MODELING AND SIMULATION OF ELECTRIC DISCHARGE MACHINE (EDM) AND WEDM USING COMSOL MULTIPHYSICS: REDUCING OVERCUT IN THE WORK PIECE

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Abstract: *The modeling provides a wide range of possibilities for simulating electric field distribution in EDM machine. This paper describes maximum electric field between tool and work piece in Electric Discharge Machining (EDM) process using different dielectric systems and co-relate with breakdown voltage, time required and gap between the tool and the work piece. EDM process is a thermoelectric, non-conventional which involves Multiphysics at multi-time scales. The single discharge phenomena in EDM consist of solid, liquid, gas and plasma states confined within a micrometers region and occur at a time scales of micro-nano seconds. When the electrode and work piece are separated by a small gap filled with dielectric oil, de-ionized water or gas; the application of high voltage between these two electrodes (tool, work piece) results in ionization of the dielectric fluid. This leads to forming of streamers which establish a plasma channel between the electrode and work piece usually at a spot where the electrostatic potential is strongest. Simulation on COMSOL gives the better result of the electric field distribution in electrostatic module by varying supply voltage and the gap between tool and work piece. The results indicate that side overcut is reduced by decreasing frontal gap in WEDM around the side of tool. The simulation result has been demonstrated with the experimental values and the results were positive.*

Keywords: Electric field, Overcut, Electrical discharge machining, Breakdown Voltage, Inter electrode gap, COMSOL Multiphysics.

1 Introduction

Electric discharge machining (EDM) is a non-conventional machining process which is based on electrical and thermal principles [1]. The EDM has several unique advantages such as exerting every small force between the work piece and tool electrode, as well as fabricating hard-to-cut materials [2]. There are many factors influencing the EDM process [3], but pulse current, pulse duration, duty cycle (defined as the ratio of pulse on time to the total pulse period), and discharge are more important than other parameters [4,5]. In addition, the effects of various machining parameters on the quality of holes which are created by the EDM process are investigated [6]. Besides a few unique advantages, this method has some drawbacks, one of which is side overcut. The side overcut is a clearance per side between the electrode and the work piece after the EDM process. Hence, the width of the EDM cavity is always larger than the electrode.

Craftsmen and researchers have presented several techniques to reduce side overcut. Using undersized electrode tool is a common technique to overcome this problem. However, the numerical value of overcut must be known to properly undersize the electrode. Besides, covering a tool by an insulation film is difficult in Nano- or micro-EDM. Several researchers study the effect of EDM parameters on the overcut to prepare accurate overcut information to produce undersized tool [3]. It is attempted to predict the overcut by neural network [7,8]. Yoshida in 2013 added high voltage externally on the work piece; this research shows that not only did the surface roughness of the machined surface improve but also the machining rate is increased by adding external high voltage [9].

1.1 Methodology and Mathematical Analysis

As the electrical field directly influences the happening of sparks, estimating its value would be helpful for prediction the dimension of side overcut, and it is possible to estimate the electrical field (E) based on physical rules on the side gap. For simplicity, it is supposed that electrical charges are located on the corner soft tools and they influence the corner of work piece [4]. The correlation between electrical field and voltage is as follows:

a) $$E = V/L$$

L is the distance from an electrical charge. Without any external voltage, the electrical field in the gap and overcut is, respectively:

b) $$E_{gap} = V/D$$

The governing equations in the Simulation of electric filed distribution using COMSOL Multiphysics software can be observed in Electrostatics module by Maxwell 'equations and the consecutive equation can be reduced to the following form:

$$\nabla \times \mathbf{E} = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

$$\nabla \cdot \mathbf{D} = \rho \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

$$\mathbf{D} = \varepsilon \mathbf{E} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

where, E is the electric field intensity, D is the electric displacement, ρ is the space charge density, ε is the dielectric permittivity of the material. Based on Eq. (1), electric field intensity is introduced by the negative gradient of the electric scalar potential V in following form:

$$\mathbf{E} = -\nabla \mathbf{V} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Substituting equations (2) and (3) and (4) in (1) Poisson's scalar equation is obtained as

$$-\nabla \cdot (\varepsilon \nabla V) = -\nabla \cdot (\varepsilon 0 \varepsilon r \nabla V) = \rho \ldots\ldots\ldots\ldots \quad (5)$$

