SIMULATION AND EXPERIMENTAL VALIDATION FOR BETA HEAT TREATMENT OF URANIUM ROD BY DIRECT HEATING METHOD

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Outline

- Introduction
- Current method and drawbacks
- Direct heating method
- Mathematical analysis
- Numerical solution
- Experimental validation
- Conclusion
- References

Introduction

Uranium Phases

α:- 20 to 665 DegC

β:-665 to 776 DegC

γ:-776 to 1132 DegC

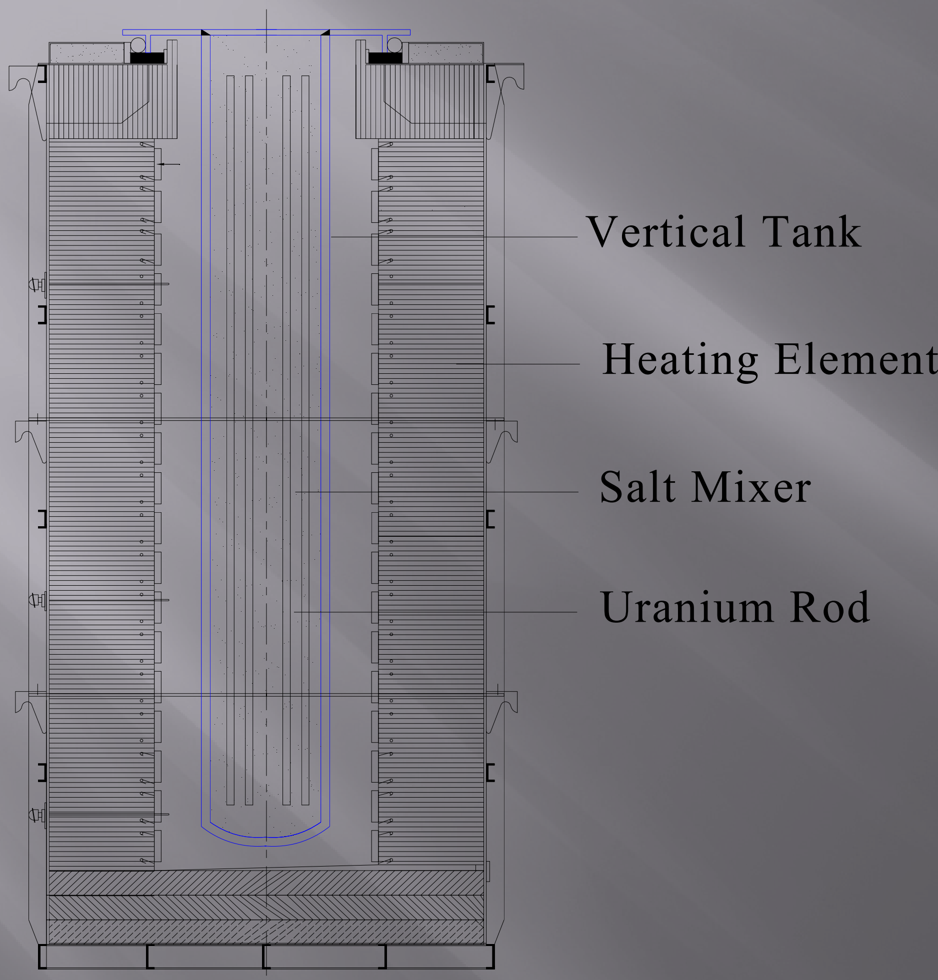
β heat treatment

Ur rods are heated upto 740 deg C and quench into water tank.

Purpose

To randomize the grains developed during rolling or extrusion.

