Study and Analysis of Travelling Wire Electrochemical Spark Machining

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Abstract

Travelling Wire-ECSM can be used for machining insulating material on large scale. OFAT (one-factor-at-a-time) technique is used to perform experiments on TW-ECSM setup. Effective combination of maximum MRR and better surface finish is subject of concern. If MRR is high than surface finish will be low, so by optimization of parameters we can get optimum MRR and good surface finish. There are several parameters like applied voltage, electrolyte concentration, electrode distance, and feed rate etc. on which MRR and surface finish depends.

Key words: ECM; EDM; ECDM; TW-ECDM; TW-ECSM

Introduction

Travelling Wire: Electro-chemical Discharge Machining (TW-ECDM) is a modern non conventional machining method. It is a combination of Electro-chemical Machining (ECM) and Electro-discharge Machining (EDM). Travelling Wire- Electrochemical Discharge Machining (TW-ECDM) is also known as Traveling Wire: Electro-chemical Spark Machining (TW-ECSM) process. It is extension of Electro-chemical Discharge Machining (ECDM) process. It can machine hard materials like ceramics, composites, alumina, glass etc. so it is important. The basic principle of TW-ECDM has similarity with ECDM process. TW-ECDM mainly uses a continuous travelling wire electrode to machine the component. In TW-ECDM method, high density bubbles formation due to electrolysis and then breakdown of gas film due to their coalescence causes the spark in TW-ECDM. Micro bubbles start forming as the supply voltage exceeds the critical value. There exists a dielectric film between the tool surface and electrolyte. This dielectric film is formed due to bubble coalesce. Occurrence of electrical discharge between tool and working component are caused by high electrical field in the gas film region. After this action, rest of the process is same as Electro chemical Machining. Due to this electrochemical reaction there is formation of the positively charged ions and gas bubbles. Space between the tool and working component contains the gas bubbles formed in the process. There is an electrical discharge action between the tool wire and the electrolyte in the gas bubble regions. As the supply voltage increases the breakdown voltage level of gas bubbles spark initiation takes place. Amount of supply voltage controls the spark discharge level. As the voltage increases, the intensity and energy of spark formed also increases. Insulating component is placed near to the spark. Material removal of the component takes place due to 3 processes. These processes are melting, vaporization and energy transmission. MRR depends mainly on parameters like supply voltage, electrolytic concentration, tool wire feed rate, pulse time.

1.1 Basic Principle of Travelling Wire-ECDM

In TW-ECDM process combination of 2 processes EDM and ECM are merged together. In this process Electrode is inside the electrolytic solution. This electrode acts as anode. Machining of materials like composites, ceramics, and glass can be easily done using this process. Electrode in this process is a movable wire which is continuously travelling during the process. In TW-ECDM method, high density bubbles formation due to electrolysis and then breakdown of gas film due to their coalescence causes the spark in TW-ECDM. As the supply voltage increases the breakdown voltage level of gas bubbles spark initiation takes place. There forms a gas bubble layer between the electrolytes surrounding the cathodic component. These formations of film between the 2 causes spark discharge between the anode tool and cathode work piece. Due to electrical discharge spark generates. As the spark generated high heat is produced. This high heat causes the material removal from the working component. It is basically a non traditional approach of removing material. It is mainly used for the purpose of slotting and slicing in components. As the heat generated due to the spark is high, wire has to move in order to prevent it from breakage. Wire is kept at high tension during the process. There is a optimum speed at which wire to be move, This speed should not be too slow or neither be too fast. Too slow speed will cause wire breakage due to excessive heat. Spark will form only once the supply voltage exceeds the critical voltage. The main feature of this process is it avoids the limitation of working at depth compared to ECM. Also this method can be applicable for the micro machining.

