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A REVIEW ON MACHINING PROCESS WITH DIFFERENT CHEMICAL ENGRAVING METHODS

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ABSTRACT
Modern high technology industries are facing challenges from machining of non- conducting materials and its cost. Gas films of appropriate thickness are the main requirement in the industry. The formation of the bubbles and the films with constant thickness is desired. To achieve this different parameters are involved in different proportion. The parameters like electrolyte concentration, temperature, critical voltage, speed, composition of electrodes, etc. are playing important role in the machining. Spark assisted chemical engraving is used for micro-structuring of glass. With the proper management of these parameters as per the models discussed by various authors it is possible to get desired machining. To do this it is necessary to have the detail study of the review of the previous valuable work. This brief review will help to get the solution for machining process using different chemical engraving methods and techniques.

KEYWORDS: Electrochemical discharge, Micro channels, sparks assisted chemical engraving, Machining, MRR, Micro-structuring, Gas film formation.

I. INTRODUCTION
The Machining is important phenomenon used in the industrial application. Generally Electrical discharge is used in the machining. Several applications in the field of micro-electro-mechanical systems (MEMS) need glass because of its unique properties such as chemical resistance, transparency, low electrical and thermal conductivity or biocompatibility. The main limiting factor for glass machining and use in MEMS devices is its limited structuring possibility. Chemical etching technologies, such as HF etching, s well established, but remain too slow and expensive for many industrial applications. Different thermal methods such as laser machining, ultrasonic machining, etc. are used in the cutting industries. Hybrid Machining Processes (HMPs) are developed to exploit the potential advantage of constituent process to diminish their disadvantage and one of is them Electro-Chemical Spark Machining (ECSM) is a hybrid machining process, which combines the features of Electro-Chemical Machining (ECM) and Electro-Discharge Machining (EDM). Modern high technology industries are facing challenges from machining of non- conducting materials (Glass, Quartz, Ceramics and Composites), stringent design requirements and machining cost. It is not possible to machine complex shape with close tolerance and fine surface quality by the traditional machining process. To meet these challenges various non-traditional machining processes are developed. However, each of them has their own advantage and limitations. The technological improvement of non-traditional machining process can be achieved by combining two or more than two machining process, which is termed as hybrid machining process.

The critical voltage, wettability, electrodes positions and gap between electrodes, concentration of electrolyte, tool vibrations, temperature, tool wear rate, MRR, etc. are the parameters used in wide variety of ways to form the gas films.

Spark Assisted Chemical Engraving (SACE) take advantage of glow discharge electrolysis to locally attack a non-conductive piece. Machining process is allowed to conduct in an electrochemical cell, as the voltage is applied across the two electrodes. For high enough terminal voltages, a gas film forms around the cathode which is used as the tool to drill glass. Discharges are generated which cause the glass piece, situated below the tool, to be machined. The material removal mechanism is believed to be a combination of thermal and chemical effects.

II. REVIEW OF VARIOUS MACHINING PROCESS

The Machining of different non-conductive material like glass and ceramic is possible with SACE because of simplicity, flexible and smooth surface possibility but the reproducibility is the hurdle in this process. For unstable gas film formation the electrical discharge is necessary while machining. The theoretical model assure that the estimation of thickness of film. This is achieved by experimenting the gas films current voltage characteristics. The repeatability is achieved by changing the wettability of the tool electrode, which produces higher repeatability. The SACE technology was initially developed by Kurafuji [1] during 1968 and his remarkable work which remained academic only as well as not used in industrial purpose. Later sensors and micro fluid devices were used in the engineering applications.

The electrical discharge phenomenon was used by SACE using I-U characteristics, which present that current I is the function of applied voltage. The DC voltage applied to centre electrode and tool electrode. The centre electrode has more surface area than the other so at low voltage electrolysis occurs. Hydrogen gas bubbles formed at tool electrode and oxygen bubble at center electrode. When voltage increases current density increases so, radius of bubble increases and coagulate in gas film and tool electrode. As the bubbles coagulates in gas film their radius increase at that time critical voltage is about 25V. The light emission is observed in the gas films and electrical discharge observed between two electrodes. The glass machining is possible when it is near the vicinity of glass sample. It is observed that for film formation, gas is necessary. So the gas films are categorized into three parts.