Current method and drawbacks



SALT BATH FURNACE

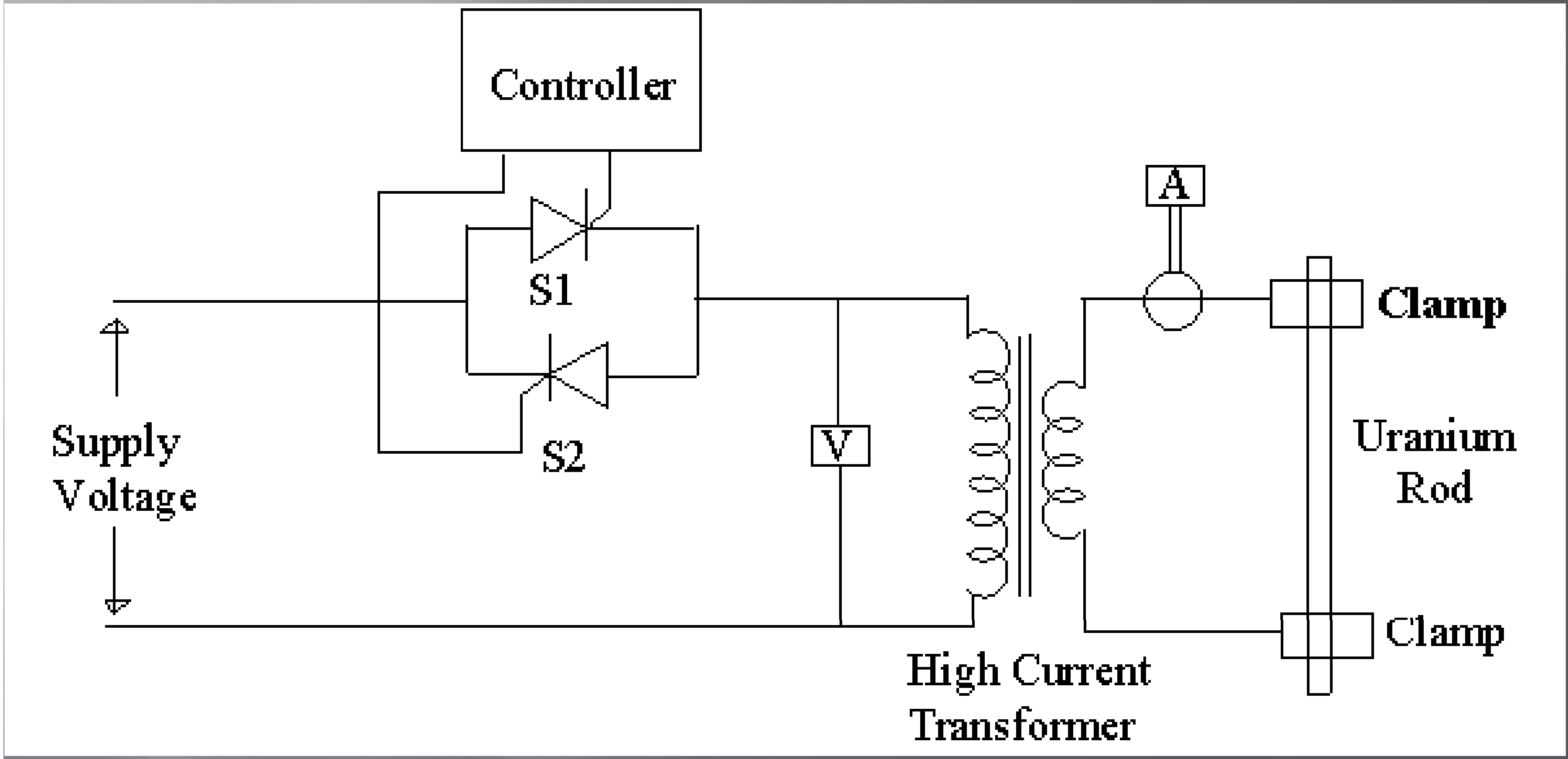
•1.5 T Slat mixture

•(barium chloride-55 %, Sodium chlorides -25 %, potassium chloride- 20 %)

Drawbacks :-

- Low efficiency
- manual Handling of molten salt (> 600 deg C)
- Batch wise production.

Direct heating method



Mathematical analysis

- Coupled field problem.

  Electric field

  Heat transfer
- Electric field

  Laplace equation $\nabla.(\sigma(T)\nabla V) = 0$

  Heat source term $Q = \sigma(T)(\nabla V)^2$
- Heat transfer

$$\nabla.k\nabla T + Q = \rho c \frac{\partial T}{\partial t}$$

Phase change analysis

- Effective heat capacity
- Enthalpy method
- Heat Source method

$$\rho C_{eff}(T)\frac{\partial T}{\partial t} = \nabla(k\nabla T)$$

$$C_{eff} = \rho c_{\alpha} \qquad (T < T_{\alpha})$$

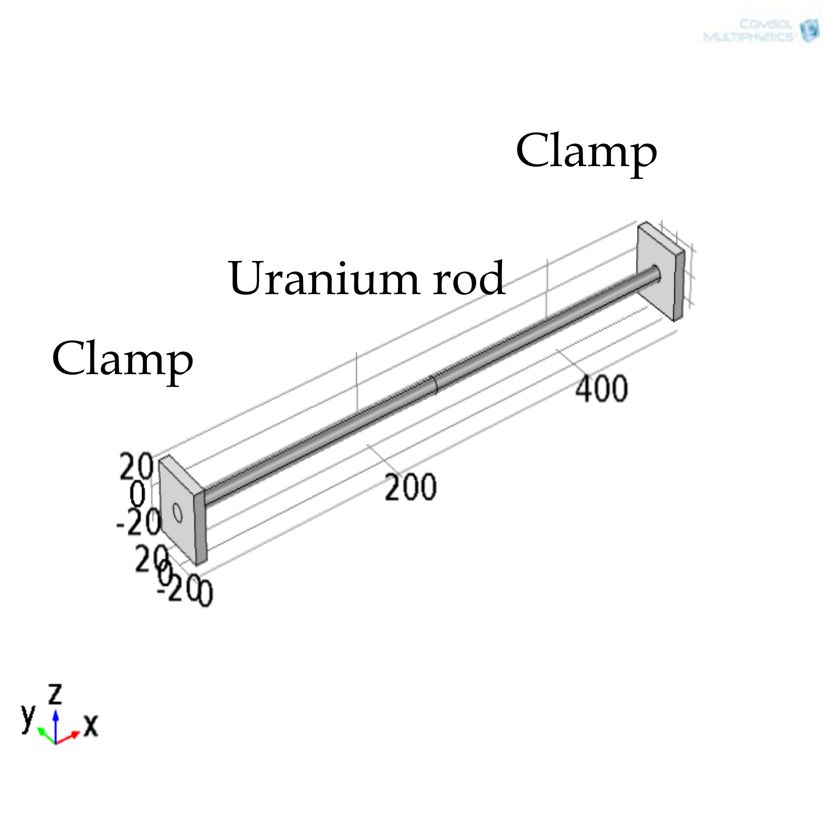
$$C_{eff} = \rho c_{\alpha-\beta} + \frac{L}{T_{\beta}-T_{\alpha}} \qquad (T_{\alpha} \le T \le T_{\beta})$$

