Surface Roughness Analysis for optimization of ECDM Performances using RSM

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Abstract-

Micro-ECDM is involved for micro-cutting operation on electrically non-conducting hard and brittle materials like glass. The paper shows effects of pulse on-time, pulse frequency, electrolyte concentration and applied voltage on surface roughness (R_a) when mixed electrolyte is used in Micro-ECDM performances. Developed mathematical models analyze by ANOVA and minimum surface roughness has been found by desirability function analysis and optimization with contour diagram also analyzes for achieving the better experimental results of micro-channeling on brittle glass by ECDM process.

Keywords- *ECDM, SURFACE ROUGHNESS, RSM, GLASS*

1. INTRODUCTION

The productions of miniature parts draw the most of attractions from industrial field to fabricate small or tiny products which have growing demands in modern society [1-4]. To accomplish the demand, the scientists and technologists are facing more and more challenges problems in the field of manufacturing industries. The difficulty in adopting the traditional manufacturing processes is caused by the three basic sources such as new materials with a low machinability, dimensional and accuracy requirements and a higher production rate with economy [5-7]. The machining is referred as the removal of some material from the job specimen by direct contact or indirect contact with tool for development of a specific geometry at a definite degree of accuracy and surface quality. Parts manufactured by casting, forming and various shaping processes often require further operations before use or assembly [8-10]. In many engineering applications parts have to be interchanged in order to function properly and reliably during their expected service lives. There is a requirement of advanced machining methods / processes in modern manufacturing industries to manufacture the products with advanced engineering materials such as ceramics, quartz, alumina and glass due to their some favorable characteristics [11-18]. In Abrasive Water Jet Machining (AWJM) process has limited applications due to the transverse cutting speed, the quality of products is not so good due to poor surface quality and large space area required for installation, high investment as well as maintenance cost. Ultrasonic Machining (USM) has some inherent limitations such as tool wear, high capital cost and there is a chance of tool bending due to contraction and vibration. In case of Laser beam Machining (LBM) the formation of very large undesirable heat affected zone degrades the quality of the product and this process requires very high investment. ECM requires high capital investment, skilled worker to operate and large space for installation. Also the disposal of used electrolyte and effect of stray current are the major drawbacks of ECM process. Again electro-discharge machining (EDM) have some drawbacks like difficult to fabricate various shapes, long machining time required to produce micro-products and high cost of equipment. Further ECM and EDM are useful mainly for electrically conductive material. So the alternative machining process is tried to bring within the minimum investment for cutting non-conducting materials like glass and ceramics that is ECDM [19-20]. Hence, there is a need of special machining process, which will be helpful for fabricating products of electrically non-conductive materials and can cope up with the above adverse effects of above machining processes. Electrochemical Discharge Machining (ECDM) process has a great ability to machine electrically non-conductive materials like glass.

2. Experimental Set up and planning

To reach the goal of the present research work and to control the process parameters such as machining voltage, pulse frequency, pulse on-time and electrolyte concentration etc. SS tool of 200 micron is used and mixed electrolyte of NaOH+KOH has been used during micro-channeling on silica glass. Table 1 represents process parameters level and ranges.

3. Proposed Aprroach for Experimental Planning and Modelling

These parameters' search ranges have been chosen to correspond to the experimental conditions reported in Table 1.

Table 1. Range of parameters

Name of input parameters	Ranges
Voltage (Volt)	45-55
Electrolytic concentration (wt%)	20-30
Pulse on-time(μs)	50-60
Pulse frequency(Hz)	50-100

3.1 Mathematical Model validation with ANOVA

Second order non-linear mathematical model of equation no 1 has been validated by R-Sq = 97.51% and R-Sq(adj) = 95.34%, for SR which shows the confidence level above 95%, indicates best fitness of models. Standard F ratio and p value for 10DOF for lack of fit is near about standard value and ANOVA table 2 and 3 shows the justified results.

