EXPERIMENTAL INVESTIGATION TO EVALUATE THE MACHINING CHARACTERISTICS OF NON- CONDUCTIVE MATERIAL BY ELECTROCHEMICAL DISCHARGE MACHINING (ECDM)

A
DISSERTATION-II REPORT

Submitted in fulfilment of the requirement for the award of degree

of
MASTER OF TECHNOLOGY

IN
MECHANICAL ENGINEERING
Submitted by

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DEPARTMENT OF MECHANICAL ENGINEERING

LOVELY PROFESSIONAL UNIVERSITY

PUNJAB

TOPIC APPROVAL PERFORMA

School of Mechanical Engineering

Program : 1208D::B.Tech -M.Tech (Dual Degree) - ME

COURSE CODE : MEC600 **REGULAR/BACKLOG :** Regular **GROUP NUMBER :** MERGD0008

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Qualification : ________________________ **Research Experience :** ________________________

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SPECIALIZATION AREA : Manufacturing Engineering **Supervisor Signature:** __________________

PROPOSED TOPIC : Experimental investigation to evaluate the machining characteristics of non- conductive material by Electrochemical discharge machining (ECDM).

Qualitative Assessment of Proposed Topic by PAC		
Sr.No.	**Parameter**	**Rating (out of 10)**
1	Project Novelty: Potential of the project to create new knowledge	7.25
2----*	Project Feasibility: Project can be timely carried out in-house with low-cost and available resources in the University by the students.	6.25
3	Project Academic Inputs: Project topic is relevant and makes extensive use of academic inputs in UG program and serves as a culminating effort for core study area of the degree program.	7.25
4	Project Supervision: Project supervisor’s is technically competent to guide students, resolve any issues, and impart necessary skills.	7.50
5	Social Applicability: Project work intends to solve a practical problem.	6.75
6	Future Scope: Project has potential to become basis of future research work, publication or patent.	7.25

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Final Topic Approved by PAC: **Experimental investigation to evaluate the machining characteristics of non- conductive material by Electrochemical discharge machining (ECDM).**

Overall Remarks: Approved

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ABSTRACT

Electrochemical discharge machining (ECDM) is micromachining process which is used to machine the micro holes in non-conducting material such as glass, composites, ceramics and metal matrix composites. ECDM has the high potential of machining of non-conducting and brittle material. Generally ECDM is the combination of two process i.e. electrochemical machining (ECM) and electrochemical discharge machining (EDM) which combines the feature of both the machining process in which machining is done with the thermal sparking and the chemical etching phenomena, both. In this study machining has been done on soda lime glass plate using the copper as a tool electrode (cathode) and stainless steel electrode used as the anode. The electrolyte used was a mixed electrolyte (NaOH+KOH). The L27 array has been used for the design of experiment by considering the variable process parameters: voltage, electrolyte concentration and current. From the experimental study it was found that the applied voltage has the maximum influence over the output responses i.e. MRR and TWR .Optimum value MRR is 3.900 & the optimum value of applied voltage is 70V, optimum value of mixed electrolyte concentration 30% wt and optimum value of current is 6A & TWR is 0.9550 mg/min at the optimum value of applied voltage is 70V, optimum value of mixed electrolyte concentration 30% wt and optimum value of current is 5A.

ACKNOWLEDGEMENT

I would like to express my deep sense of respect and gratitude towards my supervisor MR.MANDEEP SINGH, who not only guided the dissertation work but also stood as a teacher and philosopher in realizing the imagination in pragmatic way; I want to thank him for introducing me for the field of optimization and giving the opportunity to work under him. His preserve and optimism have provided an invaluable influence on my career and outlook for the future. I consider it my good fortune to have got an opportunity to work with such a wonderful person. I am especially in debuted to my parents for their love, sacrifices and support. They are my teachers after I came to this world and have set great example for me about how to live, study and work.

CHANDERKANT

CERTIFICATE

I hereby certify that the work being presented in the dissertation entitled "**EXPERIMENTAL INVESTIGATION TO EVALUATE THE MACHINING CHARACTERISTICS OF NON-CONDUCTIVE MATERIAL BY ELECTROCHEMICAL DISCHARGE MACHINING (ECDM)**" in partial fulfilment of the requirement of the award of the Degree of Master of Technology and submitted to the Department of Mechanical Engineering of Lovely Professional University, Phagwara, is an authentic record of my own work carried out under the supervision of (Mandeep Singh, Assitant Professor) Department of Mechanical Engineering, Lovely Professional University. The matter embodied in this dissertation has not been submitted in part or full to any other University or Institute for the award of any degree.

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The external viva-voce examination of the student was held on successfully ________________

Signature of Examiner

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CHAPTER 1

1. INTRODUCTION

Electro chemical discharge machining (ECDM) is micro machining hybrid process where the machining is done with the both thermal sparking and chemical etching phenomena. ECDM Generally used for the machining of electrically non- conducting, high strength and brittle materials. ECDM has the potential of machining of electrically non-conducting materials like glass, composites, ceramics and other hard and brittle materials which are electrically non-conducting materials like quartz, glass , composites, ceramics and other hard and brittle materials which having the huge application in the field of aerospace, defence, electronics and automobile. Due to larger application of all the non-conducting materials it is necessary to machine these materials with the suitable advanced machining process like ECDM. ECDM is the combination of electrical chemical machining (ECM) process and electro discharge machining (EDM) process. ECDM process has the capability of machining the non-conducting materials with the better accuracy. In ECDM process work piece is generally dipped into electrolyte solution like Noah or KOH. A proper electrolyte concentration require to maintain in electrolyte solution so that the chemical reaction between the work piece and tool tip will occur at faster rate .In ECDM process electrolyte concentration always effect the material removal rate (MRR) i.e. more will be the electrolyte concentration than more will be the material removal rate of a material. A copper electrode tool tip used to feed in downward movement over the outer surface of work piece with the help of proper feeding mechanism where the downward movement of copper tool is controlled by the feeding element mechanism like gravity feeding mechanism .Another important factor of feeding mechanism is feed distance between the spherical tool tip and work piece surface i.e. standoff distance between tool tip and work piece is 0.2 mm. A variable pulsed dc voltage applied is between the tool electrode tip and work piece surface which is generally act as cathode and counter electrode which normally act as a anode. A generally variable pulsed dc voltage range of 30V to 80V is applied between the tool electrode as the variable pulsed voltage increase its critical value the spark start initiate between the tool electrode tip and work piece outer surface and melting and vaporization and thermal erosion of work piece surface start due to high heat generated by discharge between the tool electrode tip and work piece

ECDM generally depend upon the various important parameter like voltage, current, stand of distance between tool and work piece, electrolyte concentration, pulsed duty ratio, duty factor. ECDM parameters that effect the material removal rate and tool wear rate.

1. Applied pulsed dc voltage
2. Current
3. Electrolyte concentration
4. Standoff distance between work piece and tool
5. Tool feed rate

1. Applied pulsed DC voltage: - ECDM process generally used the pulsed dc type voltage whose voltage range is varies between 20V to 70V as the voltage range exceeds its critical voltage value than sparks start initiate between tool electrode and work piece. As the applied voltage increases MRR also get increased due to high heat generated between the tool electrode tip and work piece i.e. applied voltage always have larger influence over the MRR.
2. Current: - In ECDM process current value range different for the different non-conducting materials like ceramics having the current values 0.5A to 27A, glass having the current values range 0.5V to 20V. generally current value range in ECDM process is lies between 0.5A to 50 A. current has also the greater influence over the MRR because as the current value increased between the tool electrode and work piece than MRR also get increased.
3. Electrolyte concentration: -In ECDM, MRR increase with increase in electrolyte concentration as the result of more chemical reaction between tool electrode tip which is act as cathode and work piece which is act as a anode which is responsible for the generation of greater no of sparks. Different electrolyte used in ECDM these are Noah, KOH, and mixture of Noah and KOH.
4. Standoff distance: - it is the distance between the tool electrode tip which is act as a cathode and work piece which is act as an anode. Generally standoff distance is 0.2 mm is taken during the ECDM process so that proper spark initiate between tool electrode and work piece.

5. Tool feed rate: - Tool feed rate is always important parameter during the ECDM process because it has the greater influence over the surface quality of work piece and also MRR. If the tool feed rate is high it can damage the tool electrode tip and workspace and which effects the MRR.

Normally we can term ECDM as an extension of the ECM process as the electrolyte cell used in the process is quite similar to ECM. In ECDM the anode is constituted of inert material while cathode used is basically made of metals like copper and stainless steel and various electrolytes namely KOH, NAOH and dilute Sulphur acid are used. Initially a voltage is applied and when the voltage crosses the threshold voltage hydrogen gas bubbles evolve in large number at the tip of the cathode and the bubbles increase in number and size causing electric discharge at the surface instantly.

The accurate explanation of the mechanism has not been put down yet but various theories explain that how the process usually takes place using observational and experimental studies. The setup is like this something like this that the two electrodes are the tool which is normally made cathode. And the other one is the anode which is kept partially dipped in this electrolyte, and this is completed through the work-piece. Since, the electrolyte conducts electricity. Therefore, this anode is in contact with the work-piece and the circuit is competed like this through the electrolyte.

There will be a small machining gap maintained in this zone, as we can see and this tool can have different configuration depending on the requirement of our specification then some bubbles are generated because of chemical action of the electrolyte and the gas bubble layer starts to ionize giving rise to spark between the two-piece and the electrode which is used to engrave hole in the work piece.

We have used mixture of two electrolytes basically as sodium hydroxide and potassium hydroxide which are used to show the variation of material removal rate on both the electrolytes and at what point the spark is generated in both the electrolytes.

As said earlier that ECDM is a mixture of ECM and EDM, In ECM, the material removal is purely based on the dissolution of metal from anode. The dissolution rate of electrochemical reaction is relatively low, especially as short pulses, low voltage and small current must be used in ECM to assure required accuracy. Therefore, the material removal rate of ECM is much lower than that of the EDM. As the material removal mechanism is based on ionic dissolution, the surface machined by ECM is very smooth. The generated surface does not have thermally affected layers and it is stress-free with no burr as well as micro-cracks. There is no tool wear in ECM. Hence, an appropriate combination of EDM and ECM could yield the advantages of these two processes while mitigating their adverse effects.

So that's how the idea of ECDM machining came into picture to take advantage of both the machining processes. As the technology grew many improvements came along with the processes as varying the concentration of electrolytes to changing the position of tool and changing and varying the inter electrode gap successively.

One of the major concentration has been on the change of electrode and types of electrodes used in the process and the shape of the electrodes used, the electrodes started out on common cylindrical electrodes but various shapes and sizes and cutting heads sizes and shapes have been used to enhance the spark generation.

The ECDM was mainly developed to start a new method in a much more economical way as the USM used for cutting materials like glass was too costly and there was a presence of mechanical cracks on both the surfaces due to excessive tool wear and there is another method called the laser beam machining but it has also got issues with machining shiny surfaces and transparent surfaces.

The mechanism of material removal in ECDM process involves the following four stages.

Stage 1: The reaction of sparking based on the ECM

Stage 2: Anode dissolution and spark generation as the first stage of the EDM.

Stage 3: The gas layer formation as that of EDM and then followed by bubble formation and further concentration of the bubbles formed which allow the spark to be generated

Stage 4: Continuous discharge occurring in form of spark generation in which the in intensity of the spark can be increased by increasing the voltage and varying the parameters and concentration according to the observation.

