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A REVIEW ON MACHINING BY ELECTROCHEMICAL DISCHARGE PHENOMENA

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Abstract— ***Non-conducting material having high strength, brittle nature widely used in the industries due to superior properties such as high hardness, excellent insulation, high wear resistance possessed by the material. Due to these properties, machining of these material by traditional processes are very difficult. This led the researchers to develop the alternative process, Electrochemical discharge machining (ECDM) is an advance machining process, can machine such materials with accuracy. The input parameters such as voltage, electrolyte concentration, feed rate etc. governs the process performance parameters like material removal rate, overcut, surface irregularity and surface integrity of machined surface. The process works on the principle of electrochemical discharge, the exact mechanism of machining is not well understood. The paper presents the review past research carried out in ECDM process.***

Keywords— ECDM, brittle, surface integrity, voltage, surface roughness, material.

I. Introduction

Electro chemical discharge machining (ECDM) is non-conventional machining process used to machine preferably non-conducting material irrespective to its hardness, shape and size. It is hybrid process comprising the features of electro chemical machining (ECM) and electric discharge machining (EDM)[1], and five times faster than its parental processes[2]. ECDM is alternative cost effective solution to earlier existing advance machining process such as laser machining, abrasive water jet machining and ultrasonic machining for machining non-conducting materials however some problems associated with the process[3]. The non-conducing materials such as glass and other materials are widely used in the aerospace, automobile, medical, houseware etc., the miniaturization of glasses widely used in the micro opto electromechanical system(MOEMS). Glass and other non-conducting, brittle material cannot be machine by conventional processes due to frequent tool & workpiece breakage and high cutting forces. Other advance machining processes such as laser, abrasive water jet machining (AWJM), ultrasonic machining (USM) can machine glass material but the cost, tool wear and environmental hazards limits their usage. ECDM is an emerging process in the domain of advance machining, can cut glass, its variant and other non-conducting material effectively. This process is an attempt to present the comprehensive way to understand the process, its past research, its challenges and future trends.

1.1 Principle/Mechanism

As per the schematic diagram, when two electrodes (tool act as cathode and auxiliary electrode as anode) dipped in the electrolytic solution (NaOH, KOH), under the action of applied potential difference, a potential gradient exist among them. After a certain DC voltage due to electrochemical reaction, gas bubbles start forming around the tool (cathode), further increase in voltage the bubbles start grow in size and coalescence together and shield and insulate the tool, through which thermal spark occurs. By keeping the workpiece in vicinity of spark, it melts and consequently vaporizes. Different authors proposed different statement (theoretical and experimental) to explained material removal mechanism/principle but none of theory has able to explained completely.

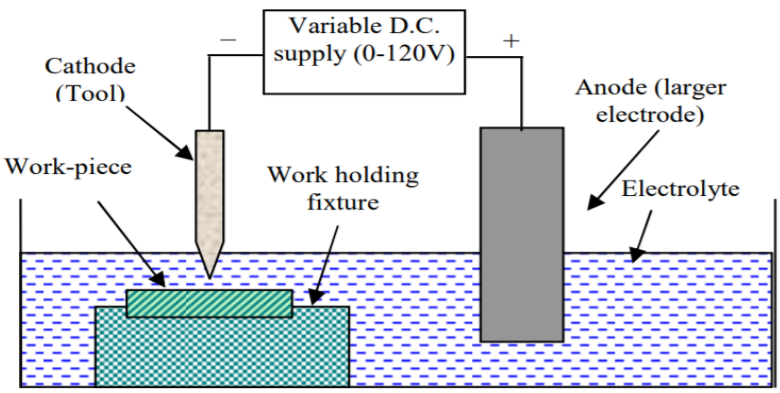

Fig. 1 Schematic diagram of ECDM process[3]

II. LITERATURE REVIEW ON WIRE ELECTROCHEMICAL DISCHARGE MACHINING

Oza et al[4] studied the travelling wire electrochemical discharge machining process for material removal rate and kerf width by developing the in-house setup. They used for quartz glass considering the voltage, electrolyte concentration and wire feed along with 0.15mm diameter zinc coated brass wire (cathode) and graphite as auxiliary electrode (anode). It can be concluded that voltage and electrolyte contribute more than 97% in MRR and SEM depicts some higher surface roughness due to crater formation during machining.