Min_SR(x)=Y(SR)=2.01857+0.46894*x(1)+0.18117*x(2)+0.02506*x(3)-0.01783*x(4)-0.35356*(x(1))^2+0.20644*(x(2))^2-0.33856*(x(3))^2+0.17644*(x(4))^2-0.03806*x(1)*x(2)-0.13194*x(1)*x(3)+ 0.05569*x(1)*x(4)-0.11069*x(2)*x(3)-0.17944*x(2)*x(4)+0.12194*x(3)*x(4); Equ. *(1)*

Table 2 Analysis of Variance (ANOVA) of Adj.SS and MSS for SR

Source	DF	Adj.SS SR	Adj.MSS SR
Regression	14	7.02398	0.50171
Linear	4	4.56617	1.14154
Square	4	1.15740	0.28935
Interaction	6	1.30041	0.21674
Lack-of-Fit	10	0.17623	0.01762
Pure Error	06	0.00280	0.00047
Total	30		

Table 3 Analysis of Variance (ANOVA) of F ratio and P value for SR

Source	**DF**	**F(ratio)for SR**	**P(value) SR**
Regression	14	44.84	0.000
Linear	4	102.02	0.000
Square	4	25.86	0.000
Interaction	6	19.37	0.000
Lack-of-Fit	10	37.76	0.000
Pure Error	06		
Total	30		

3.2 Parameter's Effects and optimization of Surface Roughness

Fig. 1-4 shows the graphical presentation of Pulse on-time, pulse frequency, voltage and electrolyte concentration effects on surface roughness using mixed electrolyte (NaOH+KOH) during micro-machining by ECDM. If voltage and pulse on-time has been increased, higher heat is produce on the machining zone and sparking spread that affects on surface roughness. Also higher pulse frequency provides higher HAZ, from figure it is clear that after 75 Hz surface roughness is increased. At moderate pulse frequency (75Hz) SR is better and at 55 micro-sec pulse on-time provides continuous sparking with better quality of micro-channel, at 50 voltage but higher electrolyte concentration provides higher surface roughness. Figure 5 shows voltage, electrolyte concentration, Pulse on-time and pulse frequency contour effects plot for surface roughness using mixed electrolyte. Figure 6 shows the minimization of surface roughness at optimal parametric settings.

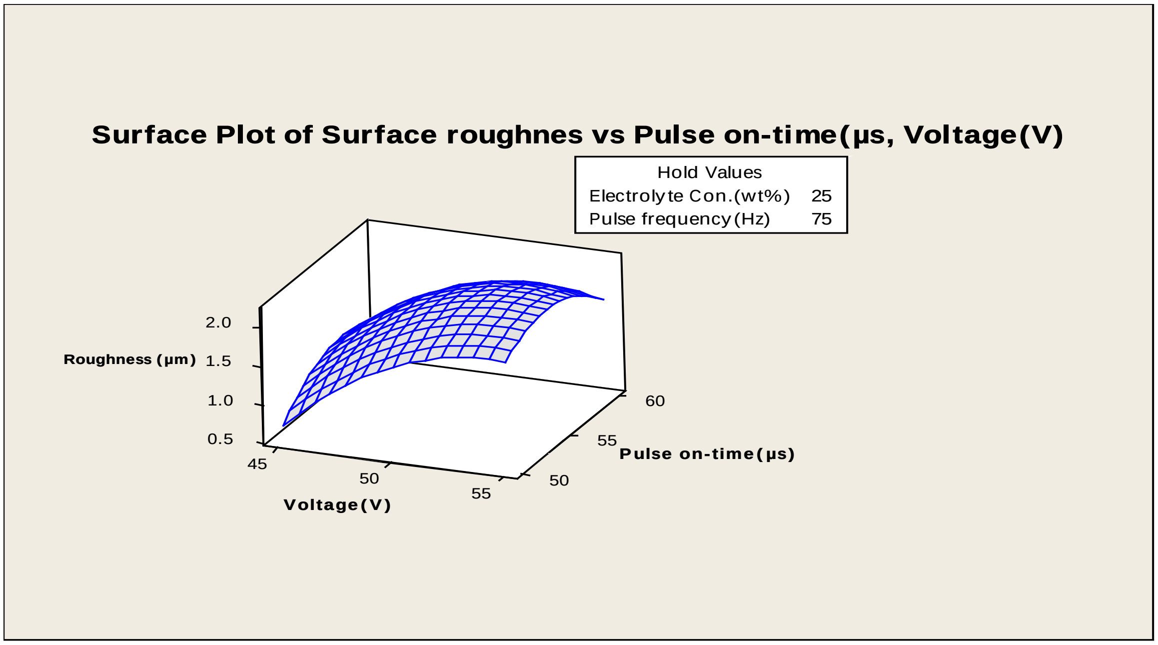

Fig. 1 Pulse on-time and voltage Effects on surface roughness using mixed electrolyte

