Pulsed Electric Field Based Material Removal in Microelectrical Discharge Machining

T. Roy[1], P. Ranjan[2], R. Balasubramaniam[2]

[1]Homi Bhabha National Institute, Mumbai, India
[2]Bhabha Atomic Research Centre, Mumbai, India

Abstract

Micro electrical discharge machining (MEDM), a scaled down version of EDM process, is a micro machining process used to fabricate micro holes and intricate shapes in electrically conductive materials irrespective of its hardness. In this process, an electric spark is generated in the gap between the two electrodes (tool as cathode and workpiece as anode) submerged in dielectric, due to charging and discharging of capacitor in an RC circuit that leads to a plasma formation, which eventually leads to material removal by melting and ablation. The mechanism of material removal in MEDM is a very complex process and hence has not been understood fully. Simulation of material removal has been carried out in this study by using COMSOL Multiphysics® software to understand the behaviour of pulsating electric field in MEDM. Assuming a constant heat flux, it has been shown that material ablation takes place whenever the electric field strength crosses the threshold value. Automatic remeshing was employed to ensure that mesh quality do not degrade during simulation and better results can be expected from this study.

INTRODUCTION
Micro electrical discharge machining (MEDM) is a micro machining process used to fabricate micro holes and intricate shapes in electrically conductive materials irrespective of its hardness. It is a scaled down version of EDM process [1]. The phenomena of material removal by melting and ablation in MEDM is a complex process and analytical modelling of the process is very difficult (Fig. 1). Various numerical techniques have been used to simulate material removal based on different forms of heat flux viz. Gaussian heat source [2], point heat source [3], uniform heat source [4] and so on. However, there has not been much work done on how the pulsating electric field generated due to charging and discharging of capacitor in RC circuit effects the heat flux and thereby material removal in MEDM. In this paper, an attempt has been made to simulate material removal by using pulsed electric field.

USE OF COMSOL Multiphysics® software: The study of material removal in MEDM includes a pulsating electric field that creates a constant heat flux during pulse on time. This heat flux is responsible for ablation of material at locations where heat flux crosses the threshold value for ablation. COMSOL Multiphysics® software was used for simulation as it perfectly meets all the requirements of the problem. A 2D geometry model was used.

Electric Currents interface from AC/DC module was used for generating pulsed electric field. Deformed Geometry interface was used to define the threshold value for ablation of workpiece in terms of electric field strength.

RESULTS: Liquid dielectrics used in MEDM usually have a dielectric strength in the range of 1-50 MV/m [5]. Breakdown of dielectric occurs as soon as electric field reaches this value. Hence, for our study 1 MV/m has been used as the threshold value for material removal. Assuming a constant heat flux delivered in the gap due to threshold electric field, the material removal process has been simulated as shown in Fig.2, 3 and 4. Table 1 shows the variation of electric field and mesh quality with time. It has been seen that the mesh quality never degrades beyond 0.4 which was used as the threshold value for remeshing.

CONCLUSION: An attempt has been made in this study to simulate material removal in MEDM using the concept of pulsed electric field. Though a number of literature are available that deals with variation of heat flux source responsible for material removal, there is little or no study of the effect of pulsed electric field on the material removal. As MEDM process uses an RC circuit, charging and discharging of capacitor leads to variation in electric field. This electric field generates heat flux which in turn is responsible for material removal. In this paper, we have considered a constant heat flux and have shown that for a particular threshold value of electric field, heat flux becomes high enough such that ablation temperature of workpiece is reached and material removal from workpiece takes place. A more detailed investigation into this problem can be considered in future by taking into account Heat Transfer module and coupling electric field with the heat flux which may provide better results.

