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RESEARCH ARTICLE

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CHARACTERIZATION OF PROCESS PARAMETERS IN ELECTRO CHEMICALMACHINING BY USING ROTARY U- SHAPED COPPER TUBE TOOL

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ABSTRACT

Electrochemical machining (ECM) has established itself as one of the major alternatives to conventional methods for machining hard materials and complex contours without the residual stresses and tool wear. ECM has extensive application in automotive, petroleum, aerospace, textile, medical and electronic industries. Studies on Material Removal Rate (MRR) are of utmost importance in ECM, since it is one of the determining factors in the process decisions. So the aim of project work is to investigate the MRR, overcut diameter and overcut depth of AISI P20 work piece by using a rotating copper U-tube tool. Four parameters were chosen as process variables: Feed rate, Voltage, Electrolyte concentration and Tool diameter.

Keywords: Electrochemical Machining (ECM), Taguchi Method, Metal Removal Rate,(MRR), Overcut (OC).

1. INTRODUCTION

Electrochemical machining (ECM) was developed to machine difficult-to cut materials, and it is an anodic dissolution process based on the phenomenon of electrolysis, In ECM, electrolytes serve as conductors of electricity. The rate of machining does not depend on the hardness of the metal. Advantages: there is no tool wear; machining is done at low voltage compared to other processes with high metal removal rate; no burr formation; hard conductive materials can be machined into complicated profiles; work-piece structure suffer no thermal damages; suitable for mass production work and low labour requirements.

Disadvantages: a huge amount of energy is consumed that is approximately 100 times that required for the turning or drilling of steel; safety issues on removing and disposing of the explosive hydrogen gas generated during machining; not suited for nonconductive materials and difficulty in handling and containing the electrolyte.

Applications: ECM is widely used in manufacturing for making moulds and dies; also used for making complicated shape of turbine blades and it is now routinely used for the machining of aerospace components, critical deburring, Fuel injection system components, ordnance components etc.

2. OBJECTIVE

The goal of this project is to investigate material removal rate (MRR), overcut diameter, overcut depth in electrochemical machining of AISI P20 tool steel. The results of experiment show the material removal increase with increasing the feed, voltage and electrolyte concentration but decreases with increasing the tool diameter, and for both overcut diameter and overcut depth they increases with increasing feed ,voltage and electrode diameter but decreases with increasing electrolyte concentration.

3. EXPERIMENTAL SETUP AND TOOL DESIGN.

3.1 Principle of Electrochemical Machining

During ECM, there will be reactions occurring at the electrodes i.e. at the anode or work piece and at the cathode or the tool along with within the electrolyte. Ion and electrons crossing phase boundaries (the interface between two or more separate phases, such as liquid solid) would result in electron transfer reaction carried out at both anode and cathode as shown in figure 3.1

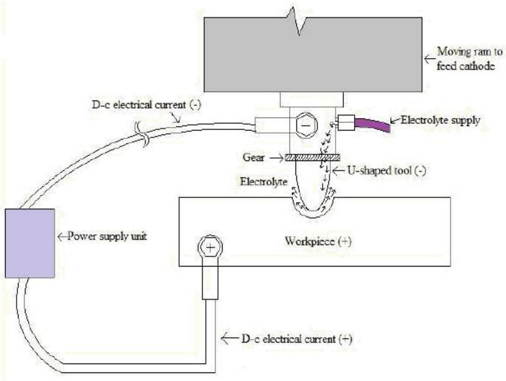

Figure3.1: Principle of Electrochemical Machining

3.2. EXPERIMENTAL SETUP

The whole experimental conducted on Electrochemical Machining set up from Metatech Industry, Hyd. which is having input Supply of - 415 v +/- 10%, 3 phase AC, 50HZ. Output supply is 0-300A DC at any voltage from 0-25V and efficiency is better than 80% at partial and full load condition. The cable insulation resistance is not less than 10 Mega ohms with 500V DC. And consist of three major sub systems which are being discussed in this chapter. The set up consists of three major sub systems.