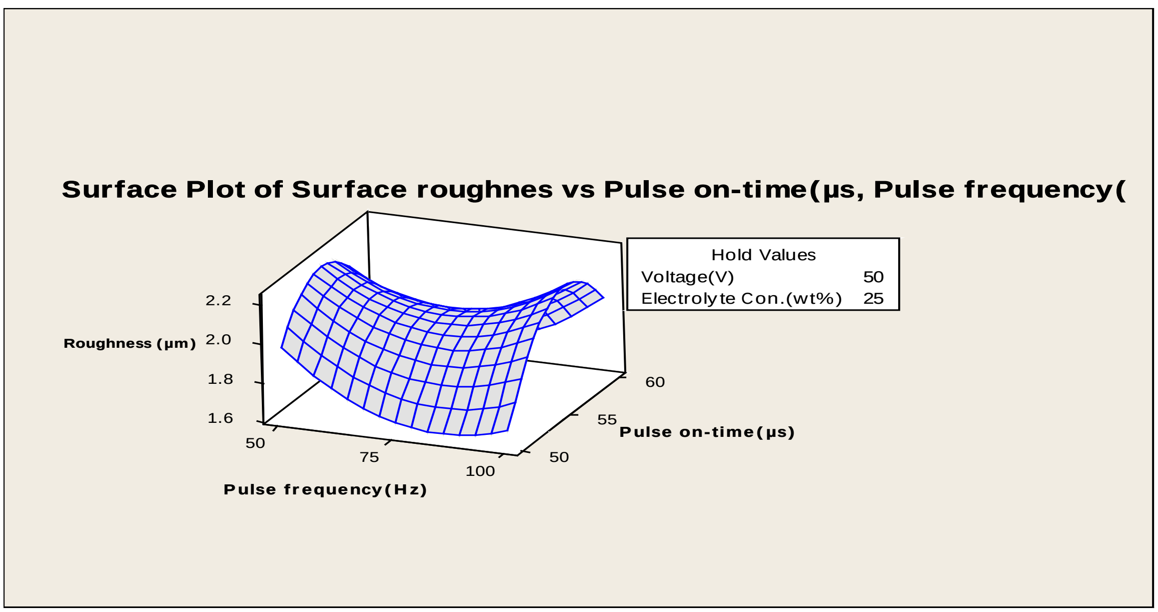

Fig. 2 Pulse on-time and pulse frequency Effects on surface roughness using mixed electrolyte

