Analysis of Variance for MRR on ECDM

[1]R.N.Panchal, [2]A.D.Awasare, [3]P.S.Jadhav, [4]S.J.Mulani, [5]V.M.Jamadar, [6]A.S.Suryawanshi, [7]R.M.Shetenawar, [8]G.V.Shinde

[1]Professor, Mechanical Engineering Department JSPM's Rajarshi Shahu College of Engineering Tathawade Pune -33
[2,4,5,6,7,8]Assistant Professor, Mechanical Engineering Dept, AGTI's DACOE Karad, INDIA
[3]Assistant Professor, Mechanical Engg. Dept, RIT, Rajaramnagar, INDIA
Email: [1]rnpanchal0@gmail.com, [2]adawasare.mech@dacoe.ac.in, [3]prashant.jadhav@ritindia.edu, [4]sjmulani.mech2dacoe.ac.in, [5]vmjamadar.mech@dacoe.ac.in, [6]assuryawanshi.mech@dacoe.ac.in, [7]rmshetenawar.mech@dacoe.ac.in, [8]gvshinde.mech@dacoe.ac.in

Abstract— Any new technology requires new machining skills. In the last century, the need for using more and more specialized materials (e.g. silicon, composites or ceramics) greatly increased the already large arsenal of machining technology. The last century also saw the birth of micromachining, in particular micromachining of silicon. At present huge variety of micromachining are available for silicon. Similar situation exists for electrically conductive materials, where, in particular electrochemical machining (ECM) and electrical discharge machining (EDM) are two powerful tools are available. However, several electrically non- conductive materials are also of great interest for many applications. Glass and composite materials are two examples. The technical requirements for using glass in micro system are growing. Medical devices requiring biocompatible materials are only one many of examples.

Index Terms—machining, micro machining, electric-discharge, composite material.

I. INTRODUCTION

Any new technology requires new machining skills. In the last century, the need for using more and more specialized materials (e.g. silicon, composites or ceramics) greatly increased the already large arsenal of machining technology. The last century also saw the birth of micromachining, in particular micromachining of silicon. At present huge variety of micromachining is available for silicon. Similar situation exists for electrically conductive materials, wherein particular electrochemical machining (ECM) and electrical discharge machining (EDM) are two powerful tools available. However several electrically non- conductive materials are also of great interest for many applications. Glass and composite materials are two such examples. The technical requirements for using glass in micro system are growing. Medical devices requiring biocompatible materials are only one amongst many examples.[16]

Ceramics (glass) and plastic materials are playing vital role in the process industries Electrochemical Discharge Machining (ECDM) is the mean to obtain absolute machining parameters using advanced materials up to present situation. Electrochemical Discharge Machining (ECDM) is newly developed hybrid process that combines both ECM and EDM (ECM + EDM = ECDM). It has been successfully used for machining electrically non-conductive advanced engineering materials such as glass and ceramics which has shown the possibility of drilling micro-holes by smaller electrodes efficiently and economically. [1] It has been found that the advanced materials are difficult to machine by conventional machining processes. [10] It is no longer possible to produce parts with better surface finish, close tolerances and complex shapes in advanced materials by conventional machining methods. To machine difficult to difficult materials some non-traditional procedures, like the laser machining or ultrasonic machining may be integrated to become a composite machining procedure. So far, it is still necessary to provide more study for machining of non-conductive brittle materials since it has become key materials in the micro-electro mechanical system (MEMS) field. For example, the glass or quartz is usually bonded with semi-conductive material due to their transparency, chemical resistant properties and so on. Likewise, the engineering ceramic is also used often in the high-tech apparatus.

The performance of ECDM, in terms of material removal rate and rate of machining, is affected by many factors. Relationship between these factors and machining performance are highly non- linear and complex in nature. Therefore it is very difficult to develop a relationship between those factors and the machining performance with conventional mathematical modeling. Electrolyte solutions are one of the major parameters that have to be considered for determining the effectiveness of ECDM process.

II. OVERVIEW ON TOOL DESIGN

Young et al. [1] discussed about the study tool electrode material in this study, the tool electrode (200 mm in diameter) is fabricated by wire electrical discharge grinding (WEDG). After the tool electrode is machined, the surface roughness of tool electrode materials (stainless steel, tungsten, carbide and tungsten) is different because of the physical properties. However, the surface roughness affects the wet ability on tool electrode, and also changed the coalescent us of gas film in ECDM. Hence, this study explores the wet ability and machining characteristics of different tool electrode materials and their impact on gas film formation.