1. Machining setup
2. Control Panel
3. Electrolyte Circulation

3.2.1. Machining Setup

This electro-mechanical assembly is a sturdy structure, associated with precision machined components, servo motorized vertical up/down movement of tool, an electrolyte dispensing arrangement, illuminated machining chamber with see through window, job fixing vice, job table lifting mechanism and sturdy stand. All the exposed components, parts have undergone proper material selection and coating/plating for corrosion protection. ECM setup is shown in Figure 3.2.

Figure 3.2: ECM Setup

3.2.2. Control Panel

Through control panel we adjust the current (I), voltage (V), feed rate (F) and time (T) for duration of experiment. The power supply is a perfect integration of, high current electrical, power electronics and precision programmable microcontroller based technologies. Since the machine operates at very low voltage, there are no chances of any electrical shocks during operation. Control Panel shown in Figure 3.3.

Figure 3.3: Control Panel

3.2.3. Electrolyte Circulation

The electrolyte is pumped from a tank, lined by corrosion resistant coating with the help of corrosion resistant pump firstly it fed to filter then it's fed to the job. Spent electrolyte will return to the tank. The hydroxide sludge arising will settle at the bottom of the tank & can be easily drained out. Electrolyte supply shall be governed by flow control valve. Extra electrolyte flow is by passed to the tank. Reservoir provides separate settling and siphoning compartments. All fittings are of corrosion resistant material or of Stainless steel, as necessary as shown in fig 3.4.

Figure 3.4 Electrolyte tank with Filter

3.3. Tool Setup:

The purpose of the experimental investigation was to find out the Material removal rate, overcut diameter and Overcut depth of plane work pieces made of AISI P20 tool steel. The tools were made up of copper. The experimental conditions are: the electrolyte is sodium chloride, the electrode gap between the tool and work piece is 0.1 to 0.3 mm, the work piece is 100 mm diameter and 50mm thickness and the cathode is copper. When the experiment is carried out, the electrolyte should be at room temperature each time and after the experiment the conductivity of electrolyte must be checked. While doing the experiment some overcuts are occurred so that overcut diameter and depth is taken with the help of Coordinate Measurement Machine (CMM).

So in this experimental work the circular cavity is formed on the work piece by using Rotary U-shaped tubular copper electrode. So to rotate the U-shaped copper electrode, three devices are necessary as follows.

1. Gear Box.
2. Variable dc controller and
3. Rotary U- Shaped Tool electrode.

3.3.1. Gear Box

Gearboxes provide speed and torque conversion between two rotating shafts for a given gear ratio and it is a major part of this experimental setup. This gear box consists of pinion gear, face gear, double spur gear and spur gear as shown in Figure 3.5. A maximum gear ratio of 1:4 has to be maintained for speed reduction at every stage. Two gear boxes with gear ratio 1:60 were assembled in series to obtain an output speed of 0.25 rpm from a driven DC motor at 600 to 800 rpm. The speed of the motor was controlled with variable DC controller ranging from 0.5 to 3v. Figure 3.5 show the assembly of reduction gear box.

Figure 3.5: Reduction Gear box assembly fitted in ECM machine.

3.3.2. Variable DC Power Controller

Need of variable DC power supply (Figure 3.6): For Carrying out Experiments, Variable DC power supply has been used because gear box gives reduction only up to 0.25 rpm output with suitable torque. But in this experiment tool needs 0.001 to 0.1 rpm output

Figure 3.7: Variable DC controller.

3.3.3. Rotary U-Shaped tool electrode

The U-Shaped tool electrode consists of tool holder, flexible pipes, U-shaped copper tool and 60 mm diameter plastic spur gear. In this experiment copper is taken as electrode material as cathode. U-shaped tool is designed to cut the cavity on AISI P20 tool steel in the similar profile. Two 75mm long copper pipes were taken with 4 mm and 6 mm diameters for making U-tube electrodes as shown in Figure 3.8. They were bending to the shape of U-tube. Care was taken so that circular pipe section was not distorted during bending of the copper pipes. These bend electrodes were then brazing to 50mm copper plate parallel to the axis of bending with 60 mm pipe protruding out. Ten holes were drilled on each U-shaped copper tube for the electrolyte flow freely between the work piece and tool.