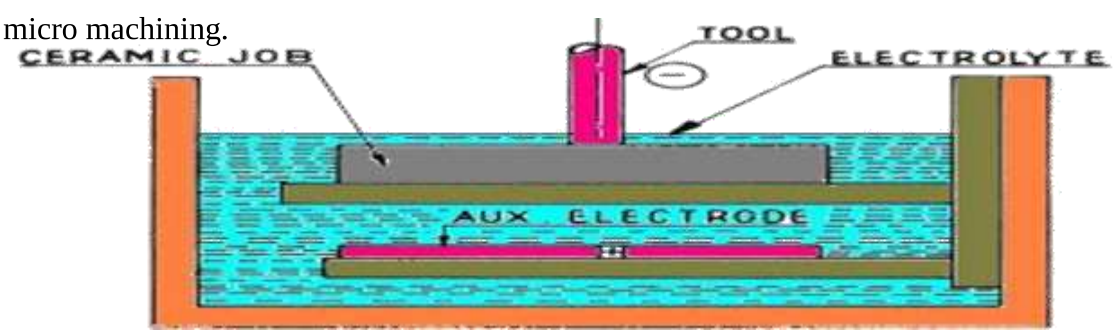

Fig.1.1 Basic elements of the TW-ECDM process

1.2 Requirement of TW-ECDM Process

ECDM process is a hybrid machining process and it is a combination of ECM and EDM process. It has application in machining of hard material which is difficult to machine by ordinary machining. ECDM is used to machine non conducting material, complex shapes, to produce holes in electrically non-conductive material. It can also machine advanced non conductive materials. TW-ECDM was introduced to machine those which were hard to machine by using ECDM process without machining large materials i.e. grooves, complex shapes and generating complex shapes on the working insulating component. TW-ECDM can produce intrinsic shapes. Also amount of material removed in producing this shapes are very less. Common problems in operating this process is wire movement and care of wire guides during the wire movement. ECDM process has some problems like limiting the depth during machining. New developments are taking place in ECDM process day by day varies rapidly.

etc. ECDM process is used to produce holes in electrically non-conductive material.

The process is difficult to install and generally required high maintenance effort. Still these problems are less compared with other processes along with the luxury of machining hard materials. TW-ECDM is a micro machining process so we desire good surface finish and this process gives good surface finish. By proper controlling of various process parameters, good accuracy, better surface finish, better machining rate can be achieved with minimum material wastage. Machining of materials like composites, ceramics, and glass can be easily done using this process. The main feature of this process is it avoids the limitation of working at depth compared to ECM.

1.3 Application of Travelling Wire-ECDM

The Travelling Wire Electro-chemical Discharge Machining (TW-ECDM) method is used mainly for working on insulating materials like glass, hard ceramics & new composites. The TW-ECDM process also founds it application for micro-slotting operations on hard materials like ceramic.

- TW-ECDM process can slice the non-conductive materials like glass, ceramic.
- TW-ECDM process can use for shaping electrically insulating component like glass, ceramics.

1.4 Benefits of TW-ECDM

- TW-ECDM process can machine electrically insulating materials.
- TW-ECDM process can easily slice the material.
- TW-ECDM process can make desired profile on hard materials.

- Machining cost is low as compared to other processes.

1.5 Limitations of TW-ECDM

- TW-ECDM process can machine only non-conducting materials. So Machining is limited.
- In TW-ECDM process, Due to side sparking over cut occurs.
- In TW-ECDM process, Surface finish is very poor.
- In TW-ECDM process, material removal rate is poor.

2. Literature Review

Sir Joseph Priestly did experiments on metal and found the principal of erosion and that erosion was taking place because of sparking but he did not do it for machining. However, later Lazarenko carried out metal machining using spark erosion technique. British scientist first patented the electro spark machine. Later, Lazarenko provided prelude the manufacturing process by introducing ECDM process which was actually sparked erosion machining. In later seventies, the research work was also done for generating complicated machining surface on very hard conducting materials. In 1968, a method which used electrical discharge system for drilling a hole in glass was explained by Late Professor H. Kurafugi. As the time passed use of ECDM increased and various researches was carried out to increase to effectiveness of this process and to explore new areas in which this process can be used. Following are some research works which have already been done by researchers in field of ECDM and TW-ECDM. **Peng and Liao [1]** found out that in TW-ECDM, a voltage higher than the transition voltage was required for the clear start discharge around the wire. The relationship between current and voltage can be emphatically indigent when applied voltage