Multiphysics Based Electrical Discharge Machining Simulation

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Introduction: Electric discharge machining removes material by series of pulsed electrical sparks. Very high flux of order of 10^{11} W/m^2 at very small time interval 10-20 μsec is applied. This work estimates and analyzes heat transfer from plasma to workpiece for such high flux in very small time using Fourier and Non Fourier model. For such system Non Fourier Model well describes the heat conduction process[1].

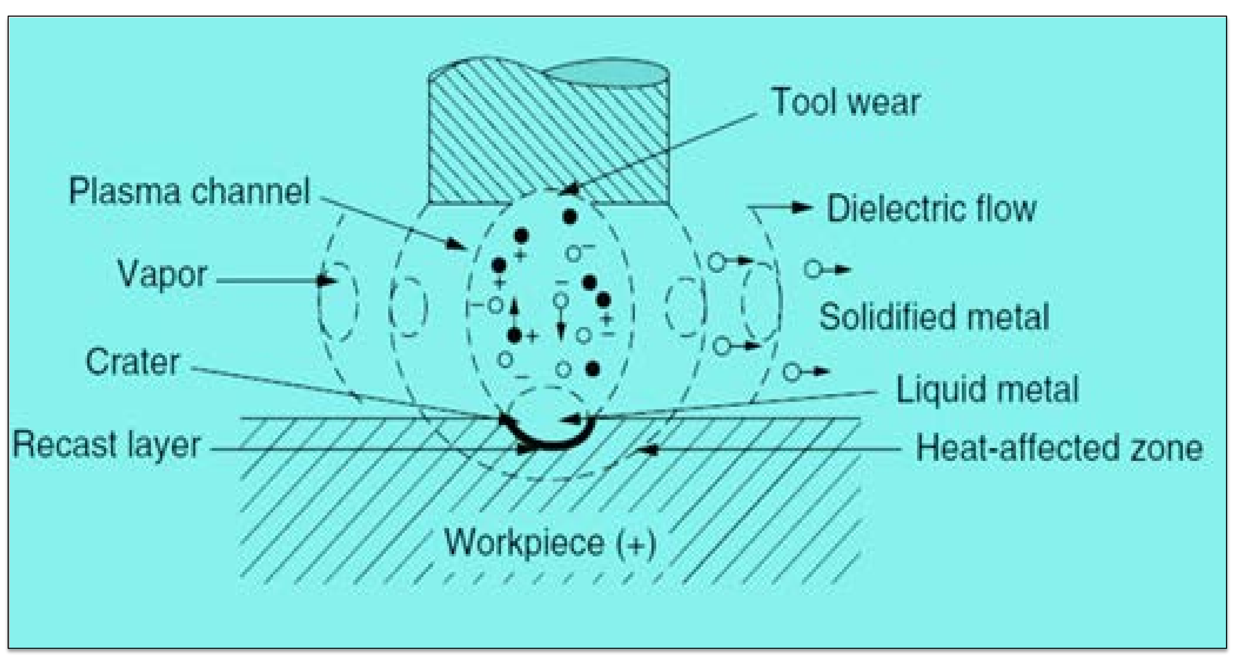

Figure 1. EDM plasma channel

Computational Method Coefficient form of PDE and Heat transfer in fluids Module of COMSOL 5.0 is used in computation. The two modules are coupled for Fourier and Non Fourier heat transfer study.

