COMSOL
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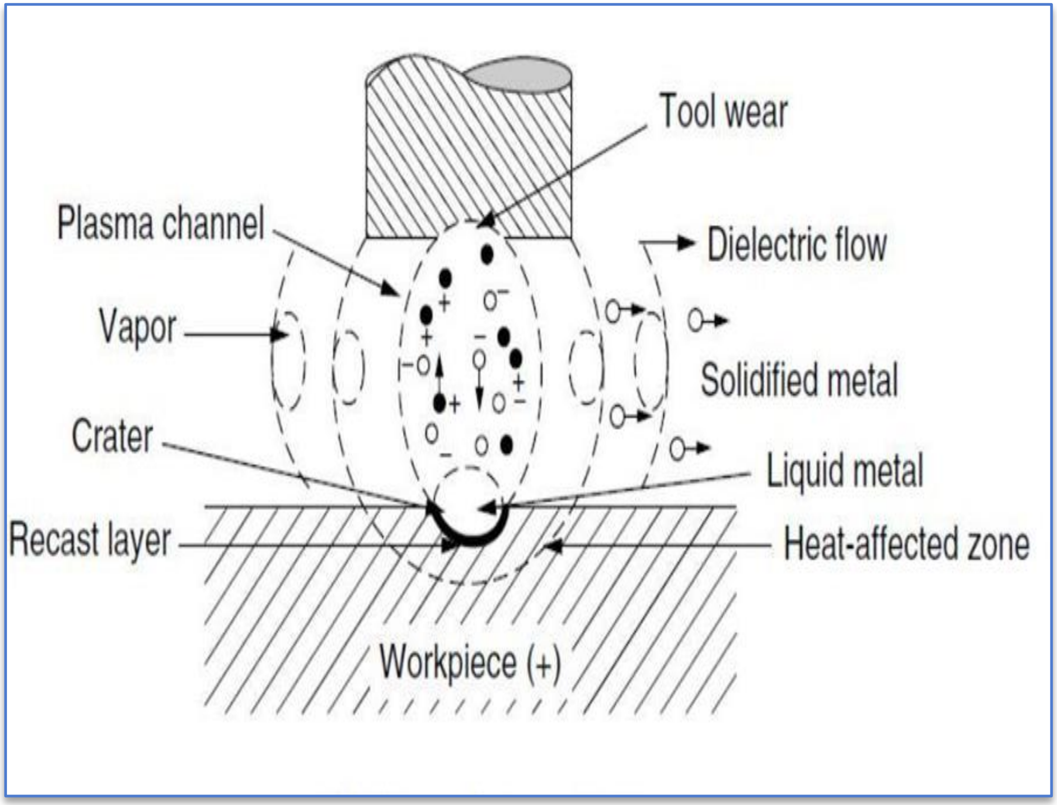
MULTIPHYSICS BASED ELECTRICAL DISCHARGE MODELING

Abhishek Mishra MSD,BARC
Dr. D.Datta HPD,BARC
S.Bhattacharya RRDPD,BARC
Dr. G.K Dey MSD,BARC
Santosh Kr. MSD,BARC

ELECTRIC DISCHARGE MACHINING

- Electric Discharge Machining (EDM) is an electro-thermal non-traditional machining Process.
- It uses electrical energy to generate electrical spark.
- The electric spark is used to remove material due to thermal energy of the spark



NUMERICAL MODELING

- COMSOL 5.0 is used in modeling the EDM process.
- Partial differential equation is used to model the heat transfer process from plasma channel to the workpiece

