Transactions of the Korean Nuclear Society Autumn Meeting, On-line, Republic of Korea
Dec. 16~18, 2020

Assessment of effective thermal conductivity model of the SPACE for fuel axial relocation in ballooned fuel rods

Jong Hyuk Lee[a*], Seung Wook Lee[a], Chiwoong Choi[a], Byung Hyun You[a], Kwi Seok Ha[a*]
[a]Korea Atomic Energy Research Institute, Yuseong-gu, Daejeon, 34057, Rep. of Korea

*Corresponding author: leejonghyuk@kaeri.re.kr , ksha@kaeri.re.kr

Background and Objective

- ☐ Under LOCA conditions, clad ballooning can occur due to internal overpressure and fuel rods can be overheated and undergo a complex process known as fuel fragmentation, relocation, and dispersal (FFRD) dependent upon fuel burnup.
- ☐ The developed model for FFRD phenomena have been added to the SPACE to take into account the effect of mass relocation on heat generation and thermal conductivity degradation.
- ☐ Objectives of this paper

To implement the effective thermal conductivity model into the SPACE and verify the thermal conductivity degradation by using simple conceptual problem when fuel axial relocation in the ballooned fuel rods occurs.

Strategy for implementation

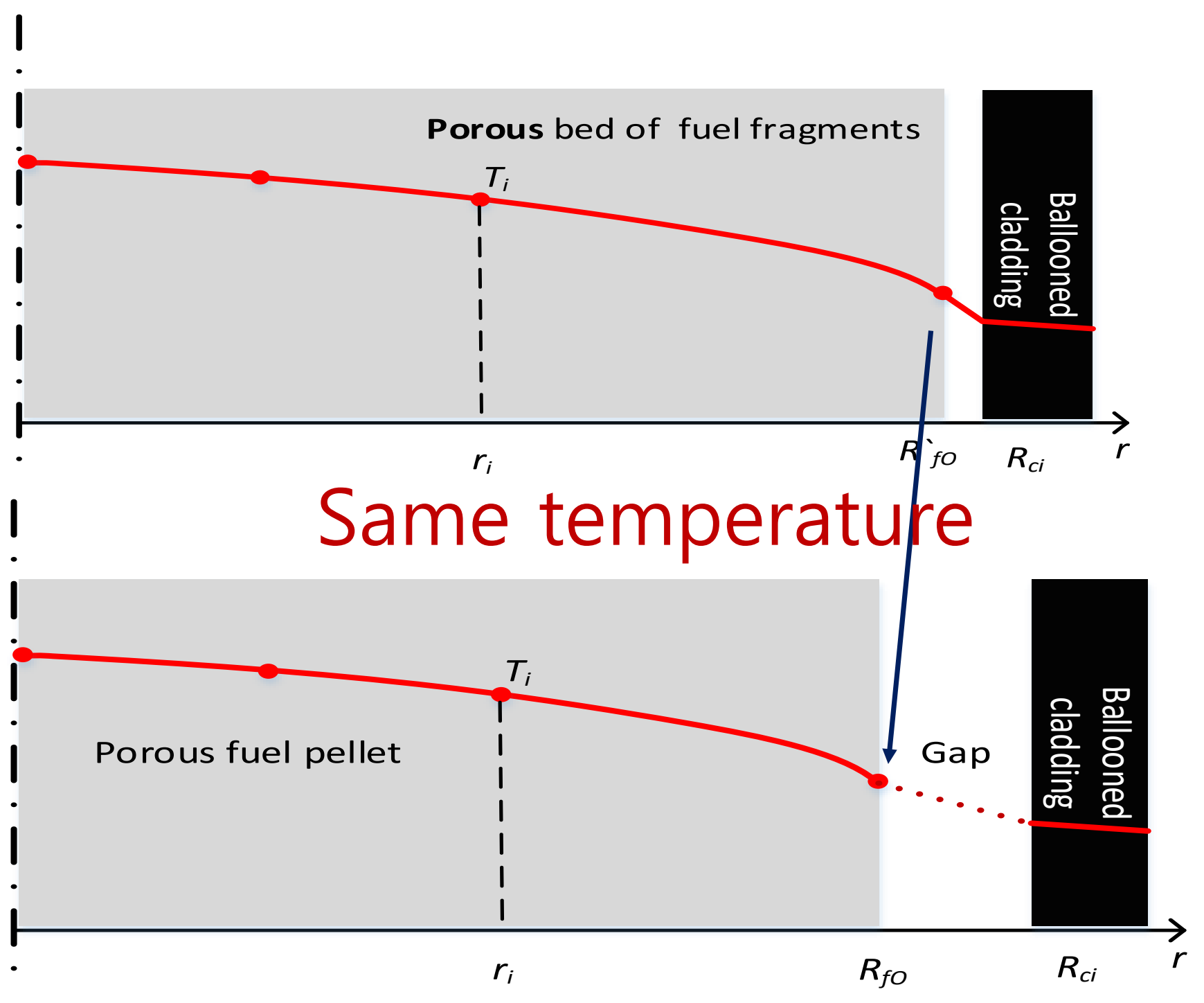
- ☐ To calculate the fuel temperature in the SPACE, heat conduction equation has to be solved.
- ☐ When the fuel balloon or collapse is occurred, heat conduction equation can still be applied but thermal properties must be modified .