Figure 3.8: U-shaped Copper Tube

3.3.4. Copper tool holder

A 75 mm long copper tool holder (Figure 3.9) was fabricated to support a plastic spur gear of diameter 60mm for its rotary movement which can be rotated with the help of belt drive. The tool holder has a M24 thread at the top which is inserted in ECM machine and at the bottom M12 threads support the plastic spur gear. A hole with diameter 60mm was made on the topside of tool holder which opens on both sides as shown in Figure 3.9. On both the sides, holes were made on the copper electrode and two 15mm copper pipes were brazed for fitting flexible pipes to supply electrolyte.

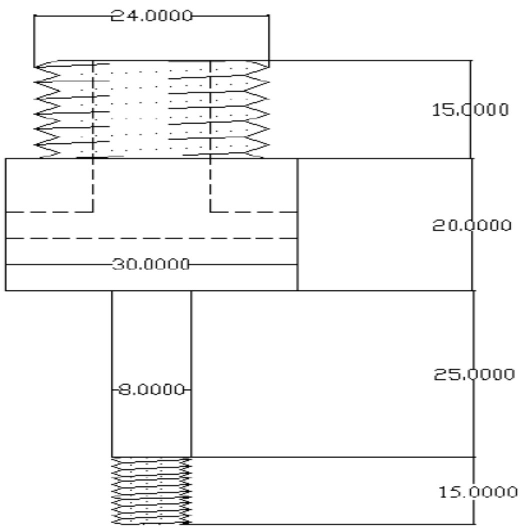

Figure 3.9: Tool Holder

Then a plastic spur gear with diameter 60mm was taken with four equally spaced holes drilled perpendicular to each other. The U-shaped tube was inserted in two holes and was tightened with the help of brass nut bolt. After that the plastic gear was inserted into the shaft of tool holder and tightened with the nuts. Flexible pipes were affixed with copper tube which comes out of the gear as shown in Figure 3.10.

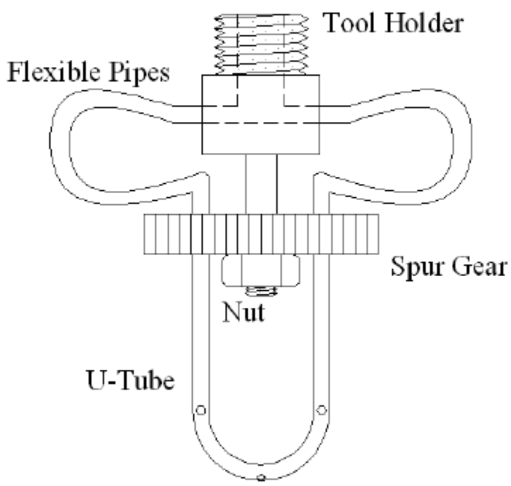

Figure 3.10: U-shaped Tool assembly

A belt drive was mounted on the gear box and the plastic spur gear as shown in Figure 3.11. The U shaped tube was later electrically connected with the ECM power supply. The plastic gear and the belt

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serve as insulators between the ECM power supply and the electronic drive controller.