Gas film formation: This study is considered important because for the thickness of the gas film formulation and stable gas has potential to produce repeatable machining. The discharge activity is used for the heat producing for the removal rate . This further strengthen the gas film and its thickness. Till now the gas film formulation and achieving reproducible machining are the major drawbacks. Due to these reasons the industry remained away from SACE. Certainly the author [2] put the model of the gas film formation using I-U characteristics with five different regions.

1. The thermodynamic region in which no electrolysis occurs.
2. The Ohmic region in which electrolysis of water takes place.
3. Limiting current region in which bubbles starts coalescing.
4. In the transition region gas film bubbles and machining is possible.
5. Arc region in which the current transportation through discharge takes place.

SACE technology was used for Joule heating hypothesis and quantitate mode was developed by Basak [3] for predicting critical voltage. But later onwards several facts proved that Joule heating is not the only method for gas film formation. The main idea is that the gas film starts growing as soon as bubbles density is high near the electrode surface. The gas film formation has two mechanisms.

1. Current transportation through electrical discharge using chemical reaction on the tool surface which helps to produce heat for machining.
2. The gas film formulation is dependent on changing wettability of the tool for formation of variable thickness films.

The model developed by Basak [3]was not able to prove the direct relationship between critical voltage and thickness of the gas films. The gas film formation due to the bubble depend on the bubble diameter and the shape which is related to the wettability of electrode on which it grows. The previous development model highlights on the critical voltage for the film formation and results lowering critical voltage gives less thickness of the films [4]. The lattice structure on which bubble formation takes place is directly related with the gas film thickness. Several Mathematical aspects were analyzed and drawn the conclusion for the film thickness. The Nickel electrode was used for the film formation and it was observed that the critical voltage at which the film formed is at 15V means thinner gas films are formed. The decrease in critical voltage increases electrolyte concentration.

Spark assisted chemical engraving is an unconventional method for machining several non-conductive materials. This technology has several very interesting properties like its simplicity, flexibility, the possibility to get very smooth machined surfaces and relatively high material removal rate. However, there is one major drawback: machining several time, the same structure under the same conditions does result in relatively wide dispersed patterns. Because of this fact, SACE has not yet been of interest to industry until this date. The gas film built around the tool electrode in SACE is the key element of the process. On one side the existence of this gas film is a necessary condition for machining and on the other side it conditions the machining. The gas film is not stable and is constantly fluctuating. This results in a non reproducible machining with SACE. The reduction of the gas film thickness would result in smaller fluctuations and therefore more reproducible machining. Another interesting consequence in gas film thickness reduction is the lowering of the critical voltage. Machining at lower voltage become possible.

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The R. Wiithrich [5] described the physical principles and miniaturization of spark assisted chemical engraving . This applicable only for small dimensions of glass for this setup was made based on AFM. From the conclusion t specifies that sharp electrodes are not useful to produce smaller patterns. It also briefs the limitations of the glass film thickness with electrochemical discharge. The wettability is increased by adding surfactants to the electrode. The wettability is increased by reducing the critical voltage. The various machining technologies are discussed and found hampering to obtain the good surface quality for electrical discharge drilling. Various names are related for process like an electrochemical arc machining Kubota [6], Electrochemical discharge machining, Ghosh and et.al [7].

In the sharp tool electrode, it is observed that the resolution limits future glass machining by SACE is around 25 µm. The resolution depend on gas film thickness. The parameters influencing the thickness and dynamic bubble growth investigated in depth and it was found that the surface tension of electrolyte affects the gas film thickness as well as resolution of machining. Surface tension and electrode wettability depend on electrolytic concentration and they can\t further influence the surfactants

Spark assisted chemical engraving in micro-factory with micro-structuring of glass was put forward by R. Wiithrich and et.al. [8] which have high aspect ration and smooth surface quality. The machining performance was affected by temperature of electrode, concentration and composition of electrode, surface of tool electrode immerged in electrolyte and gas field stability. The model carried experiments in open and closed loop mode for determining the relative position of the tool electrode.

The micro-structuration for glass was carried by V. Fascio and et.al [9]. This technology has base of electrochemical discharge beyond critical voltage. The discharge occurs around the electrode through gas films so, gas machining is possible. The author developed model based on percolation theory, predicting voltage and current critical parameters. The amplitude and duration also present the depth of machining using simulation technique.