is just bigger than the move voltage. For the machining of high-quality non-conductive materials, the ECDM process has been proved as a potential procedure. For cutting the little size (10–30mm measurement) optical glass and quartz bars, travelling wire electrochemical discharge machining (TW-ECDM), a recently created innovation, was utilized. Research was done on electrical–thermal scratching impact and its plausibility. The pulsed dc power showed some advantage like better start security and more start vitality discharge extent over consistent dc power. For machining glass and quartz materials the input power was adjusted to obtain the appropriate frequencies and obligation variables. It was found that the predominant elements of bubbles reaction were particle interpretation rate, electrolyte inundating profundity and the convergence of the salt. **Liu et al. [2]** reported that material removal rate was diminished by a high connected voltage or long pulse duration. They have showed that a low material removal rate (MRR) was obtained by using the routine WEDM-LS method could mean (MRR), and more important, a high danger of wire breakage was experienced in wire cutting. **Tandon et al. [3]** investigated another method that utilized electrochemical spark machining (ECSM) for cutting and drilling hole in fiber reinforced composites (FRP). Kevlar fiber reinforced epoxy and glass fiber reinforced epoxy was used as work materials and was used as work material. A "one variable at a time" approach and configuration of examination idea were used for parametric investigation of the procedure. MRR, TWR, OC was found to increase and relative device wear was found to decrease with increase in connected voltage over the anodes. **Bhattacharyya et al. [4]** suggested another innovation for the ECDM procedure. This ECDM method can easily machine ceramics made up of silicon nitride material. He develops the advancement of a 2^{nd} order, non linear numerical method to form a relationship among the operating parameters. These parameters are supply voltage, focus of electrolyte & terminal hole. These relations are develop by keeping in mind the machining criteria such as MRR, overcut in radial direction, width of heat affected region. Numerical model develop is created in light of reaction surface approach (RSM) utilizing the significant test information, which are gotten amid an ECDM smaller scale penetrating machining of silicon nitride. Along with it he created fluctuation examination using ANNOVA & done a test to confirm the fit & ampleness of numerical model. From the research work it has been concluded that supply voltage directly controls the material removal rate, ROC and HAZ width. **Yang, et al [5]** indicated the common consequences originated during the machining process of TW-ECDM. From the work it was shown that materials having high strength, fragility, and electrical insulation can be easily worked by using this process. Cathode component in the electrolyte is surrounded by the hydrogen bubbles formed during the chemical reactions. Thin film layer starts forming on the electrode. In this way cathode gets detached from the electrolytic solution. Condition when supply voltage increases the basic voltage, persistent release happens. The material close to the electrode is removed by the release disintegration and compound drawing. The utilization of TW-ECDM to cut electrically protecting materials has just as of late been researched. Nonetheless, the breakdown of the gas in the bubbles and the vibration of the wire in TW-ECDM unequivocally influence the shape precision. Over cut quality during the process can be enhanced by adding silicon grating in the electrolytic solution. Contemplation of process having abrasive cutting along with chemical etching is used to consolidate the discharge. **Doloi et al, [6]** carried out the machining of hylum based fiber composite using ECDM. This method can likewise utilize for miniaturized scale cutting & scoring on non leading materials. Their main area of concern was to form a framework to analyze parametric impacts of MRR.

