Finite Element Analysis of Electric Discharge Machining Process

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Introduction

Electric Discharge Machining (EDM) is a thermo-electrical non-traditional machining process in which a series of discrete spark is generated between the electrodes under controlled machining condition. Pulsed arc discharges occur in the gap, filled with a nonconducting medium, preferably a dielectric liquid like hydrocarbon oil or de-ionized (de-mineralized) water between copper elctrode and conducting work piece.

The tool moves downward towards the workpiece until gap between tool and workpiece reaches critical value(called as spark gap) so that applied voltage is high enough to breakdown dielectric and spark discharge takes place between tool and workpiece. During the discharging process, electrical energy from a pulse generator is turned in to thermal energy which generates a channel of plasma in working gap between tool and workpiece at a very high temperature.

During this interaction electrical energy is being converted into heat energy. This incoming heat flux during sparking process is distributed to entire component, which causes erosion of material and other machining characteristics like surface roughness. This heat energy is distributed between the various constituents of the system i.e workpiece, tool electrode and dielectric fluid and is shared by large number of physical processes occurring during the main stages of metal removal of EDM process.

Theory of EDM:

Whenwe apply optimum value of EDM machining parameters then sparking takes place between the tool and workpiece, this tranfer of energy between ions of plasma channel and molecules of workpiece is supposed to be take place place by conduction method of heat transfer. In past several researcher has propopsed a number of thermo-mathematical model of heat conduction phenomenon into the workpiece are available in literature. However, a generally accepted theory does not yet exist because of the complicated nature of metal removal mechanism incorporating the electrical discharge in the dielectric medium.

The distribution of heat within the workpiece is mainly depends on the incoming heat flux function. Various researches has been conducted on its thermal analysis assuming the two type of heat fluxes point heat source [2] and uniformly distributed heat flux [3,4] but unfortunately these assumptions were not able to give us true results because this approximation is neither realistic nor reliable, As the heat flux function is different at different radius of sparks.

Governing Equations & Numerical Model:

The basic mechanism of erosion involved in EDM process is thermal heating of workpiece due to high heat generated by the plasma channel, and thus Temperature of the whole domain increses above the melting point of material, occasionally it goes beyond the boiling point of the material .In present paper our aim is to perform thermal analysis of ED, in which conduction is supposed to be the main mode of heat transfer between the ions of plasma channel and molecules of the workpiece.[5,6]

As spark strike on workpiece surface then material removal phenomena takes place predominantly melting than evaporation . Thus latent heat of melting plays vey vital role in thermal analysis of EDM as this is the amount of heat consumed for the phase change of the workpiece and tool material[3,7]. The The DiBitonto's model[1] has completely ignored the latent heat of melting in his work.

The assumptions of model proposed by yadav et al.[8] are more accurate as they have considered the Gaussian distribution of heat flux. In their analysis, the Gaussian distribution of heat flux input has been used to approximate the heat from the plasma. The heat q entering the workpiece due to EDM spark is given by: [8]

$$Q_W(r) = \frac{4.47FVI}{R^2}\exp\{-4.5(\frac{r}{R})^2$$

Where F is the fraction of heat input to the workpiece
V is the brekdown voltage
I is the current

Spark radius plays a very important role in the thermal modelling of EDM. During the sparking between the electrodes it does not remain constant with time. Its growth is mainly depends on various parameters such as electrode material, pulse current, pulse on-time and polarity. Different equations have been reported by researches to identify how spark radius grows during pulse-on time. From Literature survey and as reported by several researchers, a semi-empirical equation showed that the discharge radius is related to the current intensity and pulse duration. This is called the equivalent heat input radius [R], which substitutes the radius changing of the heat supply. The equivalent heat input radius, which is dependent of the current density (I) and pulse duration (Ton), is there by:

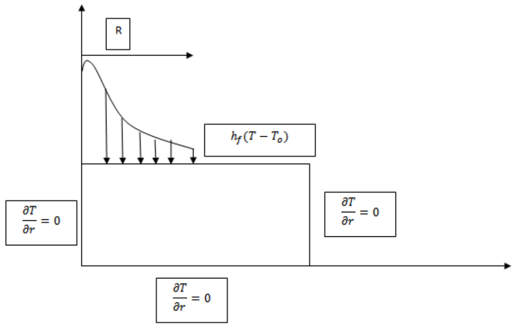
$$R = 2.04 \times 10^{-3} \times I^{0.43}\, T_{on}^{\;0.44}$$

This is a virtual radius that is used as the equivalent heat input radius. The importance of this assumption to the present research is to get a "static" thermal electrical model where a constant radius is used, different for each input current intensity case.

In this paper we have performed finite element analysis of EDM has been performed by COMSOL Multiphysics. Whch requires several important thermo physical properties such as specific heat capacity value, thermal conductivity of material and its density, plasma flushing efficiency and phase change to predict the thermal behaviour and material removal mechanism in EDM process.