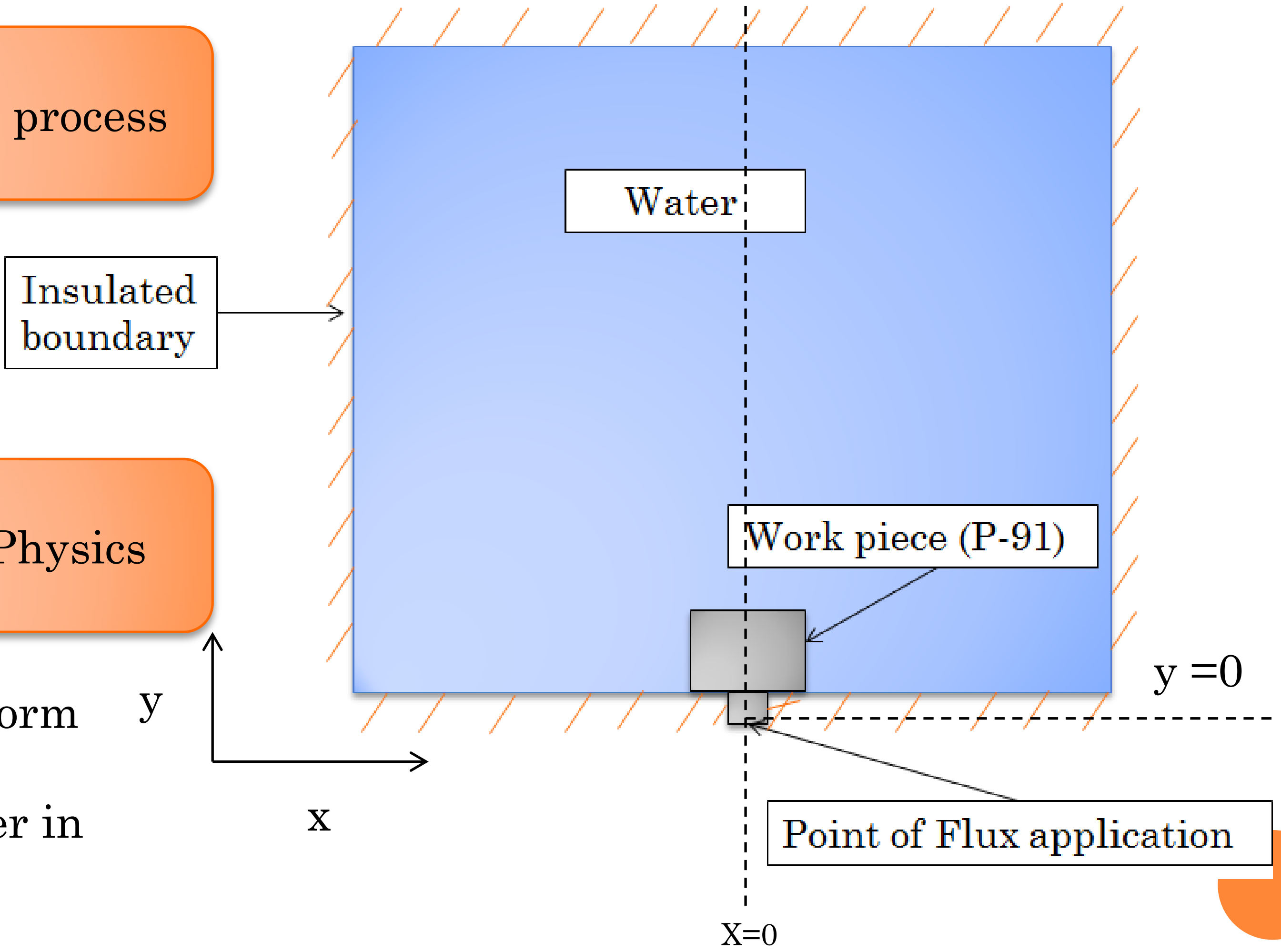
- Heat conduction from the plasma to the work piece is modeled using partial differential equations governed by Fourier and Non Fourier conduction process.
- A step pulse of flux (order 10^9 W/m^2) is applied on the workpiece to model the T_{on} and T_{off} cycle of the wire EDM
- Variable heat capacity of the work piece is taken into consideration.

FOURIER HEAT CONDUCTION MODEL

Model of EDM process

Coupling of Physics

- Coefficient form of PDE
- Heat transfer in Fluids



FOURIER HEAT CONDUCTION

Governing Equation

$$\rho Cp\frac{\partial T}{\partial t} + \rho C\, u.\nabla T = \nabla.(k\nabla T) + Q$$

Boundary conditions

$k\frac{\partial T}{\partial y}(x, 0, t) = q$

$k\frac{\partial T}{\partial x} + h[T - T_\infty] = 0$ at all boundaries in contact of water