Wuthrichet al. [4] it is found from these studies it becomes clear that during the time of machining of a single micro hole (about half a minute), it is not possible to get an error of 20 µm because of tool wear. Indeed, as already mentioned, the main limiting factor is the stability of the gas film. Newest results, which will be published elsewhere, show that it is possible by influencing the wet ability of the tool-electrode (by adding surfactants to the electrolyte for example) to reduce this variance to below 5 µm yang et al. [5] has proposed that using a tool electrode with a spherical end whose diameter (150 mm) is larger than that of its cylindrical body (100 mm). Experimental results show that the curve surface of the spherical tool electrode reduces the contact area between the electrode and the work piece, thus facilitating the flow of electrolyte the electrode end, and enables rapid formation of gas film, resulting in efficient micro-hole drilling. Moreover, the curve surface does not cause excessive concentration of current density; and hence, bubbles grow at a more uniform speed; thus, increasing the discharge frequency. Comparison between machining depth of 500 mm achieved by conventional cylindrical tool electrode and the proposed spherical tool electrode shows that machining time was reduced by 83% while hole diameter was also decreased by 65%.

III. ANOVA FOR MATERIAL REMOVAL RATE (MRR)

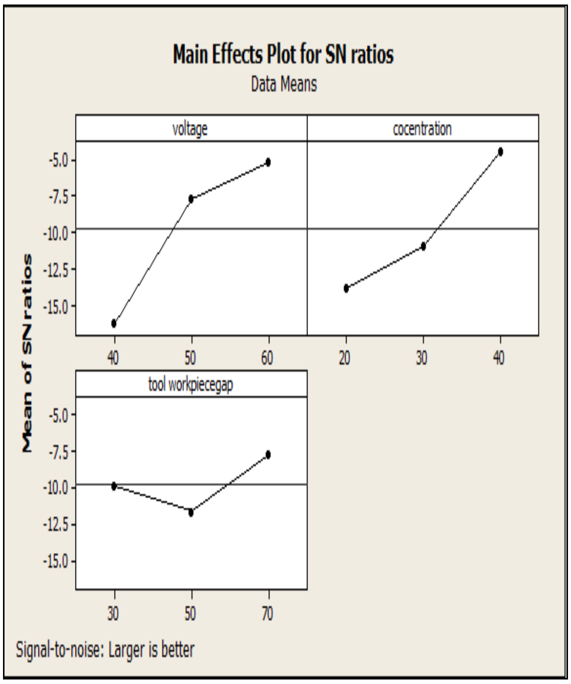
ANOVA for s/n ratio including percentage contribution at 99.81% is given in the table 6.2 the ANOVA indicates applied voltage, electrolyte concentration are most significant parameters for higher material removal rate. But tool work-piece gap is less significant for higher material removal rate at 99.81% level.

Table 1.1 Analysis of Variance for MRR

Source	DF	Seq. Sum of squares	Adj. Sum of squares	Adj Mean of Square	F	P	Contribution
Voltage		0.197238	0.197238	0.098619	246.27	0.004	46.7448%
Concentration	2	0.211844	0.211844	0.105922	264.51	0.004	50.2065%
Tool work-piecegap	2	0.012063	0.012063	0.006032	15.06	0.062	2.8589%
Error	2	0.000801	0.000801	0.000400			0.1898%
Total	**8**	**0.421946**					

S = 0.0200111 R-Sq = 99.81% R-Sq(adj) = 99.24%

From main effect plot for S/N ratio i.e. graph 1.1 it can be seen that as the value of voltage increase from 40 to 60 the material removal rate also increases. This is due to at higher voltage stronger spark is generated so melting starts at earlier, hence as the voltage increases the material removal rate is increased due to increased spark energy. But if voltage is increased beyond 60V the glass starts to get cracks.

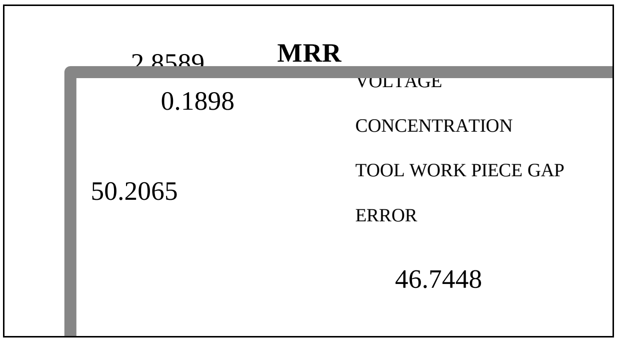


Graph 1.1 Main effect Plot for SN ratios

Secondarily, higher concentration gives high MRR. This is due to higher ionization and deionization which causes high erosion and thermal discharging. Whereas, the above range concentration helps to continue the bubble generation and spark produced during the machining process.

Effect of gap between tool and work piece also plays a role on MRR but it is not much significant as we can see in pie diagram.

From the pie chart below it can be seen that electrolyte concentration plays an important role in MRR, 50.2065% than the other factors. After electrolyte concentration voltage plays equally important role, 46.7448% .the gap between tool and work-piece also affects but has negligible 2.8589% effect on MRR.



