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MICRO DRILLING STUDIES ON STAINLESS STEEL SS304 USING ELECTROCHEMICAL MICRO MACHINING

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***Abstract*— This project aims at using Electrochemical Micro Machining for drilling holes in SS304.This experimental work is performed to investigate the effect of process parameters on material removal rate by varing voltage, current,frequency and dutycycle, hence optimize them for maximising the Material Removal Rate as well as minimizing the overcut.It is observed that the effectiveness is best when the machining current is 3 amps, voltage is 18v, frequency is 80Hz and duty cycle is 50%. In this condition, the tool wear is not observed and the resulting machined work piece is free from burrs. Experiments are conducted using 380µm tungsten electrode, where micro drilling is done in 1mm thick stainless steel sheet cut into the rectangular shape. The electrolyte used is sodium chloride and the machine in which the experiment is carried out is a Micro-ECM set up. The machining parameters are to be optimized by using Taguchi method. The three level process parameters that are chosen are discharge current, voltage, frequency and duty cycle and they are arranged in L9 orthogonal array for optimization. Morphological analysis of the machined hole is studied by Scanning Electron Microscopy Technique.**

Keywords—Electrochemical micromachiningt; material removal rate;Overcut; Response surface methodlogy; Optimization; Scanning Electron Microscopy Technique and Morphological analysis.

I. INTRODUCTION

Today needs of the society such as handy cell phones, palmtops, painless injection and many modern products require Micro hole as one of the basic elements. Several manufacturing processes are capable of meeting the requirements. Among these, electro chemical micro machining (EMM) is desired because of its advantages such as no tool wear, higher Material Removal Rate(MRR) and better surface finish. A simple table top electrochemical micromachining tool with microcontroller based Inter Electrode Gap (IEG) is used for such applications. Performance of Micro ECM is planned to investigate through machining (making micro holes) of aerospace alloy disc. Material removal techniques have a pivotal role to play in component fabrication.

In recent years many high strength alloys such as Stainless Steel and titanium alloys are produced that are extremely difficult to machine using the traditional processes. These alloys were developed for a variety of industries ranging from aerospace to medical engineering. The tool size and geometry limit the final component shapes that can be machined. Another problem with these tools is that they tend to leave burrs on the machined surface. These burrs are undesirable. For example, in the medical industry the presence of even very small burrs will damage living tissues where these machined parts are used as implants. In electronic devices where a number of components are in close contact, the burrs may lead to short circuits. In mechanical components burrs may result in misfits.

Non-Traditional Machining process can be classified into various groups according to the type of fundamental machining they employ, namely mechanical, electrical, chemical and electro-chemical machining. Mechanical energy method involves the mechanism of metal removal by erosion shear, chemical energy method and electro-chemical method involves ion displacement and thermo electric method uses the mechanism of fusion and vaporization. Devices are becoming smaller as time progresses, but their features are increasing at the same time. Machining materials on micro and sub-micron scale is considered a key technology for miniaturizing mechanical parts and complete machines. Micro manufacturing techniques find application in various industries such as electro-communications, semi-conductors, medicine, and ultra-precision machinery. Among these methods, ECM is one of the newest and most useful machining processes of metal removal by controlled dissolution of the anode of an electrolytic cell.

These processes are particularly suited to metals and alloys which are difficult or impossible to machine by mechanical machining processes.