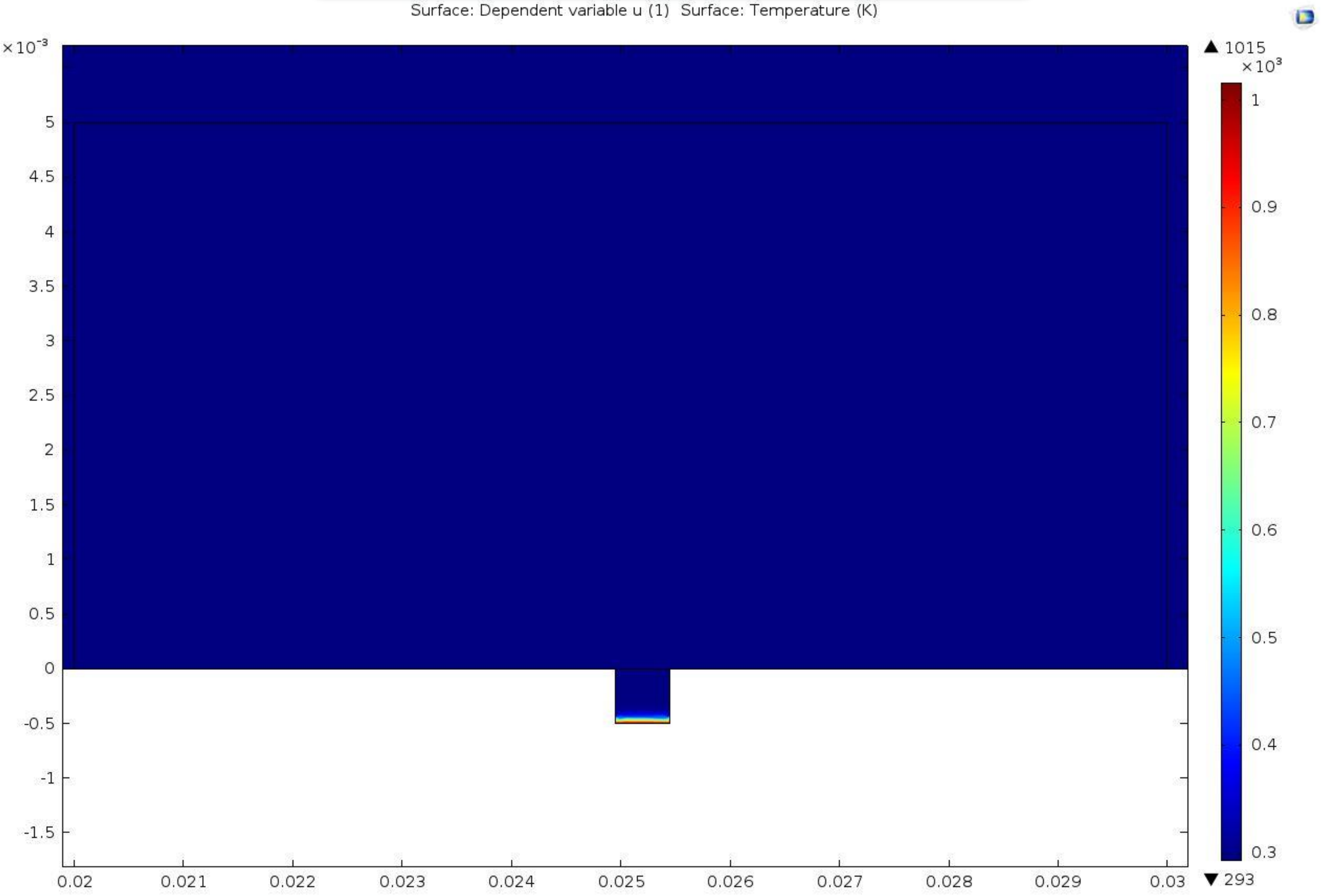
Initial condition

$$T(x, y, 0) = T_\infty$$

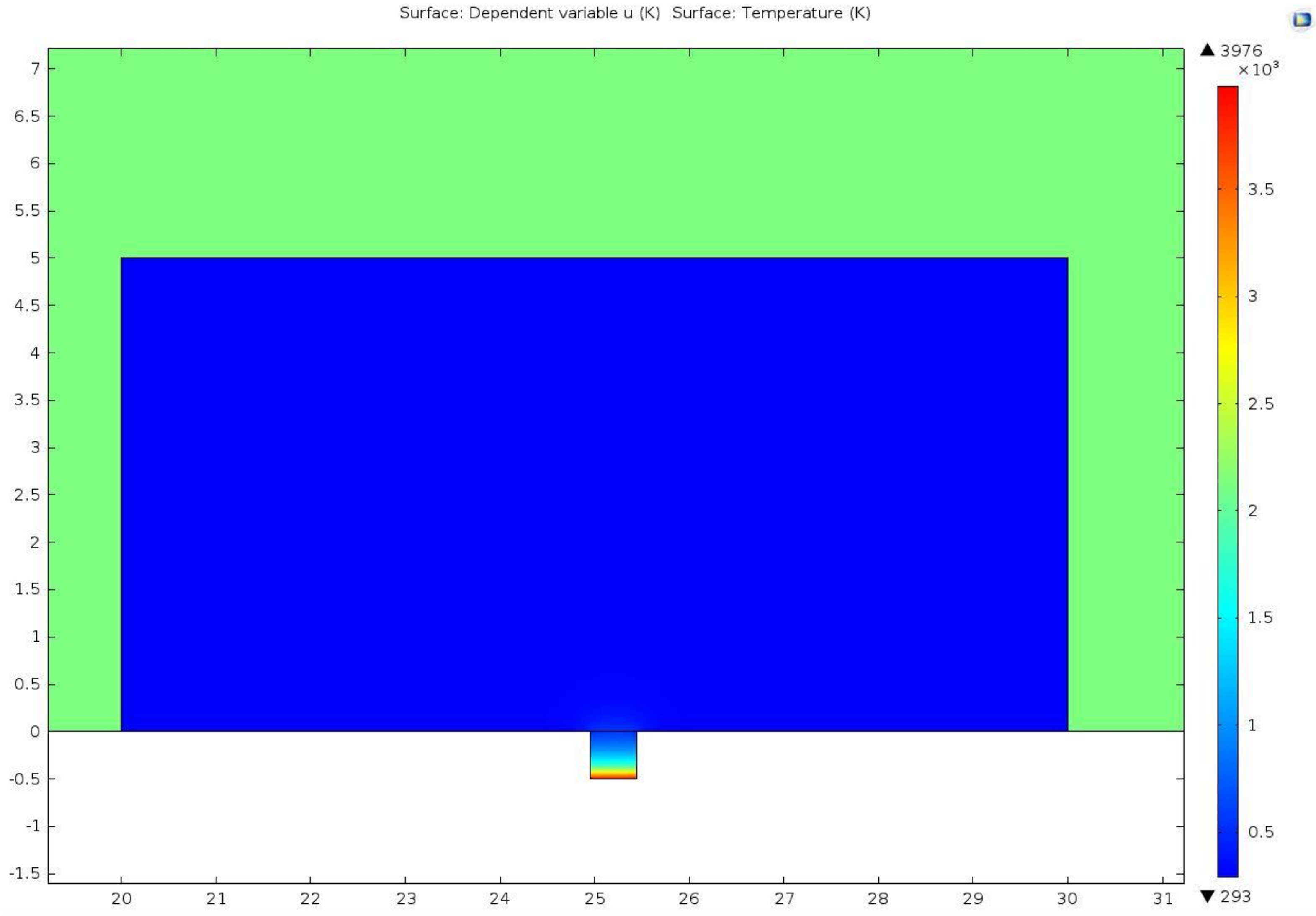
Where ρ, C_p, q, T , t ,Q, k, u , h are density, heat capacity, heat flux(pulsed),Temperature ,time, Internal energy, Thermal conductivity, velocity vector ,heat transfer coefficient respectively