SACE better way described by applying a voltage well below 25V so, electrolysis occurs forming bubbles at two electrodes. As voltage increases the current density also increases resulting increasing radius of bubble and finally coalesce open the facts of the electrochemistry.

Machining temperature during SACE of glass was carried by Jana D. and et.al [10]. Authors have discussed several models for predicting material removal rate using different machining temperature. Author also presented experiment on local glass surface temperature at the time of drilling. The machining temperature depends on machining configuration and machined surface geometry, which affects local flushing for deep structures when temperature is higher and in the molten form.

Comprehensive study of electro-chemical spark machining was given by Vevek kumar and Yadava [11]. Hybrid machining processes are developed for exploitation of potential advantage of constituent process and remove their disadvantage. In hybrid machining combine action of electrical discharge and electro chemical machining have been found which helped in increasing the efficiency of repetitive individual process. First time work was carried on the E-glass fibre epoxy composites. The improved G-ECSM process have been proposed for channel gridding and for better performance, surface roughness and material removal rate are taken. The following conclusion are made from the experiments.

- Grinding –ECSM process gives better performance in terms of MMR and Ra.
- G-ECSM gives better surface finish.
- Applied voltage, electrolyte concentration, speed plays important role in G-ECSM

Micro texturing on glass surface during machining was reported by Jana D. Abou and et.al [12]. Various textures are obtained from feathery textures. The electrolyte viscosity is found to be the most significant factor of texture. Tool work piece gap, machining voltage, tool travel speed, pulsed voltage are used to control local temperature at matching spot. Authors used electrochemical discharge machining for surface. Changing texture of glass the surface texture obtained is dependent on concentration of NaOH electrolyte used. The feathery like patters similar to Kelvin make pattern formed on the channel surface. Sometime for high electrolyte concentration cracks are observed on the channel surface. The channel machined at low speed has uniform surface, texture and flat walls. For higher speed channel becomes shallower. Hence tuning the electrolyte viscosity and tool electrode speed, different patterns and sharp edges can be obtained. The toolwork gap influences the depth of machined micro-channels. Tool speed also affects the channel depth where depth decreases as speed increases. The pulsed voltage is used to control glass and electrolyte temperature.

The 3D microstructures of glass using ECDM was studied for improving machining [13] to form the good surface effects of electrolyte, the pulse on-off time ratio, voltage, feed ratio, speed and electrolyte concentration in drilling was studied. Low voltage constant detection was used to obtain a stable gas film over electrode surface of the tool at low voltage. The use of load cells reduces voltage so high aspect ratio structures with high resolution in a glass workpiece can be machined The pulse voltage reduces hole size and improves surface quality.

The fabrication and analysis of microchannels on glass reported by A. V. Kulkarni and et.al. [14]. They have developed microchannels using electrochemical machining process on non-metals. They highlighted the process of fabrication in terms of shape surface topology and dimensions. The process used here has potential of machining of metals as well as non – metals. Meso and micro scale applications were investigated. Negative replica was observed under microscope and found the depth of microchannels as well as texture and shape.

The combination of electrochemical spark machining and electro discharge machining i.e. hybrid combination was reported by Vevek kumar and V. Yadava [15]. In this process the synergetic interactive effect of electro chemical action and electro discharge action to increase machining performance. Milling ECSM has developed and experiments conducted on borosilicate glass under changing voltage, electrolyte concentration, pulse on-off time, which affected the material removal rate. MRR increases with increasing in applied voltage and no discharge takes place below 85V so, there is randomly short circuit problem observed above 95V. An increase in the applied voltage implied higher discharge energy per spark, hence more heat generated resulting in MRR increase. Hence rate of carbon bubble generation increases and further discharge energy increases, so the MMR occurs at higher voltage. Further increase in pulse voltage ON time the MRR increase and it becomes highest at 400µS at OFF time

The study of different effects of process variables on ECDM performance during micro channel cutting on the glass was reported by M. Mallick and et. al [16] They investigated the effects of variables on micro-channeling with different electrolyte solutions like NaOH and its mixture with the help of ECDM. It was possible to generate micro-channel on hard glass with NaOH and KOH electrolyte. The surface roughness increased with increase in applied voltage, duty ratio and electrolyte concentration. Increase in pulse frequency decreases the surface roughness up to 600 Hz but further increase, so better roughness finishing is observed at 600 Hz.