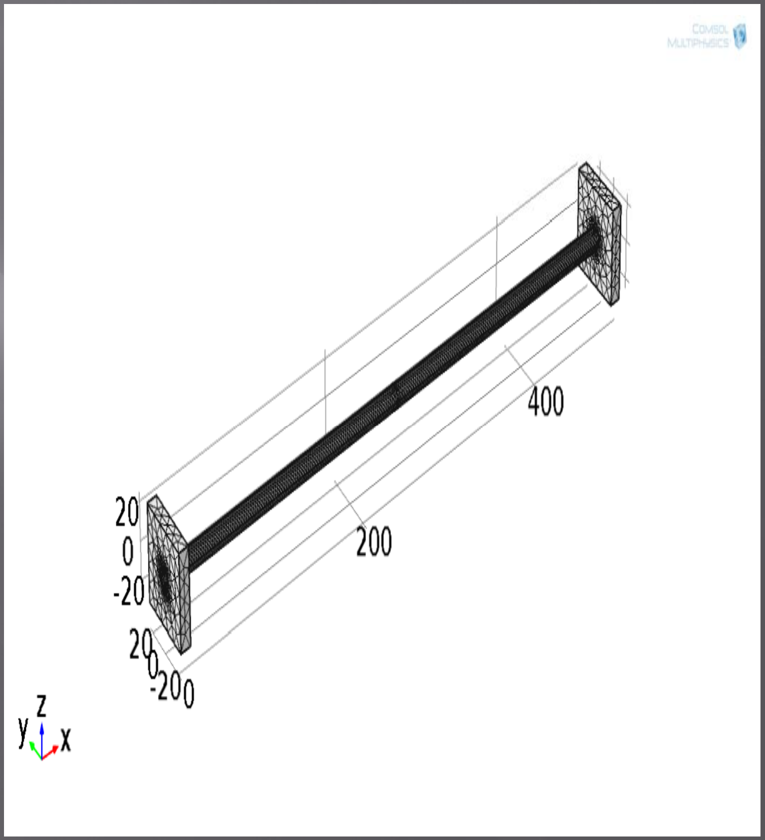
$$C_{eff} = \rho c_{\beta} \qquad (T > T_{\beta})$$

COMSOL Multiphysics software

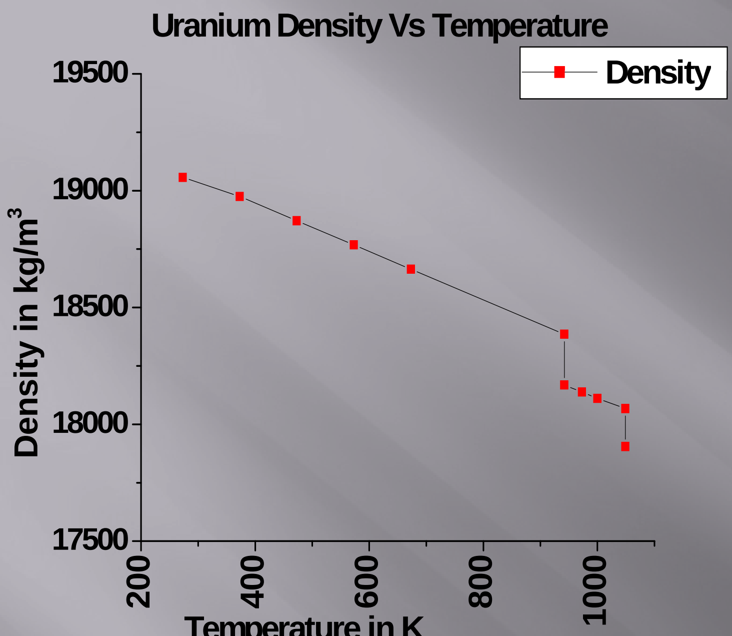
- Joule heating module.
- FEM based multiphysics software.
- Easy programming and analysis
- Phase change analysis is done by effective heat capacity method