T_∞= 273.16K

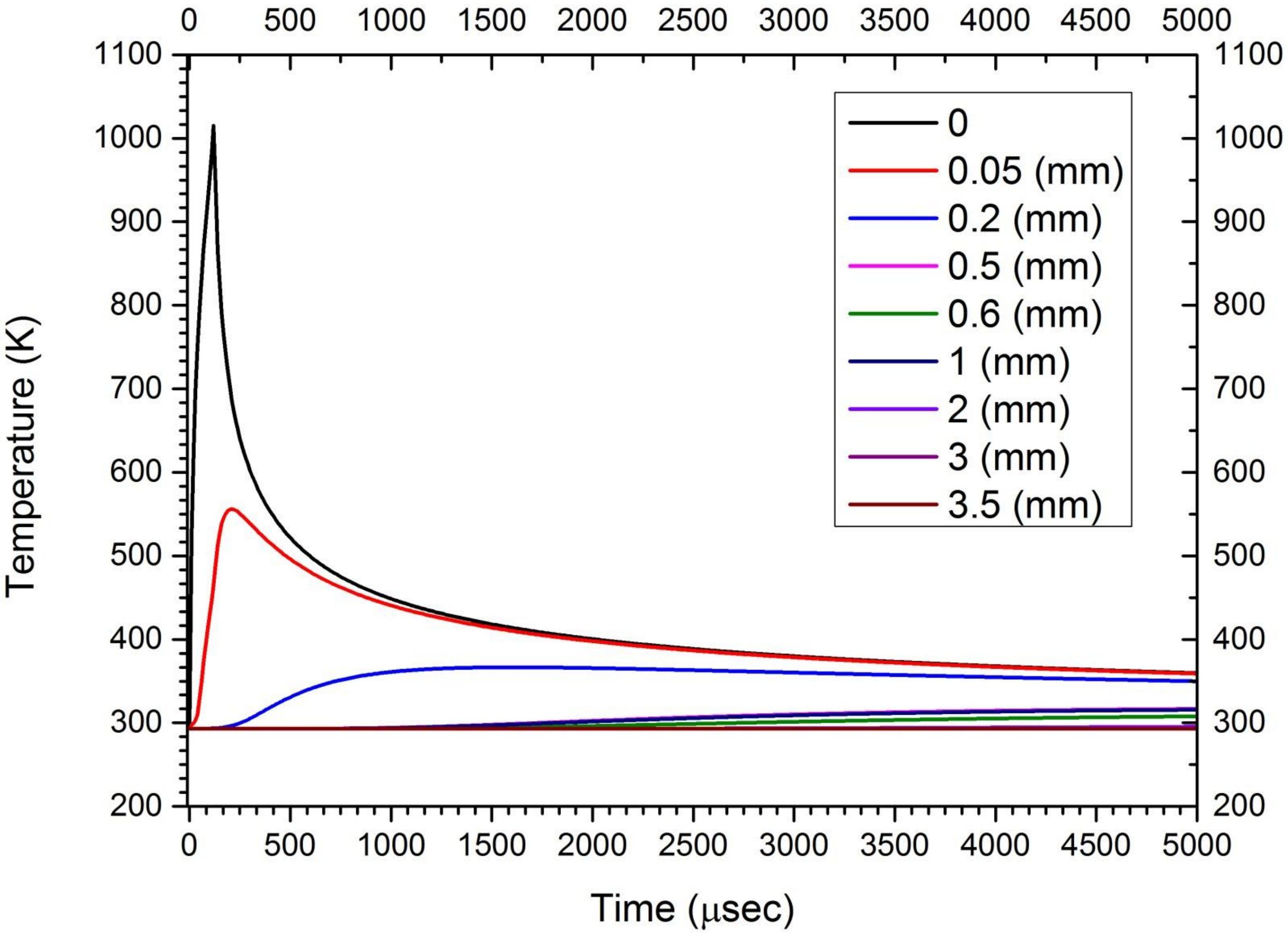
Temperature distribution on work piece surface at 130 μsec (Fourier model)