Cao et al, [7] that Micro- ECDM was concentrated on so as to enhance the machining of 3D smaller scale pieces of glass. Electrolytic concentration, feed rate, supply voltage, swirling velocity, pulse on & off time duration in the process are varied in order to get a refined microstructure surfaces. In order to form a steady gas film on the device surface on less voltage supply, another contact indicator, taking into account a heap cell, was utilized; the drenching profundity of the instrument terminal in the electrolyte was lessened however much as could reasonably be expected. **Han, et al [8]** develop a new technique to increase the surface finish & flash discharge dispersion of wire using Wire ECDM in which the wire surface is not smooth. In case of normal Wire ECDM problem is to operate under low cutting speed along with low start and release event of the wire surface when it is moving. Initial tests exhibited that by using tool wire having surface harshness of Ra= 0.14 μm machining having 1.1 mm was unable to access because of the absence of spark dispersion on the tool wire. They observed that wire surface roughening has improved flash release circulation over the surface of apparatus and have brought down the working voltage. Side protection of the wire was also observed with minimization of the responsive wire surface territory. **Bhattacharyya, et al [9]** brought attention to the fact that for the machining of non-conductive ceramic materials, electrochemical discharge machining (ECDM) has showed great potential as compared to other non-conventional machining strategies. They examined the fundamental material evacuation instrument in the ECDM process for the effective machining of non-leading ceramic materials with enhanced machining rate and greater machining precision. The ECDM procedure is dependent on different procedure parameters like the connected voltage, gap between electrode, the temperature, concentration and kind of electrolyte; the shape, size and material of the terminals; the way of the power supply. Experiments have been done in accordance to the impacts of the different procedure parameters of ECDM. Mechatronics was the highlight of the created machining set-up used for doing exploratory examinations. .For machining of aluminum oxide clay work pieces, trial examinations have been conducted using ECDM and material removal rate and over-cut phenomena have been observed under shifting procedure parametric conditions. For example, connected voltage (70±90 V),and electrolyte focus (20±30%). NaOH arrangement with differing fixation was taken as the electrolyte. For the boring operation of ceramic work-test, a pulse d.c. electric supply has been used. **Basak, et al [10]** proposed a hypothetical model for the clarification of flash era amid electrochemical discharge machining (ECDM) process. The procedure is normally termed 'electrochemical arc machining' (ECAM) at the point when the machined material is electrically conducting. It is termed 'electrochemical discharge machining' (ECDM) for non-conducting work materials. In both cases electrical discharge happened through the electrolyte and assumed as a basic part, the system of spark area has not been researched effectively. **Guo et al [11]** observed the discharge mechanism in electrochemical discharge machining (ECDM) of a particulate reinforced metal matrix composite. They also developed a model to uncover the electric field that build up on a hydrogen bubble in ECDM procedure. Experiments were conducted to verify the model and the test results matched well with the anticipated values. The trial results showed that for advancement of arcing activity in ECDM, an increment in current, duty cycle, pulse span or electrolyte concentration is required. **Adhikary et al [12]** used electrochemical flash machining (ECSM) procedure for effective cutting of quartz utilizing a controlled feed and a wedge edged tool. Both cathode and anode were utilized as a tool despite of regular belief that only cathode acts as a tool. To machine quartz plates, they have utilized ECSM with reverse polarity (ECSMWRP) and also ECSM with direct polarity (ECSWDP). Due to chemical reaction, generation of profound pit on the anode (as a tool) and work piece interface was observed in ECSMWRP. The possibility of dissolution of quartz into solution because of chemical reaction was also validated by the chemical analysis of electrolyte solution after the ECSM experiments. Reverse polarity showed advantage of faster cutting rate of quartz plate as compared to direct polarity. But higher overcut, tool wear and surface roughness was observed in reverse polarity as compared to the direct polarity machining. Difference in the mode of material removal in ECSMWDP and ECSMWRP was shown by magnified view of the machined surface. The cutting was also possible by smaller auxiliary electrode. **Fascio et al[13]** worked on MEMS. They proposed micro fabrication of glass because glass has its unique properties like transparency, non chemical reactive, non conductive to heat and current, biocompatibility. Some applications are in micro pumps, medical equipments. **Maeda et al [14]** performed experiments with the revolving tool on (ECSM) electro-chemical spark machining. For the machining of glass and ceramic (these are insulating material) ECSM machining has been employed. Electrolyte has been used as working fluid and work piece is dipped into working fluid and revolving tool is pressed on the work piece with some load. A work piece was revolve so that it can give fresh working fluid into the space between the work piece and the tool electrode in the experiments and machining soda lime glass rod using a film type rod made of tungsten in a solution of NaCl. By setting the rotating speed to 0, 0.30, 3.00 and 30.00 per min, new applied voltage was set to between 0 to 40 V and discharge was observe at applied voltage 30V. As the result of increase of applied voltage the surface roughness, depth and width of machines grooves were increased. The width of machined groove was found to be small due to decrease in thickness of vaporization near the tool electrode as the rotation speed increases. **Kozak et al [16]** investigated the nontraditional process because the use of un conventional machining is increasing because it can machine glass, ceramic, composites which are non conductive to heat and current. They stated some experimental facts about abrasive electrochemical machining (ECM) and abrasive electrical discharge machining (EDM) which are some superior technique and better control techniques. **Kulkarni et al [17]** studied the discharge mechanism analysis of ECDM. In this study, author measures the time varying current to find the basic mechanisms of rise in temperature and material removal rate and author has done experiment at applied voltage 155 V and 3% HCL as the electrolyte in different three phases or different work pieces such as Cu, tantalum, Si and brass. A gas bubble is formed which made of hydrogen, for a short duration in a spark channel (highly conducting). **Skrabalak et al. [18]** studied a model based on the rules of fuzzy logic control for study of the ECDM process. The experiment carried out in solution of 6% $NaNO_2$ with H_2O and the most important parameters are current and electrode feed at the fixed electrode temperature. The quality of surface and material removal rate both were enhanced using adaptive fuzzy-logic control system which reduced surface roughness and no. of micro cracks. **Mediliyegedara et al. [19]** investigated a study of an intelligent classification system based on ANN for ECDM. Due to overheating of work material distortion in surface of work piece takes place and reduction in MRR is taking place due to increase in electrode gap. In this process, Cu tool with mild steel work piece and sodium nitride is used and the wave form shows the EDCP, AP, SP, ECP and SCP by measuring the current and voltage. The pulse duration and duty ratio were found to be 100ms and 50%. The average classification accuracy of the neural network with SATLILS activation function was greater than the neural network with SATIL activation function. **Raghuram et al. [20]** studied the effect of circuit parameters on the ECD process and studies the effect of current and voltage at different electrolyte KOH and NaOH. In this process, the best circuit configuration was proposed for machining of non conducting materials and the studies shows the external circuit parameters had the effect on the discharge characteristics. The author had shown voltage current behavior in ECD.

