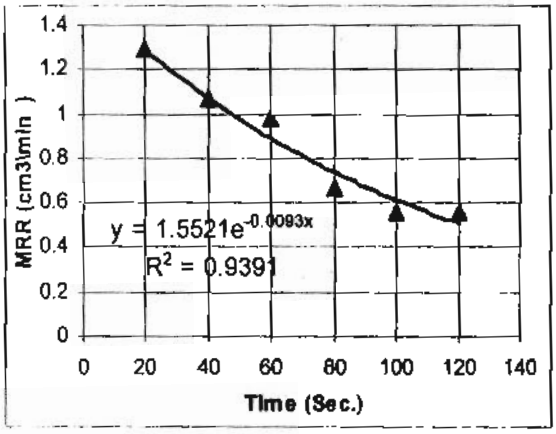

Fig.4 . Effect of machining time on metal removal rate (MRR).

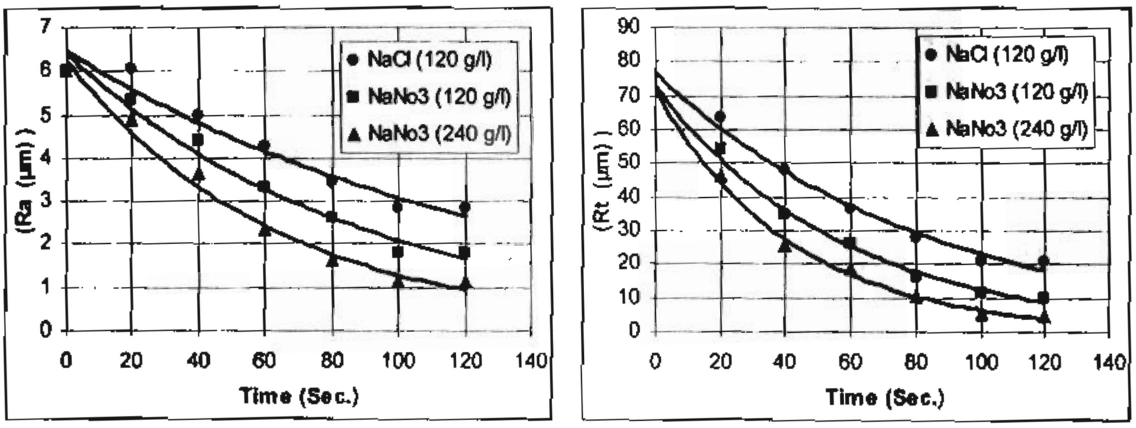

Fig.5. Effect of electrolyte type and concentration on surface roughness (R_a, R_t).

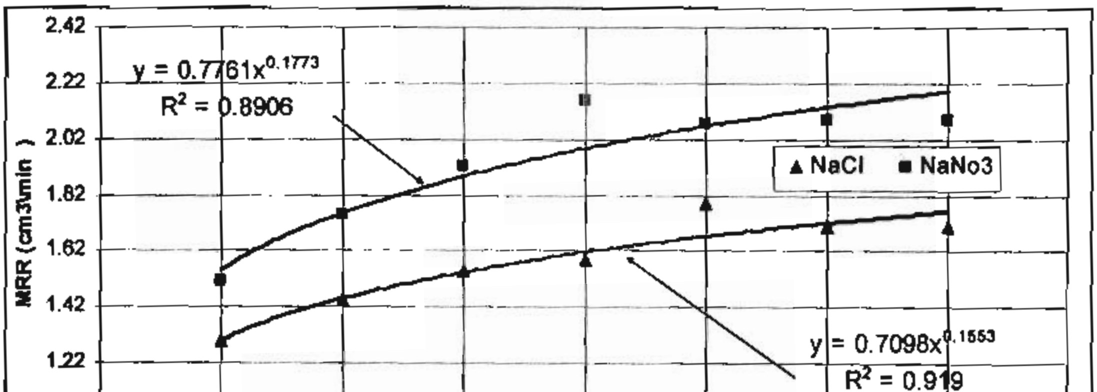

Fig.6. Effect of electrolyte concentration on material removal rate (MRR).