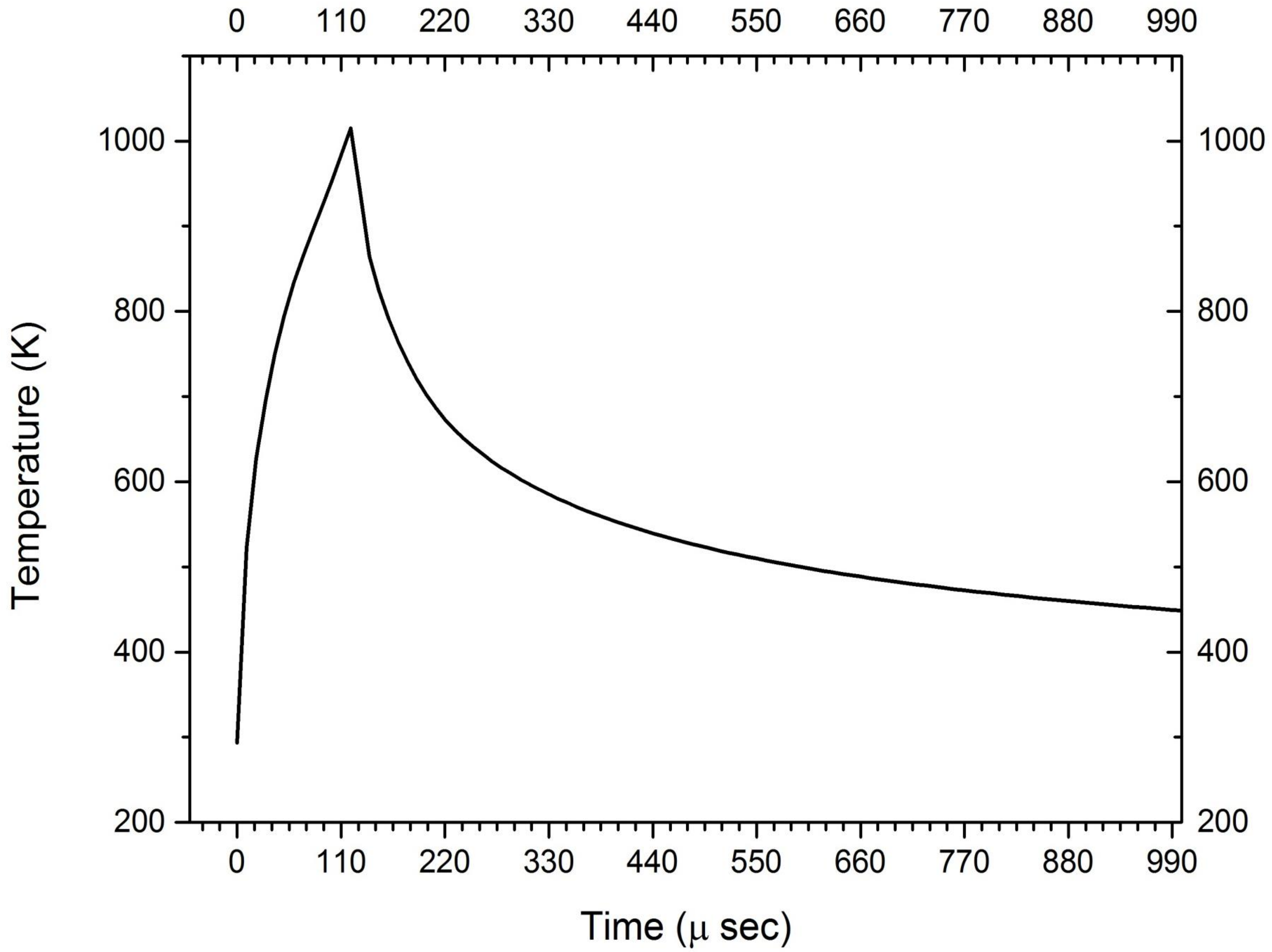
Temperature distribution on work piece surface at 130 μsec (Non Fourier Model)



Spatial Temperature variation on the workpiece (Fourier model)



Temperature variation at the point of Flux application



NON FOURIER HEAT CONDUCTION

Governing Equation

$$\frac{\tau}{\alpha}\frac{\partial^2 T}{\partial t_2} + \frac{1}{\alpha}\frac{\partial T}{\partial t} = \frac{\partial^2 T}{\partial x_2}$$