1.1 Need of ECDM

1. High Accuracy.
2. Smooth surface finish
3. Complex Surfaces
4. Technology Advancement

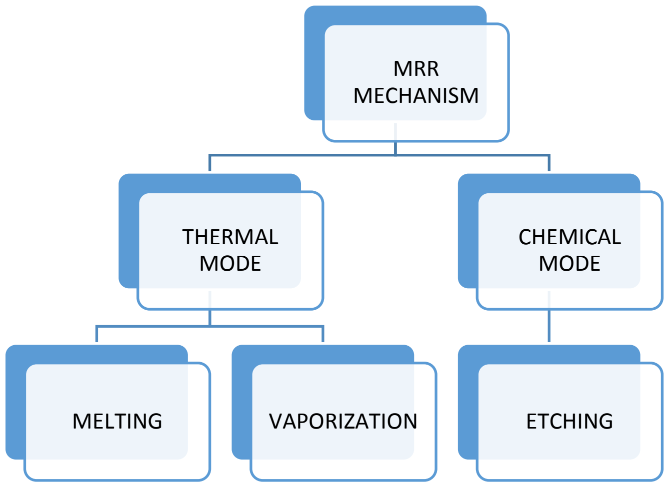

Figure 1 Material removal mechanism of ECDM

1.2 Influencing parameters in ECDM

1. Voltage Gas
2. Film
3. Spark Generation Tool
4. Electrode
5. Auxiliary Electrode
6. Electrolyte Concentration.
7. Current
8. Standoff distance

1.3 Advantages of ECDM over ECM and EDM

1. The surface obtained in ECDM process have better surface finish than EDM and ECM.
2. Suitable for non-conducting materials.
3. High accuracy.
4. Methods does not leave any chips or burrs. Less power consumption.
5. Set-up is not too costly and it can be easily developed or fabricated on existing facility through modification and attachments.

1.4 Disadvantages of ECDM over ECM and EDM

1. Electrode wear rate is high.
2. initial investment cost is high
3. Thickness of ceramic material can be machined is limited to 1.5 mm.
4. Radial overcut.

1.5 Applications of ECDM

1. Miniature features of turbine blades (micro-tabulated cooling holes) Filters for food and textiles industries
2. ECDM Process is used in Micro-electro seam welding for copper plate
3. In Industrial applications like bearings, computer parts, artificial joints, cutting tools, electrical and thermal insulators etc.
4. In Trueing and Dressing of grinding wheels.
5. ECDM used in Through and blind micro-holes
6. ECDM used in for making Micro-grooves in glass.
7. ECDM used in for making Micro-slots
8. ECDM used in for making Micro-channels and Complex shapes produced in non-conducting materials (quartz, glass, and ceramics) etc.
9. ECDM used in for making Micro-fabrication of array of holes in SU-8 material (high aspect ratio, polymer, dielectric photoresist material) to fabricate micro-filters needed in micro-EDM process

10. ECDM used in for making Micro-seam welding of copper plates and foils
11. ECDM used in for making Fabrication of miniature components
12. ECDM used in for making Heat treatment process
13. ECDM used in for making Micro-fabrication of miniature machine tools for micromachining.

1.6 Table 1 Comparision Between ECM, EDM and ECDM

ASPECTS	ECM	EDM	ECDM
PRINCIPLE	Anodic dissolution	Spark erosion	Both
POWER	10,000A,2-3V, DC	200A,50-200V, DC	3-4A,40V, DC
WORK PIECE	Conductive	Conductive	Conductive & non-conductive
MRR	Less	Less	5times faster than EDM
TOOL WEAR	Less than both	Higher than ECDM	Less than EDM
ACCURACY	Higher than EDM	Dimensional accurate: +-.03mm	+-.01mm
SURFACE FINISH	Higher than both	Less	Higher than EDM
COST	Less initial than ECDM	Less initial than ECDM	High

CHAPTER 2

SCOPE OF THE STUDY

The main scope of this study to find out the material removal rate (MRR) and tool wear rate (TRR) during the machining of non-conducting, brittle and hard materials like ceramics, composite, glasses (soda lime glass, borosilicate glass, optical glass, Pyrex glass), quartz, reinforced matrix metal composites (MMC) and stainless steel by using the different tool material like copper, tungsten carbide, stainless steel, mild steel (M.S.) with abrasives coatings and molybdenum..

CHAPTER 3

OBJECTIVES OF THE STUDY

The main aim of my study is to find out the materials removal rate (MRR) of soda lime glass and also find out the tool wear rate (TWR) of copper electrode by mixing the electrolyte which is mixture of NaOH and KOH using ECDM process.

The main objectives which we are going to find in this study are:

1. Effect .of different process parameter such current, applied voltage and electrolyte concentration on material removal rate (MRR) of soda lime glass.
2. Effect on process parameter current, applied voltage and electrolyte concentration on tool wear rate (TWR) of soda lime glass.
3. Optimization of performance measure by using taguchi method.
4. Validation of result by conducting confirmation experiment.

CHAPTER 4

LITERATURE REVIEW

Earlier it is impossible to do machining of non-conducting, brittle and hard material with the conventional machining process Like drilling, boring, milling etc. Due to this reason there were need of developing that kind of machining process which was able to do machining of non-conducting, brittle and hard materials and ECDM was the first machining process which was, able to do machining of non-conducting, brittle and other hard materials. ECDM was the first developed by Kurafuji and Suda of japan in year 1968[1]. After that they termed that machining process as electrical discharge machining this process was mainly combination of ECM and EDM in this process they defined the chances of creating micro holes in a glass. Their study was related to find out the effect of electrolyte concentration and tool electrode materials on MRR mechanism. After Kurafuji and Suda of japan worked on ECDM another researcher in the year of 1973 Cook et.al [2] give the new name of the process as electro discharge machining of electrically non-conducting brittle and hard materials, by saying that the process which is described by the Kurafuiji and Suda is different from the ECM and EDM. He applied the different process to different category of non-conducting materials and also studied the effect of that different electrolyte on different non conducting materials.

In the year 1985. T suchiya et al [3] gave another name of that ECDM process which was termed as the wire electrochemical discharge machining process. In that process he showed that this technique can be used to cut different glass and ceramics. In the year 1990 simultaneously research had been carried out on the ECDM process. In the year 1997, Another Researcher Basak and Ghosh [4] find out that the MRR in the ECDM is the combined effect of sparking and chemical reaction between the tool electrode tip and work piece. During their researched worked they also developed the simplified model of ECDM to predict the characteristics of MRR for varying different input parameters of ECDM, their work also claimed that the enhancement of the capability of the process through modification of electrolyte circuit . In the year 2004, Sakarbalak et al. [5] developed a new model of to find out the current of electrochemical dissolution and electro discharge machining in the ECDM process. In this model they tried to employed fuzzy- logic controller for ECDM process. In year 2004, Mediliyegedara et al. [6] developed a new strategy which is new as control strategy for ECDM process in which machining process is carried out a preliminary study of pulse classification system.

In year 2005, Wuithrich and Fascio [7] published a first review paper on ECDM process. In this paper they mainly highlight the electrochemical reaction and their important parameter that affect the electrochemical reaction like electrolyte concentration. In year 2006, Yang et al. [8] developed a new wire electro discharge machining process in which silicon abrasive particle mixed with the electrolyte i.e. mixture of silicon abrasives particle and Noah electrolyte are used during the machining process. He found that by adding silicon abrasives particles in electrolyte the surface roughness of material get improved, there were reduction in slit expansion, over cut over the material gets also improved and electro discharge energy get also reduced. In year 2009, Cao et al [9] had done the machining on 3D glass microstructure using ECDM process and he found that the used of small led cell and small immersion depth of tool helped to reduce the required applied voltage. He also found that the machining of high aspect ratio structures with high resolution could also easily machined with this process. In year 2013, another researcher Liu et al. [10], had done research on grinding-aided electrochemical discharge machining (G-ECDM) process. In that process he had done machining on particulate reinforced metal matrix composites. In G-ECDM process MRR is function of all the three factors i.e. Erosion developed between the tool electrode tip and work piece, spark produced between the tool electrode tip and work piece and chemical reaction between the tool electrode tip and work piece.

Liu et al. [11] had done machining on reinforced metal matrix composite using ECDM process and he found that there is discharge and spark mechanism during the machining of reinforced metal matrix composite. He also developed new model of critical voltage require for the spark ignition during the machining of reinforced mmc. In his experimental work he found that there were increase in spark ignition and erosion action with increase in electrolyte concentration, current and pulse duty ratio.

Yang et al. [12] used stainless steel, tungsten carbide in his wire electrical discharge grinding machining process to find out the wettability characteristics of tool materials. He also reported that the wettability of tool materials machining stability and the feed rate of tool.

Yang et al. [13] again done research on wire electrical discharge machining (WEDG) process using spherical tip tool to improve the machining stability of machining process by increasing the machining time, feed rate of tool and depth of cut.

Kulkarni et al. [14] had done research on ECDM process with tool tip material is covered with some coated material and he found that the MRR of this machining process in generally high as compared to previous work on ECDM which was done without covering the tool tip material.

Cao et al. [15] observed that maximum MRR of 300 micro meter per sec during the machining of soda lime glass mixed with polycrystalline diamond grinding (PCDG) with electrolyte used KOH and tungsten carbide used as tool materiel during the machining of soda lime glass.

Jaywalkers et al. [16] have done experiment on study the effect of different parameters and their different effects while machining of micro channels on Scott optical glass material by using stainless steel as a tool. By doing this experiment he found that the applied voltage having the maximum contribution (85%) on MRR while other parameter like electrolyte concentration having the contribution (7.7%) and tool feed rate having the contribution (6.7%).

Arminder Singh et al. [17] had done experiment on wire chemical discharge machining process where he used wire type electrode for machining of glass and he observed that the material removal rate (MRR) in that case increased as compared to other shape of electrode.in that experiment work his major findings was the machining of brittle hand other hard material can be easily done by using the wire type electrode shape.

C.S. Jawalkar et al. [18] discovered that micromachining is gaining wide prominence in today's firm based and research applications. It signifies procedures and approaches to achieve small structures (less than 1mm) on varied portions & components. A microcontroller is vastly used for controlling such procedures to obtain the anticipated dimensional accuracy. It is set to guide the tool in a well-ordered path to provide requisite precision in a progressive manufacturing process. The microcontrollers are inexpensive substitutes as compared to servo controllers. They can be attached with developed investigational setups and further with CPUs to get micro machined aspects understood in the laboratory. A VMC-850X microprocessor was used with 8085 based VMC 8501 control unit to machine micro-channels on a distinct optical glass work-piece. The MR (material removal) and TW (tool wear) were dignified as the response characteristic & the mutable process parameters were tool speed electrolyte concentration and applied voltage. The found experimental results exhibited that all the parameters were important. The applied voltage had 85.58% outcome in MR and 66.71% outcome in TW study. The FESEM micrograph provides the useful information on the mechanism of material removal.

Min-Seop Han et al. [19] stated that wire electrochemical discharge machining (WECDM) is recommended as a micro-cutting process for non-conductive constituents such as glass and ceramics but the WECDM process by traveling wire has to bear low surface integrity due to the great working voltage and extended reactive tool length in comparison to those of the micro-ECDM process. The research involved a cylindrical tool with micro-textures on the exterior is suggested as a cutting electrode. Fractional electrical shielding of the tool electrode was also engaged to stabilize the discharge features by minimizing the sensitive tool area. 2-dimensional outline cutting of soda-lime glass using the planned method was demonstrated.

Debangshu Das et al. [20] proposed that amongst all the non-traditional micro-machining, ECDM (electrochemical discharge machining) has high excellence of material removal rate with nil residual stress. This machining has been acknowledged as a highly up-to-date technology in micromachining. An effort has been done on micro penetration of glass using ECDM. A secure tool and a step down transformer were used to upkeep the steady machining to upsurge the accuracy of the work-piece. The ratio of area of electrode, concentration of electrolyte, voltage & enter-electrode gap are the input parameters used in the concerned experimentation. MRR has been inspected over the input limits. Feed rate and temperature of the electrolyte had been made fixed at 3μm/sec and 30˚c respectively. Taguchi method had been used for optimizing the effect of the process limits on material removal rate. The S/N (signal to noise) ratio and the ANOVA analysis had been employed to find the assistances of input parameters.