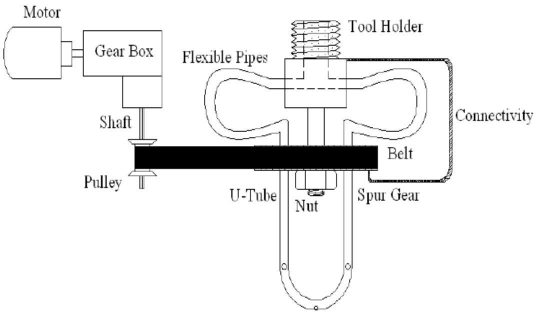

Figure 3.11: Schematic diagram of Tool

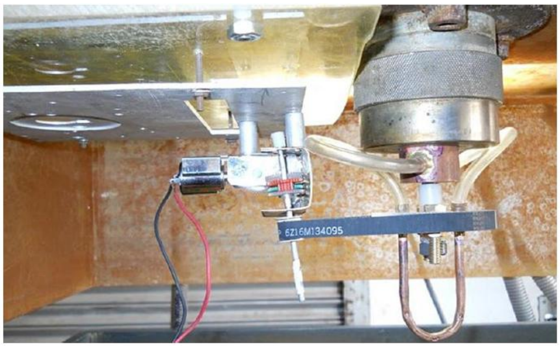

Figure 3.12: Gear arrangement with u-shaped Tool

4. EXPERIMENTAL WORK PROCEDURE

4.1. Specification of Work-piece material:

Experiment was conducted on AISI P20 tool steel as a work-piece. The specification of the material is given in Table 4.1 and chemical composition in Table 4.2. The mechanical and thermal properties are presented in Table 4.3. Work-piece dimension was 100 mm in diameter and 60 mm thickness. Five such pieces of AISI P20 steel were taken to conduct 16 experimental runs.

Table 4.1: Work piece Composition

Element	C	Mn	Si	Cr	Mo	Cu	P	S
Weight %	0.28-0.40	0.60-1.00	0.20-0.80	1.40-2.00	0.30-0.55	0.25	0.03	0.03

Table 4.3: Mechanical and Thermal Properties

Parameter		Temperature(T °C)
Density (×1000 kg/m^3) at 25 ° C	7.85	25
Poisson's Ratio	0.270-0.30	25
Elastic Modulus (GPa)	190-210	25
Thermal Expansion (10^{-6}/°C)	12.8	20-425(more)

The experiments are analyzed to achieve one or more of the following objectives:

- To establish the best or the optimum condition for a product or process
- To estimate the contribution of individual parameters and interactions
- To estimate the response under the optimum condition.

In the experiment, Minitab 14 software for Taguchi design was used. In this study, 2 level design (four factors) with total of 16 numbers of experiments to be conducted and hence the orthogonal array(OA) L16 was chosen. The machining parameters and their level are shown in Table 4.3.

Table 4.3 Machining parameters and there levels

Machining Parameter	Symbol	Unit	Level	
			Level 1	Level 2
Voltage	V	v	10	15
Feed Rate	F	mm/min	0.3	0.6
Electrolyte concentration	C	g/l	30	50
Electrode Diameter	D	mm	4	6
Flow rate	-	lpm	10	

4.2. Making of Brine Solution:

In the ECM process the making of brine solution plays an important role in material removal rate. Brine solution was prepared by adding common salt with water by maintaining the conductivity of the water. In this experiment we have taken two different concentration of electrolyte i.e. 30 g/l and 50 g/l it means mixture 30 gram of salt in 1 liter of normal water and 50 gram of salt in 1 liter of normal water respectively.

4.3. EXPERIMENTAL RESULTS

This experiment is mainly conducted in two steps.

Step 1: The initial weight of the work piece has to be taken for calculation of MRR. Keeping the flow rate constant at 10 l/m and the rest of the parameters are set according to Table 4.5 for each run. Work piece was kept in horizontal position, and by using the U-shaped electrode machining was started from the position "C" shown in Figure 4.1. Care has to be taken such that tip of the electrode should not touch the surface of the work-piece. The U-shaped electrode was fed up to the depth of 25mm inside the work piece. During the whole process the machining time was noted down. In this step only vertical feed motion has been taken rotation of tool has done on next step.

