# A REVIEW PAPER ON ELECTRO CHEMICAL MACHINING

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**ABSTRACT**

*Jet electrochemical machining is a non-traditional machining process which is developed by W.Gussef as far back as 1929. This process commercially developed in 1959 by Anocut Engineering Company. B.R. and J.I. Lazarenko was credited with proposing the use of electrolysis for metal removal. In 1960 and 1970s much research was done, particularly in the gas turbine industry. The rise of EDM in the same period slowed ECM research in the west, although work continued behind the Iron Curtain. The original problems of poor dimensional accuracy and environmentally polluting waste have largely been overcome, although the process remains a niche technique. In this process material is removing by electrochemical process which is used for mass production and for hard material or materials that are difficult to machine using conventional methods. Its use is limited to electrically conductive materials. This paper critically reviews the development of physical experimental work in Jet-ECM and corresponding hybrid technologies and their applications, e.g. laser- and air assisted Jet-ECM. In addition to discussing the merits of the physical experimental research challenges in the future of Jet-ECM development.*

**KEYWORDS:** *Micro Machining, Electrolyte, work piece, cathode.*

## 1. Introduction

ECM is one of the advanced non-traditional techniques for manufacturing which is utilized for machining alloy material which have high hardness and high ductility. ECM work on the principal of Michael Faraday law. When ECM is performed at micro meter level (range of MRR from 1-999 µm), that is called Electro Chemical Micro Machining (ECMM). It could be used in favour of making smaller size components with high precision. The high precision components with holes in micro size, various types of slots along with multifaceted surfaces which having largely wanted for mission critical applications like Nuclear power plant, Aero space industry, Electronics industry, and Biomedical field.

ECMM is a very promising technology since several advantages are offering for examples superior rate of machining, Paul Linga Prakash R, Department of Mechanical Engineering, VEL TECH MULTITECH, Avadi, Chennai, Tamilnadu, India, 600 062 betterment of precision as well as control, machining materials with extensive range, cost effective, and environmental friendly The ECMM process is capable of machining electrically conductive, hard to cut materials without introducing any deformation on machined surface. In this process, no tool wear is produced. Further, no residual stress is caused because machining is not done with direct force on the work piece. Instead, ionic dissolution is used to remove the material. Hence, there is no heat generation involved while machining. The ECMM process could be utilized effectively intended for the operation required for more precision machining with micro burrs and producing patterns for foils as well as three dimensional micromachining. Beryllium copper is an aged hardened alloy having developed higher strengths and it has non corrosive and abrasive wear resistant find wide application in aerospace automotive and other industrial.

Bhattacharyya et al (2007) stated that the rate of material removal could be resoluted through the density of the applied current along with tool and workpiece distance. Kuppan et al (2008) found that the chemical energy is one of the main factors that consider removal of material from the work piece in ECMM.

Jailani et al (2009) suggested that the best possible parameter value could be determined through the maximum level of the average grey relational. Somashekhar et al (2010) showed the level of majority influencing showed maximum-minimum along with parameters of inputs could determine characteristics of machining.

Muthuramalingama et al (2013) investigated that the process of the machining it is found that ideal sequence is one of the most excellent response. The indication of higher grey grade in the place is nearer the process optimal response. Sudiarso et al (2013) applied the voltage, concentration of electrolyte, federate of micro tool and duty cycle are taken input parameters in ECMM process.

Muthuramalingama et al (2014) found that while considering highest rate of material removal would be selected the superior quality characteristics. Muthuramalingama et al (2015) stated that the number of problems would be arising like higher rough of the workpiece surface, zone affection by heat, and stress due to thermal when machining hardened materials using traditional machining process. Teimouri et al (2015) created the permutation of artificial bee colony algorithm as well as fuzzy logic could be used for creating the map for prediction in forward through input parameters in cause of Analysis of Electro Chemical Micro Machining Process Parameters by Taguchi Orthogonal Array Palani S, Iruthayaraj R, Vijayakumar D, Selvam M, Paul Linga Prakash R Analysis of Electro Chemical Micro Machining Process Parameters by Taguchi Orthogonal Array 718 Published By: Blue Eyes Intelligence Engineering & Sciences Publication Retrieval Number: H11230688S19/19©BEIESP stir welding with the power of friction. Lu et al (2016) studied the micro milling with Inconel78 for prediction the rough of the machined surface. Panv et al (2016) found that the conventional machining process causes for introducing residual stresses into the Job materials and undesirable properties of materials. The objective of our research work is o analyze three ECMM method of process machining parameters of voltage (V), electrode concentration (gm/l) as well as the rate of feed (μm/s) and to determine the MRR and surface finish of the material during the machining process. Then it’s optimized using grey relation analysis method.

