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EXPERIMENTAL STUDY OF GLASS MACHINING PROCESS PARAMETERS IN ELECTROCHEMICAL SPARK MACHINING PROCESS

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Abstract— **Advanced machining processes show a very crucial role in the machining of high-strength brittle materials. However, process efficiency and cost are still issues in currently used advanced machining processes. Quartz glass has broad application in the area of microfluidics systems, but the high brittleness of this material poses difficulty in its machining. In the present work, the machining of quartz glass is performed through Electrochemical spark machining processes (ECSM) which is one of the hybrid advanced machining processes. Input machining parameters are voltage, duty cycle under the constant condition of electrolyte concentration and tool electrode rotation. Input machining parameter effects are observed on the surface roughness of the machined quartz glass workpiece. Taguchi method is used to identify best optimal parameters using full factorial.**

Keywords— **Quartz, ECSM, Taguchi, Surface roughness.**

I. INTRODUCTION

The electrochemical spark machining process (ECSM) is a hybrid machining process of Electric discharge machining and Electrochemical machining. Quartz glass can be machined in an economical manner through ECSM in comparison to other advanced machining processes [1]. Although there are serval issues in the machining of quartz glass due to its high brittleness as well as limitation in ECSM like limited aspect ratio and machining depth with a low value of machining accuracy [2]. To overcome these limitations, more research is still required in this particular domain. In Electrochemical spark machining, the working procedure has four steps:
(i) Electrolysis process, (ii) Hydrogen gas bubbles formation at the tool electrode, (iii) Merging of gas bubbles at the critical voltage and gas film generation (iv) Sparking

There are two electrodes in the ECSM process. One electrode is a tool electrode with negative polarity, and the other is an Auxillary electrode with positive polarity. Both electrodes are immersed in the electrolyte solution. On application of DC voltage supply, there is a potential difference generated between electrodes and bubbles formation is started. At critical voltage, the gas film is formed due to the merging of bubbles. This gas film behaves like an insulating layer in between electrodes which produces a high potential difference and results in sparks formation. This spark is responsible for material removal on the workpiece. (see Fig. 1).

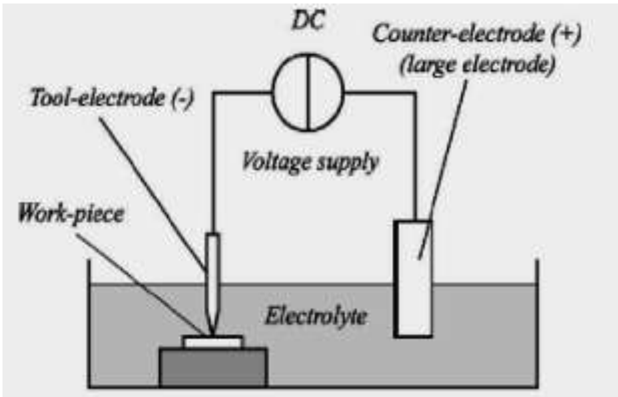

Fig.1 Schematic diagram of the basic Electrochemical spark machining process [3]

The gas film thickness affects material removal and surface roughness of the workpiece significantly in ECSM. Jiang et al. [4] concluded that bubble formation and gas film growth have a relation to surface tension and electrolyte density. Overcutting in machining can be reduced by the thin thickness of the gas film in ECSM. Gas thickness is significantly reduced by adding a surfactant to the electrolyte. The commonly used electrolytes in Electrochemical spark

machining are NaOH, NaCl, NaNO3, HCl, H2SO4, etc. [3]. Stability in discharge can be improved with the use of fine graphite powder. The conductivity of fine graphite powder decreases the dielectric strength of gas film results stability in spark [5]. It is reported that the material removal rate is enhanced with an increment in pH value of the electrolyte. Base electrolyte provides a better surface finish in comparison to acidic electrolyte [6,7].
The DC voltage significantly influences the material removal and surface finish of the workpiece. At high voltage, the material removal rate is high due to the transfer of high discharge energy from the tool electrode to the workpiece. Pulse voltage supply minimizes the overcut phenomena due to the provision of discharge off time [8,9]. Taper shape is a major issue in machining through ECSM. It can be avoided with the application of a pulse voltage supply [10]. Kim et al. [11] perform experiments with disc-type electrodes and get a less tapered final machined surface in milling ECSM. Layer-by-layer machining is a powerful method in micromachining through ECSM for higher-depth channels without any geometrical interference [12].
The presented Literature review of this paper shows the efforts of researchers for improvement in material removal and surface finish of Electrochemical spark machining processes. In the presented work, microchannels are fabricated through the milling ECSM process.

II. MACHINING AND METHODS

The experimental work is completed in the developed setup of ECSM. This setup has two main components: (a) power supply, (b) machining chamber with tool electrode and auxiliary electrode. 370 µm diameter of the copper tool is used as tool electrode. A Quartz glass plate is used as a workpiece.

Table.1 Physical properties of Quartz glass

Parameters	Typical values
Density	2200 kg/m^3
Young's Modulus	108 GPa
Thermal Conductivity	1.38 W/mk

Table.2 Input Machining Parameters with their levels

Input Machining Parameters	Level		
	I	II	III
Voltage	45	50	55
Duty Cycle	0.75	0.82	0.89

Table.3 Constant Machining Parameters

Parameters	Values
Electrolyte	NaOH with 19% concentration
Tool electrode rotation	400 rpm

Table.1 shows the physical properties of the quartz glass workpiece. Tables. 2 and 3 show variable and constant machining parameters. Tool travel speed is 2.5 mm/min in all experiments.