3. Objectives

Travelling (voyaging) Wire-ECDM is also known as TW-ECSM process. It is a combination of ECM and EDM. Here a travelling brass wire is used as a tool. Objective was to using O-FAT (one factor at a time) optimization technique to get effective combination of applied voltage ,electrolyte concentration, feed rate, electrode distance. After the experiment, calculating the MRR and after that using the surface texture machine to measure the surface finish.

i. To study the essential attributes of TW-ECDM transform and to recognize the significant procedure parameters of TW-ECDM.

ii. To complete the essential investigations for deciding the scopes of critical procedure parameters of TW-ECDM.

iii. To add to the scientific models connecting real process parameters, for example, electrolyte concentration, feed rate of wire, pulse on time and voltage with MRR after that getting surface roughness.

iv. To examine the impacts of the real process parameters on MRR and surface roughness.

4. Process Mechanism of TW-ECDM

Combination of ECM and ESM is used in TW-ECDM. Spark generation, bubbles formation, MRR, deterioration of tool wire are the various phenomena used in TW-ECDM.

4.1 Formation of Gas Bubbles

There are mainly 2 types of chemical reactions that take place during the electrochemistry of ECM process. These 2 reactions are:

- Electrochemical reaction on the tool electrodes. As a result of the reaction there takes place evolution of gas, oxidation and dissolution of electrode material takes place.
- Chemical reaction in the electrolytic solution.

On the electrolyte boundaries these reaction takes place. In the electrolytic solution the movement of ions takes place by:

- Diffusion mechanism
- Electric field migration in the solution
- Flow causing the convection

As the voltage supply reaches the appropriate value chemical reaction starts on anode and cathode terminal. These reactions take place at the gap between the electrodes in machining zone.

a. Cathodic reaction

Common reactions at the cathode terminal are plating due to metal ions and generation of hydrogen gas bubbles.

$$\mathbf{M^{+} + e^{-} = M}$$

Here M is material at anode
Hydrogen evolution takes place by following reaction

$2H^+ + 2e^- = H_2$ (in acidic electrolytic solution)

$2H_2O + 2e^- = 2(OH^-) + H_2$ (in alkaline solution)

b. **Anodic reaction**

In a similar way to cathodic reaction there are 2 types of reaction at the anode. In the electrolytic solution dissolution of ions takes place. Also at the electrode surface evolution of the oxygen takes place.

$M = M^+ + e^-$

$2H_2 +2\ O = O_2 + 4H^+ + 4e^-$

$4(OH^-) =2H_2O +O_2 +4\ e^-$

The formation of gas bubbles and the phenomenon of sparking take place in TW-ECDM.

4.2 Principle of Spark Generation

In TW-ECDM the inter-electrode gap is very large as compared to ECM process. Due to the small amount of current passing through the large inter electrode gap the MRR is small. A high voltage D.C. power supply was applied between and the anode (auxiliary electrode) and the cathode (tool / wire). In electrolyte solution the tool is immersed to depth of 2±3 mm. near the tool/wire the amount of hydrogen bubble is generated is high. Electrolyte is evaporated and the formation of steam takes place due to the heating of electrolyte. The gas bubbles are positively charged bubbles. Increasing the supply voltage a threshold voltage can be attained and the formation of spark takes place in between the gap and bubbles are also formed. Sparking doesn't takes place between the electrodes, but a layer of steam hydrogen is formed between the electrolyte and tool. The sparking voltage depends on the conductivity of electrolyte concentration and tool geometry. If the diameter of wire is small then the starting spark voltage is low. If the voltage is increased up to a particular limit then the violent sparking may take place. Material is removed from work piece due to the localized sparking because of the ionization process that occurs at high temperature which leads to melting and vaporization. Fig 2.2 represents the sparking phenomena of TW-ECDM.