## 2. Overview of the Jet-ECM process

Jet-ECM is built upon the application of the electro-chemical process of anodic dissolution. Fundamentally, as in ECM, the system requires two electrodes (an anode and a cathode), a conductive electrolyte which contains ions that can freely move and a power supply or battery connecting the two electrodes (Fig.)

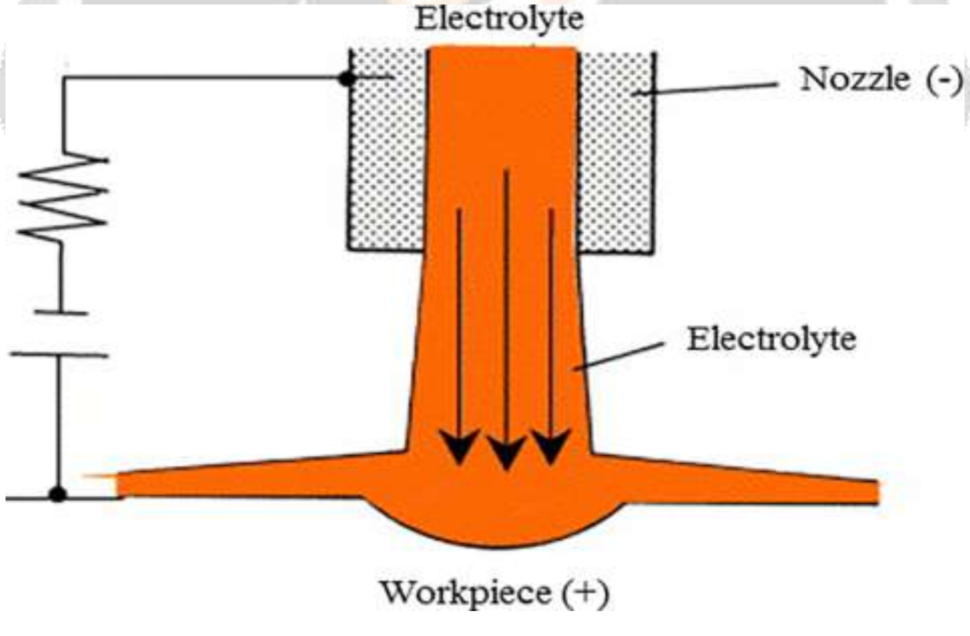


**Fig.1 Schematic of electrolyte jet machining**

In the case of Jet-ECM, the electronically conductive work piece becomes the anode, and the nozzle the cathode. The process of anodic dissolution can be complex depending on material constituents, current, passive oxide layers, and oxygen evolution and electrolyte-surface films. Using iron (Fe) as an example, and in its simplest form, the dissolution reactions are:

$$Fe=Fe^{2+} + 2e^{-}$$

At the anode (work piece), the base metal dissolves in contact with water to produce ionic metal.

$$2H_2O + 2e^- = H_2 + 2OH^-$$

At the cathode (nozzle), the free electrons flow to the nozzle where hydrogen evolution occurs.

$$Fe^{2+} + 2OH^- = Fe(OH)_2$$

At the electrolyte-anode boundary, the base metal reacts with the hydroxide ions to produce a metal hydroxide which can be carried away from the work piece.