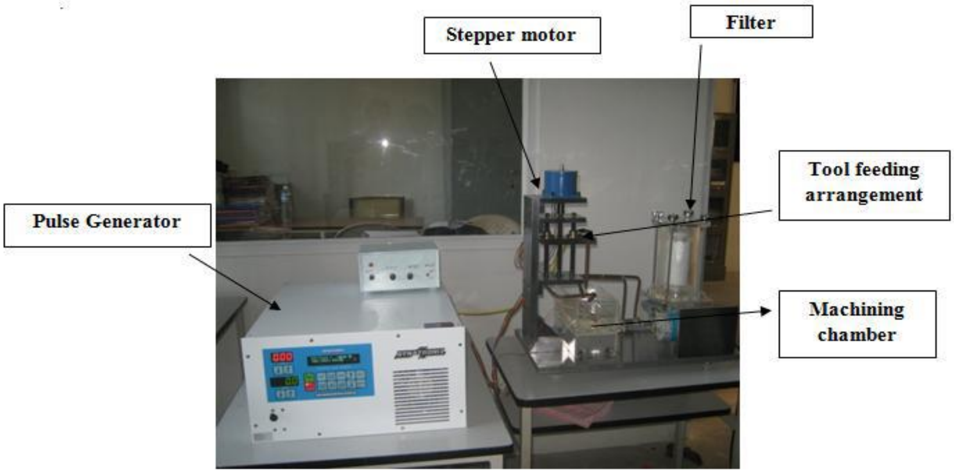
In ECM method, material is removed by ion displacement of the work piece material in contact with a chemical solution. When ECM is applied for machining ultra precision shapes in the range of microns it is called as Electro-chemical micro-machining (EMM)

II. EXPERIMENTAL SETUP

The developed EMM set-up which is used for machining is shown in Fig. 1. The EMM machine tool consists of mainly four sub-system such as Electrical power and drive system, Electrolyte supply and cleaning system, Tool and tool feed system, Work piece and work holding system.

The EMM Power supply has a voltage range of 0-20V and current rating of up to 30A average and 100A peak. The main power line has a 220V, single phase AC power supply, which is converted to a low voltage pulsed DC power by a step-down transformer and a Silicon controlled rectifier unit. Initially, the tool is moved in the forward direction to reach the work piece. Electrolyte flow system is one of the important components in EMM. The electrolyte used in this process is sodium chloride. The electrolyte is in the direction of the working zone with an average velocity with the help of a pump. The electrolyte is then passed through a settle tank along with a filter, which removes the dirtied material from the electrolyte. Then the electrolyte solution is stored in the electrolyte chamber. After that, a centrifugal pump is used to circulate the electrolyte solution through the machining gap. Two nozzles are mounted in the machining chamber, which are directed towards each other in the machining zone. The electrolyte passes throughout the nozzle with definite pressure without disturbing the tool and work piece position.

Fig. 1. Electrochemical Micromachining Power Supply



A. Experimental preparation

This study aims to find the influence of process parameters such as machining voltage in volts (V), machining current in Amps, frequency (Hz) and duty cycle (%). The electrode tool used is Tungsten electrode and the work piece used is stainless steel(ss304). The Thickness of the work piece as 1mm. Then Pulse frequencies used are 80Hz,100Hz and 120 Hz , Voltages used are 16V,17V and 18V, Currents used are 2Amps,2.5Amps and 3Amps and Duty cycles used are 40%,50% and 60%. Sodium chloride of concentration 0.5 mole per liter of distilled water is used as electrolyte. Digital micrometer is used to measure the electrode diameter .The material removal rate has been calculated using the time taken for penetrating the specimen thickness. The overcut is calculated by comparing the diameter of the tool and the diameter of the machined hole.

B. Design of experiments (DOE) and Response Surface Modeling

The Taguchi method is a powerful approach that provides a simple, efficient and systematic approach to determine the optimum process parameters, which drastically reduces the number of experiments that are required to model the response functions. It is a method based on orthogonal array (OA) of experiments, which provide the much-reduced variance for the experiment resulting in the optimum setting of process control parameters. The major influencing parameters and their levels considered are listed in Table 1. The selection of the orthogonal array is based on the number of process parameters and their levels. In the current research, the L9 orthogonal array is selected as given in Table 2.

