Effects of Transverse Power Distribution on Fuel Temperature

Daeseong Jo*, Jongkhark Park, Chul Gyo Seo, Heetaek Chae

Korea Atomic Energy Research Institute, 1045 Daeduk-Daero, Yuseong-Gu, Daejeon, 305-353, Korea

Corresponding author: djo@kaeri.re.kr

1. Introduction

Due to self-shielding effect, the edge of the fuel releases more power than that in the middle of the fuel. To represent the high power at the edge of the fuel, the fuel plate should be sufficiently divided into several segments in the direction of the fuel width. The local power peaking factor depends on the segment number. The maximum power peaking factor may increase with segments, but it converges to a certain value. In the present study, transverse power distributions with segments of 4 and 18 are evaluated. Based on the power distribution, the fuel temperatures are evaluated with a consideration of lateral heat conduction.

2. Transverse power distribution

The transverse power distributions with segment number of 4 and 12 evaluated using the MCNP code are shown in Fig.1. The fuel plate (F1, plate-2), which releases the highest power in the core, is chosen for the analysis. As shown, the maximum power peaking factor with 12 segments is higher than that with 4 segments. If the transverse power distribution evaluated with 12 segments is assumed to be true, then a 6-order polynomial can be generated to express the power distribution. Fig.2 shows the transverse power distributions with various numbers of segments generated using the 6-order polynomial. For 4 segments, the power peaking factors estimated using the MCNP code are 2.18, 1.86, 1.95, and 2.36, respectively. Using the 6-order polynomial, the power peaking factors are calculated as 2.19, 1.89, 1.95, and 2.36, respectively. The same maximum power peaking factor of 2.36 is resulted from both calculations.