The E-glass epoxy composition material study and its use in different applications such as medical, tool industry, aerospace is reported by J. S. Sarda and et.al [17]. The work was on material removal rate and reduction of tool wear rate as well as diametric over cut with tool vibrations. The experimental study was carried as per the Box-Behnken based BOE and observed that MRR increases with increase in voltage and electrolyte concentration, but at the same time DOC and tool wear also increases drastically. The work also highlight of feasibility of machining blind hole on e-glass fibre epoxy composites in ECDM using vibrational electrode. It is observed that with increase in frequency MRR increases with very less amount. The mathematical modeling based on the RSM has ability to evaluate MRR, TWR and DOC at various process settings.

Fibre glass composites has been used in many industries because it offers attractive properties like high creep, high fatigue strength, light in weight, high chemical corrosion, thermal shock and heat resistance, high strength-to-wear ratio and flexibility. Fibre glass composites have ample number of application such as cooling tower fan blades, sound insulation, electrical insulation, translucent roof panels, boat hulls, automobile bodies, FRP tanks, and vessels, building construction etc. E-Glass Fibre Epoxy reinforced composite is a non-conductive electrical material. But machining of E-Glass Fibre Epoxy reinforced composite by conventional or non-conventional (EDM, ECM, Laser etc.) posses many problems like low machinability, poor dimensional accuracy and delimitation. In ECDM, the spark discharge between the tool electrode and surrounding electrolyte is used to perform machining on non-conducting materials.

The tool wear and the tool thermal expansion was not included in SACE for achieving repeatable hole drilling upto few hundred microns in depth which was reported by Jana D. Abou Ziki and et.al [18] The extended study on the tool wear and tool expansion for three different materials like Tungstun , Steel and stainless steel. Demonstration of tool electrode temperature controlled by pulse voltage supply and results were higher accurate SACE. The thermal expansion and tool wear for tungsten, steel and stainless steel electrodes during SACE machining carried out that stainless steel have highest expansion of the three electrodes with almost zero wear. While tungsten have highest tool wear. The temperature was controlled by pulsed voltage supply. This important study for SACE gravity feed machining as well allow the correlation of measurements of machined hole by using tool wear and expansion during machining process. The changing tool length with time monitoring helps to increase the precision of machined holes.

The effect of different process parameters like applied voltage, electrolyte concentration, pulse frequency and duty ratio of different machining performance characteristics as MRR, overcut and heat affected zone. Study has reported by B. Mallick and et.al [19]. It has been concluded that the increase in applied voltage the MRR also increases. The MRR decreases with increase in pulse frequency. However the proportional growth is observed for MRR. The influence of the process parameters on overcut shows that sparking occurs at increased voltage.

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The MRR increases with increase of applied voltage, electrolyte concentration, duty ratio but decreases with pulse frequency. The overcut always increases with increase of applied voltage and vary as per the concentration percentage and duty ratio. The wok is useful for manufacturing of micro-profile generation on electronically non-conducting materials such as glass with modern technology.

III. CONCLUSION

The Machining of different non-conductive material like glass and ceramic is possible with SACE because of simplicity, flexible and smooth surface possibility. The reproducibility hurdle is overcome by various parameters like critical voltage, temperate, etc. Using the theoretical model the stable thickness gas films are formed. The repeatability is achieved by changing the wettability of the tool electrode, which produced higher repeatability. The gas film formulation is dependent on changing wettability of the tool for formation of variable thickness films as per the Basak model..

Spark assisted chemical engraving is an unconventional method for machining several non-conductive materials. The machining performance was affected by temperature of electrode, concentration and composition of electrode, surface of tool electrode immerged in electrolyte and gas field stability. The gas film is not stable and is constantly fluctuating. This results in a non reproducible machining with SACE. The reduction of the gas film thickness would result in smaller fluctuations and therefore more reproducible machining. Another interesting consequence in gas film thickness reduction is the lowering of the critical voltage. The various machining technologies are discussed and found hampering to obtain the good surface quality for electrical discharge drilling various names are related for process like electrochemical arc machining, electrochemical discharge machining.

Hybrid machining processes are developed for exploitation of potential advantage of constituent process to remove their disadvantage. In hybrid machining combine action of electrical discharge and electro chemical machining have been found which helped in increasing the efficiency of repetitive individual process.