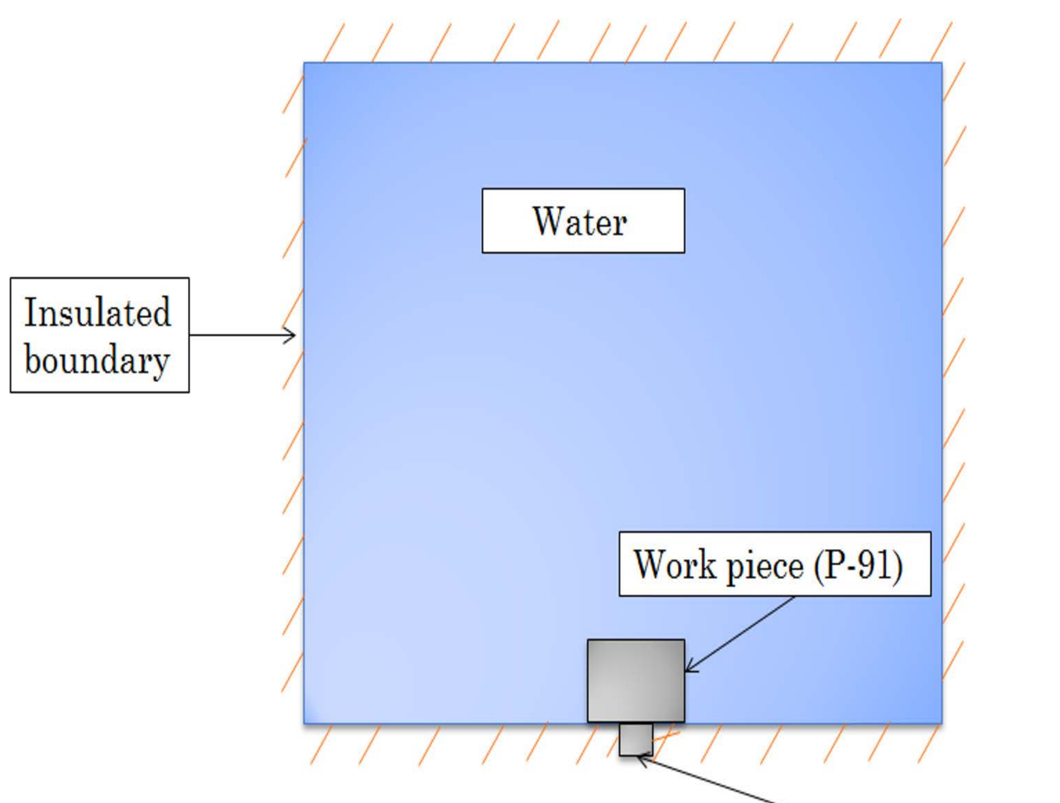

Figure 2. Model geometry

Table 1 .Mathematical Model

	Fourier heat Transfer	Non Fourier Heat Transfer
Governing Equation	$\rho Cp\frac{dT}{dt} + \rho Cu.\nabla T = \nabla.(k\nabla T) + Q$	$\frac{\tau}{\alpha}\frac{\partial^2 T}{\partial t^2} + \frac{\tau}{\alpha}\frac{\partial T}{\partial t} = \frac{\partial^2 T}{\partial x^2}$
Boundary Conditions	$k\frac{d\mathrm{T}}{dx}(x,0,t) = q$ $k\frac{d\mathrm{T}}{dx} + h[T - T_\infty] = 0$ $T(x,y,0) = T_\infty$	
Initial Conditions	$T(x,y,0) = T_\infty$	$T(x,y,0) = T_\infty$ $\frac{\partial T}{\partial t}(x,y,0) = 0$

Results: Plots of heat transfer from plasma to the workpiece. Fourier and non Fourier conduction model