Apurbba Kumar Sharma et al. [21] threw light on the topic that electro chemical discharge machining (ECDM) is an established process for micro-machining hard to process non-conductive substances. The trial results: tool wear (TW) & material removal (MR), while producing shallow holes on soda lime glass using electro chemical discharge machining process had been reported. The electrolytes NaOH and NaNO3 were used at the time of the micromachining on soda lime glass. The thorough parametric study was scheduled using the typical L9 orthogonal array. Effect of process parameters, viz. applied voltage, electrolyte concentration, electrodes distance and time of current flow on response parameter, that is, MR were examined. The results presented that NaOH was more effective as compared to NaNO3. The outcomes on MR showed that all constraints were noteworthy and applied voltage was found to be the most inducing constraint (70.14%). Field emission scanning electron microscopy (FESEM) and debris investigation were further carried out to learn the performance of the ECDM process.

J.W. Liu et al. [22] had analyzed the discharge mechanism in ECDM in case of the particulate reinforced MMCs (Metal Matrix Composites). The analysis had exposed the electric field that acts on the bubble of hydrogen in ECDM process & is now standardized. The model was found proficient forecasting the position of the highest field strength on the surface of the bubble. Also, the critical breakdown voltage for the initiation of the spark, for the given condition of processing was found out. The model had been verified with the help of a set of experiments. The occurrence of arcing action in case of the electrochemical discharge machining was found to be associated with the increase in duty cycle, current or the concentration of the electrolyte. The Al_4C_3 phase was detected in the case of EDM, however, there was no such detection of phase in case of ECDM.

Anjesh H Sahasrabudhe et al. [23] gave their viewpoint that the machining of nonconductive ceramic such as Al2O3 (aluminum oxide) is a chief task for user industries. The electrochemical discharge machining (ECDM) is a substitute to process the hard to machine materials such as aluminum oxide, glass etc. Their research focused on the advancement of gravity feed ECDM set up for machining of nonconductive aluminum oxide ceramic. This particularly designed set up contains fixture to hold the work piece and the tool container to keep a check on the tool used for experimentation. The assisting electrode had been kept at the lower side of the fixture. The fresh electrolyte was supplied for the electrochemical discharge machining process by using duo of pumps, one for delivering new electrolyte at machining point and another for the elimination of electrolyte from the machining point. The viability of the invented setup had been experimentally confirmed. Tests were carried out by stainless steel and copper tool to examine the effect of various process constraints of ECDM on diametric over cut (DOC) & the material removal rate (MRR). From trial results and analysis of modification, it is obvious that voltage and concentration of electrolyte are the noteworthy factors affecting the responses. S/N ratio (Signal to Noise ratio) is evaluated to determine the relative contributions of vital machining constraints. The optimization technique called “Rotating Vector Operator Process” (ROVOP), were used for the determination of the optimal parametric blend. It was used to determine the conduct of the curve between two extreme standards of the chosen variables

CHAPTER 5

RESEARCH METHODLOGY

Different methodologies are used during the study which are listed below.

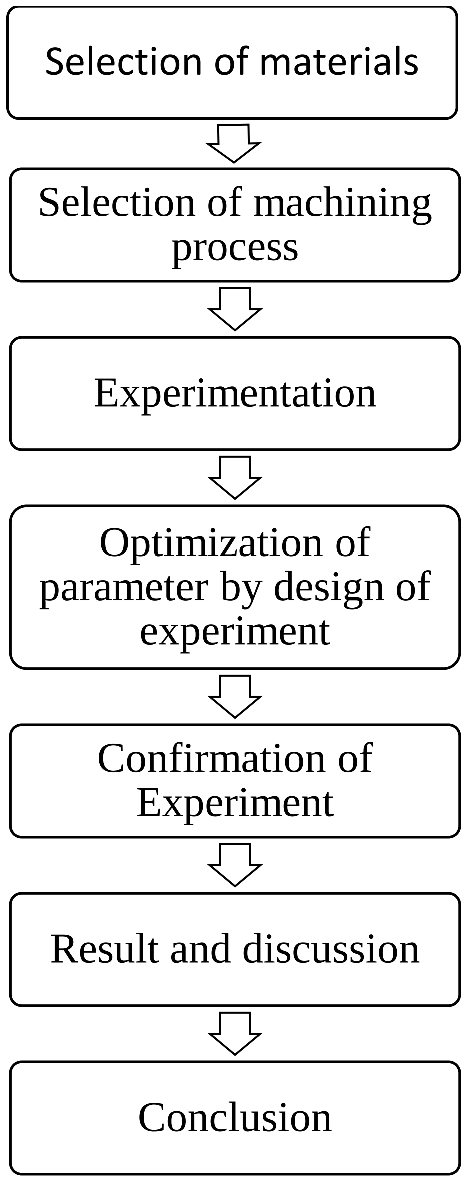

Figure 2 Flow chart of different methodology

5.1.1 SELECTION OF WORK PIECE MATERIAL

All the non-conducting, hard and brittle material like a ceramics, glass, quartz and composites are used as works piece material in ECDM process. Different materials are used for ECDM process which are given below.

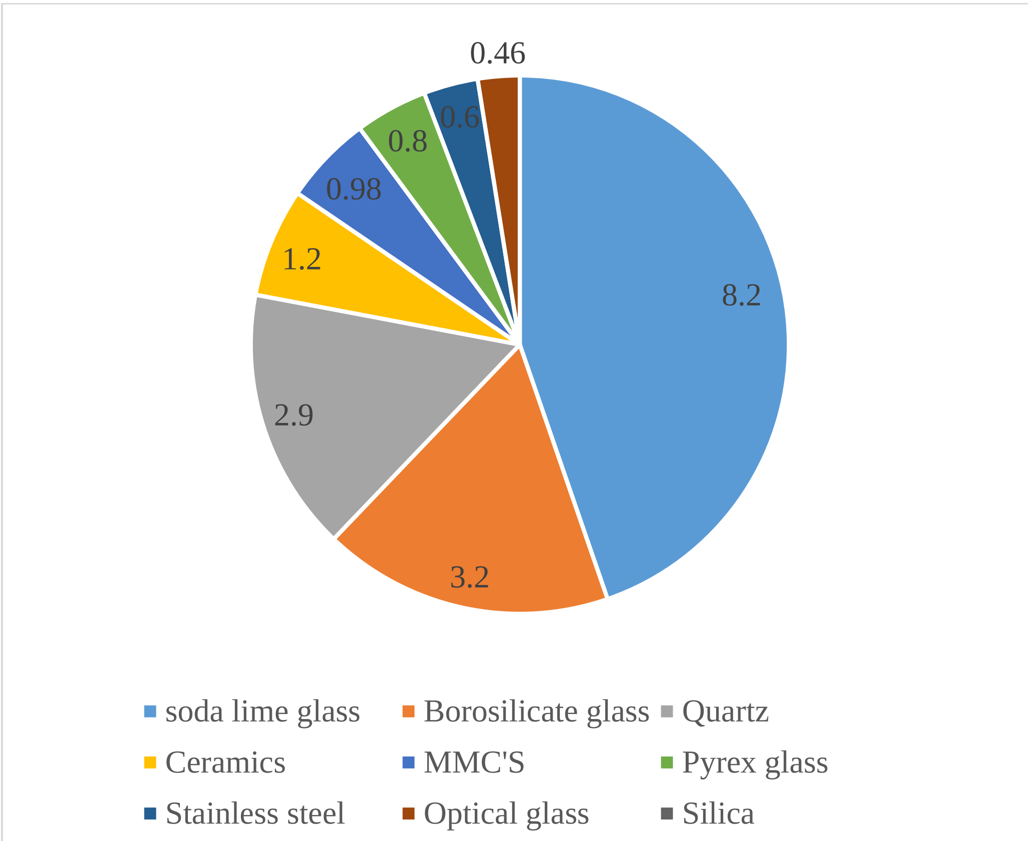

Figure 3 Worked on different work piece materials[24]

5.1.2 SELECTION OF TOOLS MATERIALS

Different tools materials are available for ECDM process which are given below.

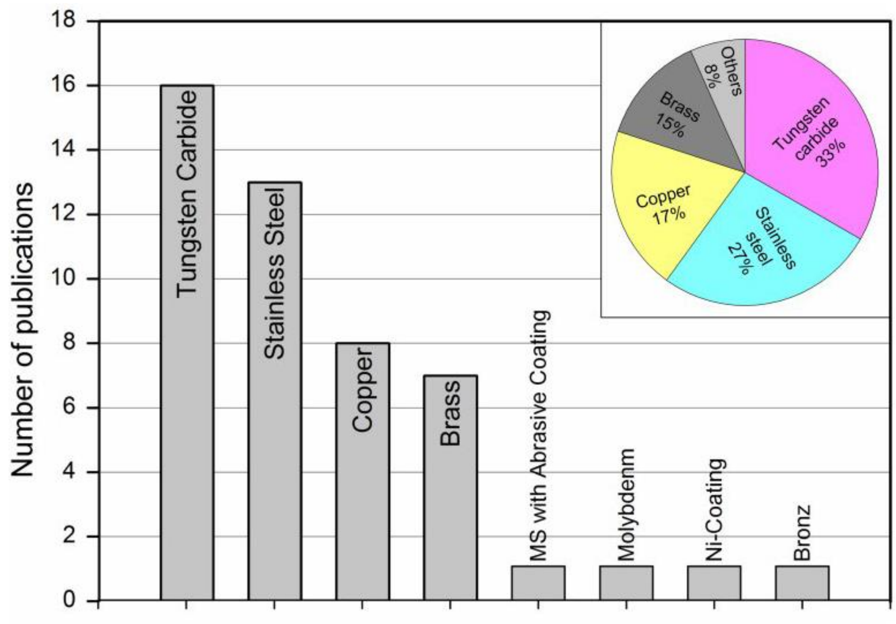

Figure 4 Worked on different tool materials [24]

Above chart show that the percentage of different tool material used in ECDM process for different work piece which are used in ECDM process. In my present work I used copper as a tool material with the diameter of 1mm.

5.1.3 SELECTION OF ELCTROLYTE

Selection of electrolyte is the most important parameter of ECDM process. Different electrolyte are available which are used in ECDM process they are given below in chart. I used the mixture of Noah and KOH as electrolyte.

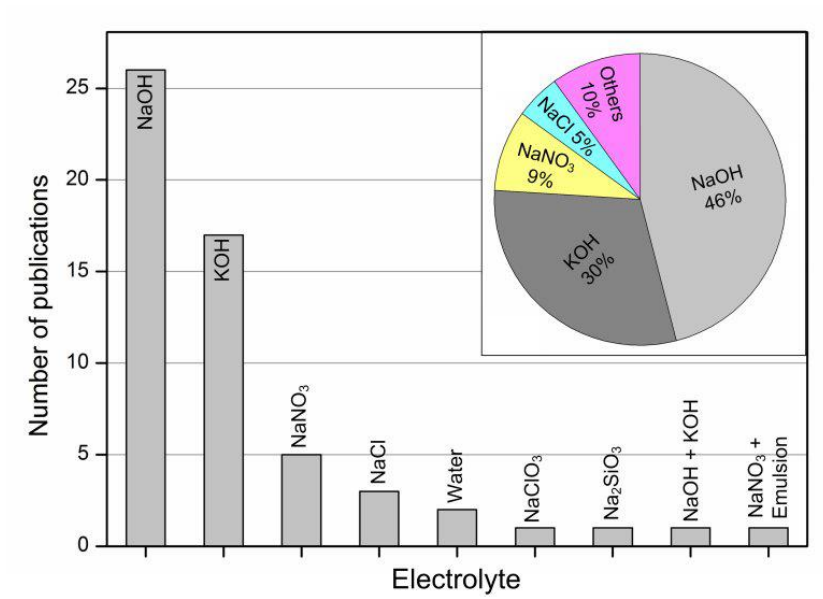

Figure 5 work on different electrolyte used[24]

5.2 SELECTION OF MACHINING PROCESS

After selecting the work piece material, tool material and type of electrolyte the next step to selection of particularly machining process according to required machining operations like if we want to do grinding of non-conducting material than we have to used electro grinding discharge machining, similarly if we want to do wire drilling on work piece than we select the electro wire chemical discharge machining process.