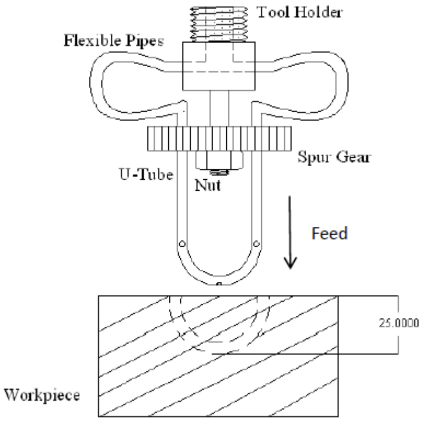

Figure 4.1: Machining step 1

Step 2: In this step, the vertical feed of the tool was stopped and it was fed in circular direction at constant rpm. After tool rotated a half revolution, the cavity was formed on the work-piece. The final stage after step 2 is shown In Figure 4.2. The final weight of the work-piece was noted and the machining time was being noted down.

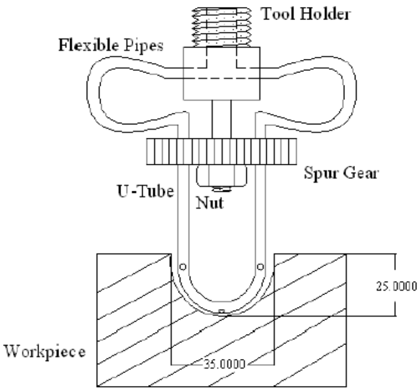

Figure 4.2: After Machining in step 2

Figure 4.3: Work-piece after machining (number inscribed represents run order)

Figure 4.3 shows the work-piece of after machining first four runs after machining. Figure 4.4 shows the work-piece of AISI P20 tool steel material after machining Run order number 5th, 6th, 7th and 8th. Figure 4.5 shows the work-piece of AISI P20 tool steel material after machining Run order number 9th, 10th, 11th and 12th. Figure 4.6 shows the work-piece of AISI P20 tool steel material after machining Run order number 13th, 14th, 15th and 16th. The experimental observations are tabulated in Table 4.4.

Figure 4.4: Work-piece after machining 5th, 6th, 7th and 8th run

Figure 4.5: Work-piece after machining 9th, 10th, 11th and 12th run

Figure 4.6: Work-piece after machining 13th, 14th, 15th and 16th run

Table 4.4: Experimental observations

Run order	Voltage (V)	Feed (F) mm/min	Electrolyte concentration (C) g/l	Tool Diameter (D) mm	MRR (mm^3/min)	OC diameter (mm)	OC Depth (mm)
1	10	0.3	30	4	0.05600	4.825	6.500
2	10	0.3	30	6	0.04431	4.929	6.730
3	10	0.3	50	4	0.05830	4.812	6.287
4	10	0.3	50	6	0.05550	4.856	6.609
5	10	0.6	30	4	0.09850	5.128	6.980
6	10	0.6	30	6	0.09870	5.260	7.180
7	10	0.6	50	4	0.10800	5.089	6.830
8	10	0.6	50	6	0.09890	5.212	7.080
9	15	0.3	30	4	0.09120	4.893	6.620
10	15	0.3	30	6	0.07970	4.972	6.880
11	15	0.3	50	4	0.09110	4.853	6.474
12	15	0.3	50	6	0.08880	4.966	6.830
13	15	0.6	30	4	0.13510	5.207	7.274
14	15	0.6	30	6	0.12800	5.301	7.410
15	15	0.6	50	4	0.13640	5.208	7.140
16	15	0.6	50	6	0.12750	5.256	7.376

5.0. Analysis of Experiment and Discussions:

5.1.1. Effect on MRR

The influence of various machining parameters on MRR (means) are shown in Fig. 5.1. The electrode feed rate has enormous effect on MRR and it increases with increase in feed rate. This result was expected because the material removal rate increases with feed rate because the machining time decreases. MRR also increases with voltage and electrolyte concentration; however, the effect is less than the feed rate on MRR, while by increasing the tool diameter MRR decreases and the effect of tool diameter and concentration of electrolyte has very little effect on MRR and doesn't give any conclusive evidence of any impact on MRR.