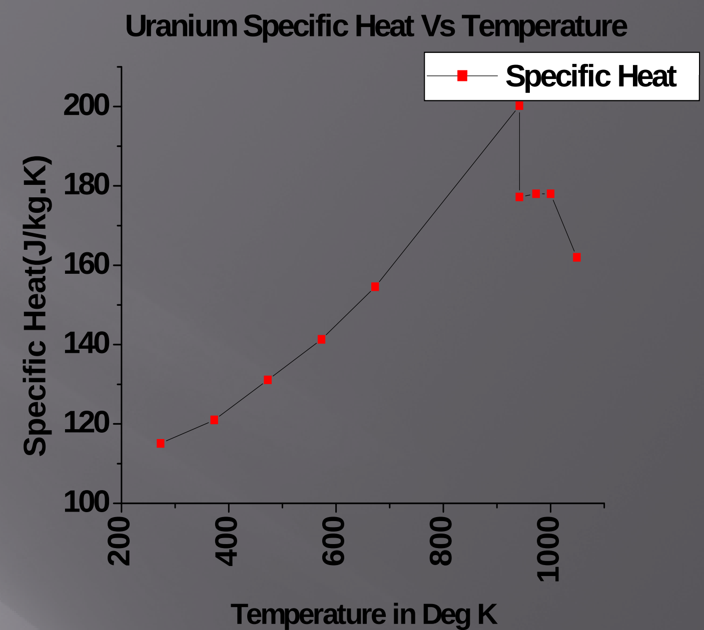
Geometry and meshing

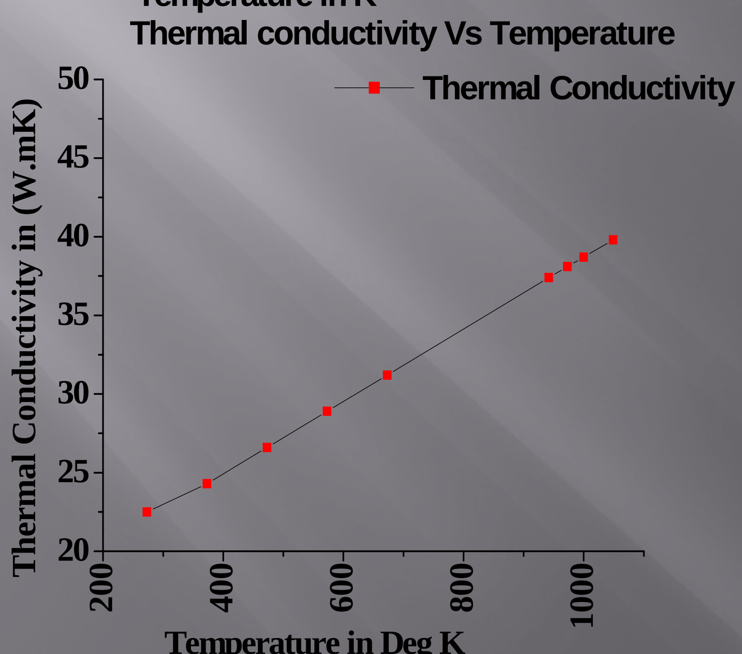


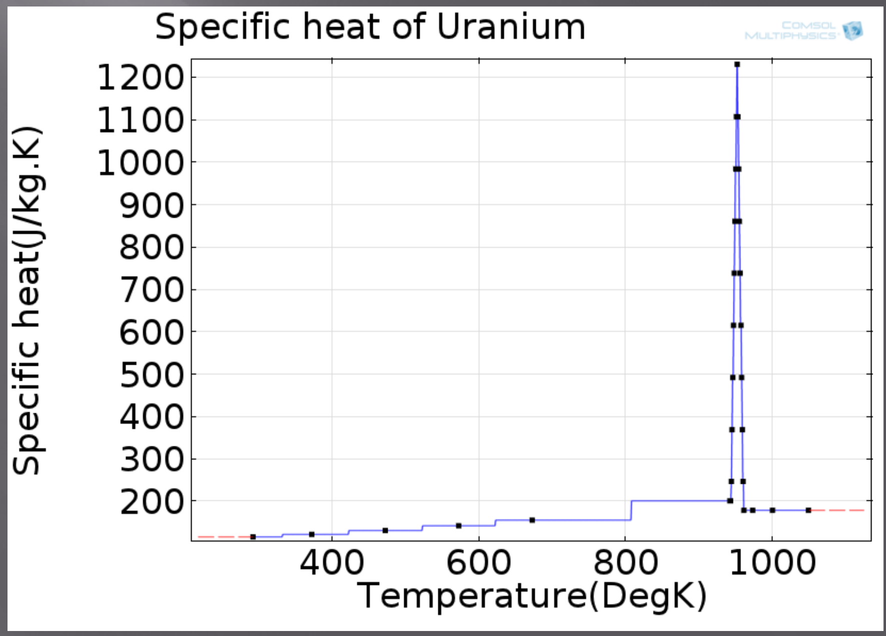


Material properties





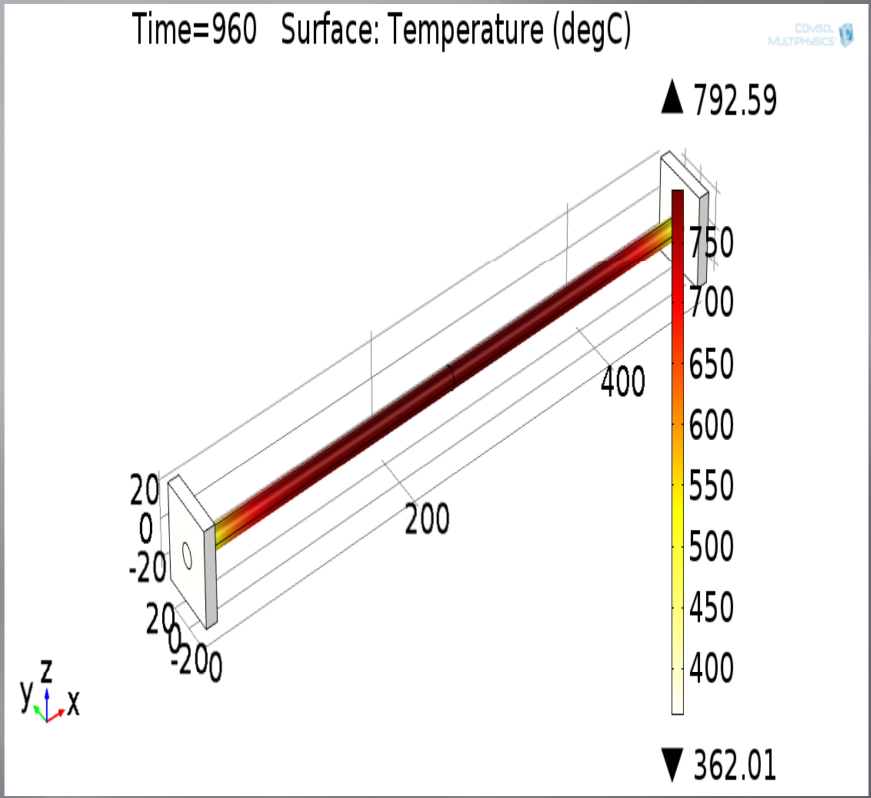


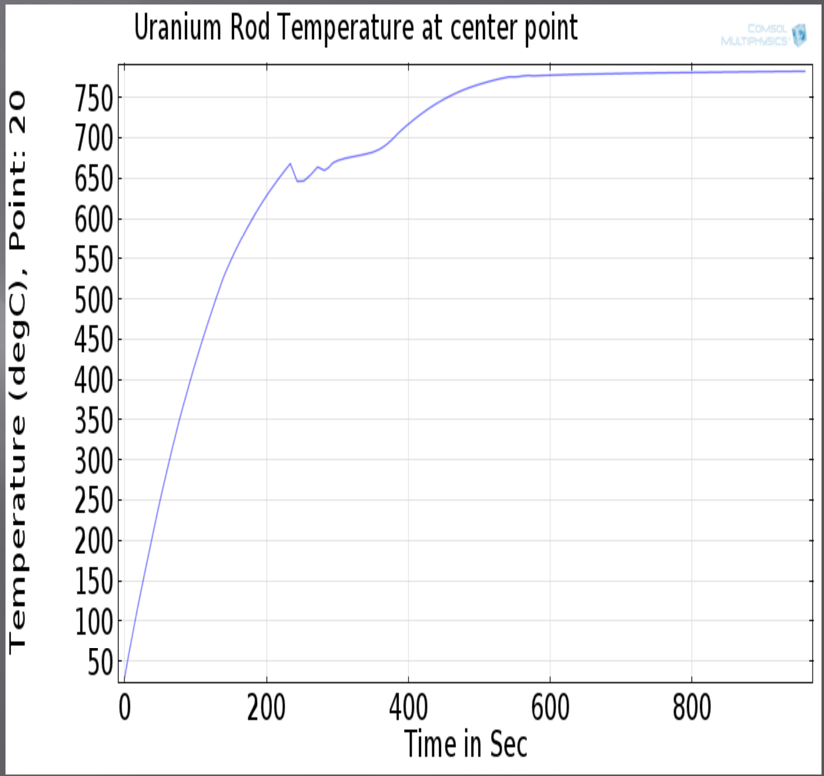