The dissolution process continues in this continuous cycle. However, as previously mentioned, there are several dissolution mechanisms and variables. For example, in oxygenated environments, the ionic metal can react with the oxygen to produce new oxide layers on the material surface which in turn have to be overcome. Due to this process occurring only at areas on the work piece in contact with the electrolyte jet, the electrochemical reaction provides localised and controlled material removal. When material removal rates and profiles are known with controlled process parameters, Jet-ECM has the ability to machine micro features.

## 3. EXPERIMENTS AND DISCUSSION

In order to testify the stability of flow channels contraction cathode, some comparison experiments were executed with the ordinary and flow channels contraction cathode under the condition of vibration. The ECM fixture of multiple slots and some important components in the machining process are demonstrated in Fig. The clamping fixture is made of epoxy materials which has small deformation rate and good size stability. The cathode and workpiece are all made of SS304 stainless steel.

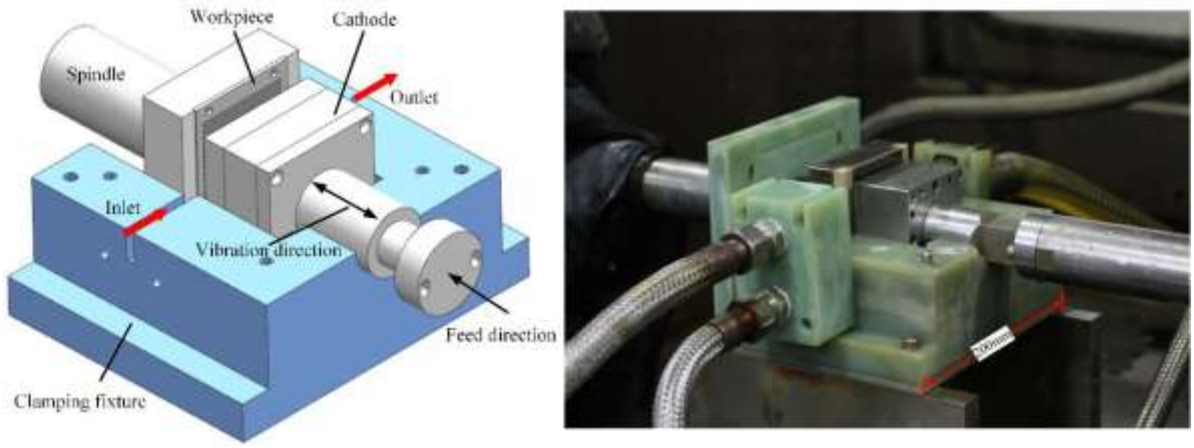


**Figure 2. The ECM fixture and important components (a) model (b) real object**

The ECM experimental conditions and parameters are shown in Table1. The time of one period is 0.1s because the vibration frequency *f* is 10Hz. A vibration period of 0.1s consists of machining time and non-machining time. The machining time means the time of circuit break over when the inter-electrode gap is less than the effective gap between cathode and workpiece. The proportion of the machining time to one period can be seen in Fig.10. The proportion of the machining time to one period is 25%, so the duty cycle is 25%.

**Table 1.** ECM experimental conditions and parameters

| conditions | value |
|---|---|
| Electrolyte | 20%NaNO3 |
| Voltage | 20V |
| Electrolyte inlet pressure | 0.8MPa |
| Electrolyte outlet pressure | 0.1MPa |
| Temperature of electrolyte | 30±1℃ |