Boundary conditions

$$k\frac{\partial T}{\partial y}(x, 0, t\,) = q$$

$$k\frac{\partial T}{\partial x} + h[T - T_\infty] = 0$$

at all boundaries in contact of water

Initial condition

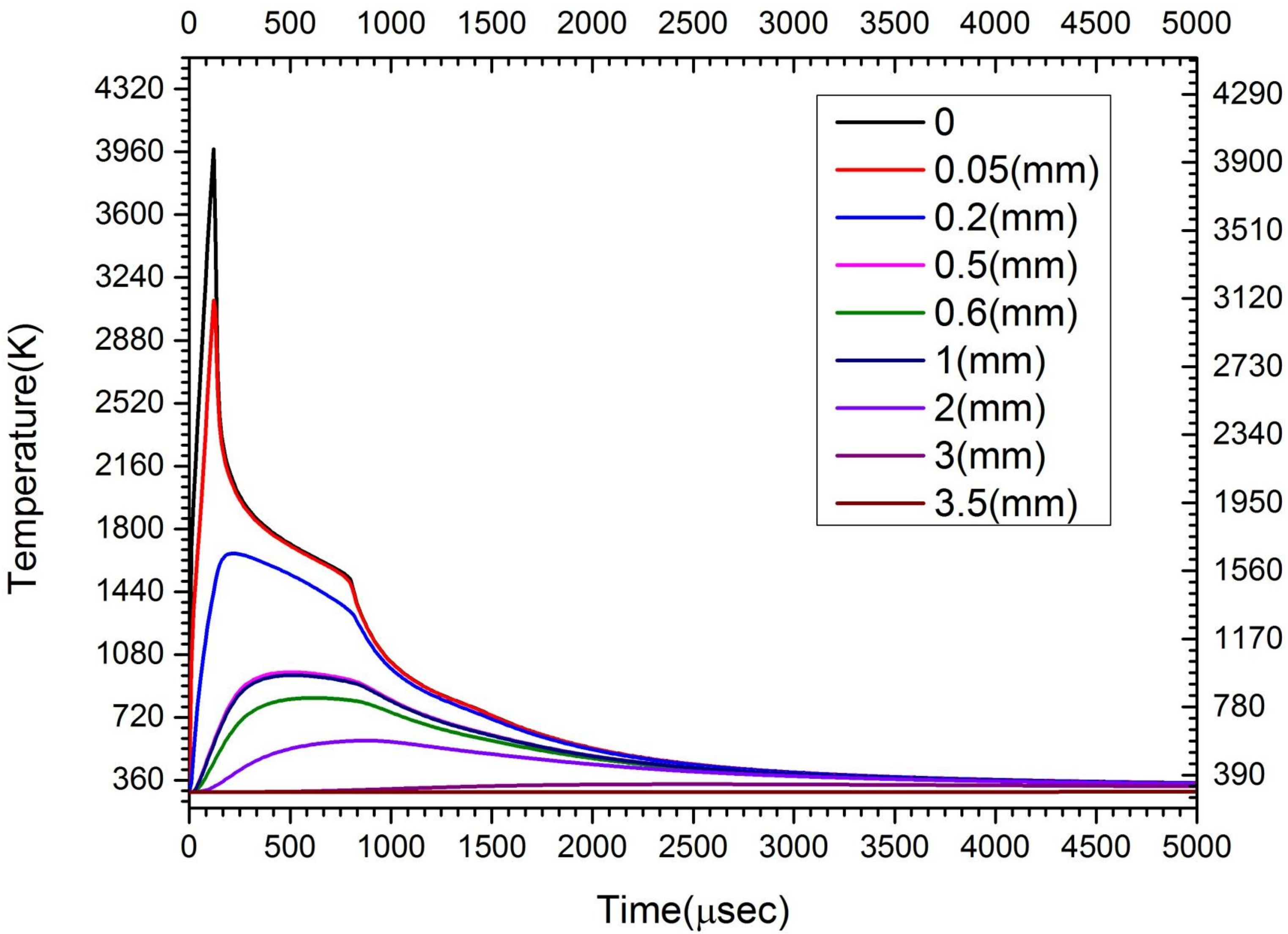
$$T(x, y, 0) = T_\infty$$

$$\frac{\partial T}{\partial t}(x, y, 0) = 0$$

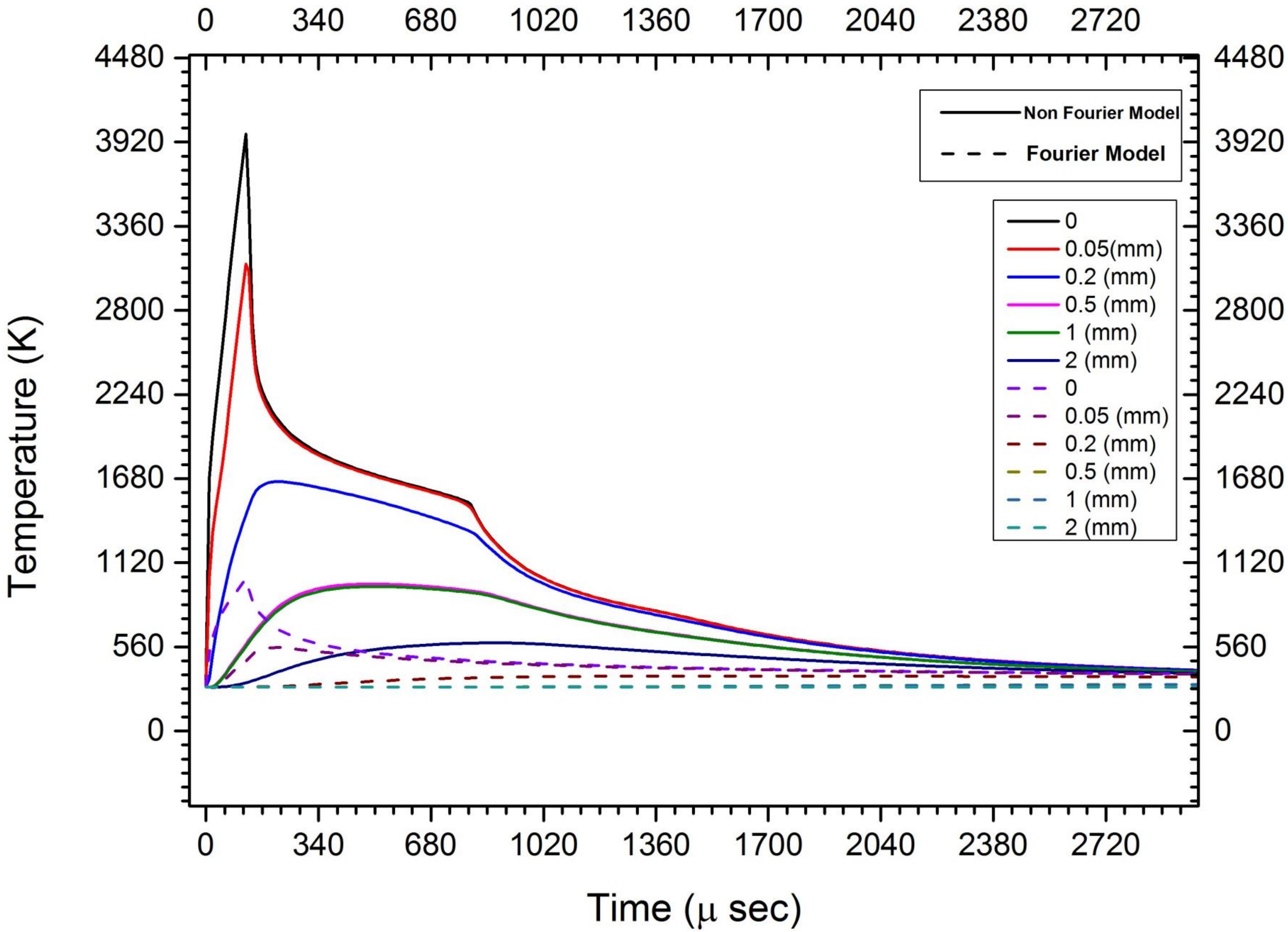
Where τ, α, q, h , T, t are Thermal relaxation time, thermal diffusivity flux , heat transfer coefficient , temperature ,time respectively