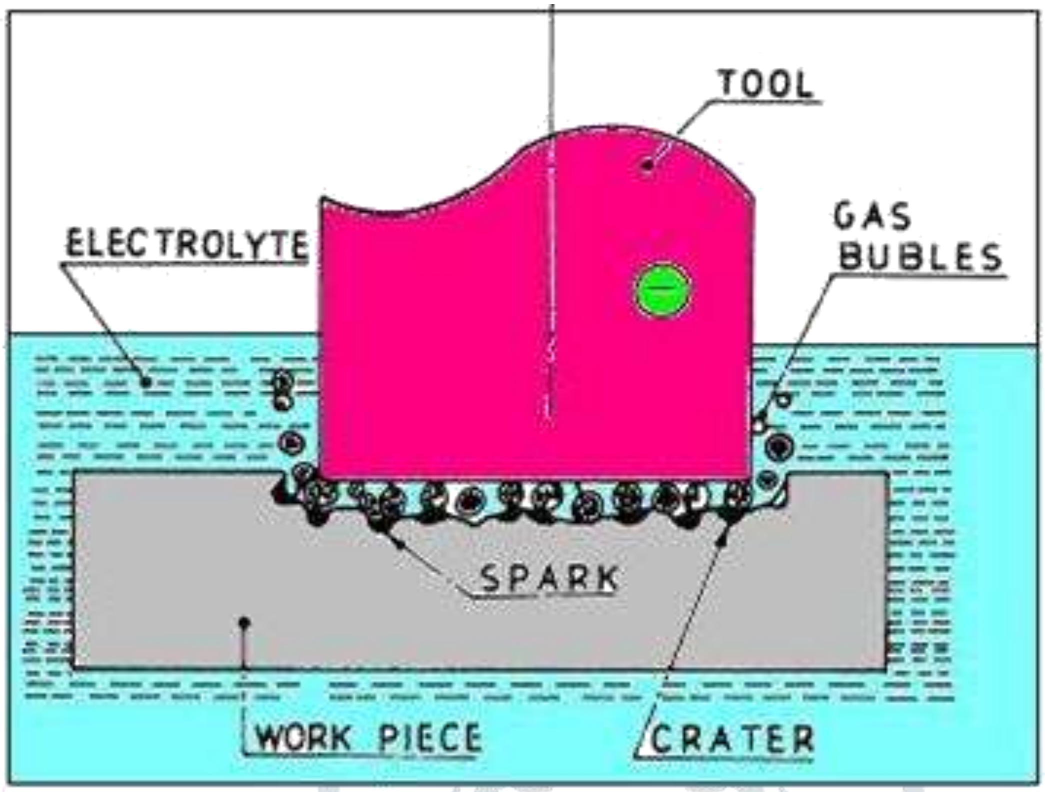

Fig. 4.1: Sparking Phenomena of TWECDM

4.3 Material Removal Mechanism

In TW-ECSM process, material is removed with the combined effect of electrochemical reaction and electric spark action. Electrical spark generated is proportional to pulse energy of the spark because of this material is removed which transform into heat during machining. The surface of the tool wire and working component are not perfectly fine. There are irregularities in surface. These irregularities are of micro level. So whatever is the closeness of tool wire with the work piece there is still some gap left. Due to presence of micro gap between the tool and work piece electrolyte occupies the space between them. This electrolyte results in the formation of bubbles and generation of heat. Thin gas layer forms between the tool and work piece due ion formation. As the voltage increases a level, breakdown of the bubbles start. This leads to formation of a conducting path due to ionization of the bubbles. In this path current starts flowing. With each spark produced electron starts moving with very high velocity from the cathode toward the work piece. These electrons when reaches anode produces a shock impact on the surface. All this happens within a microsecond time. As electrons hits with an impact, large heat generates. It leads to very high temperature. As this temperature exceeds the melting point, material melts and finally evaporates. This impact is like a blast, that creates crater on the work piece surfaces.

5. Experimental Setup

The setup for TW-ECDM was fabricated by a research scholar Mr. Navrattan. A proper approach toward the process TW-ECDM was developed and working of setup was studied in detail for performing experiments. TW-ECDM system consists of some subsystems as following:

a) Mechanical component; b) Electrolyte supply unit c) Electric Power supply unit

The setup of TW-ECDM process is shown in schematic diagram fig.5.1.

The direct DC voltage is applied between auxiliary electrode (+) and wire (tool electrode) (-). The wire just touches the work piece and these are immersed into the electrolyte solution up to a certain depth. Stepper motors are used to provide motion to the wire spool and job holder. Motor control unit (MCU) is used for varying the speed of stepper motor and wire velocity.

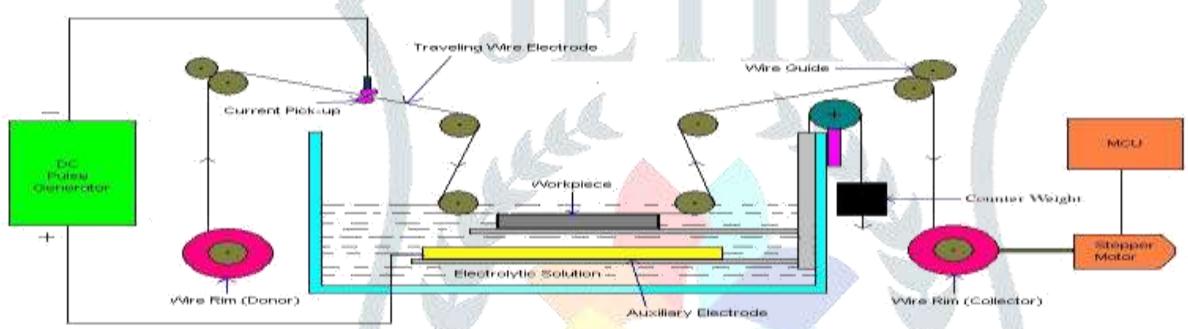

Fig 5.1: schematic diagram of TW-ECDM setup

Fig 5.2: Photograph of TW-ECDM setup

5.1 Mechanical Components

Travelling wire ECDM setup has different mechanical sub system modules. The snapshot of Travelling Wire-ECDM experimental set-up has been shown in fig. 5.2.