5.3 EXPERMENTATION

In these methodology we have to do all the experimental work like designing the setup of experiment , designing all the parameter which like machining voltage , machining current , standoff distance between electrode tool tip pressure gap between tool and work piece and feed movement of tool and workspace. The experimental setup of ECDM consists of following components:

1. A pulsed D.C. power supply unit
2. A work piece holding arrangement unit
3. A tool holder equipment unit
4. Feeding mechanism arrangement tool feeding unit
5. A machining chamber unit

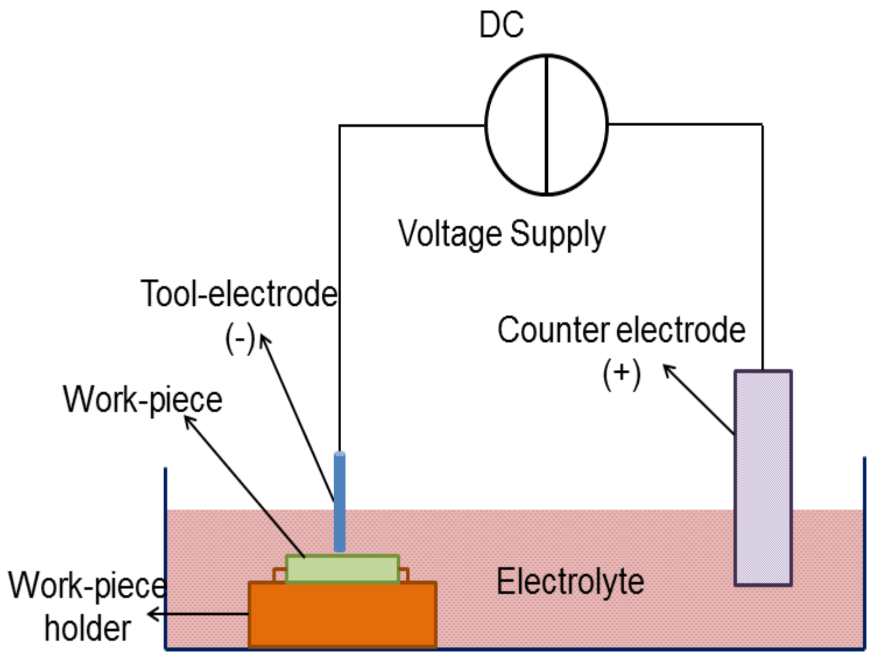

Figure 6 experiment setup[24]

1. A pulsed D.C. power unit:-A pulsed D.C. power supply consist of three phase half wave rectifier which is used to convert the ac signal into the dc signal and also used to generate the different pulsed signal from a signal dc power source. A pulsed D.C. power supply must have capability to supply the frequency of range 50HZ and also having the capability of providing voltage range of 0-200V.
2. A work piece holding arrangement unit: - a work piece holding arrangement must have the fixed support which used to hold the work piece tightly so that there is no looseness of work piece during the cutting operations.
3. A tool holder equipment unit: - It is the device which is used to hold the tool and also used to provide the tool movement.

4. Feeding mechanism arrangement tool feeding unit m: - feeding mechanism arrangement for tool feeding arrangement is used to provide the feed of tool against the work piece and it is also used to provide the movement of tool. Different feeding mechanism used to feed the tool for example, gravity feed mechanism.
5. Machining chamber: - A machining chamber is used to carry the electrolyte which is provide the working medium of cutting process i.e. it is chamber where the all the cutting operation is being carried out.

5.3.1 EXPERIMENTAL SETUP

The experimental setup we have built includes a voltage box to provide the voltage to the setup it is connected with a ammeter and it has a display monitor installed in it to help us show and control the voltage with the nobs provided having a step sixe of ten it is then connected with a copper wire to the electrodes which are installed to a stand which has both the electrodes fitted to each other with a marked scale to manage the inter electrode gap between the electrodes , the wires are attached at the electrode and then the electrodes are dipped inside an electrolyte which is poured in a borosilicate glass container which is used because the borosilicate glass does not react with the used electrolyte and then it is covered using an acrylic box which is also made up of non-reacting material which covers the setup from emitting harmful gases and pungent smell produced during the reaction of the electrodes with the electrolyte and spark generation the voltage provide device is alternatively connected to a mustimeter which provides us with the exact digital output for the voltage we provide and it is also simultaneously connected with a rheostat to vary the current provided along with the voltage supplied .

5.3.2 VARIOUS COMPONENTS OF THE EXPERIMENTAL SETUP

Electrodes Used

Electrodes used in this experiment is made up of copper and stainless steel grade 316 in which copper was made as the cathode and stainless steel is made as the anode.

Table 2 Dimensions & Properties Of Materials

Copper	Stainless Steel
Copper electrode is made as anode.	Stainless steel electrode is used as cathode
Diameter = 2mm	Diameter = 5mm
Density =8.96 g/cm^3	Density = 7.80 g/cm^3

Copper electrode used is in spherical shape because as we have studied in the earlier studies that the spark produced in spherical shape is more directed on the work-piece.

Figure 7 Copper electrodes with spherical shape on its tip

Figure 8 stainless steel electrode with diameter of 2mm

Battery Charger

The battery charger which used in experiment is also called as the VVD , it is used to provide voltage to the electrodes and it has a digital display which indicates the ampere current and there are separate knobs provided to change the voltage from 10 to 80 V.

The first knob changes the voltage from 10 to 80 while the other knob is step size voltage in the units of 1 to 10. The voltage provided is varied accordingly until the spark is generated there is a separate connection which is used to connect the rheostat and are future connected to a mustimeter which shows the exact digital output of the voltage supplied.

The battery charger is also unstilled with a fuse of 5 amperes to cut off the power supply and stop the device in case of any overheating and excessive current failure of voltage fluctuations.

Figure 9 Battery charger

Electrolyte Used

Electrolytes used in this experiment is mixture of two electrolytes namely NAOH (Sodium Hydroxide) and KOH (Potassium Hydroxide). As the earlier studied suggested that mixture of both sodium and potassium hydroxide is best for preparing the electrolyte solution.

Sodium hydroxide (NAOH) pellets and potassium hydroxide (KOH) are dissolved in water in a conical flask to prepare the solution of the mentioned in varying concentrations. I have used concentration ranging from 25 to 35% depending upon the requirement if the spark generation. Electrolyte prepared are to be stored in a proper condition to avoid the adulteration ad change in concentration of the electrolyte.

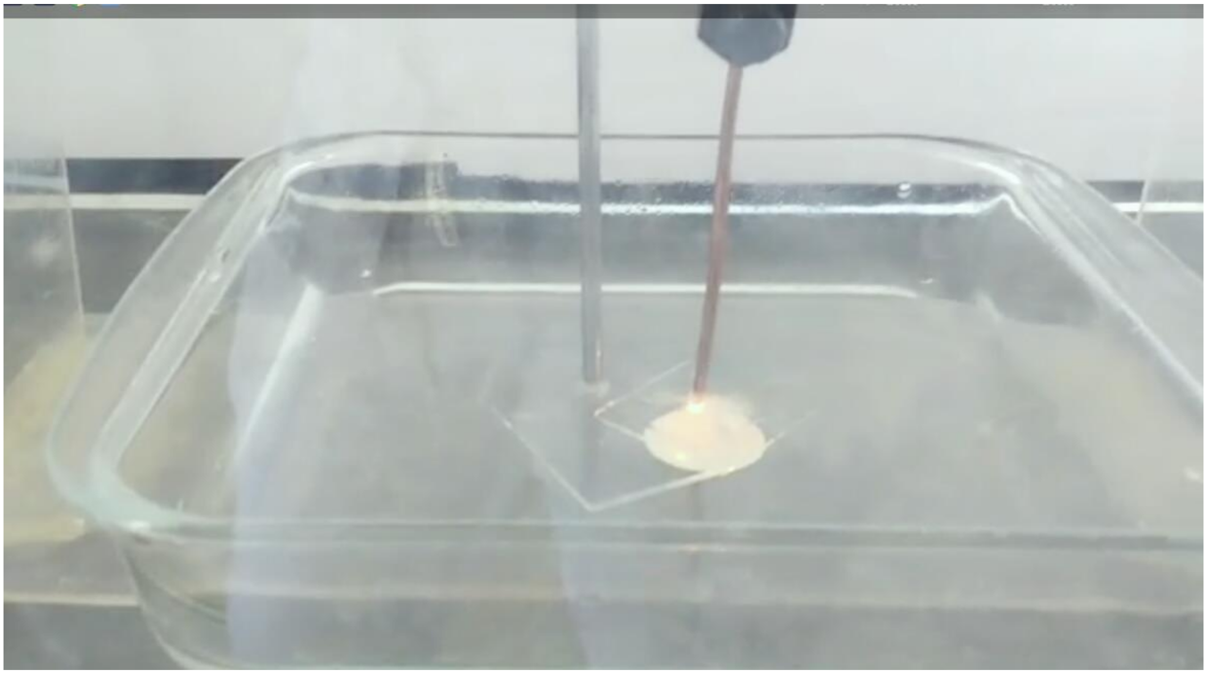

Figure 10 mixed electrolyte solution of NaOH and KOH

Electrode holding Apparatus

The electrode holding apparatus is totally made up of acrylic sheet which is totally unreactive with the given electrolytes and remain unaffected for most portion of the time.

The electrode stand includes two large nut bolt mechanisms to which the electrodes are attached out of which one is stationary and one moves across the path according to the inter electrode gap.

The top of the stand is marked with scale to measure the inter electrode gap in which the copper electrode is kept stationary while the stainless steel electrode is moved across the bottom of the apparatus includes the container in which the electrolyte is kept and the electrodes are dipped in and wires from the battery charger are connected to both the electrodes.