TABLE. I MACHINING PARAMETERS AND THEIR LEVELS

FACTORS	LEVEL 1	LEVEL 2	LEVEL 3
CURRENT(Amps)	2	2.5	3
VOLTAGE (V)	16	17	18
FREQUENCY (Hz)	80	100	120
DUTY CYCLE(%)	40	50	60

C. Experimental Finding:

TABLE. II EXPERIMENTAL VALUE

CURRENT (amps)	VOLTAGE (Volts)	FREQUENCY (Hz)	DUTY CYCLE (%)	PULSE		MACHINING TIME (mins)	MRR (micron /sec)	HOLE DIAMETER (micron)	OVER CUT (micron)
				ON TIME (µs)	*OFF TIME (µs)*				
2	16	80	40	5	7.5	38	0.43	850	470
2	17	100	50	5	5	35	0.59	940	560
2	18	120	60	5	3.3	43	0.38	720	340
2.5	16	100	60	6	4	41	0.40	780	400
2.5	17	120	40	3.3	5	40	0.41	690	320
2.5	18	80	50	6.2	6.2	32	0.52	880	500
3	16	120	50	4.1	4.1	32	0.52	870	490
3	17	80	60	7.5	5	27	0.61	750	370
3	18	100	40	4	6	29	0.57	700	310

D. Main effect plot

The main effect plot is the graph of the average or mean of response at each level of the factor or input parameter. The main effect plot helps one to determine the influence of individual input parameters on the responses measured, by disregarding the effect of any other input parameter present. The main effect plots of each response are explained below:-

E. Material removal rate (MRR)

Fig. 2 shows the main effect plot of the MRR depicting the effect of various machining parameters on MRR. As seen from the above graph obtained, the MRR increased with increase in both voltage and current. This is due to the fact that with increase in voltage the current increases in the frequency thus increasing the MRR. Duty cycle is another important parameter. An overall increase in the MRR was also observed with increase in the Independent variables.

Fig. 2. Main effect plot for means in MRR (larger-the-better)

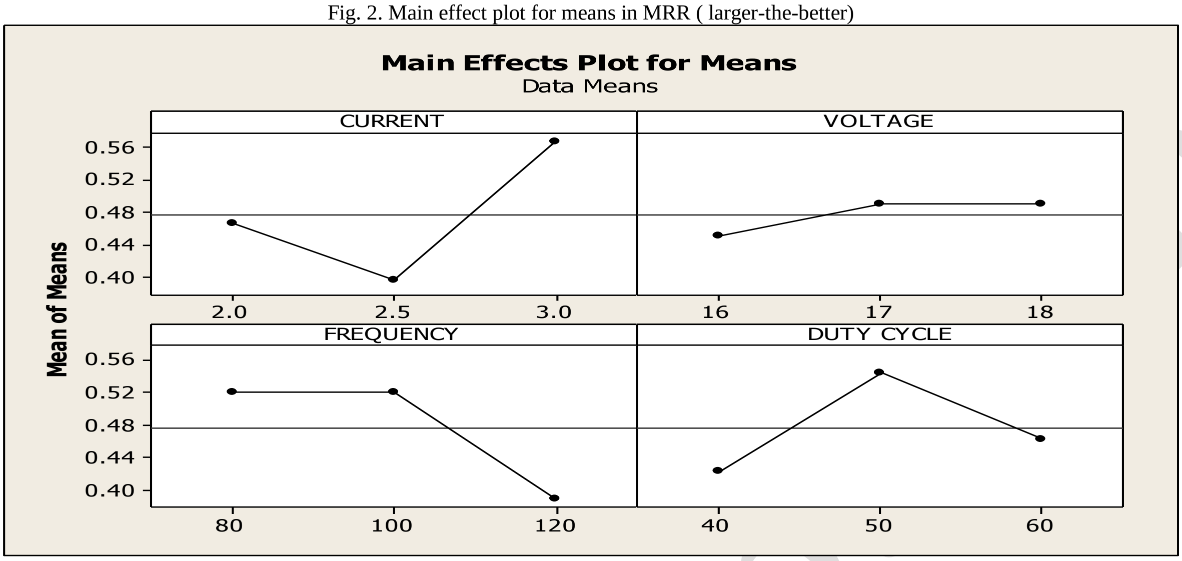


TABLE. III OPTIMAL VALUES OF PROCESS PARAMETERS

Process Parameters	Units	Optimum Values
Current	Amps	3
Voltage	Volt	18
Frequency	Hz	80
Dutycycle	%	50