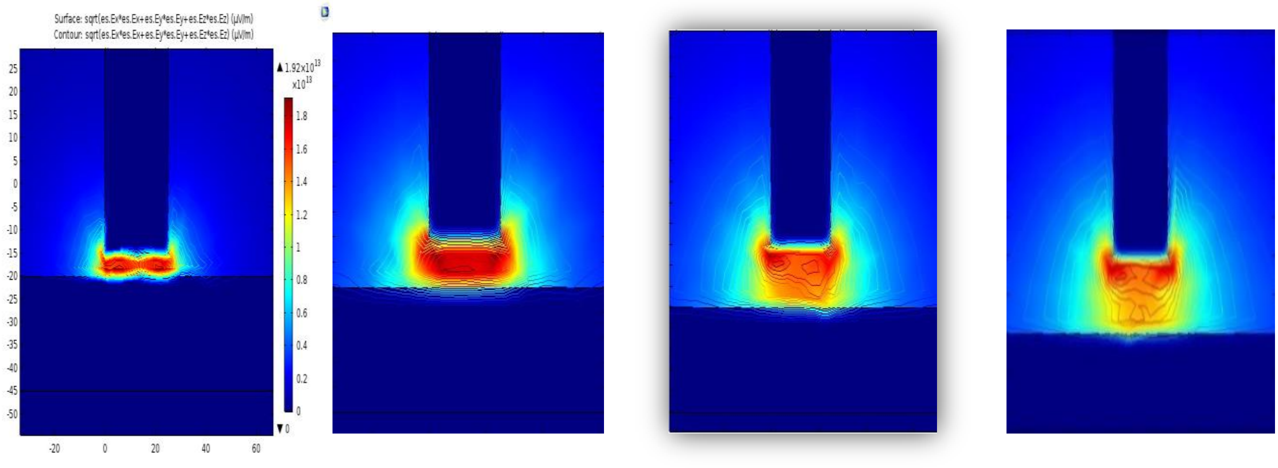
Where ε0 is the permittivity of free space, εr = εr (E, x, y, z) is the relative permittivity and ρ is the Space charge density. If the permittivity ε is constant such as in the isotropic dielectrics, Eq. (4) becomes

$$\Delta V = -\rho\ \varepsilon \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

For space charge free (ρ = 0) fields, field is expressed by Laplace's equation as ΔV = 0. In this study, solution of the problem is obtained from solution of Laplace's equation in rectangular coordinates.

2. Simulation Using Different Di-Electric Systems:

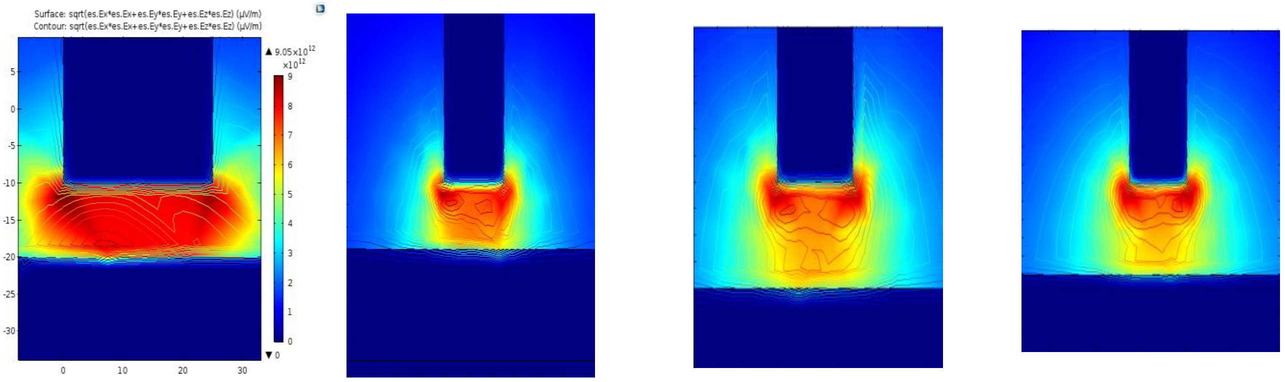
2(A) Estimating the Electric field distribution using Di-Electric medium as **Air** with constant supply voltage(80V) by varying inter electrode gap **(IEG)**.