5.1.1 Machining Chamber

Perspex was used for fabrication of chamber for machining process. The rectangular box type machining chamber has dimensions 650 mm x 405 mm x 500 mm. The thickness of Perspex plate is 12 mm. There is a bottom plate and four other vertically oriented plates. Among three of plates with 8.5 mm thickness and the cross vertical plates have dimensions 650 mm x 300 mm and thickness 8.5 mm. Longitudinal vertical plates have dimensions 405 mm x 300 mm and thickness 8 mm and 12.5 mm. The wire feeding arrangement, job holding arrangement and motion controlling unit are attached to the main machining chamber.

5.1.2 Wire Feeding and Controlling Unit

The non-conductive work piece can be fixed using the holding unit and submerging it in the electrolyte. Connecting a stepper motor so as to receive end wire spool generally called as power spool so that we can feed the wire at the zone where machining is done. The donator wire spool which is unconstrained also known as dead spool. Keeping the wire almost straight along horizontal direction. Using the stepper motor, we can change the feeding speed of the wire manually. Since the wire tension is one of the most critical parameter so we use pulley based system to make it uniform throughout the process. Now this wire is passed between the two plates and during passing between the gap it touches the plate. The plates are connected with the positive pole of DC power supply and the wire or tool electrode is made cathode. The main requirement of the experiment is that the wire should attain a particular speed during the experiment because wire breakage can also occur so the speed of wire is to be controlled by stepper motor. In this unit the proper positioning of the wire with respect to work piece before each experiment, for getting better results, has to be adjusted. In this sub-system the movement of power spool unit (receiver end), dead spool unit (donator end), guide pulleys, are to be controlled.

5.1.3 Job Holding Apparatus

For translating up and down, job holding apparatus has been mounted on a spindle type structure. A stepper motor is applied for giving the motion to the job holding unit and a gear train for converting the rotating motion to translating motion. For holding the job a hub is made and it is made of Teflon because Teflon has a property to withstand a higher temperature. The whole job holding device has fastened with a vertical Perspex plate which helps in keeping the job holder rigidly in horizontal plane.

5.2 Power Supply System

Using a continuous DC power supply in TW-ECDM. Input and output voltage is used as main DC power supply unit (120 volt, 20 A). To control the frequency pulse generator is used. The D.C. output power characteristics are observed by a Cathode Ray Oscilloscope is connected to observe the DC output power characteristics. Some control units are used such as frequency control unit, voltage controlling unit. Current is supplied to the wire which results in the generation of hydrogen gas bubbles which finally causes the electrical discharge.

Fig.5.3 photograph of pulsed DC power supply system.

5.3 Electrolyte Supply System

The electrolyte supply unit is a reservoir of electrolyte. The temperature is very high during the machining process which causes the evaporation and heating of electrolyte. So for maintaining the same level of the electrolyte it is necessary to provide electrolyte to the pool. A flask is used as the electrolyte reservoir which is kept at a higher altitude as compared to the level of electrolyte pool and a pipe is used to provide electrolyte to the pool during the machining process drop by drop. Generally KOH or NaOH solution is used as the electrolyte solution. The electrolyte is added to the pool from the reservoir drop by drop rather than flow from pipe. If electrolyte is fed with pipe it will reach the pool at very high velocity causing splash and waves into the electrolyte pool and the formation of insulating layer of gas bubbles will be disturbed. As the evaporation rate is slow in this process, the electrolyte should be added slowly. By mixing salt or water electrolyte concentration can be increased or decreased.

6. Experimental Methodology

Three process parameters are considered for conducting experiments on TW-ECDM. The optimization technique known as One-factor-at-a-time (OFCAT) was used for designing of the experiments. A brass wire (0.25mm diameter) has been selected as the tool electrode. Electrolyte selection is also one of the important parameter for this kind of machining processes because the chemical reaction depends upon the concentration of electrolyte. NaOH solution is selected as the electrolyte for this experiment. The electrolytic concentration varied from 9%, 13%, and 17% wt. The other important decision was to select the power supply nature and the range of applied voltage. Here a continuous DC power supply was selected and experiments were done at three different voltage levels: 25 V, 29 V and 32 V. The experiments were done according to OFAT (one-factor-at-a-time) experimental design. During experimentation some of the process parameter were kept fixed, are listed in Table 5.0.