F. Overcut

Fig .3 shows the main effect plot of the overcut depicting the effect of various machining parameters on overcut. As seen from the below graph obtained, the overcut decreases with increase in both voltage and current. This is due to the fact that with increase in voltage, the current and the frequency increase thus decreasing the overcut. Duty cycle is another important parameter. An overall decrease in the overcut was also observed with increase in the independent variables.

Fig.3. Main effect plot for means in overcut (smaller-the-better)

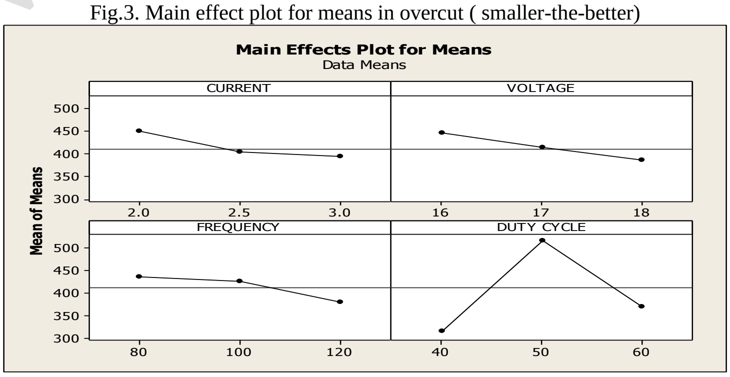


TABLE. IV OPTIMAL VALUES OF PROCESS PARAMETERS

Process Parameters	Units	Optimum Values
Current	Amps	3
Voltage	Volt	18
Frequency	Hz	120
Dutycycle	%	40

G. Mathematical Model of MRR

It is possible to obtain regression equation correlating the dependent response with the independent variables using MINITAB software, as listed below. The calculated mathematical regression equation of MRR for material SS304 is as follows.

MRR = 0.11 + 0.10 C + 0.02 V -0.003F+0.002D

predicator	coefficient	SE coefficient	T	P
constant	0.4766	0.040	11.87	0.715
Current	0.0500	0.04918	1.017	0.367
Voltage	0.0200	0.04918	0.407	0.705
Frequency	-0.0650	0.04918	-1.322	0.257
Duty cycle	0.0200	0.04918	0.407	0.705

S = 0.020 R-Sq = 92.11% R-Sq (adj) = 88.45%

TABLE. V ANALYSIS OF VARIANCE

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	4	0.4515	0.4515	0.0112	6.70	0.059
Linear	4	0.4515	0.4515	0.0112	6.70	0.059
Residual Error	4	0.0580	0.058050	0.01451		
Total	8	0.1032				

H. Mathematical Model of Overcut

It is possible to obtain regression equation correlating the dependent response with the independent variables using MINITAB software as listed below. The calculated mathematical regression equation of overcut for material SS304 is as follows.