$T_\infty = 273.16\text{K}$

Spatial Temperature variation on the workpiece (Non-Fourier model)



Comparison of Fourier and Non Fourier Model Temperature Distribution

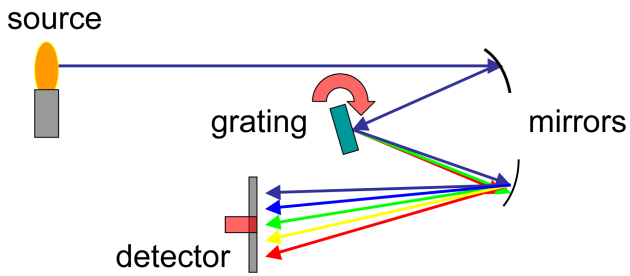


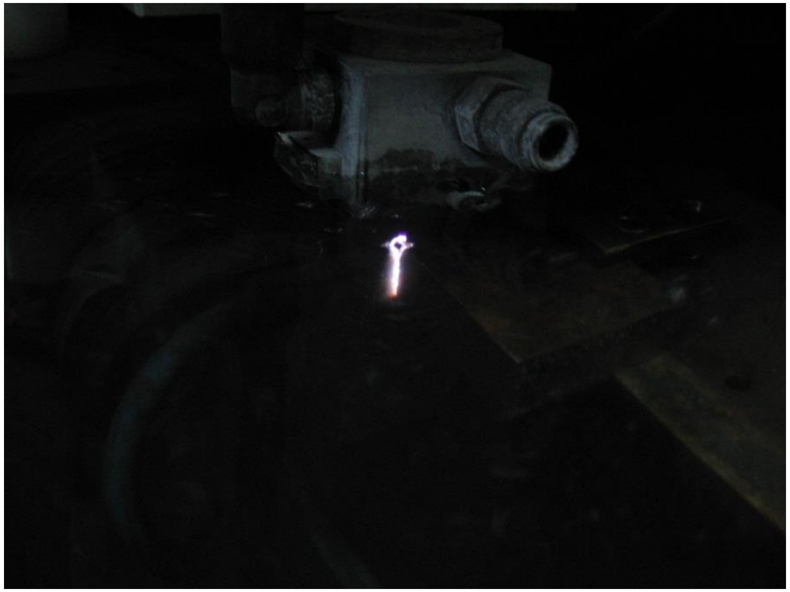
EXPERIMENTAL OBSERVATIONS

- The temperature is measured by K-Type thermocouples.(Chromel-Alumel)
- Eurotherm recorder is used to record the output of thermocouples.

