<u>Part-3 Report</u>

Parameters used:

$Fuel\ radius, R_f = 0.5\ cm$

$Thermal\ conductivity\ of\ fuel, k_f = 0.035 \frac{watt}{cm}.K$

$Gap\ thickness, t_g = 0.005\ cm$

$Thermal\ conductivity\ of\ gap, k_g = 0.001514 \frac{watt}{cm}.K$

$Cladding\ thickness, t_c = 0.1\ cm$

$Thermal\ conductivity\ of\ cladding, k_c = 0.226 \frac{watt}{cm}.K$

$Linear\ heat\ rate, LHR = 350 \frac{watt}{cm}$

$Cladding\ outer\ temperature, T_{co} = 550\ K$

Cladding inner temperature, T_{ci} :

$$T_{ci} - T_{co} = \frac{LHR}{2\pi R_f} \times \frac{t_c}{k_c}$$

$$or, T_{ci} = \left(\frac{LHR}{2\pi R_f} \times \frac{t_c}{k_c}\right) + T_{co}$$

$$T_{ci} = 599.3\ K$$

Fuel surface temperature, T_f:

$$T_f - T_{ci} = \frac{LHR}{2\pi R_f} \times \frac{t_g}{k_g}$$

$T_f = 967.2\ K$

Fuel center-line temperature, T_o:

$$T_o - T_f = \frac{QR^2}{4\pi k_f} = \frac{LHR}{4\pi k_f}$$

$T_o = 1762.97\ K$

Result and Discussion from Part-2

The results are plotted and added below. As the maximum fission rate occurs at the center of the fuel and mid length of the fuel approximately, the nature of the curve obtained from the plot can be verified as well.

Fig. 1-3 represents linear vector line temperature profile at the fuel height of 25 cm, 50 cm and 100 cm. It can be seen that as coolant is moving upward through the rod the fuel temperature profile through the road is maximum toward the center and minimum toward the upper and lower part of the fuel rod. In order to have a clear idea, a temperature profile for fuel centerline is plotted axially taking points at 0, 25, 50, 75 and 100 cm respectively which clearly shows the cosine nature of the axial fuel rod temperature.