Before $$\int_V \rho_f C_{pf} \frac{\partial T}{\partial t} = \int_s K_f \cdot \nabla T\, ds + \int_V P dV$$

$$\downarrow$$

After $$\int_V \phi \rho_f C_{pf} \frac{\partial T}{\partial t} = \int_s K_{eff} \cdot \nabla T\, ds + \int_V \phi P dV$$

- ☐ Temperature distributions need to be synchronized according to the fuel relocation because it is difficult to consider the changes of computing nodes due to the fuel ballooning in real time.



Conclusions

- ☐ Effective thermal conductivity model is well implemented into the SPACE.
- ☐ The calculated results are well-matched with analytical solution.
- ☐ As a further work, we will simulate the SET/IET to validate the newly implemented models for FFRD phenomena.

Thermal conductivity Model

- ☐ Effective thermal conductivity of crumbled fuel
  - ● Chiew and Glandt model (implemented in FRAPTRAN)

$$\frac{\lambda_{eff}}{\lambda_f} = \frac{(1-\beta)}{(1+2\beta)(1-\beta\phi)}\left(1+2\beta\phi+\left(K_2-3\beta^2\right)\phi^2\right)$$

Where,
Thermal conductivity of fuel fragmentation (λ_f),
Thermal conductivity of gas (λ_g), and
Packing fraction (ϕ)

$$\beta = \frac{\lambda_f - \lambda_g}{\lambda_f + 2\lambda_g}$$

$$K_2(\beta,\phi) \approx K_2^{(0)}(\beta) + K_2^{(1)}\phi$$

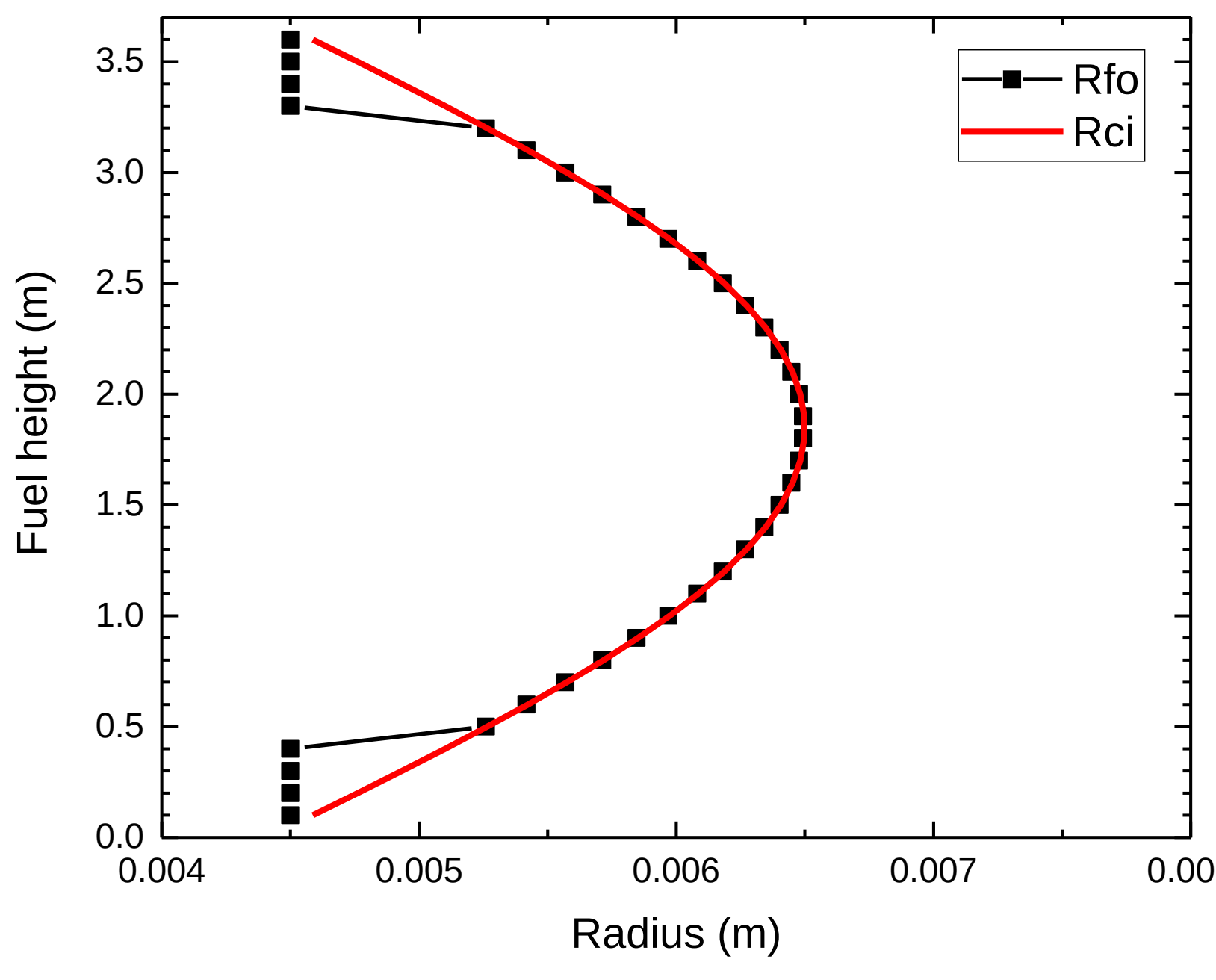
$$K_2^{(0)}(\beta) = 1.7383\beta^3 + 2.8796\beta^2 - 0.11604\beta$$