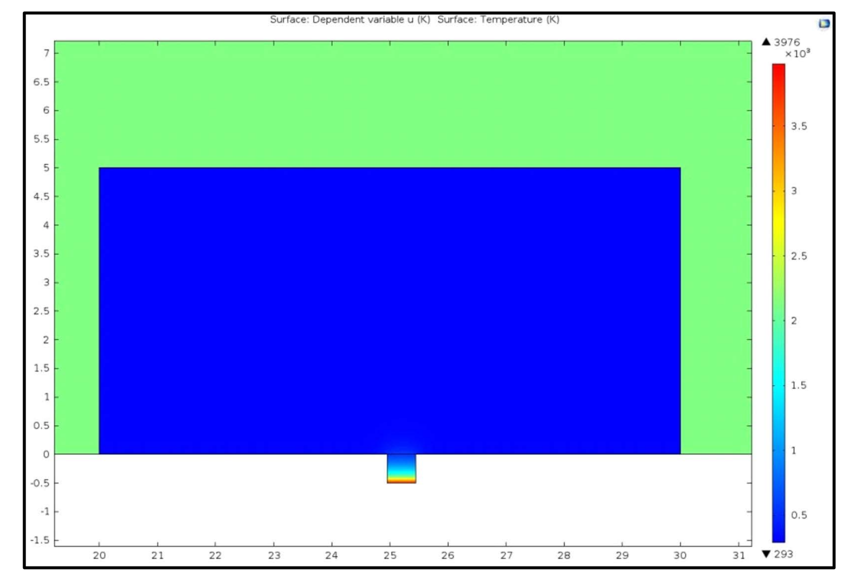

Figure 3. Surface plot of temperature at 1.2x10^{-4}sec By Non-Fourier Model

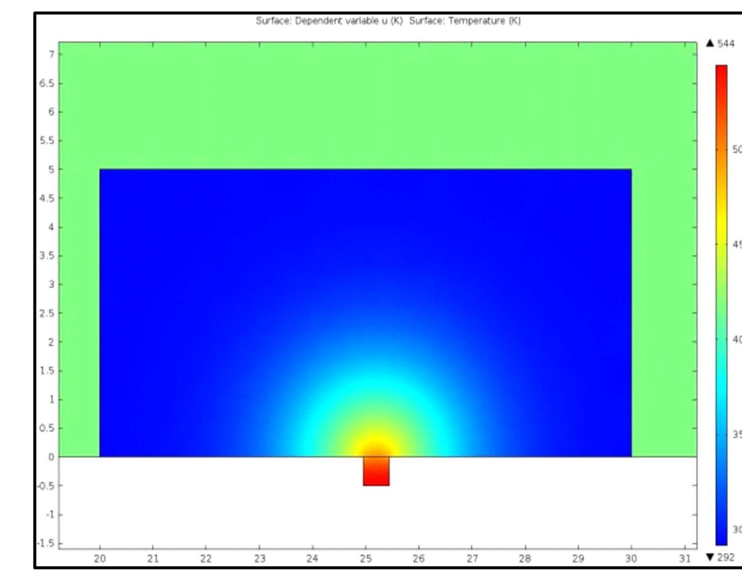

Figure 4. Surface plot of temperature at 0.002sec by Non–Fourier Model

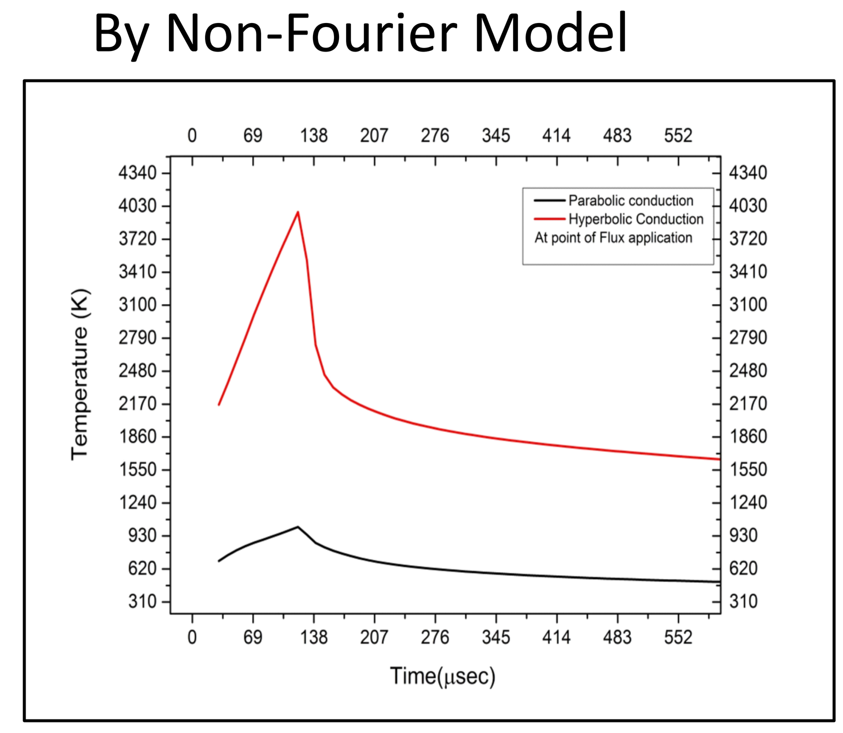

Figure 5. Comparison of Temp. rise at point of flux application

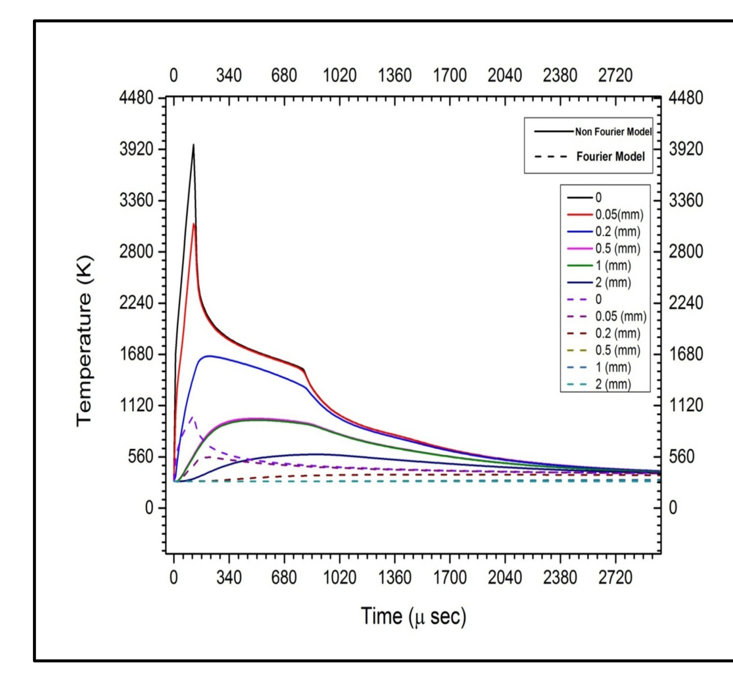

Figure 6. Comparision of Fourier and Non Fourier conduction at different points

Tool wire = Zinc Coated Brass,0.025mm diameter Workpiece Material : P-91 Voltage : 150V Current : 1.5A Cutting Speed : 0.75mm/min Flushing Pressure : 4Kg/cm^2 Tool wire diameter = 0.25mm	Distance from point of Flux Application (mm)	Experimental observation of temperature(K) using K-type thermocouples at (0.005sec)
	1 mm	303 K
	2 mm	296 K
	3 mm	295 K
	3.5 mm	294 K

Table 2. Experimental validation by EDM cutting

Conclusions Non Fourier heat conduction occurs in systems involving high flux applied in small interval of time.Transfer of heat takes place in wave form with finite speed of propagation of heat signals. This has been found in good agreement with the experimental results.

References:

1. S. Saedodin, et.al. Electrical discharge machining (EDM) by using non-Fourier heat conduction model, Contemporary Engineering Sciences 3 (2010)