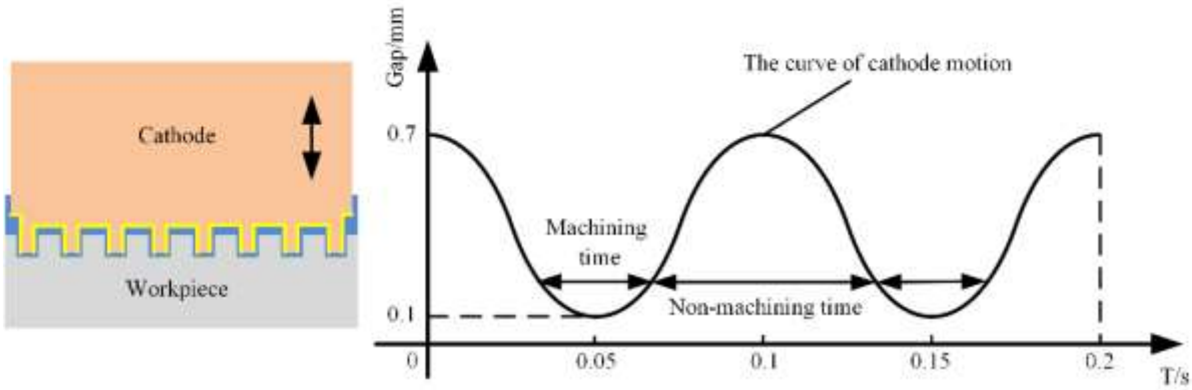


**Figure 3.** The proportion of the machining time to one period

Under the same machining parameters, feed rate comparison experiments with different cathodes were conducted. Firstly, the ordinary cathode was adopted. When the feed rate is 0.05mm/min, the machining process could go smoothly. However, with the feed rate increased to 0.06mm/min, the short circuit happened in the outlet of the workpiece. The work piece with short circuit is shown in Fig.4 (a). Secondly, experimental tests carried out with the flow channels contraction cathode. Multiple slots were machined with different feed rate which starts from 0.05mm/min. The experiments could be conducted as normal when the feed rate reached 0.1mm/min and the machined workpiece is shown in Fig.4 (b). However, the short circuit happened when the feed rate was 0.11mm/min. Compared with the ordinary cathode, the feed rate of the flow channels contraction cathode could increase by 100%. As shown in Fig.5, the local three dimension surface images were measured with a digital microscope (VHX-5000, Keyence, Japan).

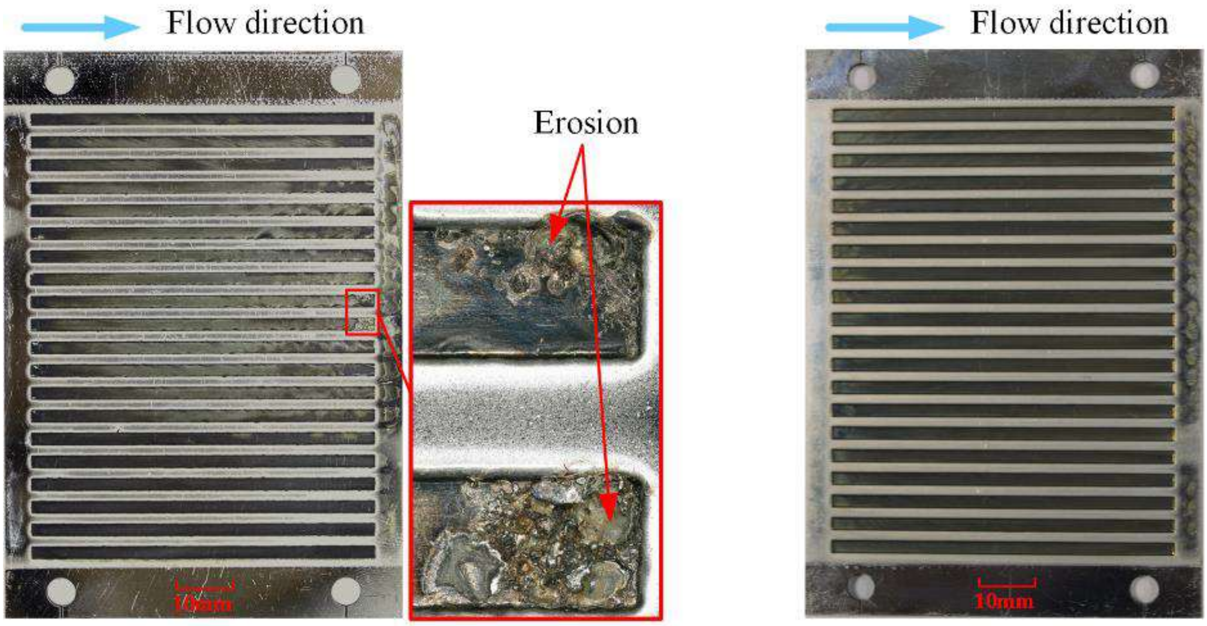


**Figure 4. The work piece with different cathode and feed rate, (a) Ordinary cathode, feed rate 0.06 mm/min (b) flow channels contraction cathode, feed rate 0.1 mm/min**