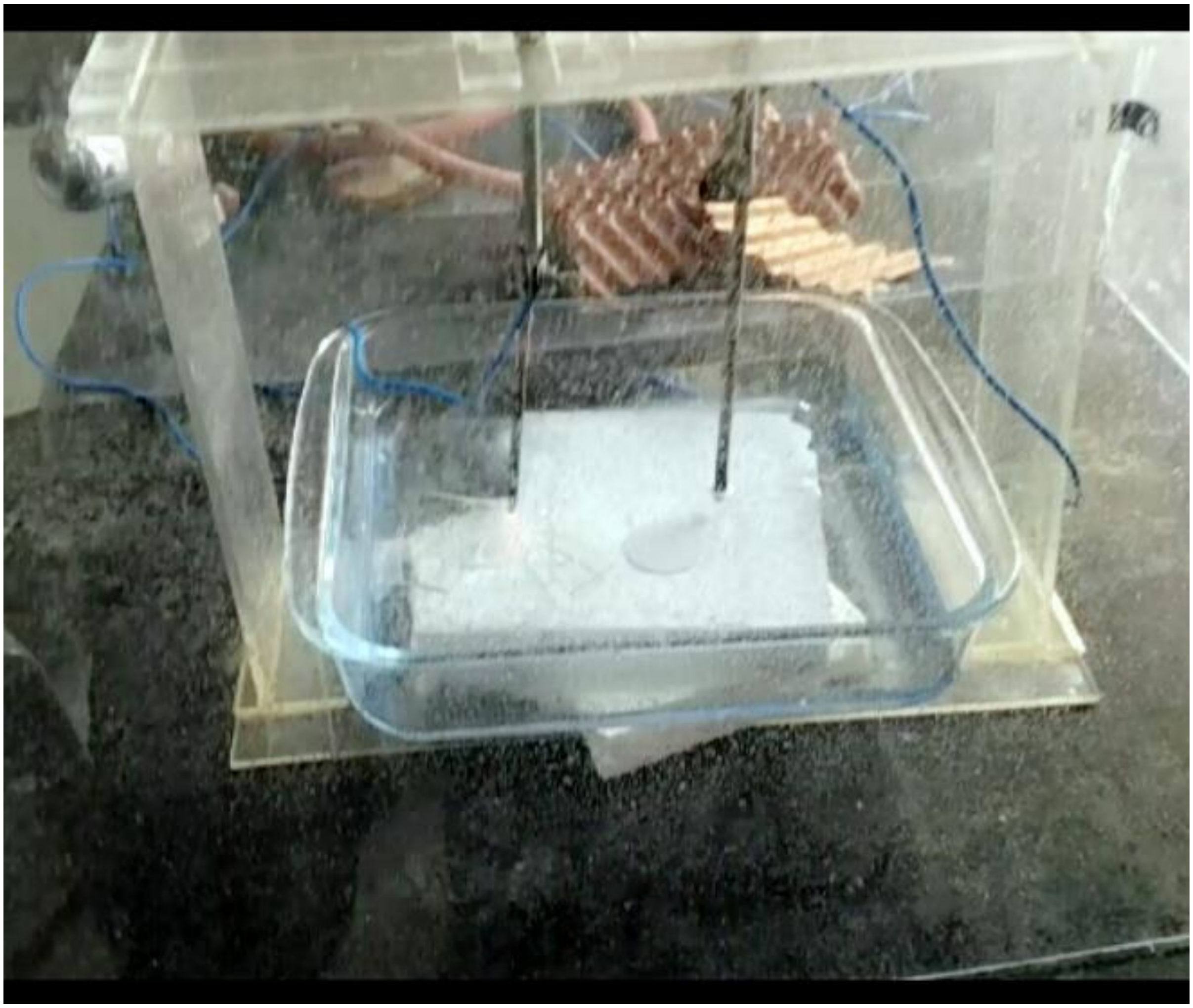

Figure 11 Electrolytic Tank / Beaker Electrolyte Holding

The electrolytic tank is totally made up of thick borosilicate glass or Pyrex glass we chose the borosilicate glass because it is also totally unreactive the electrolyte and etching of the glass surface is totally negligible.

The electrolyte tank has a capacity up to filling around 1000 ml of the electrolyte and the electrodes are dipped inside the electrolyte.

The workpiece is also kept inside the beaker which is either kept on an acrylic stand or on the surface of the beaker according to the requirement.

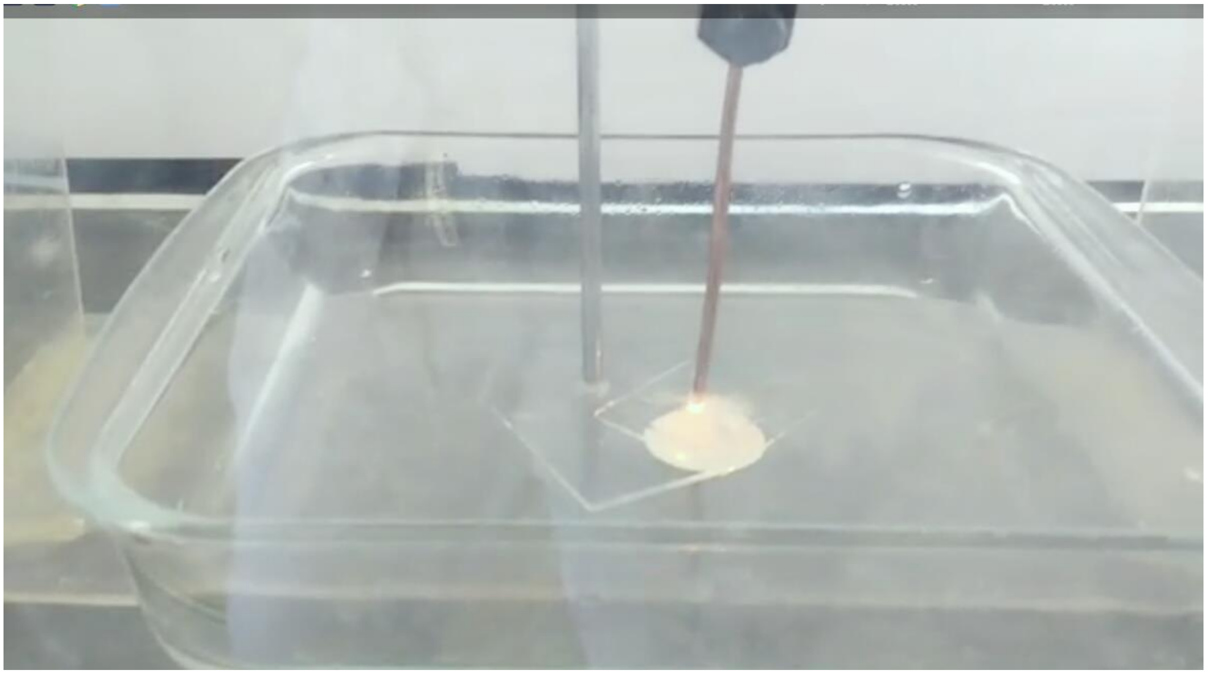

Figure 12 Borosilicate Glass Beaker

WORKPIECE MATERAIL: SODALIME GLASS

Soda lime glass is glass which is composed the composition of three element silica, lime and soda so that's why soda lime glass also called the soda lime silica glass. Soda lime glass is generally considered as a most powerful preventive glass which has the high value of toughness and hardness. Generally soda lime glass is used in window panes, bottles and jars. All the window glass is generally made of soda lime glass.

Properties of soda lime glass

1. soda lime glass is chemically stable glass
2. soda lime glass is rescannable hard
3. soda lime glass is extremely workable

Table 3 Composition of soda lime glass

Chemical composition		
Chemical	**symbol**	**Percentage**
Silicon dioxide (silicate)	SiO_2	**68-73%**
Calcium oxide(lime)	**CaO**	**6-13%**
Sodium oxide(soda)	Na_2O	**11-15%**
Magnesiun oxidw	**MgO**	**1-17%**
Aluminium Oxide	AL_2O_2	**0-4%**

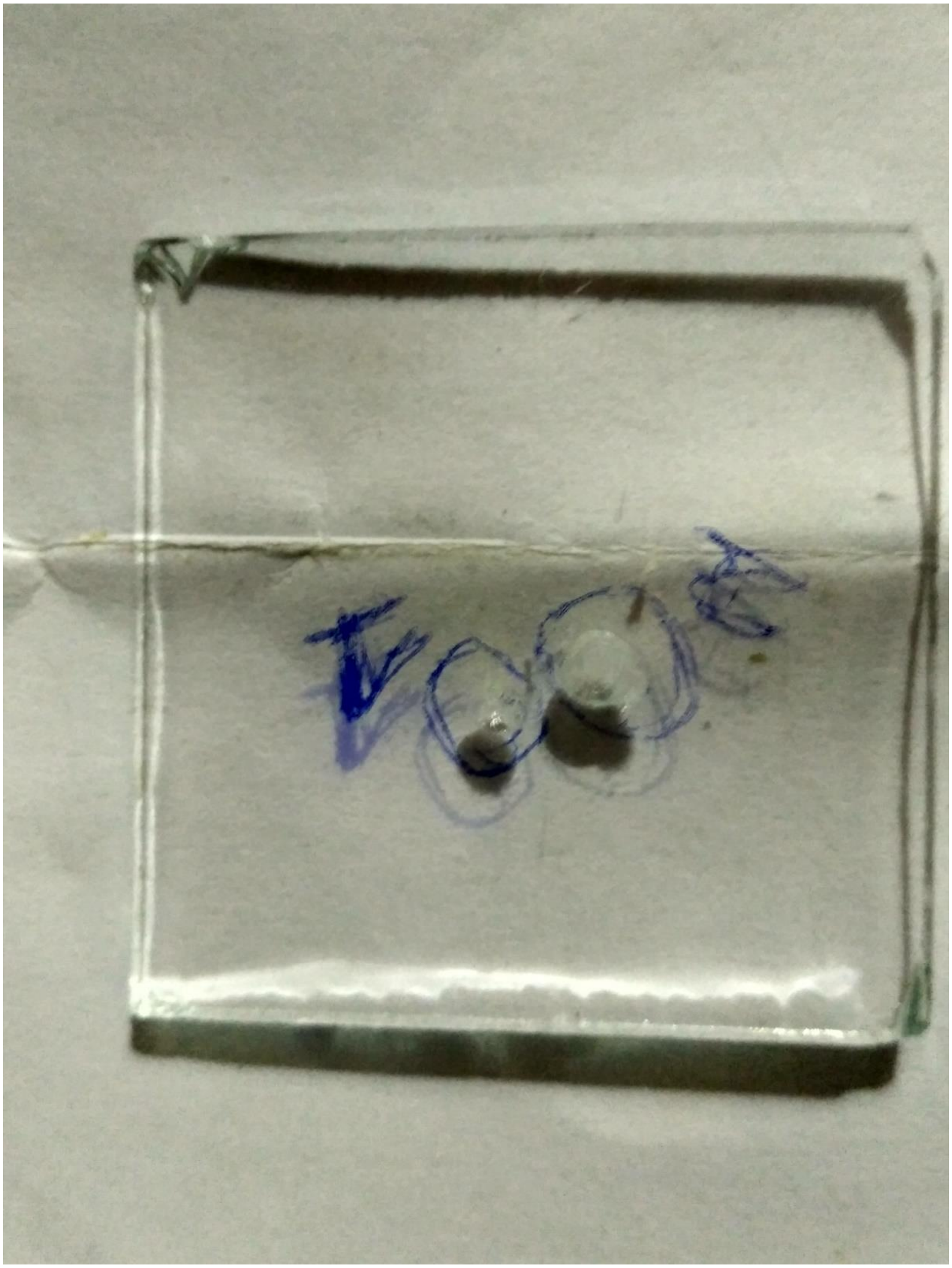

Figure 13 Sodalime Glass

Shielding Case

The shielding case is a big acrylic box which is used to cover the whole apparatus while the experiment is going on and even while the setup is switched off it helps in shielding the apparatus from any foreign particle falling in the electrolyte.

The case is provided with a proper hole in the top corner where it is connected to an outlet pipe which acts as a way to push the pungent gases out of the chamber and preventing us from inhaling the gas. The box is constructed by joining it with glue and reinforcing using adhesives to provide strength and to seal the container properly from all sides.

Shielding Case

Figure 14 Shielding Case

Multimeter

Multimeter is connected to the battery charger it is basically used to measure the voltage and the current provided digitally.