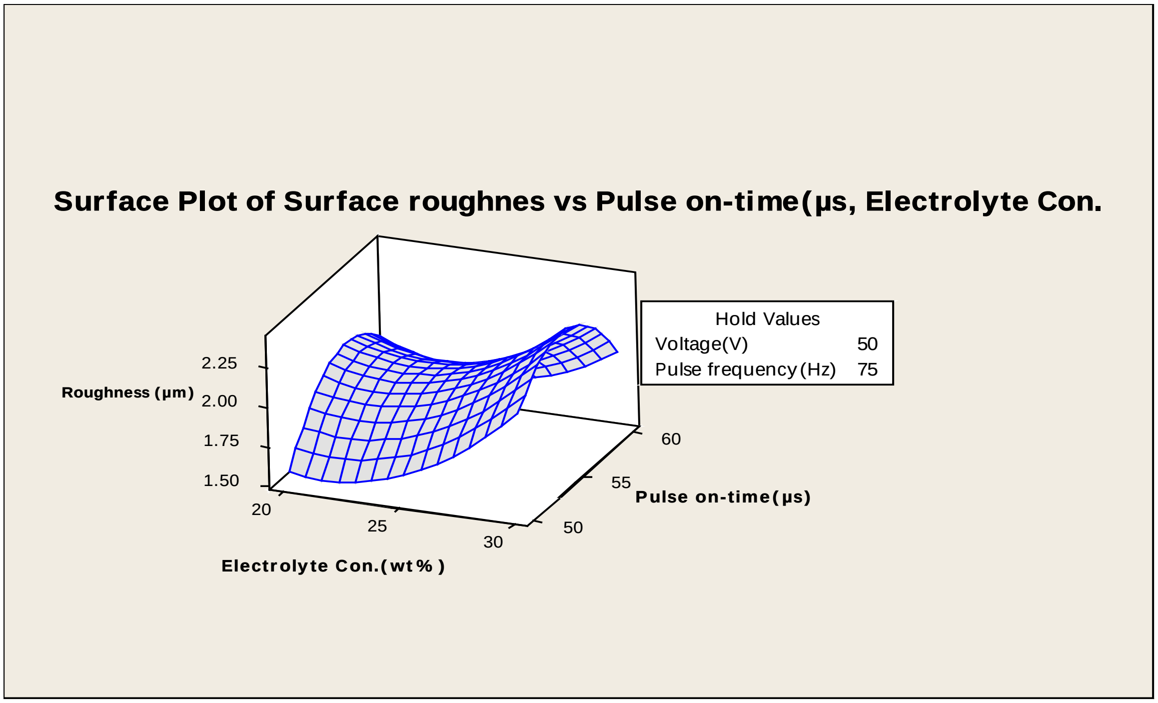

Fig. 3 Pulse on-time and electrolyte concentration Effects on surface roughness using mixed electrolyte

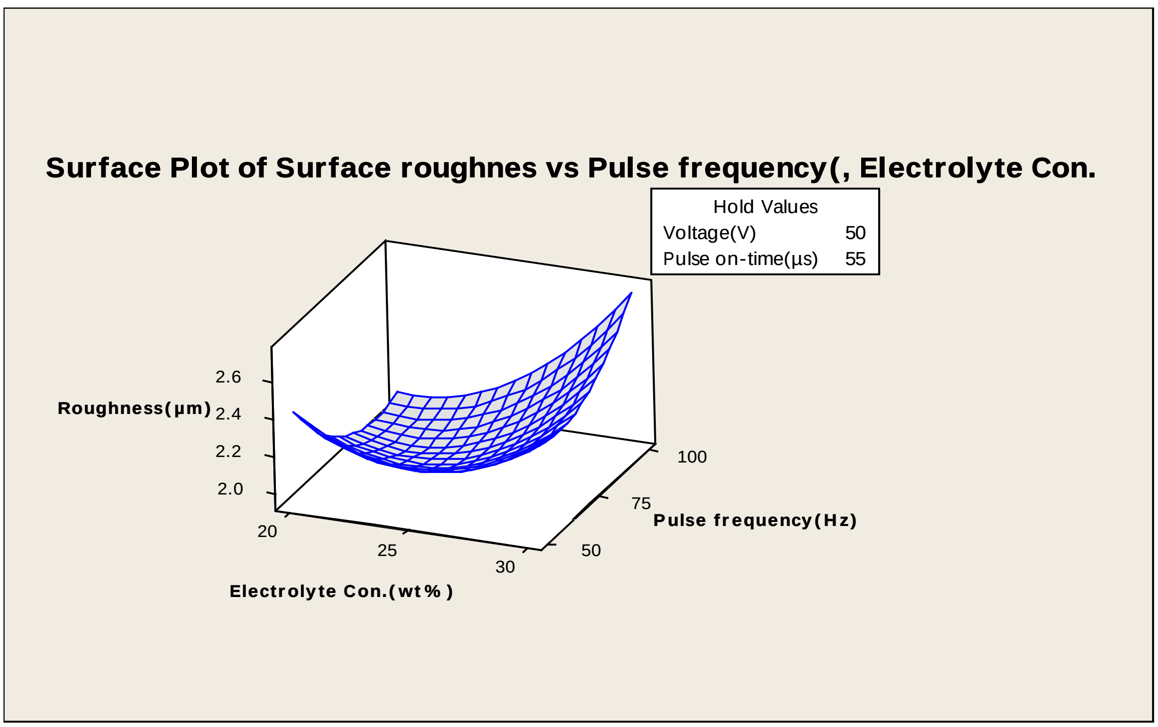

Fig. 4 Electrolyte concentration and pulse frequency Effects on surface roughness using mixed electrolyte