$$K_2^{(1)}(\beta) = 2.8341\beta^3 - 0.13455\beta^2 - 0.27858\beta$$

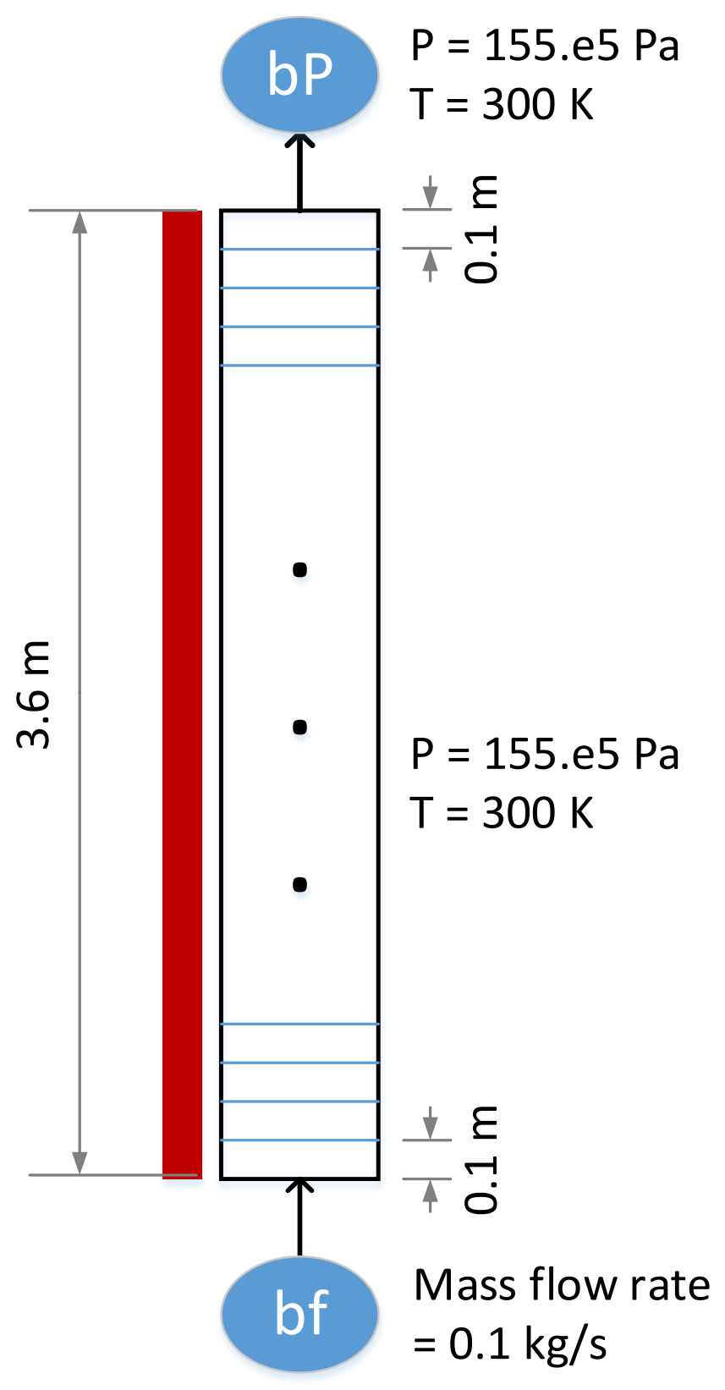
Verification

- ☐ Conceptual problem is introduced with simple boundary condition. The SPACE results compares with analytic solutions.
- ☐ ICs & BCs

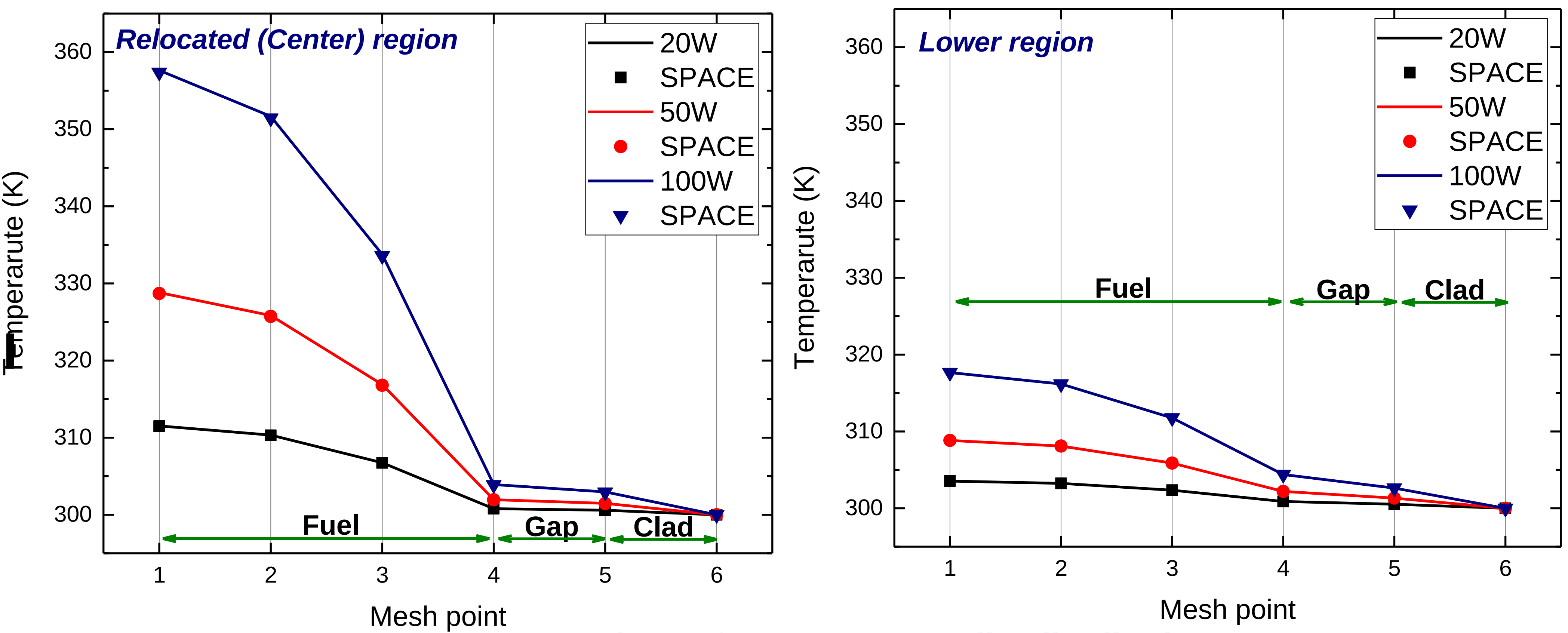
Properties		Value
Radius of pellet [m]		0.00450
Gap thickness [m]		0.00001
Cladding thickness [m]		0.00099
Thermal conductivity [W/k-m²]	Fuel	6.0
	Gap	0.2
	Clad	12.0



Deformation pattern
(black: fuel, red: cladding inner radius)



<SPACE nodalization>



Comparison of temperature radial distribution
between calculated results and analytic solution