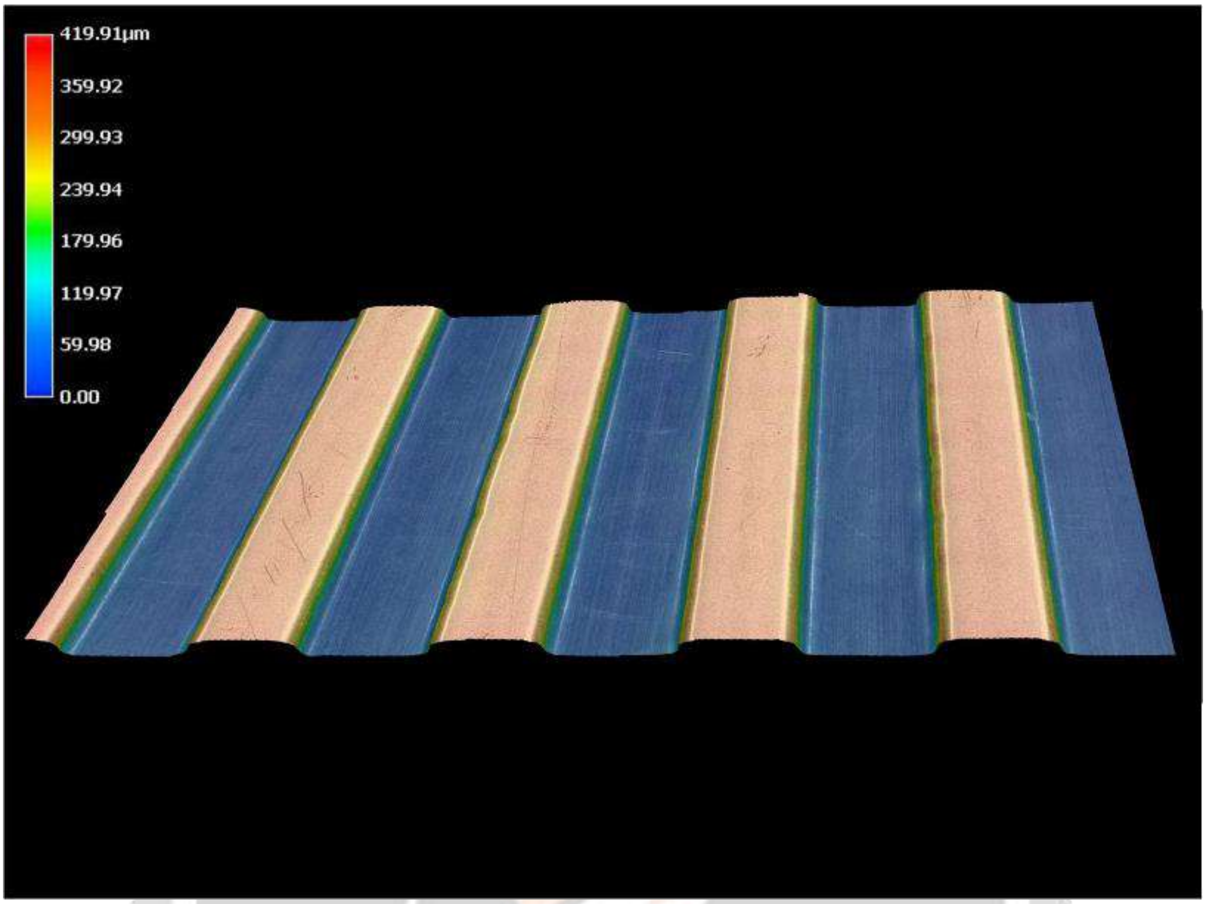


**Figure 5. Local three dimension surface images**

The depth of multiple slots which is fabricated by the flow channels contraction cathode has been measured by using a profile meter (DVM 5000, Leica, Germany). As shown in Fig.6, the measuring positions are located in the intersection of red line and green line. The depth values are shown in Fig.7. The maximum and minimum depths of all measuring positions are 324.2μm and 271.1μm respectively, which means that the depth of machined workpiece is 300±30μm. The experimental results show that using the flow channels contraction cathode is able to improve the flow field and fabricate multiple slots with good depth uniformity. This result is agreed with the report by Rajurkar et al., which improved machining accuracy and uniformity through reducing the flow field disrupting phenomena. Under the condition of vibration, the flow channels contraction cathode makes good effect on renewing electrolyte and making conductivity uniform, which can improve the machining efficiency greatly and ensure the uniformity of depth.