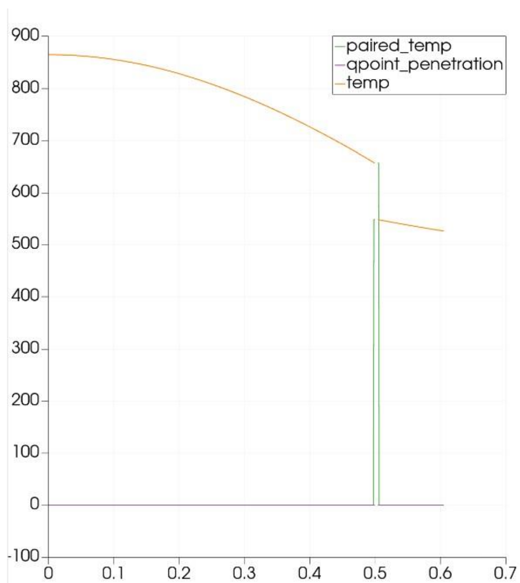

Fig. 1: Fuel radial temperature profile at 25 cm height

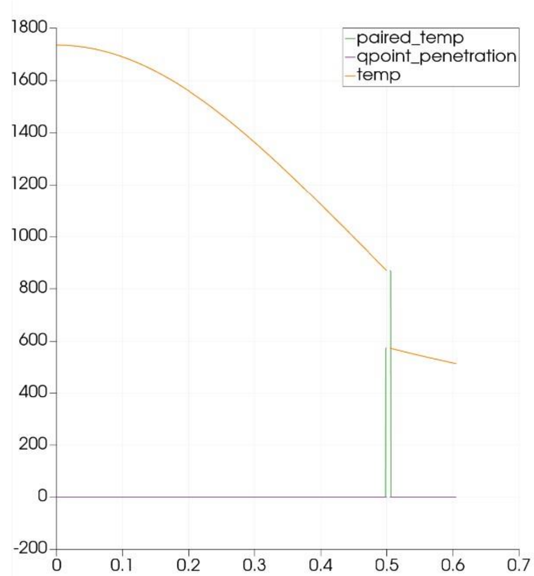

Fig. 2: Fuel radial temperature profile at 50 cm height

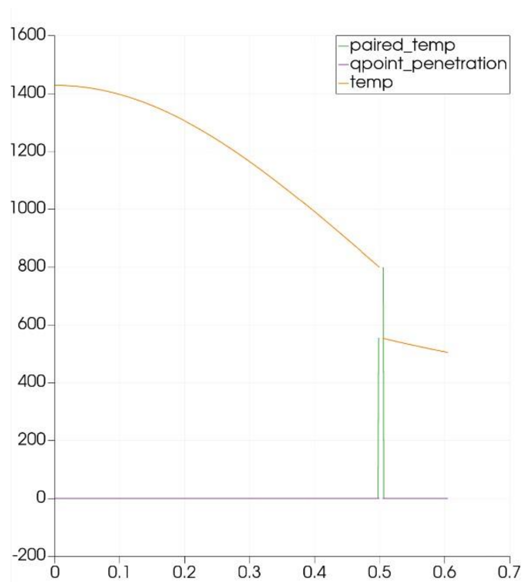

Fig. 3: Fuel radial temperature profile at 100 cm height

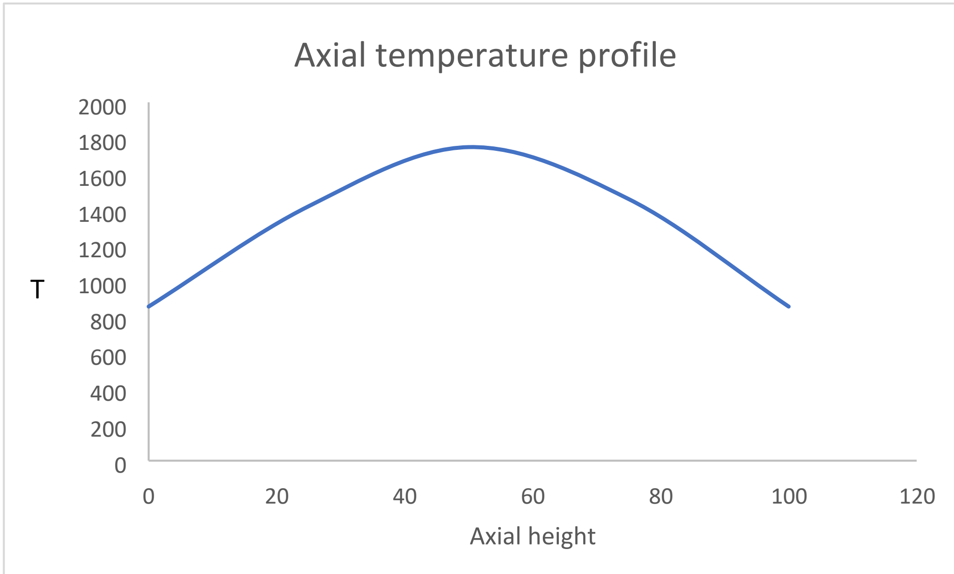

Fig. 4: Axial cosine nature of the fuel centerline temperature profile

Conclusion: The final peak centerline temperature was found at 51 cm height of the fuel rod which is close to the ideal case. Also, the cosine nature of the fuel centerline temperature is not uniform at the both sides as there may be some problem with the convergence of the meshing of the rod. The geometry is meshed as 300 X 300 in both directions but fuel height and width are not the same. It would be very practical to compare many more meshing size combinations to find the optimum result which will give a smother cosine curve. Some considerable points that can be considered are stated below:

1. Changing the meshing size can be done.
2. Increasing or decreasing the coolant flow is also observable.
3. Built in empirical co-relation was used for the gap region which had no mesh. This empirical relation may also had some adverse effect on the analysis.

Result and Discussion- Part 3

There are two parts to part three of the project. One where we used a fixed linear heat rate value another part where linear heat rate is used as a function of temperature. Figure – 5 to 7 shows plots taken from constant linear heat rate value. From figure-5, it can be seen that the fuel centerline temperature shows uniform nature keeping the central height at middle which is ideal case. Compared to project part – 2, the curve is more uniform.

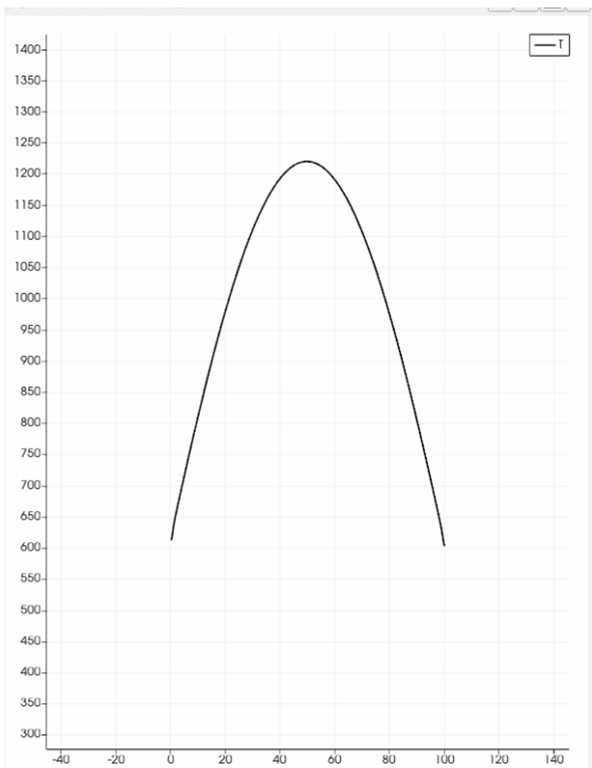

Fig. 5: Axial nature of the fuel centerline temperature profile.