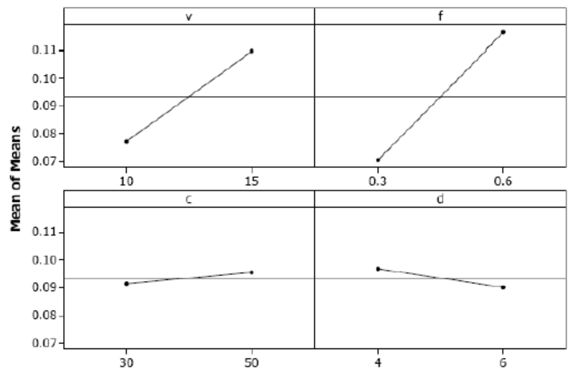

Figure 5.1: Main effect Plot for MRR

Table 5.1: Taguchi analysis response table for MRR: larger is better

Level	Voltage (V)	Feed (F)	Concentration (g/l)	Diameter (mm)
1	0.07728	0.07061	0.09144	0.09683
2	0.10973	0.11639	0.09556	0.09018
Delta	0.03245	0.04577	0.00412	0.00665
Rank	2	1	4	3

In Table 5.1, the main effects of voltage, feed, electrolyte concentration and diameter of electrode are 0.03245, 0.04577, 0.00412 and 0.00665 respectively, on MRR in mm^3/min, in order of significance. In which there feed rate is important factor and then voltage then electrode diameter and then electrolyte concentration. These results are in good agreement with the observations of many researchers.

5.1.2. Effect on overcut-diameter

The influence of various machining parameters on overcut-diameter (means) are shown in Figure 5.2. The electrode feed rate has enormous effect on width over cut and it increases with increase in feed rate. Overcut-diameter also increases with larger diameter of electrode and when increasing the voltage. While overcut diameter decreases with increasing in electrolyte concentration.

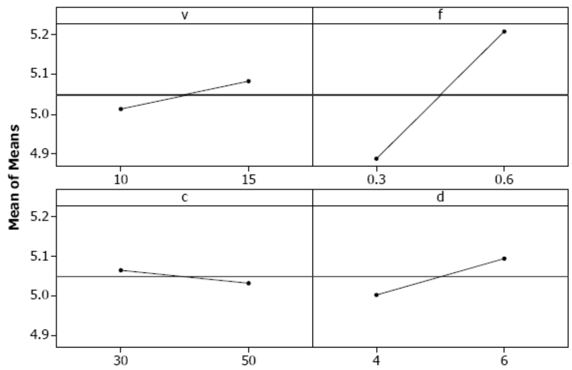

Figure 5.2: Main effect Plot for overcut-diameter

In Table 5.2 the main effects of voltage, feed, electrolyte concentration and diameter of electrode are 0.068, 0.319, 0.033 and 0.092 respectively, on overcut-diameter in mm, in order of significance. In which there feed rate is important factor and then electrode diameter then voltage and lastly is electrolyte concentration.

Table 5.2: Taguchi analysis response table for OC-diameter

Level	Voltage (V)	Feed (F)	Concentration (g/l)	Diameter (mm)
1	5.014	4.888	5.064	5.002

2	5.082	5.208	5.032	5.094
Delta	0.068	0.319	0.033	0.092
Rank	3	1	4	2

5.1.3. Effect on overcut- depth

The influence of various machining parameters on overcut-depth (means) are shown in Figure 5.3. The electrode feed rate has enormous effect on overcut-depth and it gradually increases with increase in feed rate also overcut-depth increases with increase of voltage and electrode diameter. While as in case of electrolyte concentration no change in overcut-depth is observed.