Table 6.1: Fixed Process Parameters

FIXED PARAMETERS	DESCRIPTION
Work piece material	Glass
Electrolyte	NaOH
Effective wire length	25 mm
Wire tension	Constant
Tool material	Brass wire(.25 mm diameter)
Wire and work-piece	Touching each other

The influence of the above process parameters on MRR on the basis of previous research and experiments and the appropriate range of the process parameters for TW-ECDM have been mentioned.

a) **Applied Voltage**

The material removal rate is low when the applied voltage is low and it increases with the increase in applied voltage but at very high voltage there is a possibility of rapture of the sample. The range of applied voltage used in the experimentation is 15-35 volt.

b) **Electrolytic Concentration**

Electrolytic concentration is between the range 10% to 30%.The electrochemical reactions takes place between counter electrode at higher electrolyte concentration (30%) and tool electrode (wire) and gas bubbles formation at the sparking zone increases which results the generation of a higher number of sparks.

c) Velocity of Travelling Wire

Wire velocity is a factor that influences the performance of TW-ECDM process. When the wire feeding rate is higher, the discharge cannot be uniform and the wastage of wire is more. Higher wire feeding rate results in higher operating cost. Too low wire velocity has also some results as frequent breakage of wire can take place and it will reduce the productivity. So there is always need an optimum wire speed with which the TW-ECDM operation is done efficiently.

d) Wire Tension

The wire tension setting should be at maximum stretched condition of loading so that the wire is perfectly horizontal at the machining zone to avoid wire rupture. For this condition the wire is passed through upper and lower wire guide and by tensioning rollers. It is also constant.

e) Wire feeding rate

Feed rate is set firstly before machining. It can be handle manually or automatically. Its appropriate range is 60 -120 mm/sec. Very low feed rate will result in breakdown of the wire. So its proper maintenance is very important. Very high feed rate results low discharge and MRR will be very less.

f) Type of electrolyte

Electrolyte selection is also one of the main factors. For particular machining alkaline salt solution has to be used. For TW-ECDM process generally NaOH and KOH solution are used. NaOH solution is selected for experiments.

7.1 Experimental Modeling

On TW-ECDM set up, Number of experiments was conducted and the experiment was done in two sets. For conducting experiments on TW-ECDM three process parameters have been considered. OFAT (One-factor-at-a-time) methodology was used to conduct the experiments. In the first step, By keeping two parameters fixed, applied voltage was changed and fixed parameters are electrode distance and electrolyte concentration. On the accomplishment of experiments the value of applied voltage which were having maximum material removal rate was known. Now in the second step, Electrolyte concentration is varied by keeping two parameters fixed which are applied voltage and inter electrode distance and maximum material removal rate is known. After this step the value of electrolyte concentration having maximum MRR is known. In step three the inter electrode gap is varied by keeping two others parameters constant. Maximum MRR is known and by cutting the slides from between surface finish is measured on the surface texture machine. The

experiments have been done in two sets.

7.2 Influence of Parameters on Surface Finish

As per the process result it is evident that surface finish is the function of applied voltage, electrode distance, electrolyte concentration and MRR. As the applied voltage is increasing, MRR is also increasing and surface finish is decreasing and as the electrolyte concentration is increasing result of that sparking is increasing and MRR is also increasing and surface finish is decreasing. At very large electrode distance surface finish is decreasing and at very low electrode distance surface finish is also decreasing and same case is with the MRR. So to get best optimization optimum parameter was chosen given in previous table. To get the surface finish, the inter electrode distance should be neither too small nor too large.

8. Conclusion and Future Scope

Travelling Wire-ECSM can be used for machining the insulating material on large scale. OFAT (one-factor-at-a-time) technique is used to perform experiments on TW-ECSM setup. Effective combination of maximum MRR and better surface finish is subject of concern. If MRR is high than surface finish will be low so by optimization of parameters we can get optimum MRR and good surface finish. Several inferences has been drawn from the work done:

1. As the voltage is increasing, MRR is also increasing and surface finish is decreasing. The reason behind that is with increase in applied voltage, the HAZ is increasing because of increment in spark generation.
2. As the electrolyte concentration is increased, from the experiments, we saw MRR is also increasing and surface finish is decreasing.
3. From the experiments, I observed at very low electrode distance i.e4cm, the surface roughness value is above 40µm and at very high electrode distance i.e16cm, the surface roughness is 38.723µm so it can stated electrode distance should be optimum to get surface finish higher. Optimum value of parameters to get higher surface finish are 26V applied voltage, 9cm inter-electrode gap and 10% electrolyte. The best surface finish was got which is 5.53µm.

Future scope of TW-ECSM is given as follows:

1- Efficiency of the setup should be increased as I observed from results surface finish is best at low MRR. Work can be done in the field of parameter optimization.

2- In case of very complex shapes, accuracy is major concern because accuracy is not good in this method due to sparking and heat affected zone (HAZ).

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