Plasma temperature measurement by Optical Emission Spectroscopy

Principle

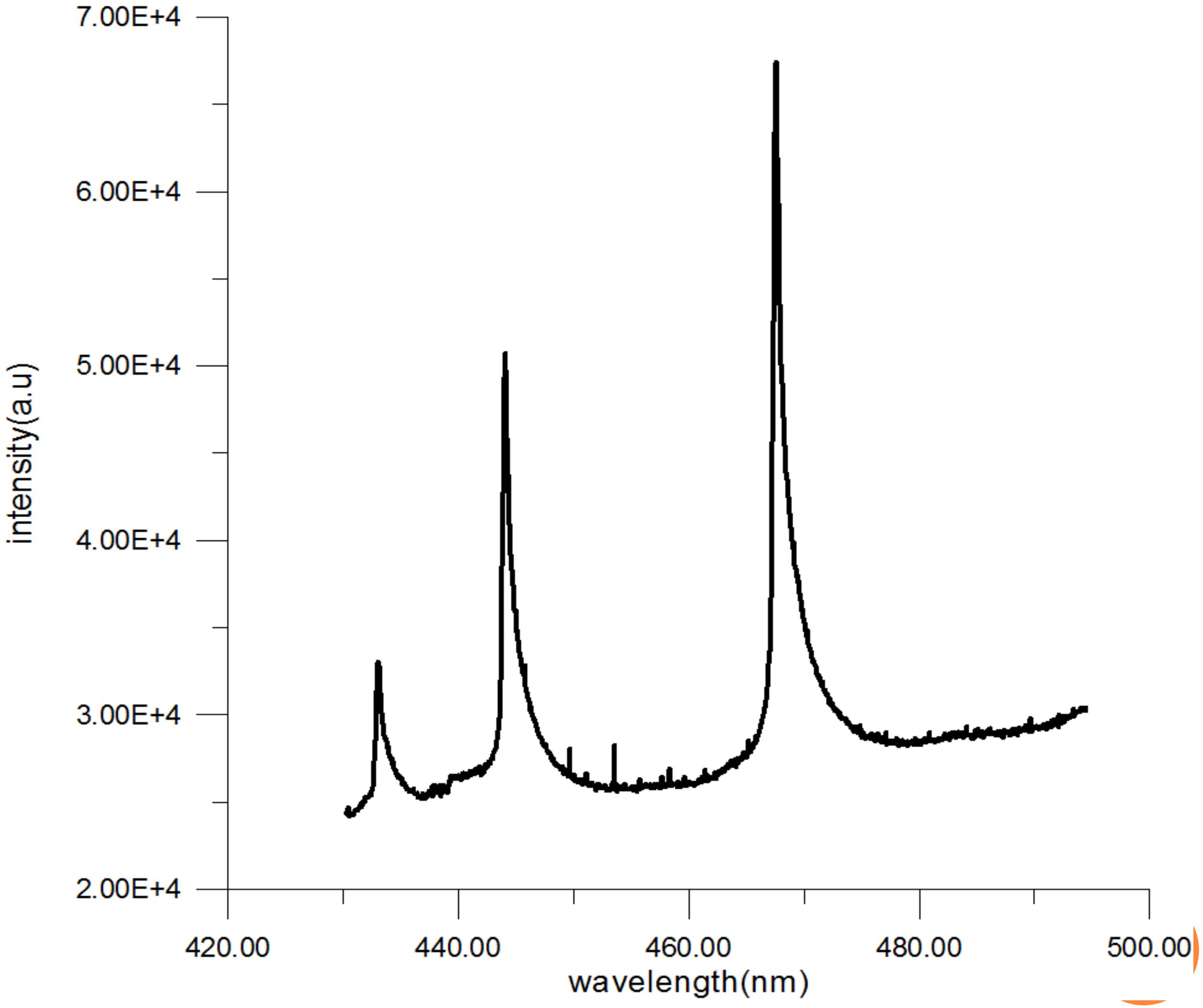




Results of Optical Emission Spectroscopy on P-91

Spectra of Wire EDM Plasma Channel With P-91 cutting

A standard method of spectroscopy 'Line Pair Method' is used to estimate the temperature of the Plasma



Plasma Temperature Estimation from results of Spectroscopy

$$T = \frac{E_m - E_i}{k}(ln\frac{A_{mn}.g_m.\lambda_i.I_i}{A_{ij}.g_i.\lambda_m I_m})^{-1}$$

- Where λ_i is the wavelength of the light emitted from the plasma species due to transition from energy level i to j.
- I_i is the radiant intensity of emitted light of wavelengthλ_i
- g_i is the statistical weight of energy level i

Temperature at different point on the workpiece

Tool wire = Zinc coated Brass
Work piece material = P-91
Voltage = 150V
Current = 1.5 A
Cutting speed =0.75mm/min
Flushing Pressure=4 kg/cm^2
Tool wire Diameter = 0.25mm

Distance from the line of Cutting (mm)	Temperature (K) at 0.005sec
1	303
2	296
3	295
3.5	294

Thank you