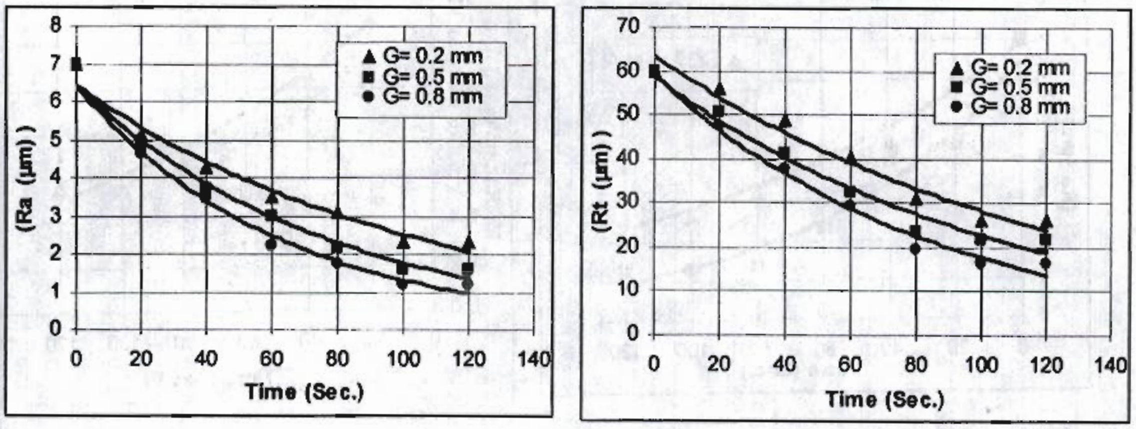

Fig. 7. Effect of initial working gap on surface roughness (R_a, R_t).

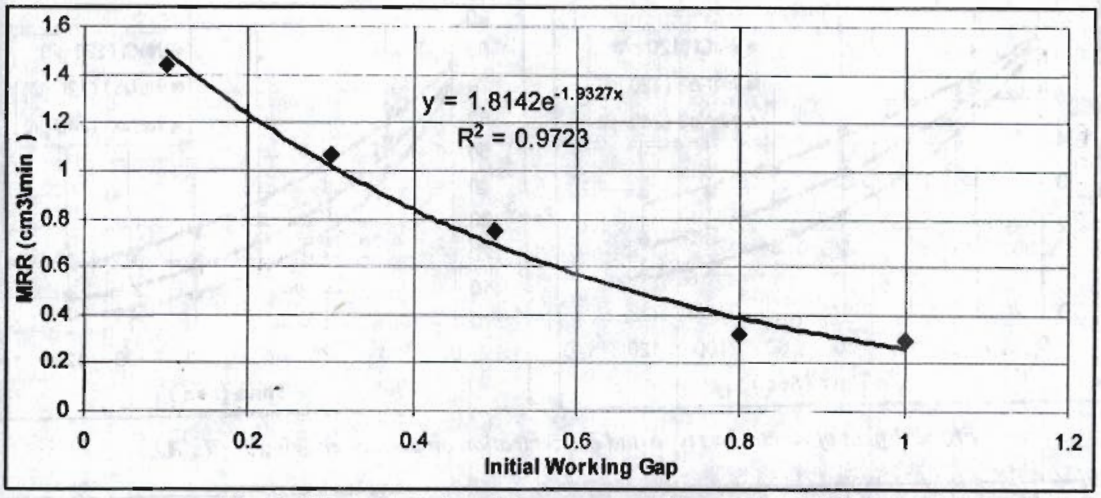

Fig. 8. Effect of initial working gap on metal removal rate (MRR).

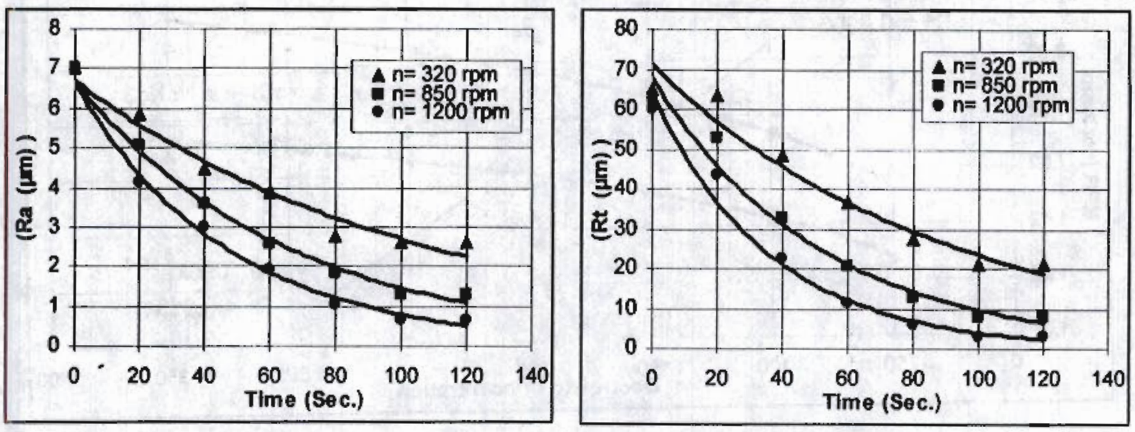

Fig. 9 .Effect of tool rotational speed on average surface roughness(R_a, R_t)