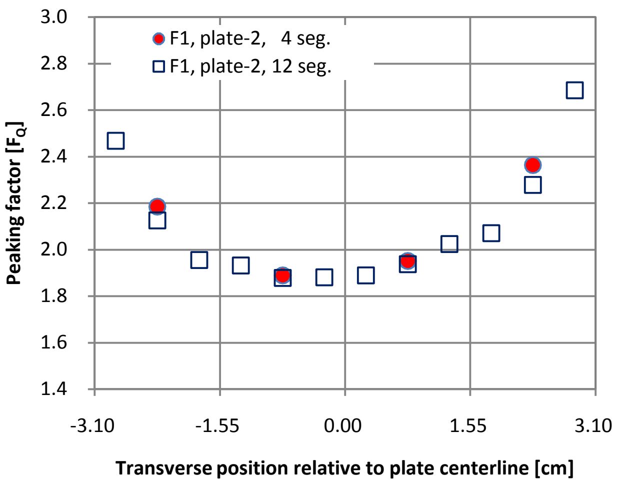

Fig.1. Transverse power distributions

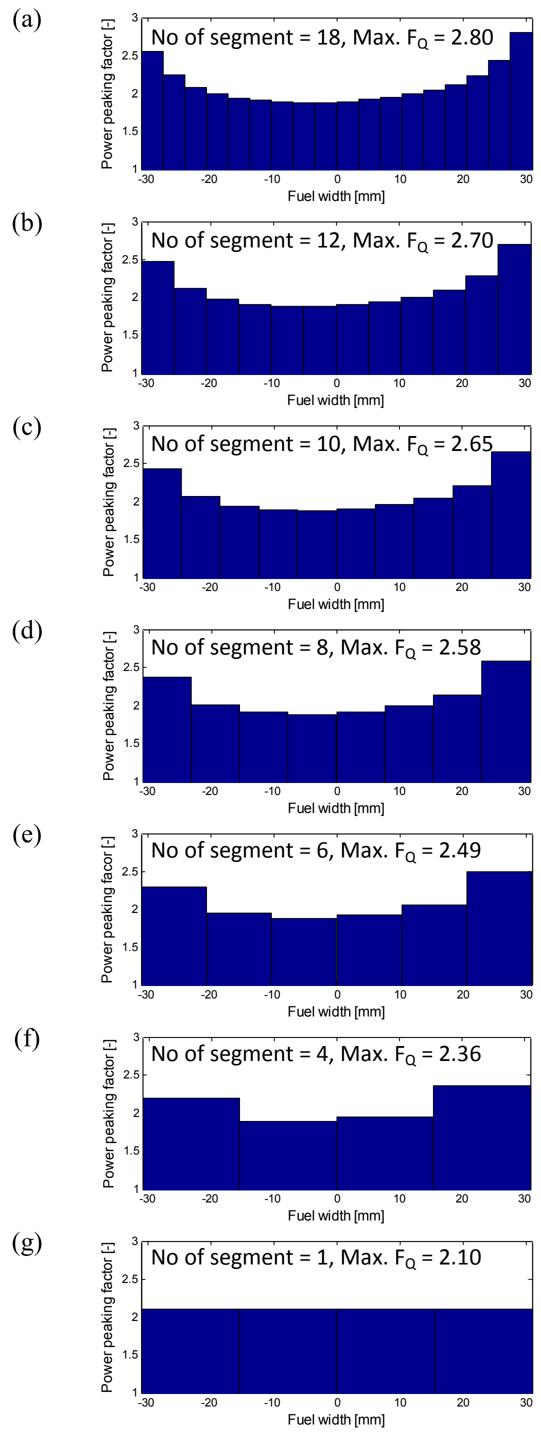

Fig.2. Transverse power distribution with segments

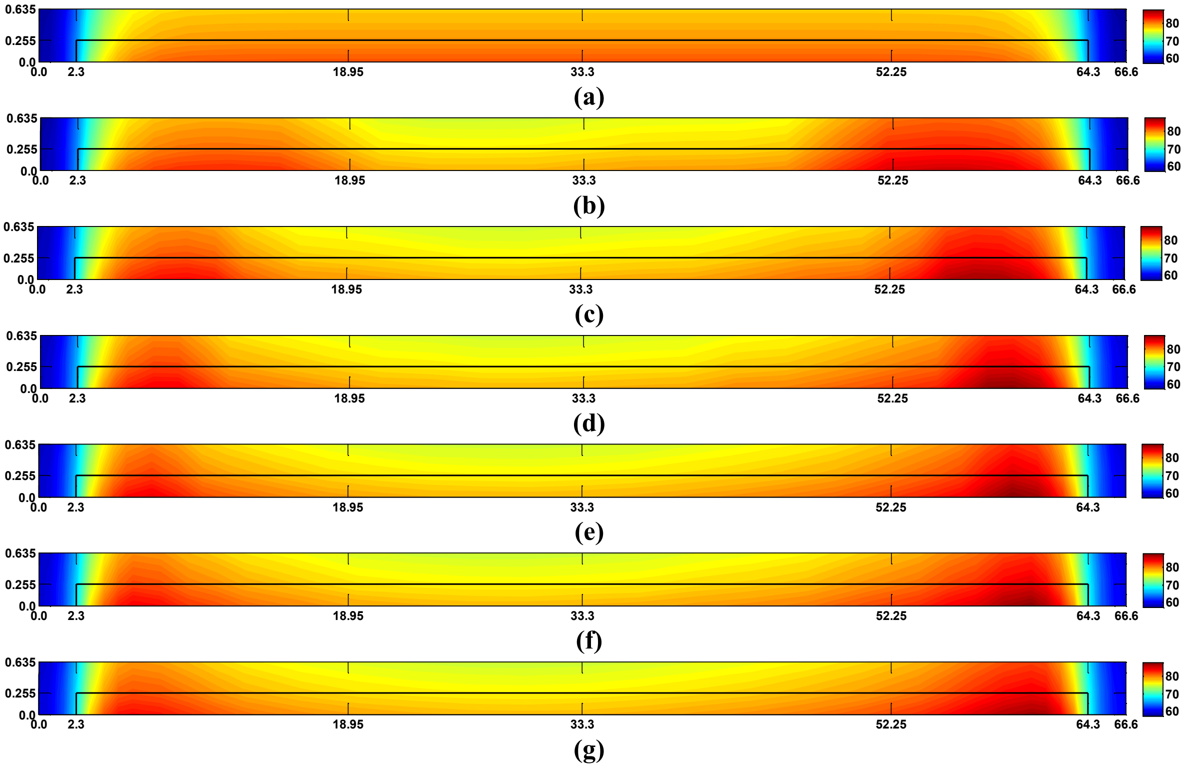

Fig.3. Fuel temperature with transverse power distribution: (a) 1 segment, (b) 4 segments, (c) 6 segments, (d) 8 segments, (e) 10 segments, (f) 12 segments, and (g) 18 segments