Graph 1.2 Contributions of different parameters in percentage in MRR

IV. REGRESSION ANALYSIS

Regression analysis of MRR using Minitab 15 software as shown in equation 6.1

MRR (mg/min) = -0.994 + 0.0178A + 0.0183B – 0.00083C------------------eq. 6.1

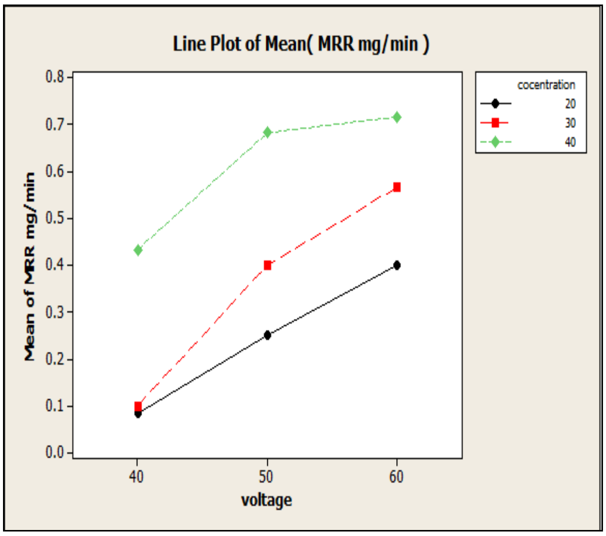
Where, A = Voltage

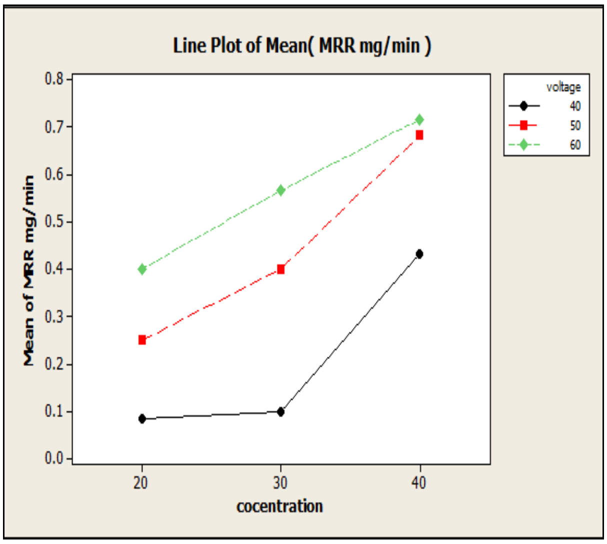
B = Concentration

C = Tool Work-piece gap

Eq. (1) also shows that 'B' i.e. electrolyte concentration is major affecting parameter. 'A' i.e. Voltage is also major affecting but little less than electrolyte concentration.

The graphs below shows interrelation of trends like MRR, voltage, concentration, gap. There is an increased trend in MRR observed at voltage of 60V and concentration of 40%. At low voltages rate of increase of MRR with increase in concentration is much more than that of at higher voltages.





Graph 1.3.Effect of process variables on MRR. a) Effect of voltage on MRR for different concentration. b) Effect of concentration on MRR for different voltages.

V. ELECTROCHEMICAL PROCESS

When supply to electrolytic cell is applied in proper polarity, electrochemical action starts. Electron moves from the cathode-electrolyte interface and go the solution. At the anode electrolyte interface, equal numbers of electrons are discharged from the solution to the anode. The type of reaction depends on the characteristics of electrolyte, electrode and applied voltage.

Potassium hydroxide is reacted with silicate and water is formed.

$2KOH + SiO_2 \rightarrow K_2SiO_3(s) + H_2O\ (l)$

1. At cathode-electrolyte interface, the following electrochemical cause evolution of hydrogen gas.

$Cu^{+2} \quad +2e^{-} \rightarrow \quad Cu$

$2H^{+} \quad + 2e^{-} \rightarrow \quad H_2 \uparrow$

$K^{+} \quad + \quad e^{-} \rightarrow \quad K$

$2K \quad + 2H_2O \quad \rightarrow \quad 2KOH + H_2 \uparrow$

$2H_2O \quad + 2e^{-} \rightarrow \quad H_2 \uparrow + 2OH$

2. At anode-electrolyte interface, the following electrochemical reaction causes generation of oxygen gas.

$4(OH)^{-} \rightarrow 2H_2O + O_2 + 4e^{-}$

As KOH is the strong base, the ion mobility of it is higher and hence good material removal rate take place.

According to Arrhenius theory, in base electrolytes are OH^{-}donors in its aqueous solution and according to Lowry and Bronzed theory H^{+} accepter. Hence whenever the electric charge is passed through the electrolyte solution the bubble generation and hydrogen gas formation takes place at cathode which result in erosion helping in constant desired material removal rate and at the same time oxygen or oxide are formed near anode. The potential difference between the two electrodes is responsible for sparking phenomena.

VI. CONCLUSION

The work we have done was for material removal by drilling hole by using ECDM set up made by our own. The experimentation was designed and performed by Taguchi method. Analysis was done using software known as 'Minitab 15'. The experiment was performed on soda lime glass using KOH as electrolyte of different concentration and copper rod were taken as tool electrodes. Electrolyte concentration, voltage and tool work-piece gap were taken as process parameters and Material removal rate (MRR) was taken as response variable. From above experiment it is concluded that: A test rig was designed and developed for ECDM for non-conducting materials. Electrolyte concentration is most significant parameter for MRR. Voltage was second most influential parameter.

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