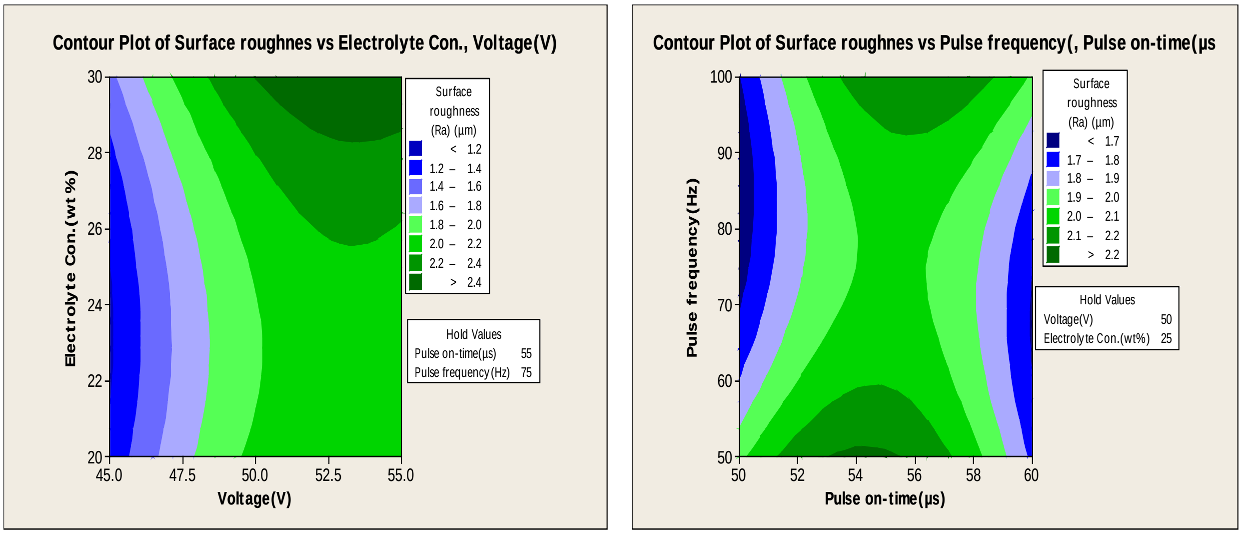

Fig. 5 Voltage, electrolyte concentration, Pulse on-time and pulse frequency contour Effects plot for SR using mixed electrolyte

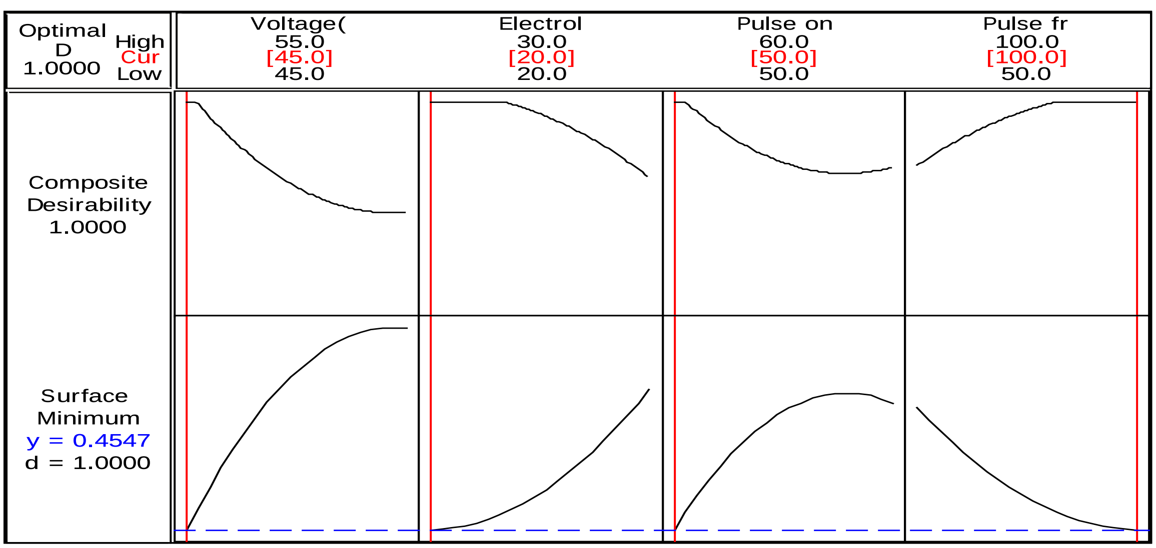

Fig. 6 Optimization Plot for Surface Roughness

4. Conclusions

From the desirability of function analysis of machining depth and surface roughness it may be concluded that in this set of performances-

- Better surface quality with higher machining depth of 893µm is achieved.
- Applied voltage directly influences Pulse on time to reach the critical voltage.
- Moderate pulse frequency and lower voltage provides better surface finish at 20 wt% of electrolyte concentration.
- Optimized surface roughness is achieved at 50V/25wt%/55 µs/75 Hz during micro-channeling on glass by ECDM.

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