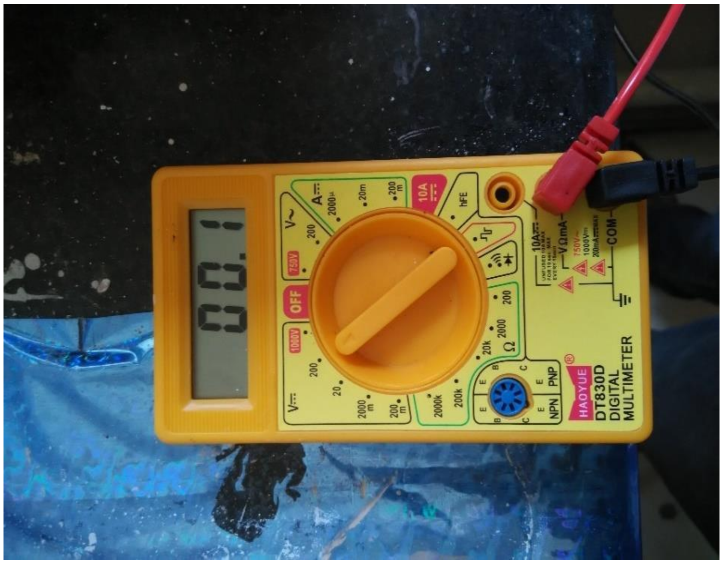

Figure 15 Multimeter

5.4 FINAL EXPERIMENTAL SETUP

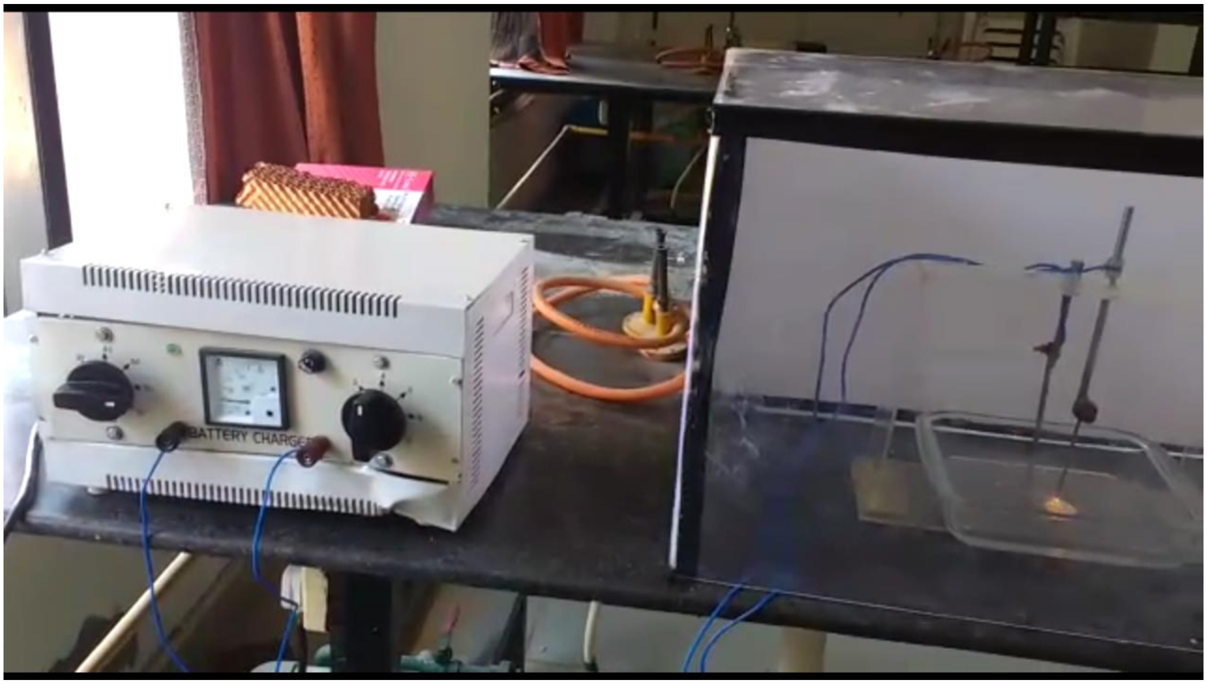

Figure 16 Final Experiment Setup

5.5 OPTIMIZATION OF PARAMETER BY DESIGINING OF EXPERIMENT

There are various parameter which are affect the MRR of the ECDM process due these reason it is necessary to consider effect of the machining parameter while doing the designing of experiment . The parameter which effect the MRR these are:

1. Applied voltage
2. Electrolyte and their concentration
3. Tool feed rate
4. Current
5. Standoff distance

1. Applied voltage: - for designing the experiment a power source must supplied the Voltage range 0 to 80V.i.e optimize value of applied voltage is 70 V.
2. Electrolyte and their concentration: - While designing the experiment it is necessary to choose the suitable electrolyte according to work piece material and their concentration

level also having the optimum value so the proper chemical reaction takes place during the cutting operation.

3. Tool feed rate: - An optimum feed is given to the tool so that cutting operations should have maximum MRR.
5. Current: - while designing the experiment it is necessary that the current value range lies between 0 to 50A. And optimum value of current from the design of experiment we get 6A.
6. Standoff distance: - A proper standoff distance is given between the tool and work piece i.e. a 0.02 mm standoff distance is kept between tool and work piece.

CHAPTER 6

6. EXPERIMENT DESIGN

Micro machining of soda lime glass is done with the copper electrode rod of 2mm diameter as a tool, with the stand of distance between tool i.e. copper rod and workspace surface i.e. soda lime glass is 0.2mm. Machining is done with the by moving the tool in downward direction with the help of gravity feeding mechanism with the constant feed.

Experiment are designed by using the taguchi method in which L27 orthogonal array are taken for the design of no experiment with the process parameter applied voltage(V), electrolyte concentration (EC) and current(C). Each process parameter are having the tree different level i.e. Applied voltage has the levels of 50V, 60V and 70V.similarly electrolyte also has three different level which are 25%, 30% and 35% and current also has three different level which are given by 4A,5A and 6A.

Material removal rate (MRR) and tool wear rate (TWR) are taken as output responses for experiment.

Table 4 Different process parameter with their different level

Name	Level
Applied voltage (V)	50 60 7 0
Electrolyte concentration (Noah+ KOH) (Wt %)	25% 30% 35%
Current (A)	4 5 6

Table 5 L27 array with experimental results

Experiment no	Applied voltage(V)	Electrolyte concentration(%wt)	Current(A)	MRR(mg/min)	TWR(mg/min)	SNRA1	SNRA2
1	50	25	4	0.2510	0.1750	-12.0065	-15.1392
2	50	25	5	0.1750	0.1500	-15.1392	-16.4782
3	50	25	6	0.1250	0.1000	-18.0618	-20.0000

4	50	30	4	0.3660	0.1900	-8.7304	-14.4249
5	50	30	5	0.9250	0.4250	-0.6772	-7.4322
6	50	30	6	0.5250	0.1000	-5.5968	-20.0000
7	50	35	4	0.2750	0.1250	-11.2133	-18.0618
8	50	35	5	0.7500	0.1500	-2.4988	-16.4782
9	50	35	6	0.5700	0.2500	-4.8825	-12.0412
10	60	25	4	0.7500	0.2500	-2.4988	-12.0412
11	60	25	5	0.9270	0.2250	-0.6584	-12.9563
12	60	25	6	0.7500	0.4750	-2.4988	-6.4661
13	60	30	4	0.9900	0.4500	-0.0873	-6.9357
14	60	30	5	1.0100	0.7500	0.0864	-2.4988
15	60	30	6	1.2500	0.3500	1.9382	-9.1186
16	60	35	4	0.2000	0.1750	-13.9794	-15.1392
17	60	35	5	0.0002	0.1750	-73.9794	-15.1392
18	60	35	6	0.4700	0.1800	-6.5580	-14.8945
19	70	25	4	2.1250	1.1192	6.5472	0.9782
20	70	25	5	2.7500	1.1592	8.7867	1.2832
21	70	25	6	1.2700	0.9500	2.0761	-0.4455
22	70	30	4	1.5500	0.4000	3.8066	-7.9588
23	70	30	5	2.7500	0.9500	8.7867	-0.4455
24	70	30	6	3.9100	2.0000	11.8435	6.0206
25	70	35	4	0.4500	0.1500	-6.9357	-16.4782
26	70	35	5	0.7000	0.2500	-3.0980	-12.0412
27	70	35	6	0.5500	0.1700	-5.1927	-15.3910

From the experimental results It was found that the materials removal rate (MRR) is more in case of mixed electrolyte concentration (NaOH+KOH) as compared to single electrolyte concentration (NaOH).It was also found that the applied voltage has major influence over the MRR and TWR

6.1 **Confirmation of experiment**

From the design of experiment by using taguchi analysis I get the optimum value of applied voltage, is 70V, electrolyte concentration is 30%wt and current is 6A for getting the optimum material removal rate (MRR) is 3.9100 mg/min. after getting the optimum value the final step to doing confirmation test for the MRR and TWR at the optimum value of parameter

Now by getting the this value we need to do confirmation of experiment by using this data for getting the final MRR and TWR at the optimum value of machining parameters

Table 6 Confirmation Test Table for MRR

s.no	Applied voltage (V)	Electrolyte concentration(C)	Current(A)	MRR(mg/min)
1.	70	30	6	3.8700
2.	70	30	6	3.8701
3	70	30	6	3.8704
4	70	30	6	3.8702
mean	70	30	6	3.8701

From the table it is clear that the by doing the confirmation experiment the mean value of MRR is 3.8701 mg/min which comes the near about the optimum value of MRR 3.900 mg/min which proves that the optimum value which I get is correct.

Table 7 Confirmation Test Table for TWR.

S.no	Applied voltage (V)	Electrolyte concentration(C)	Current(A)	TWR(mg/min)
1.	70	30	5	0.9400
2	70	30	5	0.9410
3	70	30	5	0.9412
4	70	30	5	0.9412
Mean	70	30	5	0.94085

From the table the conferment value of TWR is at the mean optimum value of process parameter i.e. applied voltage of 70V, electrolyte concentration of 30% and at the current value of 5A is comes to be 0.9408mg/min.

After getting the confirmation test for both the machining characteristics output responses i.e. MRR and TWR we need compare the both the machining characteristics MRR and TWR in both the cases first MRR and TWR which we get the at the optimum value of machining parameter and second MRR and TWR which we get in confirmation test result.

CHAPTER 7

7. RESULTS AND DISCUSSION

Figure 17: shows that the main effects plot for the SN ratio is used to describe the optimum process parameter for getting the maximum MRR while the soda lime glass with the mixed (NaOH+KOH) electrolyte**.**

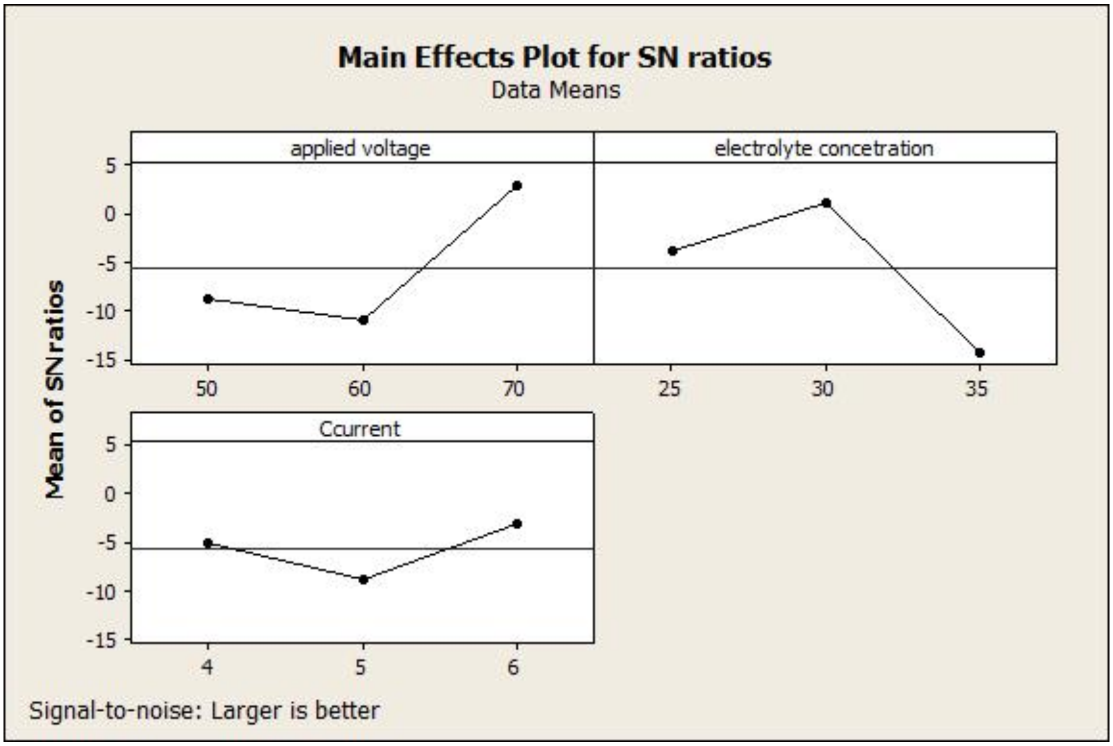

Figure 17 Main Effect Plot for signal to noise ratio is used to optimize the Process Parameter

From the above figure it is clearly shown that the maximum MRR is obtained for voltage of 70V**,** electrolyte concentration of 30 wt% and current 6A**.**

So therefore optimum value of MRR at optimum value of applied voltage of 70V, electrolyte concentration of 30 wt% and current 6A obtained from the L27 orthogonal array table is 3.9100 mg/min.