Boundary condition and forcing function

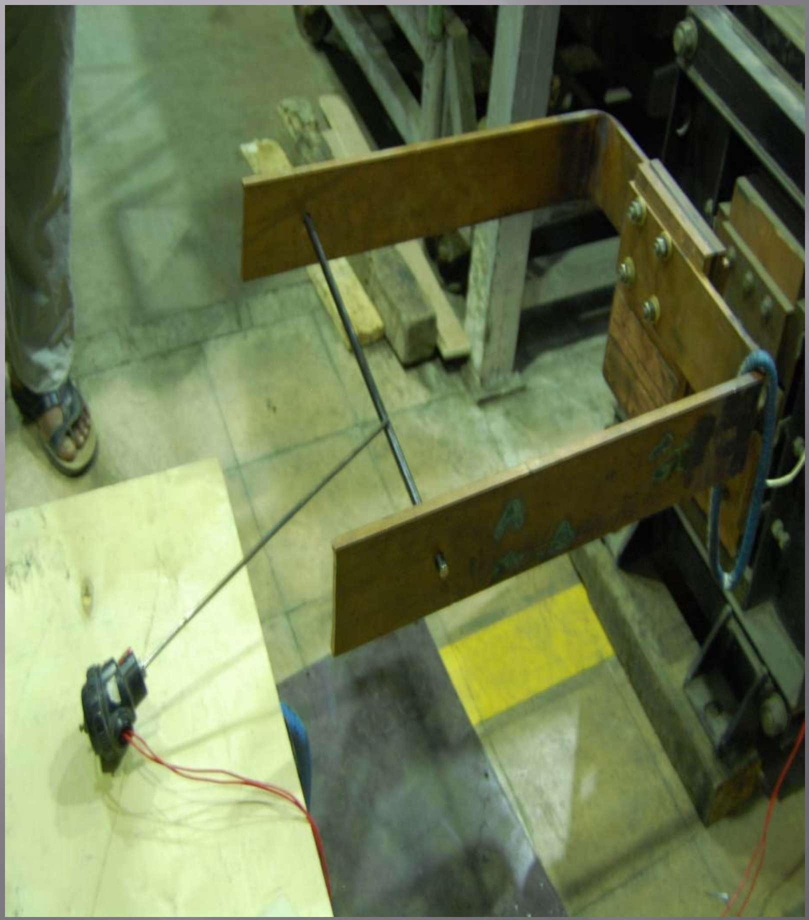
Sr no	Description	Values
1	Convection coefficient (h)	5
2	Emissivity(ε)	0.4
3	Initial temperature (Deg K)	304
4	Current	0- 60 Sec:-521 A 60- 960Sec:- 827 A