Rattan et al[5] attempted to improve the WECDM process by applying the magnetic field through the disc magnet having intensity 0.40T of Nd-Fe-B material. The quartz material of size 25.4*8*1.6mm and brass tool wire of 0.1mm were used to develop TW-ECDM setup. The effectiveness with magnetic field on the process can improved up to 200%.

Mitra et al[6] established the Artificial neural network (ANN) model for the prediction of response parameters. They used brass wire of 0.25mm diameter to cut the hylam composite. The experiments ware performed as per the Taguchi L25 orthogonal array, further mathematical models was also designed using the response surface methodology (RSM). From the analysis pulse on time, concentration and voltage were most significant parameters for material removal rate while voltage, wire feed rate and concentration were significant parameters for radial overcut.

Pallvita et al[7] machined the alumina epoxy nanocomposite (ANEC) using wire electrochemical spark machining. The kerf characteristics were studied using brass wire of 0.2mm diameter and NaOH electrolyte. The results show that quality of cut was affected by wire velocity and voltage.

holy et al [8] performed the experiments to cut the mild steel workpiece of 12mm thickness using the 1.5mm diameter of copper wire as tool. The 20% sodium nitrate electrolyte at 7bar is pumped perpendicularly. At low applied voltage and feed rate, lowest wire wear occurred. The cutting speed and voltage are main parameters responsible for material removal.

Malik et al[9] micro-sliced the non-conducting e-glass fibre epoxy composite by WECSM process. Brass wire of 0.2mm diameter used as a tool with NaOH as electrolyte. The response parameters material removal rate and gap width have been studied considering the voltage, supply current, inter-electrode gap, electrolyte concentration and wire speed as input parameters. The experiments were conducted using the Taguchi L16 orthogonal array and results were optimized. The mathematical model was developed for material removal rate. The electrolyte concentration and voltage contributes more than 95% to material removal rate.

Peng et al[10] studied the wire electrochemical discharge process for machining of optical glass and quartz bars. Stainless steel wire of 0.25mm diameter used as a tool to study the surface morphology of the surface. It can be concluded that pulsed DC power supply generate the more spark energy proportion and have better thermal spark stability.

Yang et al [11] attempted to improve the wire electrochemical discharge process by adding the SiC abrasive. Brass wire of 0.25mm diameter, graphite as auxiliary electrode, pulse DC voltage used to machine the pyrex glass. To keep the contact between tool and workpiece weight loaded mechanism was used. The surface roughness of machined surface was significantly improved by abrasive action. The workpiece used is quartz glass.

Kuan et al [12] attempted to improve the surface quality by introducing the SiC powder in the KOH electrolyte for machining the quartz glass by WECDM process. The tool electrode was CuZn73 brass wire of 0.15mm diameter with titrated flow of electrolyte in the machining area. It was concluded that both quality and machining efficiency can be ensured with proper flow of electrolyte.

Bhuyan et al[13] machined the borosilicate glass using travelling wire electrochemical spark machining on borosilicate glass. The brass wire of 0.25mm diameter, graphite as auxiliary electrode was used to study the effect of voltage, pulse duration (on and off) and concentration for response parameters material erosion rate and kerf overcut. The scanning electronic microscopic (SEM) images shows the tiny craters on the surface integrity along with shallow cracks.

Liu et al[14] studied the machining characteristics of aluminium alloy 6061(Al2O3 reinforced) using the wire electrochemical discharge machining. Molybdenum wire of diameter 0.18mm was used for machining 10% and 20% compositional ALO composite. L9 Taguchi orthogonal design was used to perform experimentation. It was concluded that by increasing the electrolyte concentration, the ECM action increased while MRR increases with increase in the current density.

Bhuyan et al[15] modelled(TMRSM) and optimized(TMGRA) the TW-ECSM process for the machining of glass(Pyrex) using brass wire of 0.25mm diameter with graphite as auxiliary electrode. It was concluded that high level of electrolyte concentration leads to low value of kerf width. For multi-performance results wire feed, voltage, concentration, pulse on time, pulse off time are significant parameters in decreasing order.