The 3D microstructures of glass using ECDM were studied for improving machining to form the good surface. Structure the effects of electrolyte, the pulse on-off time ratio, voltage, feed ratio, speed and electrolyte concentration in drilling was studied. Low voltage constant detection was used to obtain a stable gas film over electrode surface of the tool at low voltage. The use of load cells reduces voltage so high aspect ratio structures with high resolution in a glass work piece can be machined. The pulse voltage reduces hole size and improves surface quality.

The fabrication and analysis of microchannels highlighted the process of fabrication in terms of shape surface topology and dimensions. The E-glass epoxy composition material study and its use in different applications. Fibre glass composites have been used in industries due to attractive properties. The MRR increases with increase of applied voltage, electrolyte concentration, duty ratio but decreases with pulse frequency. The overcut always increases with increase of applied voltage and vary as per the concentration percentage and duty ratio. The work is useful for manufacturing of micro-profile generation on electronically non-conducting materials such as glass with modern technology.

IV. REFERENCES

[1] H. Kurafuji, K. Suda, Electrical discharge drilling of glass, Annals of the CIRP 16 (1968) 415–419.
[2] I. Basak, A. Ghosh, Mechanism of spark generation during electrochemical discharge machining: a theoretical model and experimental verification, Journal of Material Processing Technology 62 (1996) 46–53.
[3] R. Wu¨thrich, E.A. Baranova, H. Bleuler, Ch. Comninellis, A phenomenological model for macroscopic deactivation of surface processes, Electrochemistry Communications 6 (2004) 1199–1205.
[4] R. Wu¨thrich, L.A. Hof, A. Lal, K. Fujisaki, H. Bleuler, Ph. Mandin, G Picard, Physical principles and miniaturization of Spark Assisted Chemical Engraving (SACE), Journal of Micromechanics and Microengineering, in press.
[5] Kubota M 1974 *Proc. Int. Conf. Production Engineering (Tokyo)* p 51
[6] Allesu K, Ghosh A and Muju M K 1992 Preliminaryqualitative approach of a proposed mechanism of material removal in electrical machining of glass *Eur. J. Mech. Eng.***36** 202–7
[7] R. Wiithrich, K. Fujisaki, Ph Couthy, L A Hof and H. Bleuler, Spark Assisted Chemical Engraving (SACE) in Microfactory, Journal of Micromechnica and microengineering, 15 (2005) pp. S276-S280.

[8] V. Fascio, R. Wiithrich, H Bleuler, Spark assisted chemical engraving in the light of electrochemistry, Electrochemica Acta, 49 (2004), 3997-4003.
[9] Jana D. Abou Ziki, L. A. Hof, R. Wiithrich, The machining temperature during spark assisted chemical Engraving of glass, Elsevier, Science direct, 3 (2015) 9-13.
[10] Vevek Kumar and Vinod Yadava, Development and comparative study of electro chemical spark machining and drinding- electro chemical sparking Machining. Proceedings of 6th internationals na 27th All India manufacturing Technology , design and research Conference Pune -2016, pp 307-311.
[11] Jana D. Abou Ziki, T. F. Didar, R. Wiithrich, Micro-Texturing channel surfaces on glass with spark assisted chemical engraving, International Journal of Machine tools and Manufacture, 57 (2015) 66-72.
[12] Xuan DoanCao, Bo Hyun Kim, Chong Nam VChu, Mixro-structuring of glass with features less than 100 µm by electrochemical discharge machining. Elsevier, Precison Engineering, 33 (2009) 259-265.
[13] A. V. kulkarni, V. Kumar, K. A. Mishra, Travelling down the microchannels: Fabrication and analysis, 2010 IEEE/ASME International conference on Advanced Intelligent Mechatronica, Montereal, Canada, 1186-1190.
[14] Vevek Kumar , Vinod Yadava, Experimental study of Milling- Electro-Chemical spark Machining process on Borosilicate glass,
[15] B. Mallick, R. M. Tayade, B. R. Sarkar, B. Daloi, B. Bhattacharyya, Effects of process variables on ECDOM performance during Micr-Chennel cutting on glass, Proceedings of 6th internationals and 27th All India manufacturing Technology , design and research Conference Pune -2016, pp 1580-1584.

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