(a) (b) (c) (d)

Fig. 2(A): Variation in Electric field with inter electrode gap (a) 5 µm (b) 10 µm (c) 15 µm (d) 20 µm

2(B) Estimating the electric field distribution using Di-Electric medium as **Deionized water** with constant voltage 80(V) by varying inter electrode gap (IEG).



(a) (b) (c) (d)

Fig. 2(B): Variation in Electric field with inter electrode gap (a) 5 µm (b) 10 µm (c) 15 µm (d)20 µm

Table 1. Standard value of IEG and their respective electric field values in Air and De-ionized water.

IEG(µm)	2(A)Air(Maxm.ElectricField) (µV/m) 10^{13}	2(B) De-ionized water (Maxm. Electric Field) (µV/m) 10^{13}
5.0	1.92	0.905
10.0	0.88	0.692
15.0	0.69	0.552
20.0	0.55	0.444

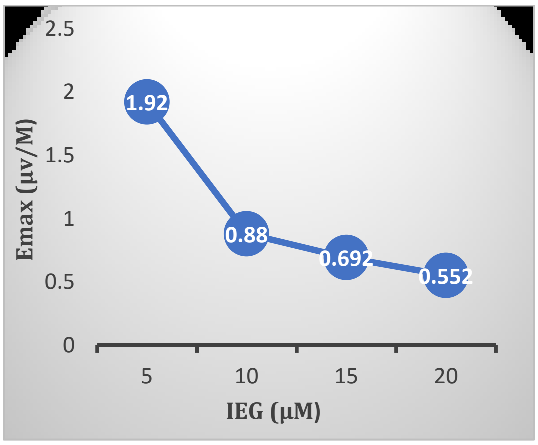


Fig.2(A). (Air)

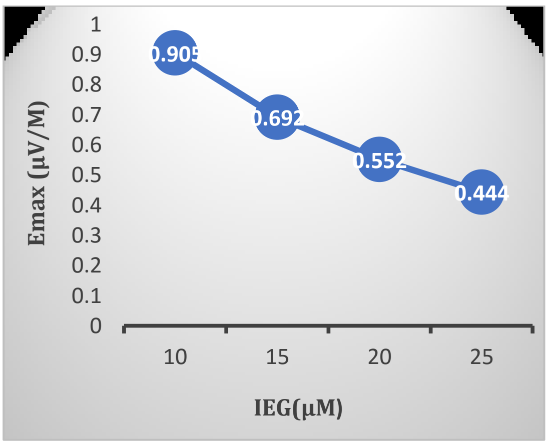
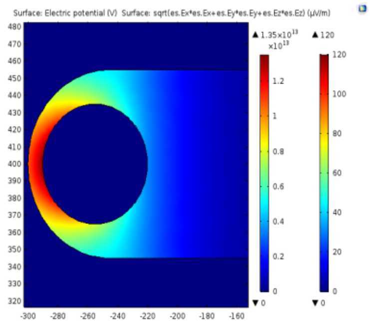
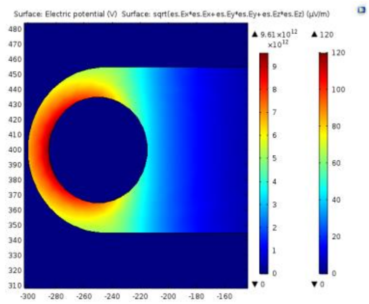