From the graph it is clearly seen that the MRR is going to increase as the applied voltage increases i.e. maximum MRR occur at the maximum or peak applied voltage. Graph als shows that that the electrolyte concentration has also influences the MRR because from graph the we can see that by increasing the electrolyte concentration from 25 %wt to 30

%wt firstly the MRR is going to increase but when we further increases the electrolyte concentration ranging from 30 %wt to 35 %wt than suddenly the MRR IS going to decreases because the high electrolytes concentration .due to this reason optimum value of electrolyte concentration is 30 %wt where we got the optimum value of MRR.
Current has also important parameter which affect the MRR and we can see that from graph as the current increases ranging from 4A to 6A than MRR also get increases, 6A is the optimum value of current where we get the optimum value of MRR.

Figure 18: shows that the main effects plot for the SN ratio is used to describe the optimum process parameter for getting the minimum TWR while the soda lime glass with the mixed (NaOH+KOH) electrolyte**.**

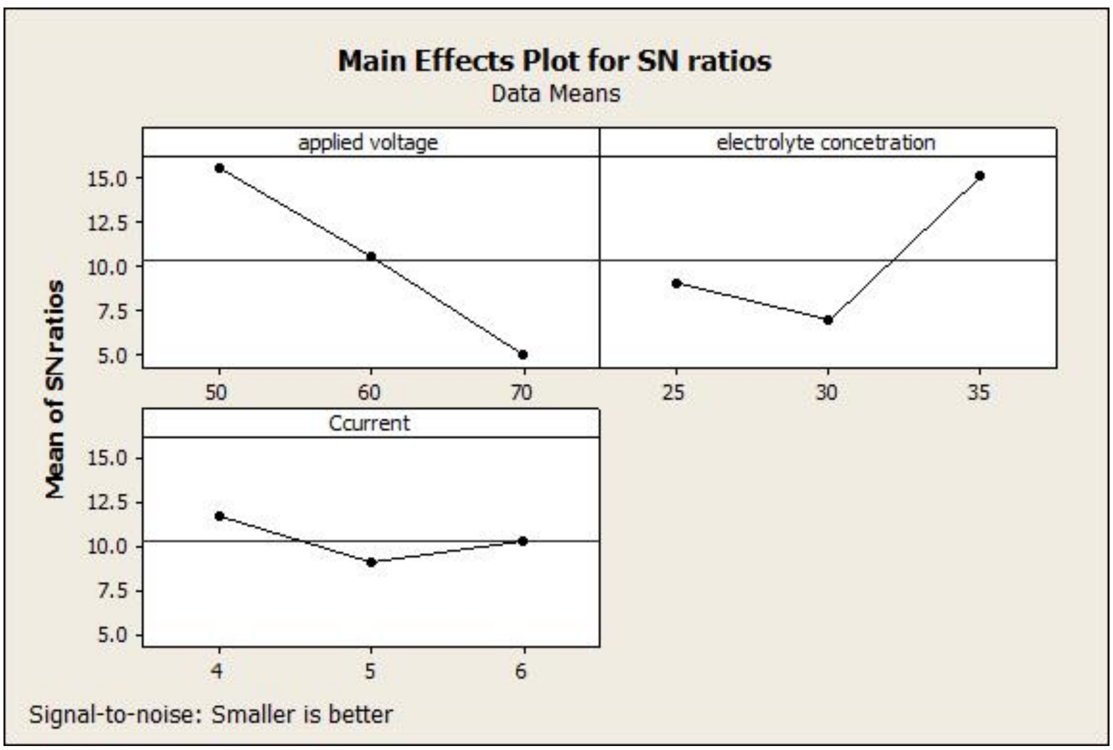

Figure 18 Main effect plot for signal to noise ratio

From the above figure it is clearly shown that the minimum TWR is obtained for voltage of 70V, electrolyte concentration of 30 wt% and current 5A.

So therefore optimum value of TWR at optimum value of applied voltage of **70V**, electrolyte concentration of 30 wt% and current 5A obtained from the L27 orthogonal array table is 0.950 mg/min.

The optimum value of tool wear rate is 0.950 mg/min is show that the optimum tool wear rate is much higher than the in case of mixed electrolyte concentration (NaOH+KOH) as compared to single electrolyte concentration (NaOH).

The above result shows that the material removal rate (MRR) is much higher in case of mixed electrolyte as compared to single electrolyte. This result also compare with the Lijo Paul et al [25] research work where he show that the machining rate get increases with mixed electrolyte in ECDM process .--

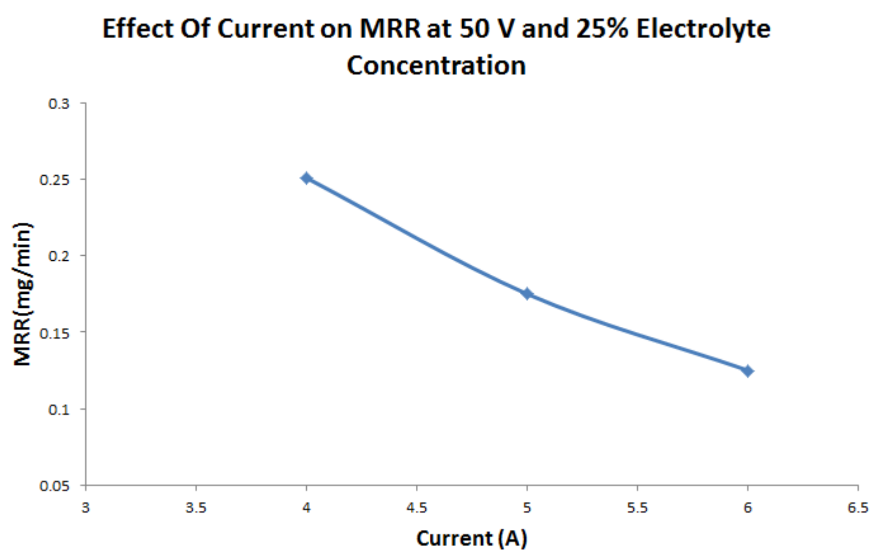

Figure 19 Effect Of Current on MRR at 50 V and 25% Electrolyte Concentration

At the constant values of voltage at 50 V and electrolyte concentration at 25%, for the current values of 4 A, 5 A and 6 A, the MRR values in mg/min are 0.251, 0.175 and 0.125 respectively.

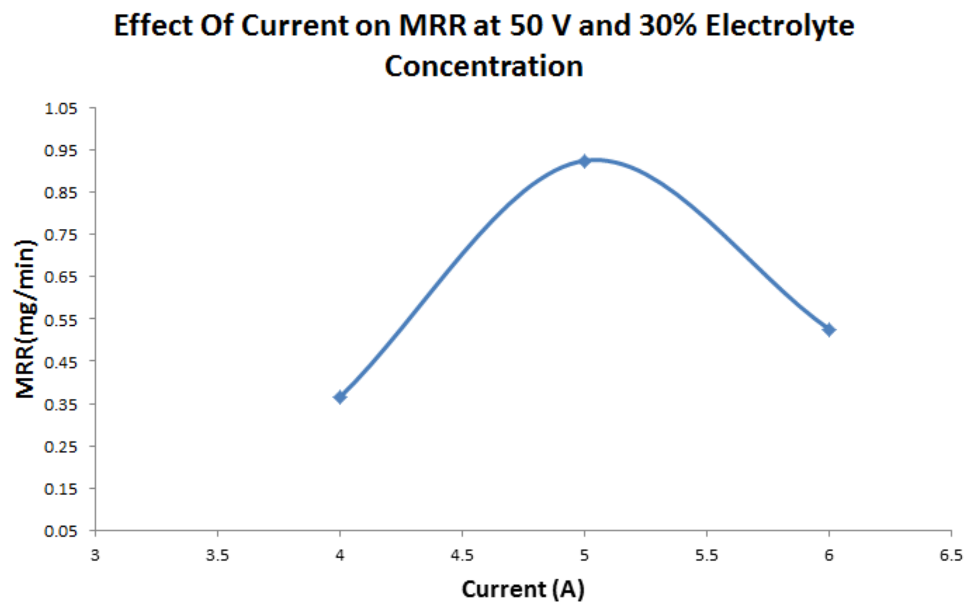

Figure 20 Effect Of Current on MRR at 50 V and 30% Electrolyte Concentration

At the constant values of voltage at 50 V and electrolyte concentration at 30%, for the current values of 4 A, 5 A and 6 A, the MRR values in mg/min are 0.366, 0.925 and 0.525 respectively.

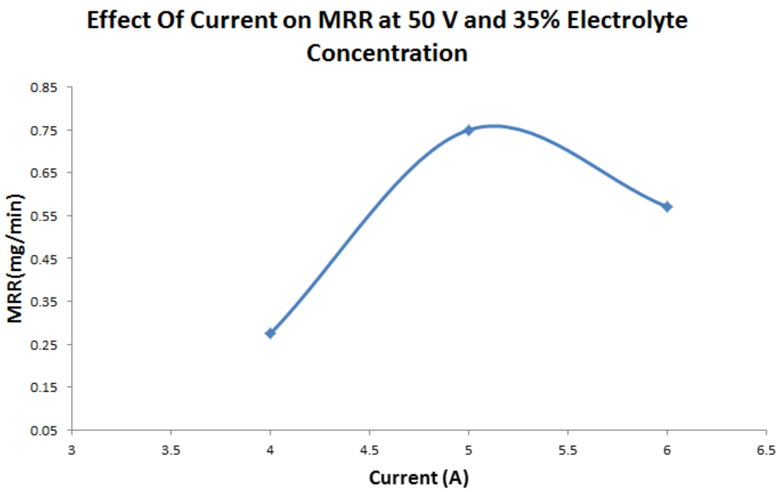

Figure 21 Effect Of Current on MRR at 50 V and 35% Electrolyte Concentration

At the constant values of voltage at 50 V and electrolyte concentration at 35%, for the current values of 4 A, 5 A and 6 A, the MRR values in mg/min are 0.275, 0.75 and 0.57 respectively.

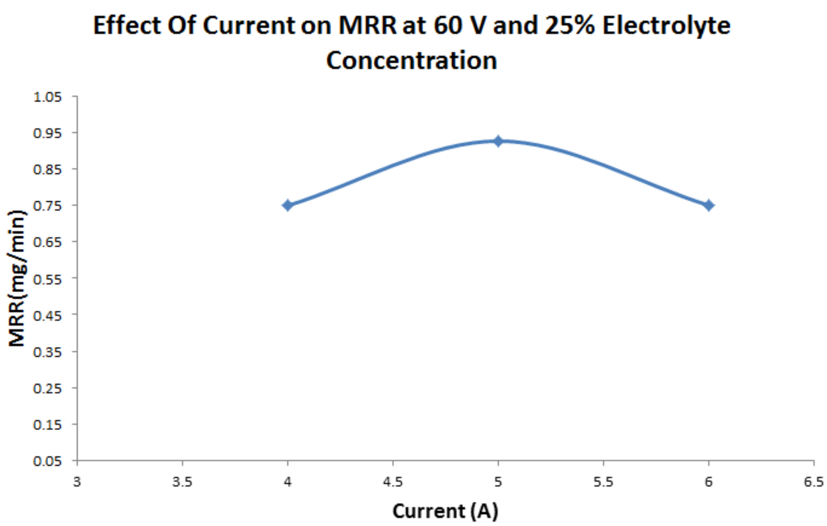

Figure 22 Effect Of Current on MRR at 60 V and 25% Electrolyte Concentration

At the constant values of voltage at 60 V and electrolyte concentration at 25%, for the current values of 4 A, 5 A and 6 A, the MRR values in mg/min are 0.75, 0.927 and 0.75 respectively.