A thermo mechanical contact was expected from the simulation which is absent in fig-6 & 7 mainly because the simulation was run for only 4 seconds due to convergence issues. But the two curve still represents the ideal temperature profile for a fuel rod which can be relate with practical applications.

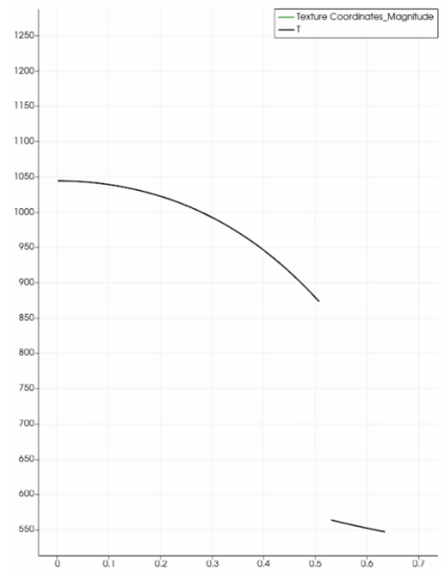

Fig. 6: Radial temperature profile at 25cm height.

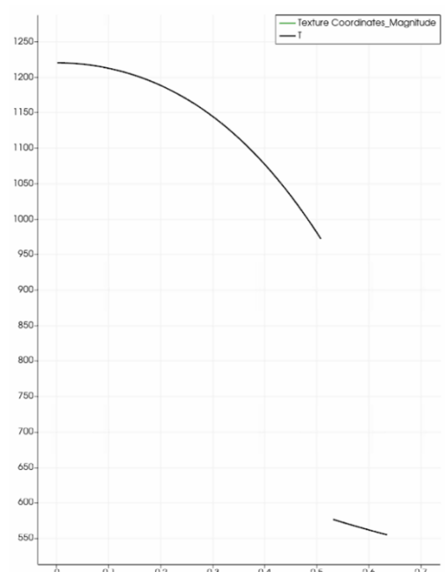

Fig. 7: Radial temperature profile at 50 cm height.

Two different ways were used to model heat transfer in a fuel rod using MOOSE (Multiphysics Object-Oriented Simulation Environment) software: a basic model that ignores mechanical stresses and strains (Part 2), and a more intricate model that considers mechanical elements like Von Mises stress, axial stress, stress in the xx and yy directions, strain, solid mechanics, and thermal contact.

Heat transfer without stress: By concentrating just on heat transfer, this model lowers computational load and simplifies simulation setup. ignores any mechanical impacts or interactions with structural elements in favor of focusing solely on the fuel rod's thermal aspect, estimating how heat is transported and perhaps radiated within the material.

Advantages:

- Less computer resources needed for setup, resulting in faster simulation times.
- Accurately computes temperature profiles, which are essential for assessing the operation of fuel rods in a reactor.

Disadvantages:

- In situations where heat transmission is influenced by mechanical phenomena such as thermal expansion, predictions may not be correct.
- An insufficient understanding of the behavior of the fuel rod under operational conditions may result from ignoring mechanical strains and deformations.

Heat transfer including stress: Heat transport and solid mechanics are included in this model, together with potential thermal contact resistance and stresses and strains (such as Von Mises stress, axial stress, stress in xx and yy, etc.).

Advantages:

- Provides a comprehensive view by considering the interplay between thermal and mechanical properties, which is essential for safety and integrity evaluations.
- Required for precise simulations in a range of operational scenarios where mechanical stresses can have a substantial influence on safety and performance.

Disadvantages:

- Complex to set up and requires much more computer power and time.
- The results can be more difficult to comprehend due to the interactions between thermal and mechanical variables.

The full model is superior for in-depth and safety-critical research because it offers insights into the potential effects of mechanical and thermal stresses on the fuel rod's integrity and performance, which is crucial for design and safety assessments. However, a basic model of heat transmission is sufficient for initial research. As we can also see that from our project being divided into three parts, where stresses were considered at the last part only. The first part used more assumptions and constant value than the 2nd one and third one is even less. But the result of part three is relatable with part-1 and 2 which is consistent throughout the whole project.

So, after the initial research with more assumptions, constant heat rates etc, one can gain a general insight before moving toward more practical applications similar to transient phenomena and more practical conditions.