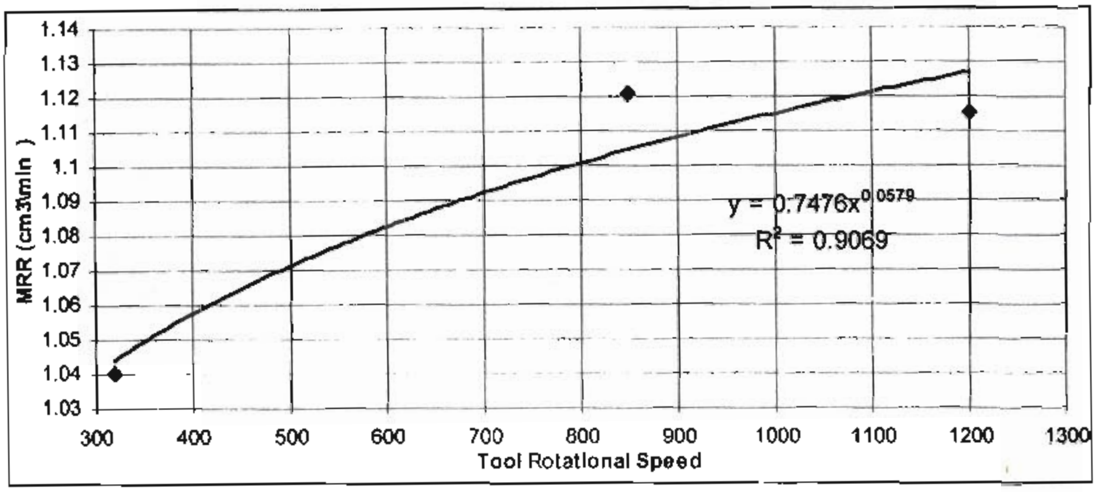

Fig. 10 .Effect of tool rotational speed material removal rate (MRR).

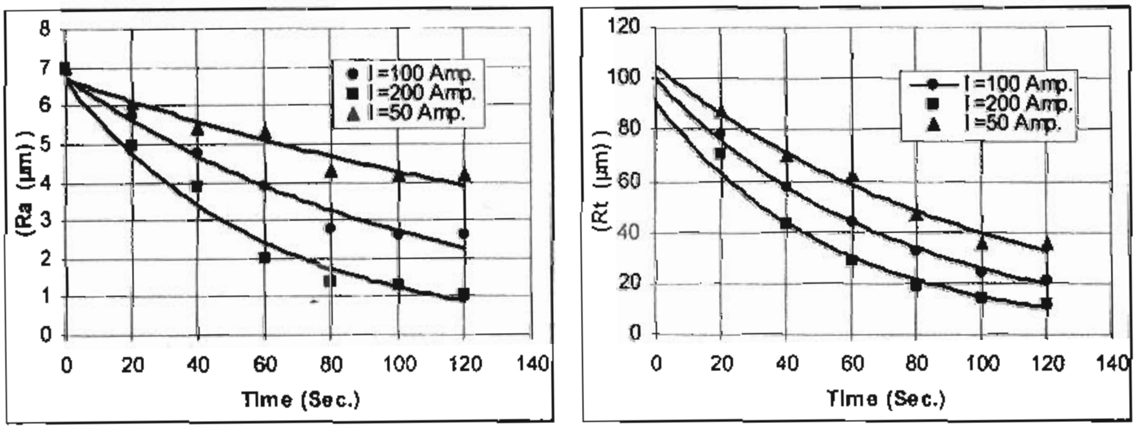

Fig. 11. Effect of applied Current on surface roughness (R_a, R_t).