Rattan et al [16] studied the TW-ECSM process by optimizing the parameters using magnetic field. The permanent magnet (Nd-Fe-B) with graphite as auxiliary electrode, brass tool wire of 0.1mm diameter used for machining the quartz glass. The response parameters MRR and surface roughness are effected by voltage, wire feed and electrolyte concentration. The multi objective optimization is done by utility function approach. The maximum improvement in response parameters MRR and Surface roughness were 39% and 100% respectively.

III. Literature Review On Electro Chemical Discharge Machining (ECDM)

Rajput et al[17] experimentally investigated the effect of tool shapes (pointed end and cylindrical end section) for material removal rate on developed ECDM setup considering the voltage, electrolyte concentration and inter-electrode gap as input parameters. They used same stainless steel material as tool (cathode) and auxiliary electrode (anode) along with electrolyte level approximately of 1mm. The L9 orthogonal array was used using Taguchi design of technique for conducting the study. It can be concluded that pointed end tool yield better results for material removal when compared to cylindrical tool when experiments were performed on the same experimental conditions.

Nguyen et al[18] studied the machining characteristics (milling and drilling) of quartz material by ECDM process. The tungsten carbide alloy of diameter 80-85μm as tool, platinum as auxiliary electrode and KOH as electrolyte were used for machining. The parameters such as electrolyte level, concentration, electrical power characteristics (pulse voltage, pulse on/off duration) and tool travelling rate were studied. It was concluded that tool erosion and machine resolution improved by offset pulse voltage while low electrolyte level gave better machining efficiency due to high discharge current and low resistivity among the electrodes.

Chak et al[19] compares the drilling operation by two different tool electrode using the ECDM process. They used brass hollow cylindrical (stationary) and solid cylindrical abrasive tool (rotary), each of diameter 1.5mm. The alumina ceramic is used as workpiece to study the effect of DC voltage, electrolyte conductivity and duty factor for response parameter amount of material deduction. The mathematical model was developed in both the cases and it was concluded that rotary action of abrasive tool has better machining than stationary hollow electrode, partially due to the abrasive action of tool. It was also observed that at high value of voltage, abrasive electrode has lesser tendency of cracking compared to hollow electrode.

Zheng et al[20] studied the electrochemical discharge machining process for 3D milling operation on pyrex glass using tungsten carbide electrode of 0.5mm as tool. The tool has gravity feed with digital indicator to ensure the proper distance between tool (cathode) and pyrex glass. The effect of DC voltage, travel rate and tool rotation rate were the machining parameters. It was concluded that 3D machining is possible with layer by layer micro-milling. The DC pulse voltage improves the machining quality compares to the regular DC voltage.

Paul et al[21] modelled the electrochemical process for drilling of borosilicate glass using response surface modelling. The tungsten carbide of 0.3mm used as tool electrode while graphite plate used as auxiliary electrode. Voltage, concentration and duty factor were used as input factor to study the response parameters MRR, tool wear rate, and radial overcut. It was concluded that MRR is directly related to input parameters while tool (cathode) wear rate found increased with increase in the concentration.

Maillard et al[22] studied the geometrical characterization of drilling process on soda lime glass (optical microscope glass). The stainless steel tool of 0.4mm diameter and electrolyte of 30% NaOH used for experimentation. The tool used gravity feed with optical sensor for sampling rate during the micro drilling operation. It was concluded that when the voltage slightly higher than critical voltage, best results were obtained.

IV. Discussion & Future Scope

ECDM process can machine the hard to machine non-conducting material which is cost effective solution. Most of the work has been done for glass, very few attempt has been made to machine hard strength composite, super alloy and advance ceramics. In WECDM most of the work has been done using brass wire to slice the workpiece. The 3D machining with WECDM like WEDM is missing in the past research. Toxic fumes released during the experimentation leads to suffocation which demerits its commercial use, further handling and disposal of chemicals is also a problem. In most of the research repetitive parameters have been taken for the process evaluation, a very few literatures available on the gas film formation and its governing factors. Though various theories have been proposed to explain the mechanism of material removal, exact explanation about the process is not available.

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