Simulation Results





Experiment Results

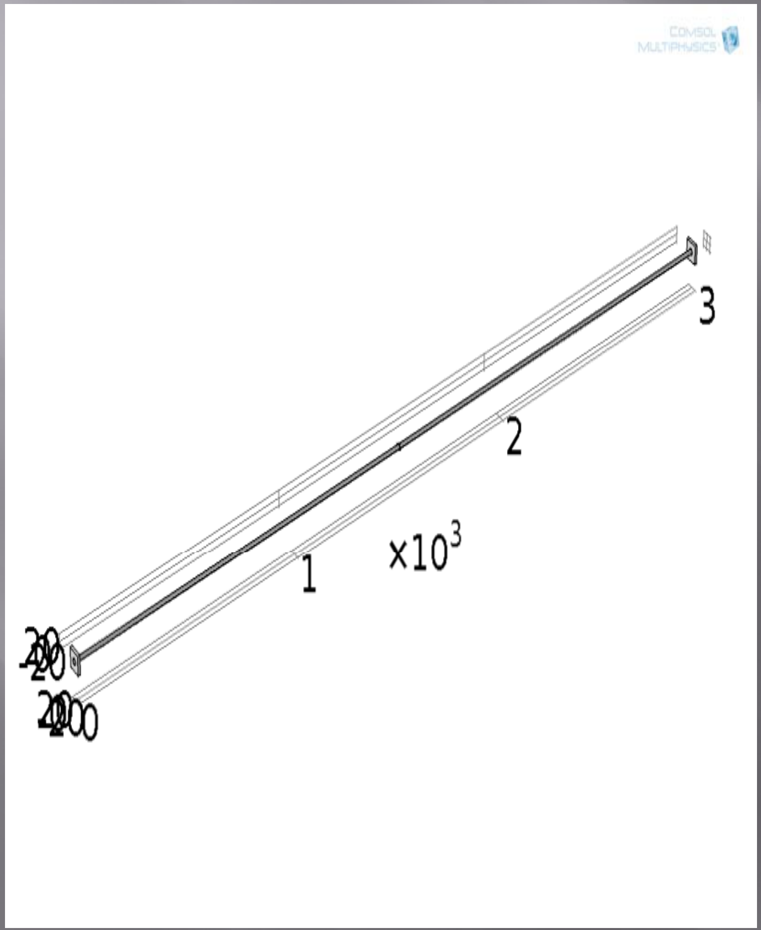


Simulation and Experiment Results

Sr no	Uranium rod 6mm dia X 500 mm L	Uranium rod 50mm dia X 1200 mm L
Simulation results	792 DegC	670 Deg C
Experiment results	810 Deg C	681 Deg C

Simulation on Direct heating of Uranium rod (16 mm dia X3000mm L)