Table 1: Electric field variation and mesh quality with time

Time (secs)	Electric field strength (max) (MV/m)	Mesh quality (min)
0	7.0556	0.7311
0.02	1.4159	0.7267
0.04	1.3611	0.7219
0.06	6.0232	0.7177
0.08	1.0355	0.7106
0.1	5.2114	0.7033
0.12	1.5615	0.6974
0.14	2.0411	0.6901
0.16	1.389	0.6844
0.18	3.8581	0.6792
0.20	3.3478	0.6681
0.22	1.4869	0.6592
0.25	3.0974	0.6432
0.27	1.3273	0.6298
0.29	2.7305	0.6184
0.31	2.8611	0.6094
0.33	1.5542	0.6029
0.35	5.4034	0.5868

0.37 8.5437 0.569
0.39 2.6632 0.544
0.41 3.8 0.5171
0.43 2.8143 0.4888
0.45 1.4015 0.4638
0.47 1.3733 0.4441
0.5 2.4127 0.422

Reference

[1] Dhanik, S., Joshi, S.S., ‘Modeling of a Single Resistance Capacitance Pulse Discharge in Micro-Electro Discharge Machining’, Journal of Manufacturing Science and Engineering, 127, 759-767, 2005.
[2] Allen, P., Chen, X., ‘Process simulation of micro electro-discharge machining on molybdenum’, Journal of Materials Processing Technology, 186, 1–3, 346–355, 2007.

[3] DiBitonto, D.D., Eubank, P.T., Patel, M.R., Barrufet, M.A., ‘Theoretical models of the electrical discharge machining process. I. A simple cathode erosion model’, J. Appl. Phys., 66, 4095, 1989.

[4] Yeo, S.H., Kurnia, W., Tan, P.C., ‘Electro-thermal modelling of anode and cathode in micro-EDM’, Phys. D: Appl. Phys., 40, 2513–2521, 2007.

[5] Dielectric Strength of Insulating Materials, L. I. Berger, http://chemistry.mdma.ch/hiveboard/rhodium/pdf/chemical-data/diel_strength.pdf

Figures used in the abstract

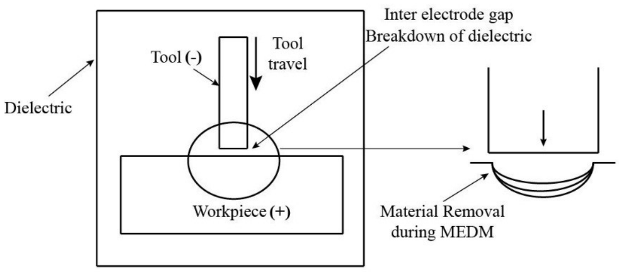

Figure 1: Material Removal during MEDM process.

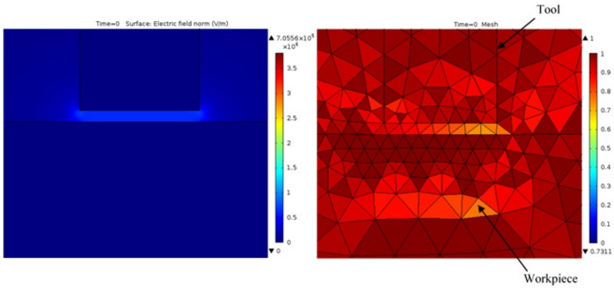

Figure 2: Electric field and Mesh quality at time t=0.

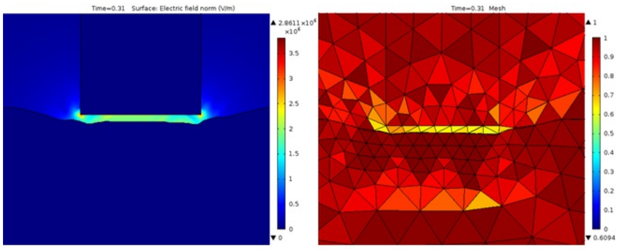

Figure 3: Electric field and Mesh quality at time t=0.31 seconds.

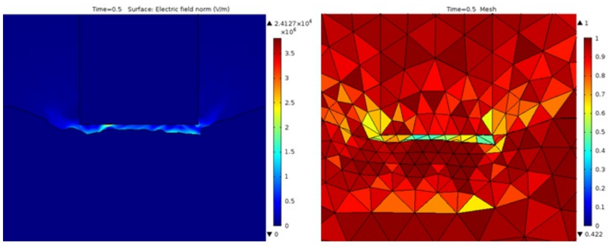

Figure 4: Electric field and Mesh quality at time t=0.51 seconds.