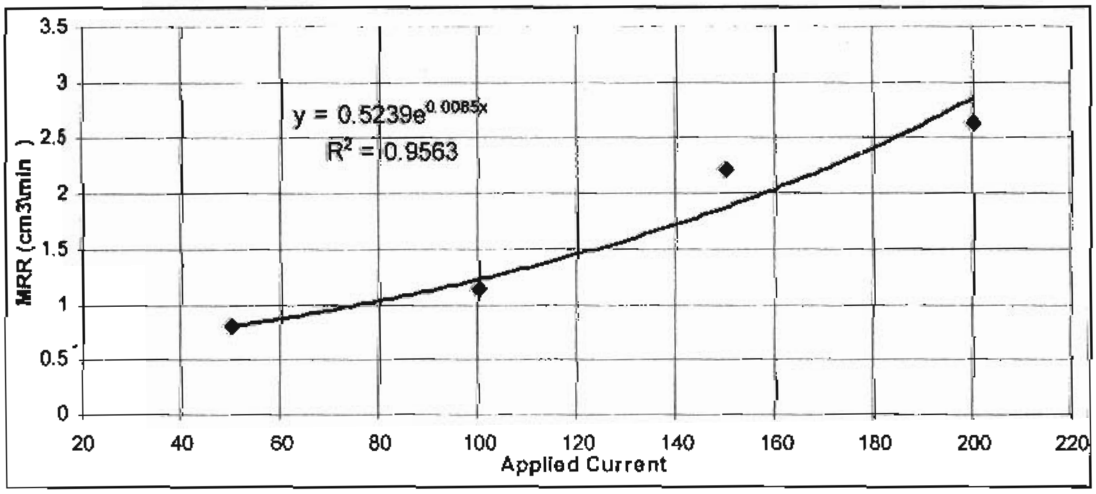

Fig.12. Effect of applied current on metal removal rate (MRR).

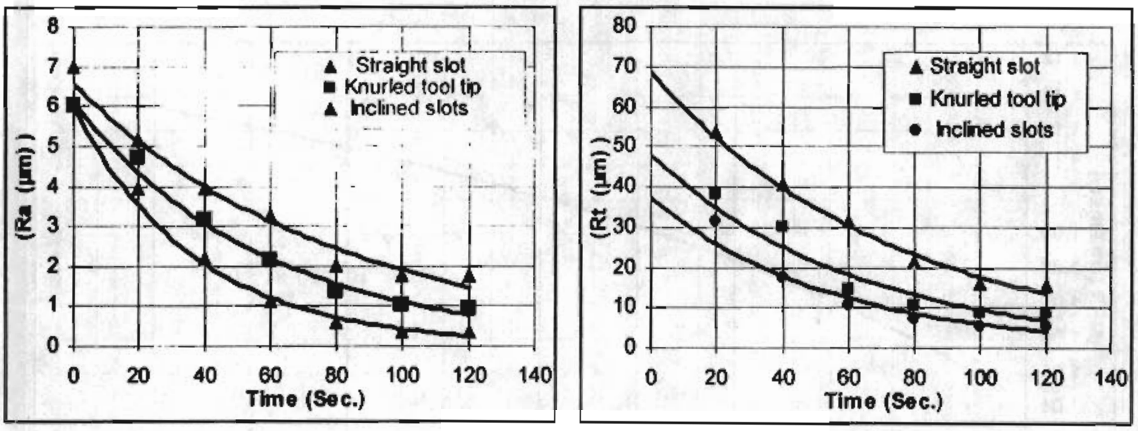

Fig. 13. Effect of tool tip shape on surface roughness (R_a, R_t).

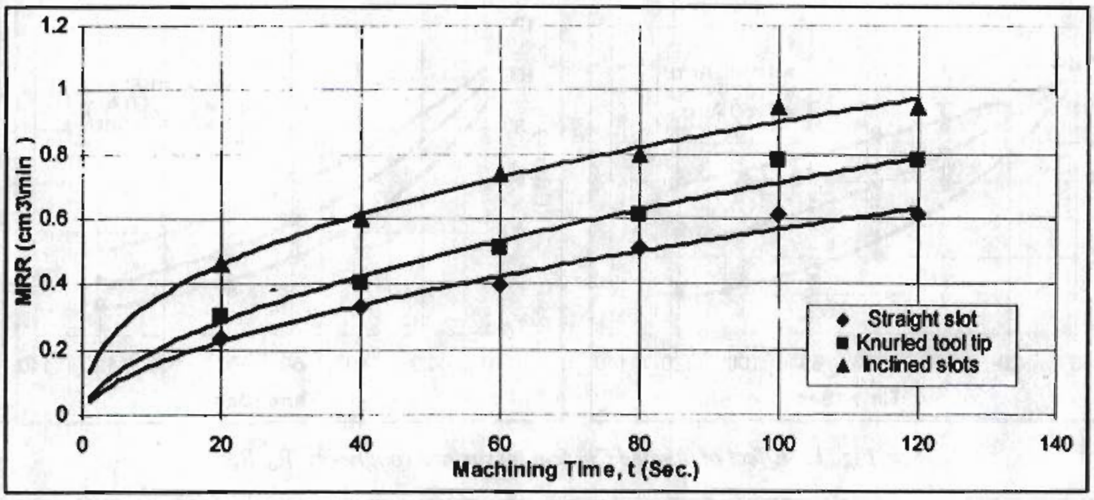

Fig. 14. Effect of tool tip shape on metal removal rate (MRR).

CIVIL ENGINEERING