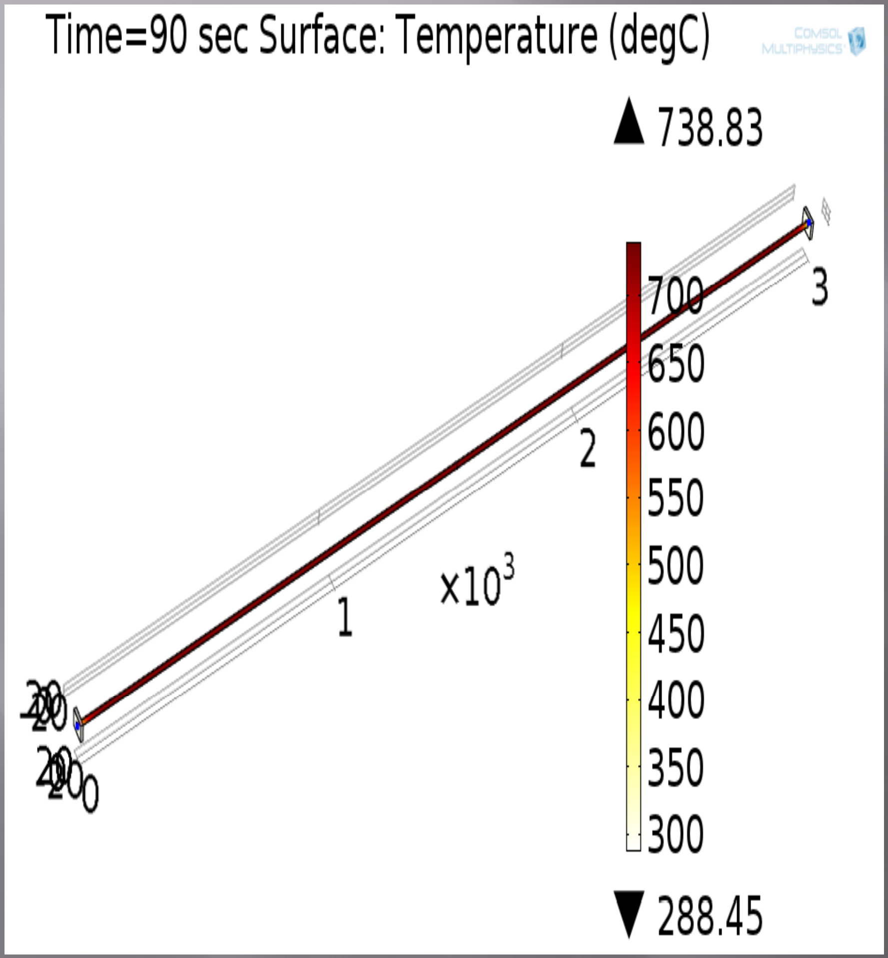
- Geometry

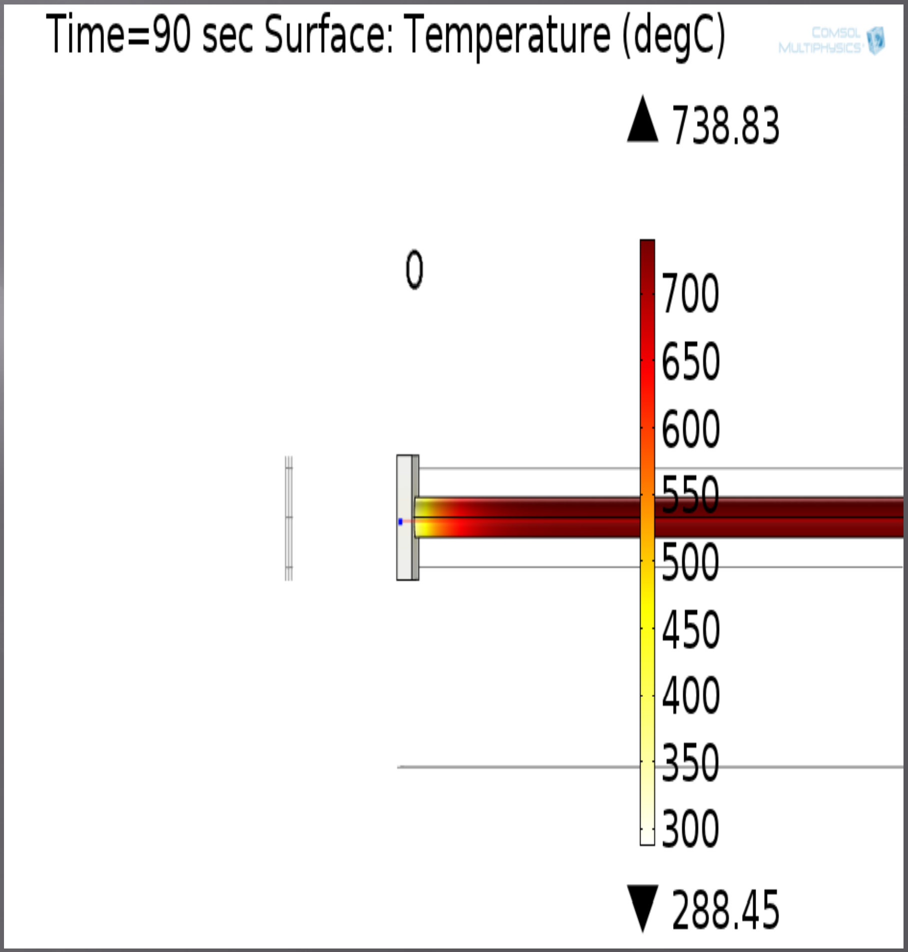


Boundary Condition

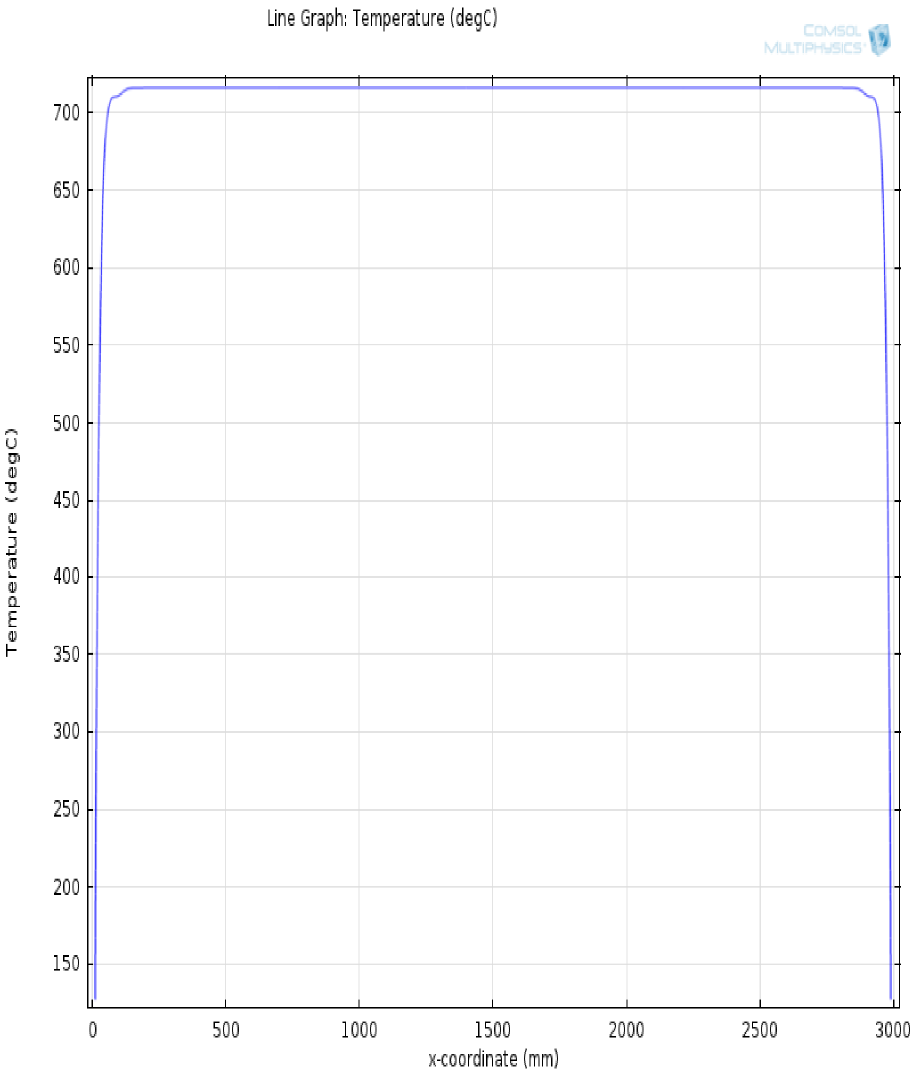
Sr No	Boundary conditions and forcing function	Value
1	Electrical Current	1500 A
2	Heat Transfer Surface to space radiation coefficient Convection heat transfer coefficient	 0.4 5