OVERCUT = 2191.94 –126.66 C -33.33V-0.0833F+0.016D

PREDICATOR	COEFFICIENT	SE COEFFICIENT	T	P
constant	1301	83.457	1.567	0.192
Current	-63.33	86.976	-0.728	0.507
Voltage	-33.33	43.488	-0.766	0.486
Frequency	-1.67	2.174	-0.766	0.486
Duty cycle	0.17	4.349	0.038	0.971

S = 106.52 R-Sq = 89.5% R-Sq (adj) = 87.7%

TABLE.VI ANALYSIS OF VARIANCE

SOURCE	DF	SEQ SS	ADJ SS	ADJ MS	F	P
Regression	4	19366.7	19366.7	4841.7	6.64	0.0785
Linear	4	19366.7	19366.7	4841.7	6.64	0.0785
Residual Error	4	45388.9	45388.9	11347.2		
Total	8	64755.6				

The calculated F-ratio values (6.70, 6.64) are higher than the tabulated F-ratio values (6.39) for 95 % confidence. The factors which have an F ratio larger than the criterion (F ratio from the tables) are believed to influence the average value for the population, and factors which have an F ratio less than the criterion are believed to have no effect on the average. R2 is the percentage of total variation in the response which depends on the factors in the model. The higher the value of R2, the better the model fits the data.

III. RESULT AND DISCUSSION

A. Analysis of the influencing parameters on MRR

The experimental studies were carried out to analyze the effects of the various process variables on MRR using the developed mathematical model. Response surface plot for MRR was generated and shown in Fig.4.It shows the effects of applied voltage, current, frequency and duty cycle on MRR for SS304 Austenitic stainless steel. The value of MRR is more than 95% which means that regression model provides an excellent relationship between independent variables and response. The contour plots have significantly strengthened the relationship between the influencing parameters and MRR. At higher voltage, MRR increases with the increase of current. The increase in frequency level improves the ECM performance at higher current and voltages. A maximum MRR 0.61microns/sec is achieved under a current of 3A, applied voltage of 18 V, frequency of 80Hz and duty cycle of 50% as conditions. From Fig. 4 shows contour plot for MRR on SS304 and Fig.5 shows surface plot for MRR on SS304

Fig.4. contour plots for MRR on SS304

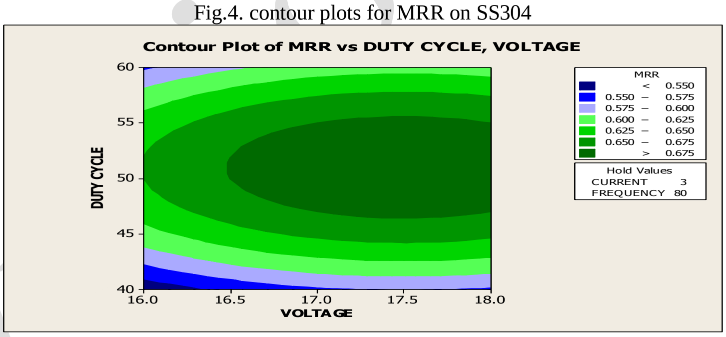
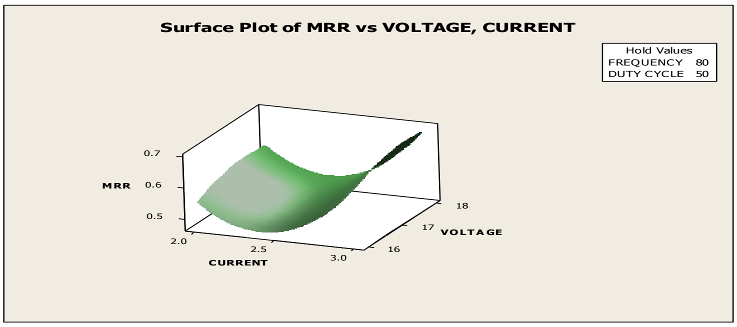


Fig. 5. Surface plots for MRR on SS304



B. Analysis of the influencing parameters on the overcut

The experimental studies were carried out to analyze the effects of the various process variables on overcut using the developed mathematical model. Response surface plot for overcut was generated and shown in Fig.6 .It shows the effects of applied voltage, current, frequency and duty cycle on overcut for SS304 Austenitic stainless steel. The value of overcut is also more than 95% which means that here again the regression model provides an excellent relationship between independent variables and response. The surface plots have significantly strengthened the relationship between the influencing parameters and overcut. At lower duty cycle, the overcut decreases with the increase of frequency and current. A minimum overcut of 320microns is achieved under a current of 3A, applied voltage of 18 V, frequency of 120Hz and duty cycle of 40%.