Problem Definition:

Incorporating factors such as plasma flushing efficiency, latent heat of melting, and Gaussian distribution of heat flux, considering material properties constant w.r.t temperature, we can determine the temperature variation along length & depth of workpiece, crater diameter and depth of crater which is being created on the workpiece surface also can be measured from 2-D temperature profile.



COMSOL Results:

Parameters

Name	Expression	Value	Description
F	0.185	0.185	Fraction Of Energy
I	10	10	Current
V	80	80	Voltage
Ton	100*10^(-6)	1E-4	On Time
a	23.39*10^(9)[watt/m^2]	2.339E10 W/m²	parameter
R	95.418* 10^(-6) [m]	9.5418E-5 m	Spark Radius

Figure 1. EDM Parameters Value

Variables

Name	Expression	Unit	Description
w	a*exp(-4.5*x^2/R^2)	W/m²	Gaussian Heat Flux

Figure 2. Heat Flux function as variable

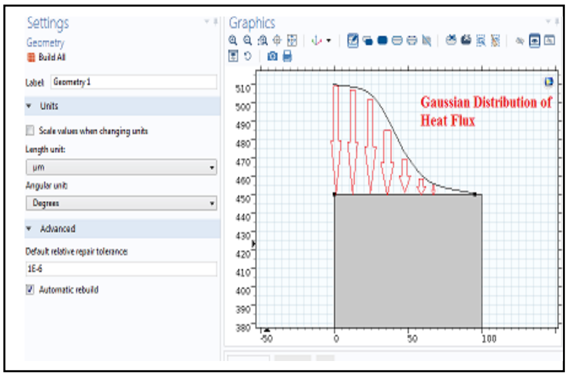


Figure 2. Gaussian Distribution of Heat Flux

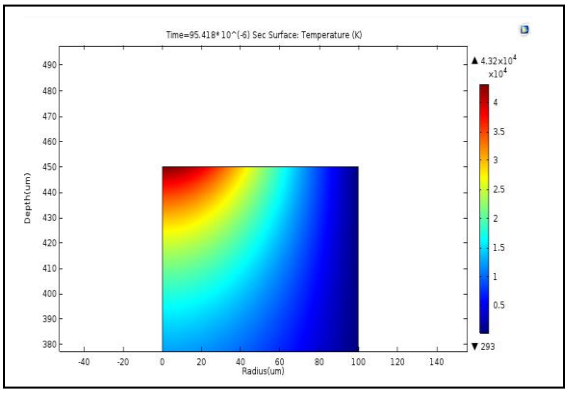


Figure 4. Temperature Distribution within the domain

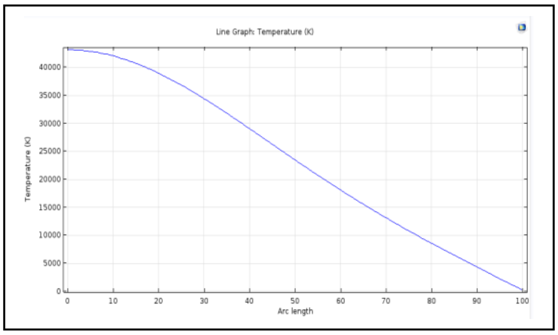


Figure 5. Temperature distribution along the length

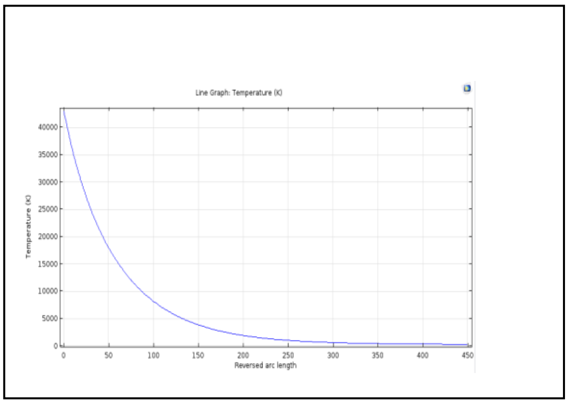


Figure 6. Temperature distribution along the depth of workpiece

Conclusions:

A two dimensional cross sectional model for tool steel workpiece was developed using Heat Transfer Module of COMSOL Multiphysics software, which analyze the temperature variation within the workpiece. Finite element simulation and modeling were carried out for a single spark in EDM. with time dependent material properties i.e specific heat, density & thermal conductivity of the material. The diameter and height of resulting crater is found to be 42 µm & 21 µm respectively. From the temperature distribution figure it can be easily found tha the shape of the resulting crater is elliptical in nature. In this simulation we have performed one step further to DiBitonto's model[1], considering gausssian distribution of heat flux. His model has approximated the resulting spark as a point heat source on the workpiece, which has created hemispherical crater cavity.

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