In the present research work, surface roughness of workpiece is analyzed as an output machining parameter to find the most influencing input machining parameter through the Taguchi method. A commercial software Minitab is used for this analysis. The selected input machining parameters are voltage and duty cycle, and the output parameter is the surface roughness of the workpiece. The full factorial method (a total of nine experiments) is used for this analysis.

III RESULT AND DISCUSSIONS

Taguchi method is applied to investigate the influence of each input machining parameter (voltage and duty cycle) on the surface roughness of the workpiece.

Calculate S/N ratio for each response with the formulas given below
For surface roughness, smaller-the-better characteristics response

$$\eta_{ij} = -10log\left[\frac{1}{n}\sum_{i=1}^{n}\bar{y}_i^2\right] \quad (1)$$

where η_{ij} = S/N ratio for ith experiment and jth response.
n = Number of repetitions of each experiment.
$\bar{y}_i$ = Mean value of y_i data.

Table.5 Variable machining parameters with surface roughness

S.No.	Voltage	Duty Cycle	Surface Roughness (µm)
1	45	0.75	1.9
2	45	0.82	1.8
3	45	0.89	2.1
4	50	0.75	1.595
5	50	0.82	1.461
6	50	0.89	1.910
7	55	0.75	1.5
8	55	0.82	1.385
9	55	0.89	1.814

Table.6 Response table for S/N ratio

Level	Voltage	Duty Cycle
1	-5.708	-4.384
2	-4.323	-3.742
3	-3.841	-5.746
Delta	1.867	2.003
Rank	2	1

Table.7 Response table for Means

Level	**Voltage**	**Duty Cycle**
1	**1.933**	**1.665**
2	**1.655**	**1.549**
3	**1.566**	**1.941**
Delta	**0.367**	**0.393**
Rank	**2**	**1**

Table.5 shows the response table for the S/N ratio and Table.6 shows the response table for means. Tables 4 and 5 suggest that the duty cycle is a more dominating factor in comparison to voltage for surface roughness of the workpiece at a constant 19% electrolyte concentration of NaOH and 400 rpm tool rotation. Fig. 2 shows the mean effect plot for surface roughness and Fig.3 shows the S/N ratio plot for surface roughness.

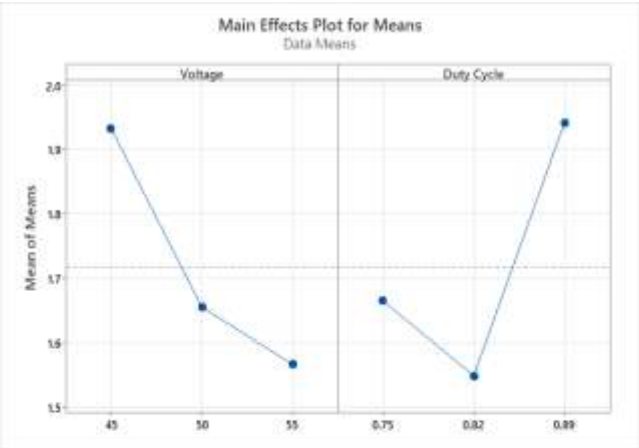

Fig.2 Mean effect plot for surface roughness

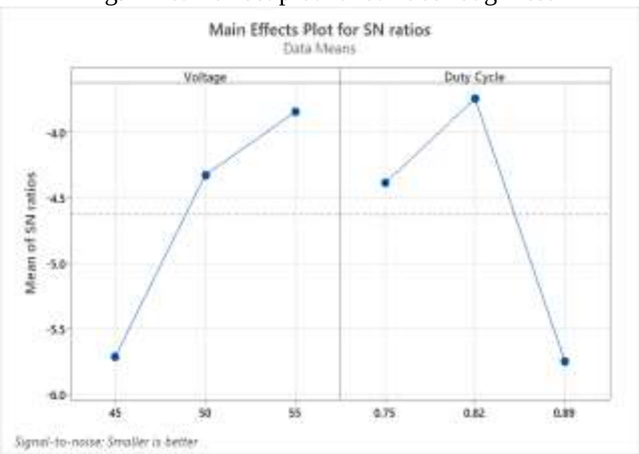

Fig.3 S/N ratio plot for surface roughness

Fig.2 shows that surface roughness is decreased with an increment in applied voltage whereas in the case of duty cycle, on an increment of a duty cycle from 0.75 to 0.82, surface roughness decreases and from 0.82 to 0.89 region, surface roughness decreases. Fig.2 and Fig.3 suggest the most optimal parameters for surface roughness are 55V and 0.82 duty cycle at constant tool rotation at 400 rpm and 19% electrolyte concentration.

IV.CONCLUSION

In the present research work, experimental analysis is performed on quartz glass machining through the ECSM process.

A total of nine experiments are performed to get surface roughness with variable voltage and duty cycle machining parameters at a constant 19% electrolyte concentration of NaOH and 400 rpm of tool electrode. With the help of the Taguchi method, optimal parameters are achieved which are 55 V and 0.82 duty cycle at constant tool rotation at 400 rpm and 19% electrolyte concentration.

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