Fig.2(B). (De-ionized Water)

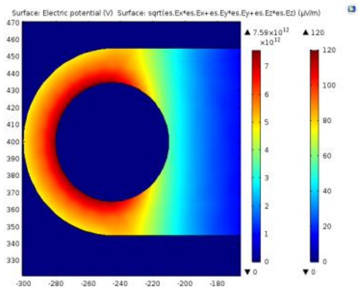
2(C) Analyzing Electric Field Variation using De-ionized water as dielectric fluid in **WEDM** machine. Keeping Vo (120V) constant, side gap = 20 (μm),



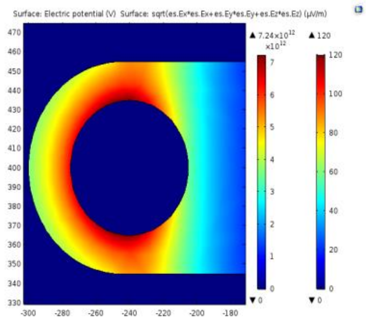
(a)



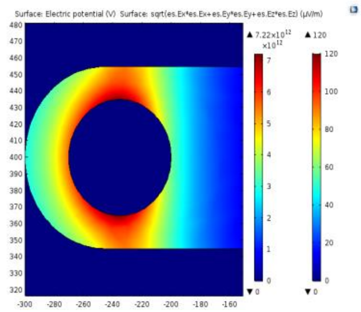
(b)



(c)



(d)



(e)

Fig.2(C): Variation of Electric field distribution with increasing frontal gap (a) 10μm (b) 15 μm (c) 20 μm (d) 25 μm (e) 30 μm

Table 2. Observation of electric field range with increasing frontal gap

Frontal gap(μm)	Angle of Max. Electric field Distribution (degree)
10	248.43
15	279.89
20	303.13
25	313.63
30	313.99

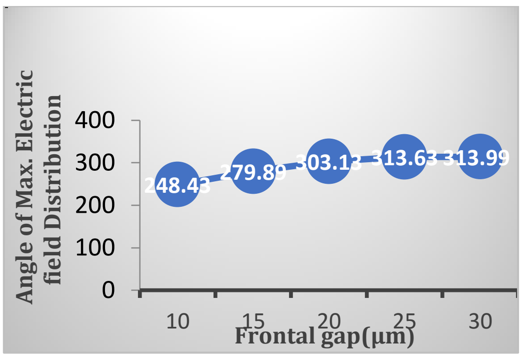


Fig.2(C). frontal gap vs electric field range

3 Conclusion:

In this study of the Electric Discharge Machining process, Electric field distribution has been investigated between the tool and work piece by simulation with COMSOL Multi Physics. It has been studied from the result in both dielectric fluid (air and DI water) that the maximum electric field intensity not only changes with the geometrical configuration of electrodes but also changes with other parameters like distance between the electrode and tool, applied voltage between the electrode and work piece, etc. Magnitude of Electric field depend upon the inter electrode gap. Material removal rate will maximum where the IEG is less. In case of Wire Electric Discharge Machine, Magnitude of electric field increases in the frontal side as the frontal gap decreases and vice versa. Similarly, Magnitude of electric field increases in the side gap resulting in more overcut with the increase in frontal gap. As per the simulation results, firstly, run the machine for some second and then change the frontal gap to minimize the overcut of the work piece by tool servomechanism. The tool positioning can be manually change after few second run and then reducing frontal gap can help to minimize the overcut issue in micro-EDM can be resolve. After the simulation in COMSOL, the result show that the minimization of the frontal gap can reduce the overcut of the work piece and as a result finished and efficient product can be achieved.

4 References:

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