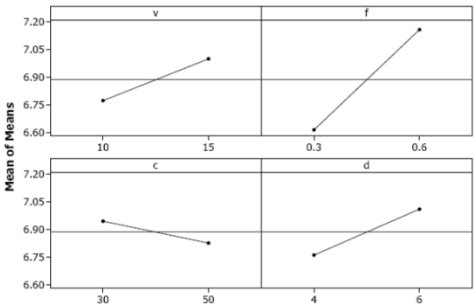

Figure 5.3: Main effect Plot for over cut-depth.

In Table 5.3 the main effects of voltage, feed, electrolyte concentration and diameter of electrode are 0.226, 0.543, 0.119 and 0.249, respectively, on overcut-depth in mm, in order of significance. In which there feed rate is important factor and then tool diameter then voltage and lastly electrolyte concentration.

Table 5.3: Taguchi analysis response table for OC-depth

Level	Voltage (V)	Feed (F)	Concentration (g/l)	Diameter (mm)
1	6.775	6.616	6.947	6.763
2	7.001	7.159	6.828	7.012
Delta	0.226	0.543	0.119	0.249
Rank	3	1	4	2

6. Conclusion: Four factors are considered voltage, feed rate, electrolyte concentration and tool diameter. AISI P20 steel as a work-piece and 16 experiments to be conducted to obtain an optimum level in achieving high material removal rate, minimize over cut-diameter and minimize over cut-depth. The following conclusions are arrived:

- Among the four process parameters, feed rate influences highly the MRR, followed by applied voltage then electrode diameter and then by the concentration of electrolyte.
- For both over-diameter and over cut-depth the most influencing parameter are feed rate followed by electrode diameter then voltage and lastly the concentration of electrolyte.

REFERENCES

[1]. S.J.Ebeid,M.S.Hewidy,T.A.El-Taweel, A.H. Youssef, *Towards higher accuracy for ECM hybridized with low-frequency vibrations using the response surface methodology,* Journal of Materials Processing Technology 149 (2004) 432-438.

[2]. P.S.Pa, effective *form design of electrode in electrochemical smoothing of end turning surface finishing,* Journal of materials processing technology 195 (2008) 44-52.

[3]. Chunhua Sun, Di Zhu, Zhiyong Li, Lei Wang, *Application of FEM to tool design for electrochemical machining freeform surface,* Finite Elements in Analysis and Design 43 (2006) 168-172.

[4]. J.A.Westley,J.Atkinson,A.Duffield, *Generic aspects of tool design for electrochemical machining,* Journal of Materials Processing Technology 149 (2004) 384-392.

[5]. M.S. Amalnik,J.A.Mc Geough, *Intelligent Concurrent Manufacturability Evaluation of Design for Electrochemical Machining,* Journal of Materials Processing Technology 61 (1996) 130-139.

[6]. K.P. Rajurkar and M.S. Hewidy, *Effect of Grain Size on ECM Performance,* Journal of Mechanical Working Technology, 17 (1988) 315 - 324.

[7]. K.P.Rajurkar,D.Zhu,B.Wei, *inimization of Machining Allowance in Electrochemical Machining,* Annals of the CIRP Vol. 47(1998) 165-168.

[8]. T. Haisch, E. Mittemeijer, J.W. Schultze, *Electrochemical machining of the steel 100Cr6 in aqueous NaCl and solutions: microstructure of surface films formed by*

carbides, Electrochimica Acta 47 (2001) 235–241.

[9]. D. Zhu, W. Wang, X.L. Fang, N.S. Qu, Z.Y. Xu, *Electrochemical drilling of multiple holes with electrolyte-extraction,* CIRP Annals - Manufacturing Technology 59 (2010) 239–242.

[10]. Xiangyu Zhao, Liqun Ma, Meng Yang, Yi Ding, Xiaodong Shen, *Electrochemical properties of Ti–Ni–H powders prepared by milling titanium hydride and nickel*, international journal of hydrogen energy xxx (2009) 1-4.

[11]. Minghuan Wang,Wei Peng ,Chunyan Yao, *Electrochemical machining of the spiral internal turbulator*, International Journal of Advanced Manufacturing Technology 49 (2010) 969–973.