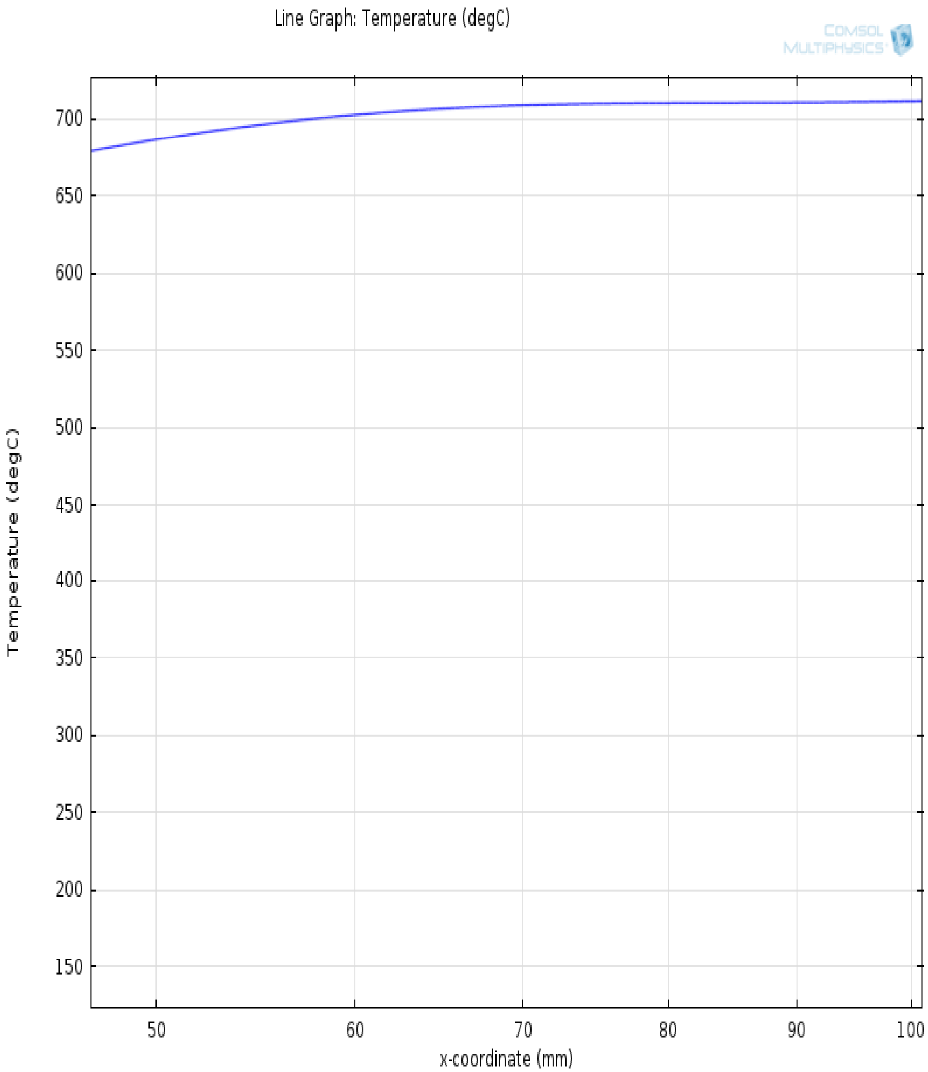
Temperature Profile on Uranium rod





Result


Line Graph: Temperature (degC)
COMSOL MULTIPHYSICS
Temperature (degC)
700
650
600
550
500
450
400
350
300
250
200
150
0
500
1000
1500
2000
2500
3000
x-coordinate (mm)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350
300
250
200
150
50
60
70
80
90
100
x-coordinate (mm)

Conclusion

- Direct heating of Uranium rod is possible.
- Simulation results were very close to experiment results.
- Direct heating is more efficient compare to indirect heating.
- No batch wise production is required.

References

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Thank you