Fig. 6 shows surface plot for overcut on SS304 and Fig.7 shows contour plot for overcut on SS304

Fig. 6. Surface plots for overcut on SS304

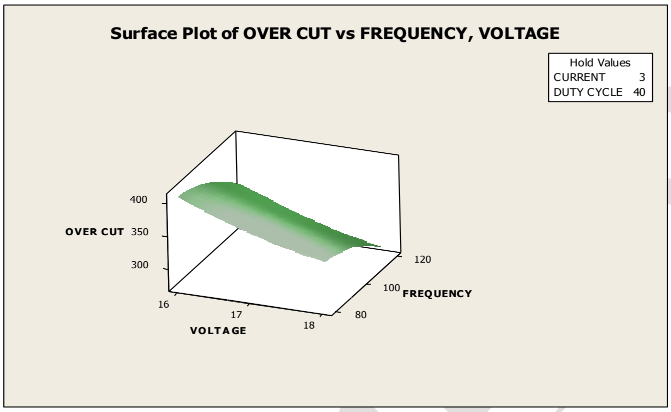
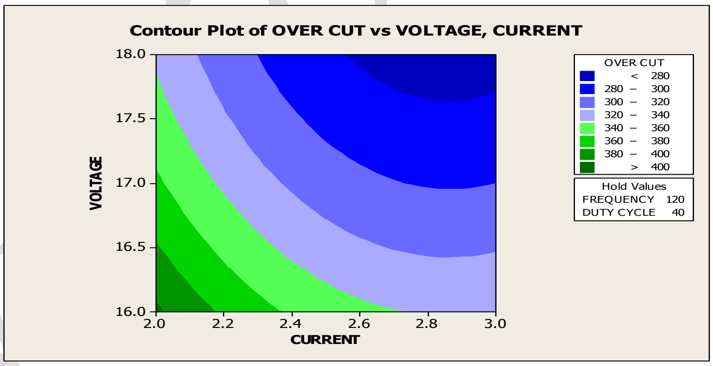


Fig .7. contour plots for overcut on SS304



C. SEM Graphs

The SEM pictures of the machined hole at entry and exit are shown in Fig.7 below. The overcut is observed due to the non localization of current in the inter electrode gap. This results in the formation of the accurate shape of machined micro-hole.

A SEM micrograph of micro hole machined by EMM at a particular parametric combination i.e .current 3A ,voltage of 18v, frequency of power supply of 120Hz, duty cycle of 40% is shown. In this condition, least overcut has been observed.

Fig. 8. SEM picture view of entry side of the machined hole (machining voltage of 18V, machining current of 3A, frequency of 120Hz, duty cycle of 40%).

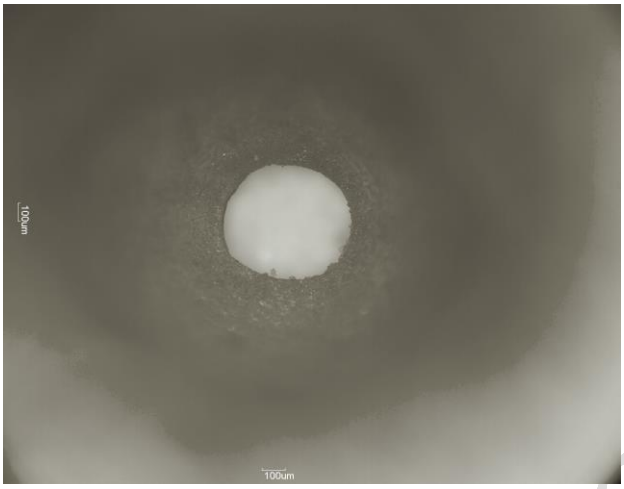


Fig. 9. SEM picture view of exit side of the machined hole (machining voltage of 18V, machining current of 3A, frequency of 120Hz, duty cycle of 40%).

