Multiphysics Based Electrical Discharge Machining Simulation

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Abstract

Electric Discharge machining uses electrical spark for cutting of materials with good conductivity. Very high heat flux for a very short interval of time, in the form of spark is applied for cutting. Several researchers have developed different heat source models and tried to address the temperature distribution in the work piece and plasma channel expansion in Electric Discharge Machining [1].
However, all the previous research was based on Gaussian heat source without using the temperature dependent thermodynamic properties. The physical process involved in electric discharge and heat transfer along with Material Removal Rate (MRR) are not yet fully understood. EDM flux source is of the order of 1011W/m2.For such high flux applied in very short time interval the standard Fourier's heat conduction did not address the temperature distribution properly [4].
Non Fourier's heat transfer process is addressed in this paper, which is similar to Telegrapher's equation used in communication problems. The theory of Non Fourier heat conduction is of relativistic heat conduction [3] which claims to be the only model for heat conduction (and similar diffusion processes) which gives the flow of heat in finite speed and that is compatible with the theory of special relativity, the second law of thermodynamics, electrodynamics, and quantum mechanics, simultaneously. It gives a finite speed of heat propagation rather than infinite speed as admitted in Fourier's heat conduction, and allows for relativistic effects when heat flux transients approach that speed[3].
The temperature dependent thermodynamic properties are considered in this work, which COMSOL Multiphysics® provides an easy way to incorporate in the model. Numerical results for temperature profile and Material Removal Rate are compared with published results and experiment to assess the efficiency and systematic procedure of this novel approach to solving hyperbolic heat conduction problem in Electric Discharge Machining.
Use of COMSOL Multiphysics: The study of heat transfer in EDM includes hyperbolic heat transfer model resembling the telegrapher's equation. It is solved in COMSOL Multiphysics using 'Coefficient form of PDE 'interface. Since the work piece is completely submerged in dielectric fluid, 'Heat transfer in Fluids' interface is used as additional constraints in the hyperbolic heat transfer equation. As heat is also getting dissipated to dielectric heat transfer in fluids is also to be taken in to consideration. 'Coefficient forms of PDE' and 'Heat transfer in

fluids' interfaces are coupled so that smooth transition of heat can take place. At the interface of the domains the variable of the problem, here temperature, is defined in interchanged manner.

Reference

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[3] Ali, Y. M.; Zhang, L. C. (2005). "Relativistic heat conduction". Int. J. Heat Mass Trans. 48 (12): 2397.

[4] M. J. Maurer, H. A. Thompson, Non-Fourier Effects at High Heat Flux, Journal of Heat Transfer, 95 (1973)284-286.

Figures used in the abstract

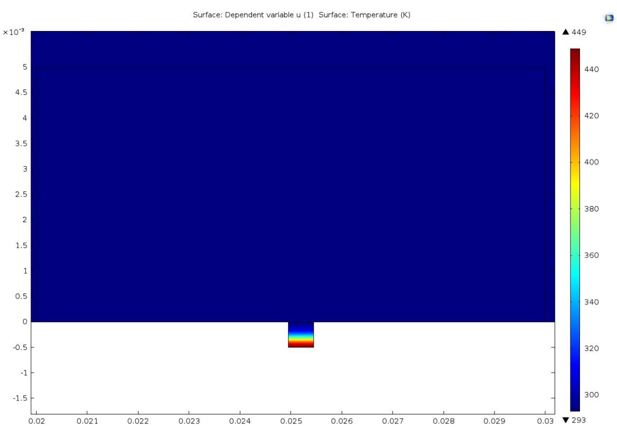

Figure 1: Temperature Distribution by Fourier Heat Transfer.

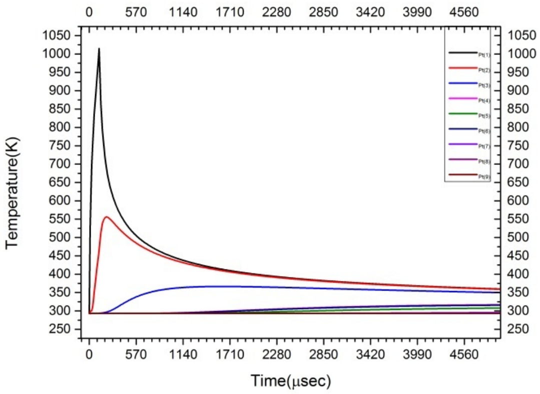

Figure 2: Temperature Variation at Different Points in Work-piece W.R.T Time(Fourier heat transfer).

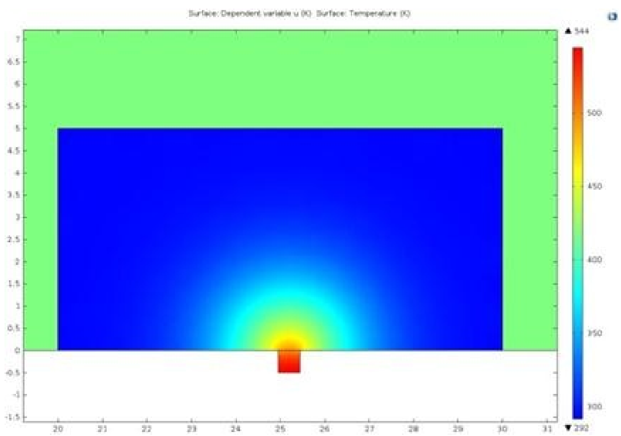

Figure 3: Temperature Distribution by Non Fourier Heat Transfer.

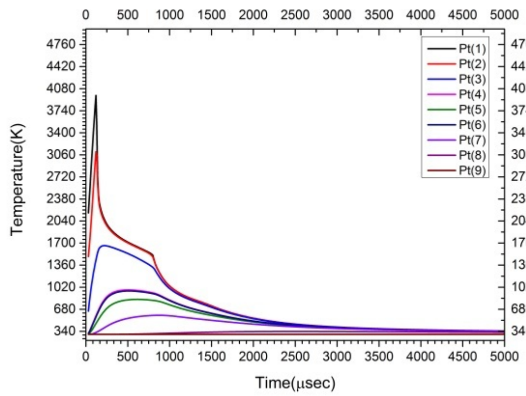

Figure 4: Temperature Variation at Different Points in Work-piece W.R.T. Time(Non Fourier heat transfer).