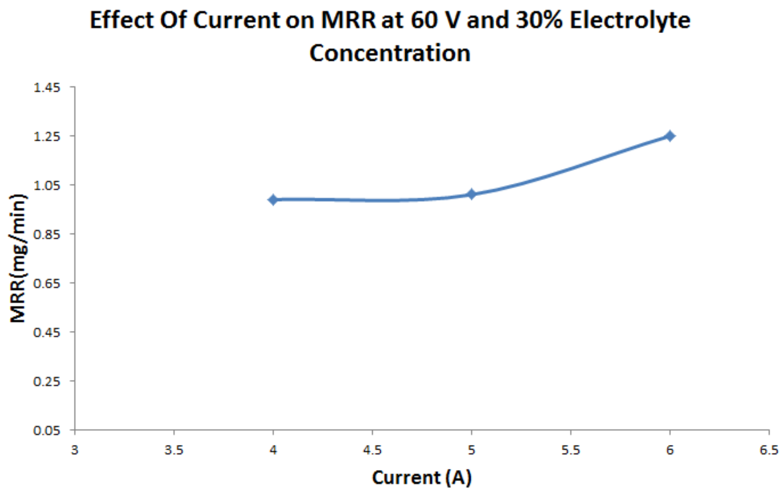

Figure 23 Effect Of Current on MRR at 60 V and 30% Electrolyte Concentration

At the constant values of voltage at 60 V and electrolyte concentration at 30%, for the current values of 4 A, 5 A and 6 A, the MRR values in mg/min are 0.99, 1.01 and 1.25 respectively.

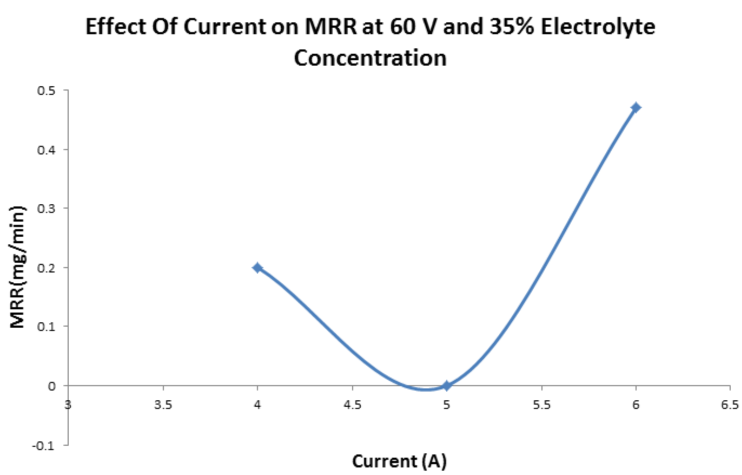

Figure 24 Effect Of Current on MRR at 60 V and 35% Electrolyte Concentration

At the constant values of voltage at 60 V and electrolyte concentration at 35%, for the current values of 4 A, 5 A and 6 A, the MRR values in mg/min are 0.25, 0.1 and 0.47 respectively.

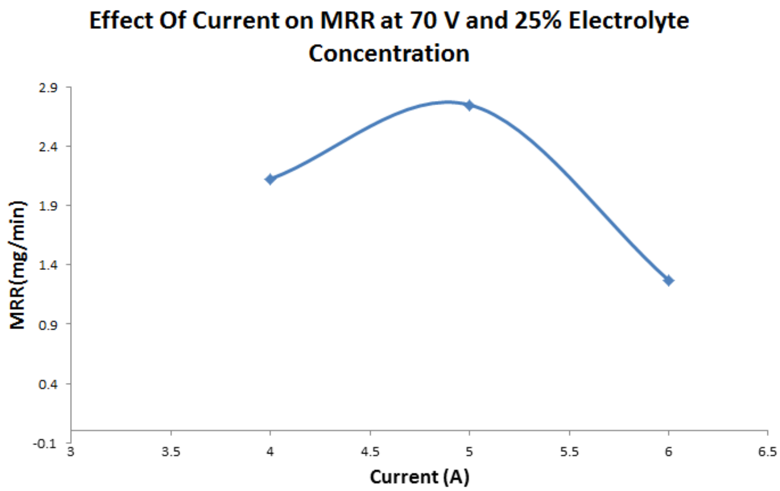

Figure 25 Effect Of Current on MRR at 70 V and 25% Electrolyte Concentration

At the constant values of voltage at 70 V and electrolyte concentration at 25%, for the current values of 4 A, 5 A and 6 A, the MRR values in mg/min are 2.125, 2.75 and 1.27 respectively.

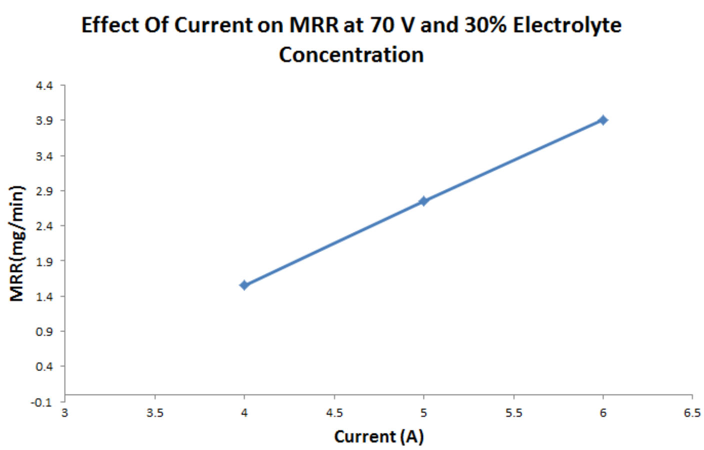

Figure 26 Effect Of Current on MRR at 70 V and 30% Electrolyte Concentration

At the constant values of voltage at 70 V and electrolyte concentration at 30%, for the current values of 4 A, 5 A and 6 A, the MRR values in mg/min are 1.55, 2.75 and 3.91 respectively. From the graph it is clear shows that MRR get increases as the current increases.

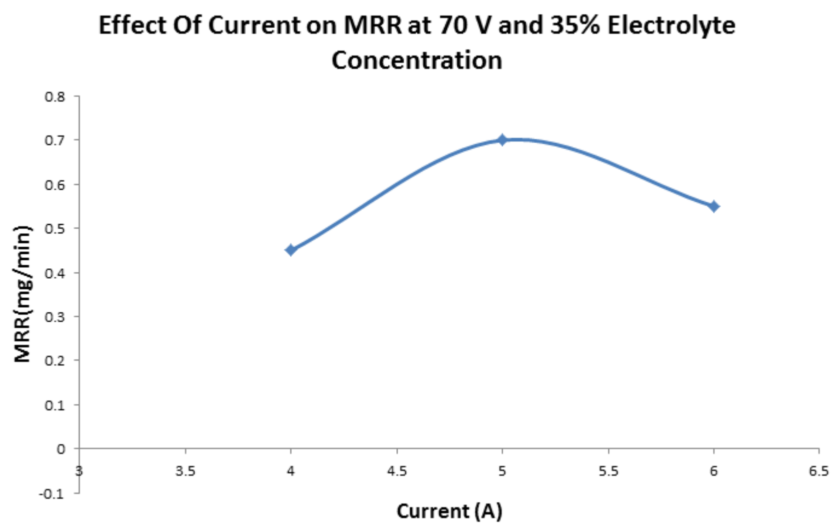

Figure 27 Effect Of Current on MRR at 70 V and 35% Electrolyte Concentration

At the constant values of voltage at 70 V and electrolyte concentration at 35%, for the current values of 4 A, 5 A and 6 A, the MRR values in mg/min are 0.45, 0.7 and 0.55 respectively.

7.1 Analysis of variance (ANOVA)

In analysis of variance we apply the (ANOVA) to determine which machining parameter has the highest distribution over the machining characteristics responses and which machining parameter significantly affect the quality of machining characteristics of ECDM process. In this analysis we also find out the relative contribution of each machining parameter to controlling the machining responses of ECDM process.

General Linear Model: MRR (mg/min) versus applied volt, electrolyte concentration and current

Table 8 ANOVA data with different factors with their different level

Factor	Type	Levels	Values
Applied voltage	Fixed	3	50, 60,70
Electrolyte concentration	Fixed	3	25, 30, 35
Current	Fixed	3	4, 5, 6

Table 9 Analysis of Variance for MRR (mg/min), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P	Contribution (%)
Applied voltage	2	9.1175	9.1175	4.55787	11.67	0.00	64.72
Electrolyte concentration	2	4.8349	4.8349	2.4147	6.19	0.008	34.33
Current	2	0.5767	0.5767	0.2883	0.17	0.491	0.9428
Error	20	7.8122	7.8122	0.3906			
total	26	22.3412					

From the above table it is clear shown that the by analysis of variance f table define the contribution of each machining parameter. From the table we can see that the applied voltage has the greater contribution by having the highest contribution value 64.72%. After that the electrolyte concentration has second highest contribution % which is 34.33%. Current has a least effect over the MRR having the contribution 0.9428.

General Linear Model: TWR (mg/min) versus applied volt, electrolyte concentration and current

Table 10 ANOVA data with different factors with their different level for TWR.

Factor	Type	Levels	Values
Applied voltage	Fixed	3	50, 60,70
Electrolyte concentration	Fixed	3	25, 30, 35
Current	Fixed	3	4, 5, 6

Table 11 Analysis of Variance for TWR (mg/min), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P	Contribution (%)
Applied voltage	2	1.8108	1.8108	0.9054	7.95	0.003	62.15
Electrolyte concentration	2	0.9561	0.9561	0.4780	4.20	0.030	32.83
current	2	0.0.1456	0.1456	0.078	0.64	0.538	5
Error	20	2.2781	2.2781	0.1139			
total	26	5.1906					

From the above table it is clear shown that the by analysis of variance f table define the contribution of each machining parameter. From the table we can see that the applied voltage has the greater contribution over the TWR by having the highest contribution value 62.15% but has the little lower value as compared to MRR. After that the electrolyte concentration has second highest contribution % which is 32.83% but contribution % is low as compared to MRR. Current has a least effect over the MRR having the contribution 5% but current has the higher contribution over the TWR as compared to MRR.

CHAPTER 8

8.1 CONCLUSION AND FUTURE SCOPE

1. The above result which is obtained from the experiment its shows that the applied voltage has the greater influence over the MRR and TWR. Maximum MRR occur at the maximum value of applied voltage i.e. 70V.
2. Experimental results also show that mixed electrolyte concentration (NaOH+KOH) enhance the MRR as compared to the single electrolyte concentration.
3. The optimum value of electrolyte concentration where we get the optimum value of MRR is 3.900 mg/min. From the experimental results it was also concluded that lower value of applied voltage gives the MRR as the lower rate.
4. Spherical Electrode shape has the greater influence as compared to cylindrical shape electrode because of spherical shape of electrode produce the concentrated spark at work-piece surface.
5. From the ANOVA table it’s also concluded that applied voltage having the highest 64.72 % contribution over the MRR as compared to other two machining parameter electrolyte concentration and current which has the contribution value 34.33% and 0.9428.
6. Similarly from the ANOVA table it’s also concluded that applied voltage also having the highest 62.15% contribution over the TWR as compared to other two machining parameter electrolyte concentration and current which has the contribution value 32.83% and 5.0%.

In today world machining of glass is increasing day by day because now days is used in every field like In automobiles in furniture’s, in textiles and other many household products.

Soda lime is glass is one the glass which is generally used in every glass product like window glass. Container glass, solar cell glass and other household bottles glass is expected to be high demand in the near future.

The main future used of soda lime glass is solar cell glass because the glass which is used in solar cell is only made of soda lime glass and machining of that glass only done with the ECDM process.

All other windows glass also manufactured by the using the composition of soda lime glass so that why soda lime glass is most important glass used in glass industries.

Other than of glasses ECDM process also used machining of electrically non conducting material like ceramics, composites, cermet, and other glasses which has various application in field of defence, aerospace and automobiles etc.

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