IV. Conclusions

The analysis of the experimental observations shows that MRR and over cut in ECM is greatly influenced by the selected process parameters. Based on the experimental results, the following conclusions are drawn.

- Material removal rate increases linearly with applied voltage and current and it decreases with frequency.
- Overcut decreases with increase in the applied voltage, current and frequency and it increases with duty cycle.
- The optimum range of influencing parameters in obtaining a better MRR and Overcut are observed from RSM contours.
- The results reveal that applied voltage of 3 V, current of 18 A, frequency of 80Hz and duty cycle of 50% would be the optimum values of MRR in ECM of SS304 under the selected conditions.
- The results reveal that applied voltage of 3V, current of 18 A, frequency of 120Hz and duty cycle 40% would be the optimum values of overcut in ECM of SS304 under the selected conditions.
- The results obtained by Taguchi method through both ANOVA table as well as manual study of experimental values, are conformed through the images obtained by Scanning Electron Microscopy Technique.

References

[1] Bhattacharyya.B, S. Mitra, A.K. Boro, "Electrochemical machining: new possibilities for micro machining", Robotics and Computer Integrated Manufacturing 18 (2002) 283–289.

[2] Bhattacharyya. B, J. Munda, "Experimental investigation into electrochemical micromachining (EMM) process", Journal of Materials Processing Technology140 (2003) 287–291

[3] Bhattacharyya. B, S.K.Sorkhel.S.K.,"Parametric control for optimal quality of the work piece surface in ECM",Journal of materials processing Technology,40(1994) 271- 286 271

[4] Bhattacharyya .B, J. Munda, M. Malapati," Advancement in electrochemical micro-machining", International Journal of Machine Tools & Manufacture 44 (2004) 1577–1589.

[5] Datta. M, D.Landolt ," Fundamental aspects and applications of electrochemical microfabrication ", Electrochimica Acta 45 (2000) 2535 – 2558.

[6] Junz Wang .J.J , C.K. Chung, B.H. Wu, Y.Y. Liao," Fabrication of wedge-shape tool via electrochemical micromachining with diamond-like carbon coating", Journal of Materials Processing Technology 187–188 (2007) 264–269.

[7] Mohan Sen, HS. Shan, "A review of electrochemical macro- to micro-hole drilling processes", International Journal of Machine Tools & Manufacture 45 (2005) 137–152.

[8] Munda .J, M. Malapati, B. Bhattacharyya," Control of micro-spark and stray-current effect during EMM process", Journal of Materials Processing Technology (2007).

[9] Madhav Datta and Derek Harris, "Electrochemical micro machining: An environmentally friendly, high speed processing technology", Ekcfrochimica Acm , Vol. 42, Nos 20-22, pp. 3007-3013, 1997.

[10] Strode and M. B. Bassett," The effect of electro chemical machining on the surface integrity and mechanical properties of cast and wrought steels", *Wear*, 109 (1966) 171 - 180 171.

[11] Se Hyun Ahn,Shi Hyoung Ryu,Deok Ki Choi,Chong Nam Chu," Electro-chemical micro drilling using ultra short pulses", Precision Engineering 28 (2004) 129–134.

[12] Sriharsha Srinivas Sundarram,"Development of electro chemical Micro Machining ", Office of Graduate Studies of Texas A&M University. August 2008.

[13] V.Subburam, S.Ramesh ,RM.Arunachalam, "Effect of acidified electrolyte on the performance of electro chemical micro machining proceedings of the international conferences on advanced material processing and characterization"-2013 conducted by Anna University, Chennai. AMPC-2013.