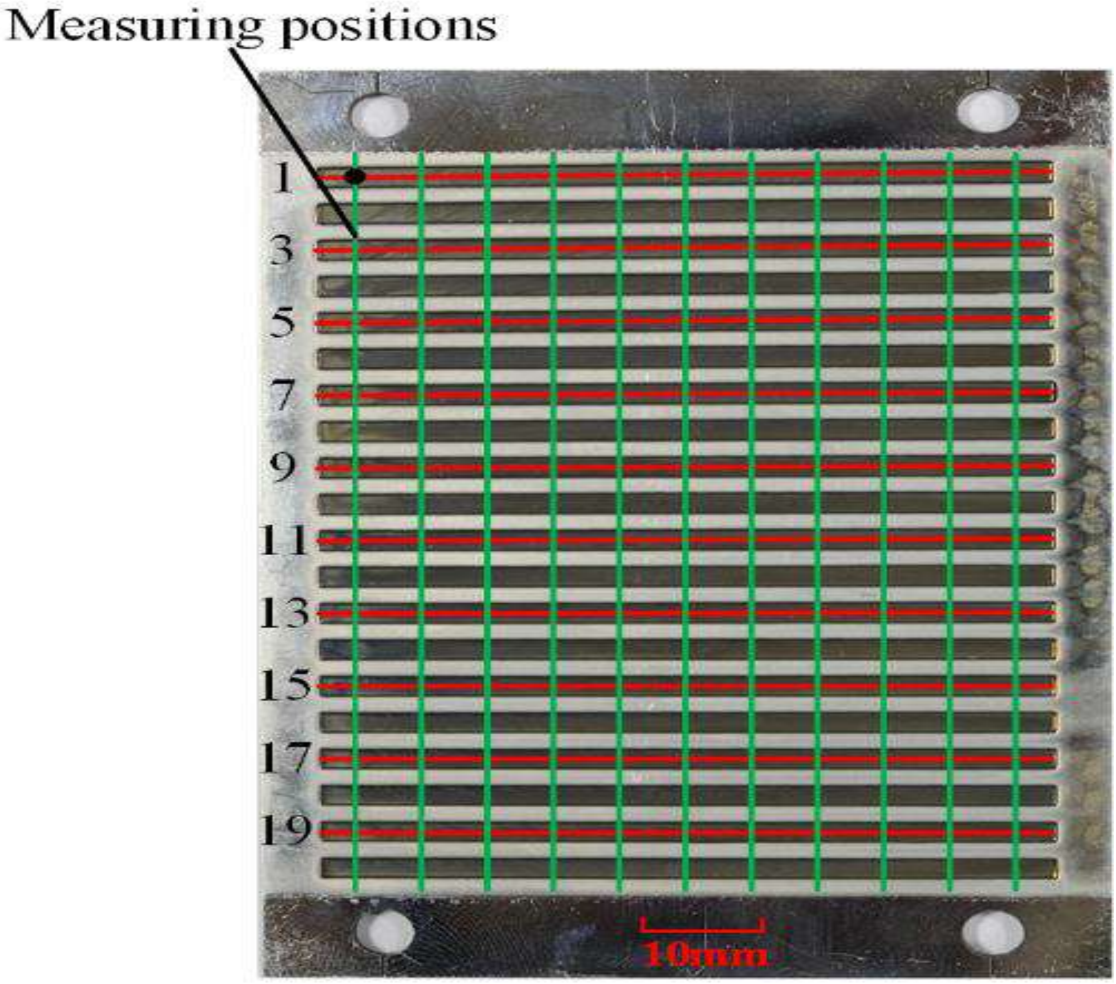


**Figure 6. Measuring positions with flow channels contraction cathode**

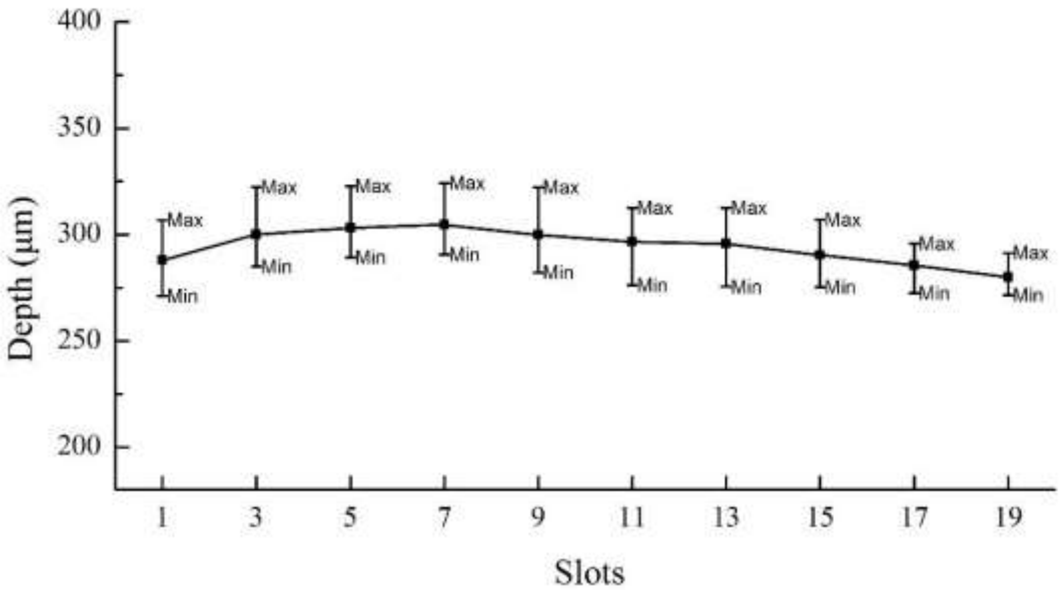


**Figure 7. Depth of multiple slots machined with ECM process**

## 4. Advantages and Disadvantages

**Advantages**

1. Complex concave curvature components can be produced easily by using concave tools.
2. Tool wear is zero; same tool can be used for producing infinite number of components.
3. No direct contact between tool and work material so there are no forces and residual stresses.
4. The surface finish produced is excellent.
5. Less heat is generated.

**Disadvantages**

The saline (or acidic) electrolyte poses the risk of corrosion to tool, workpiece and equipment.

Only electrically conductive materials can be machined. High Specific Energy consumption.

It cannot be used for soft material.

## 5. Applications

Some of the very basic applications of ECM include:

- Die-sinking operations
- Drilling jet engine turbine blades
- Multiple hole drilling
- Machining steam Turbine blades within close limits
- Micro machining
- Profiling and countering

## 6. CONCLUSION

Due to the electrolyte flows in the direction of slots length, the long and constant cross-section flow channels will make the electrolyte velocity decrease and electrolysis products accumulate in the outlet of electrolyte. In spite of adopting vibration, the machining effect with the ordinary cathode is still not optimistic. Therefore, a different cathode structure is proposed which can enhance the stability of process and take away electrolysis products effectively. The following conclusions can be reached on the basic of simulations and experiments:

(1) The flow channels contraction cathode structure with variable cross-section is proposed through numerical simulations. And the final model parameter is determined.

(2) Under the same machining parameters, the maximum feed rate of flow channels contraction cathode doubles that of ordinary cathode.

(3) A bipolar plate with depth of 300±30μm and length of 60mm is fabricated on a stainless steel sheet.

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