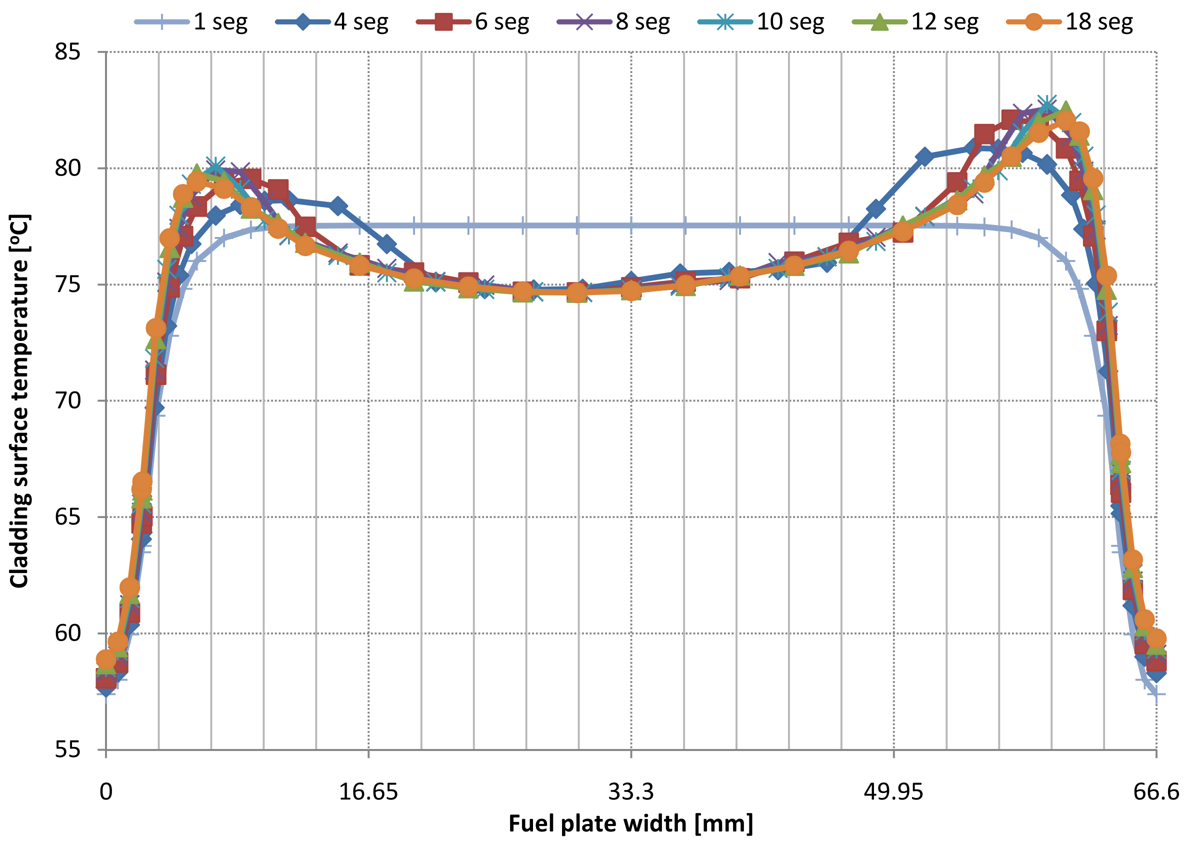

Fig.4. Wall temperature distribution with various numbers of segments

3. Fuel temperature

2-dimensional analysis model has been developed to investigate the fuel temperature regarding the transverse power distributions shown in Fig.2. The dimensions of the fuel meat are 62 mm wide and 0.51 mm thick, and the fuel is clad in aluminum based alloy with a thickness of 0.38 mm. The width of the cooling channel is 66.6 mm. Thermal conductivities of the fuel and cladding are 55 and 165 W/m/K, respectively. The boundary conditions of the model are symmetry at the centerline of the fuel, insulated at the side ends of the cladding, and forced convective cooling with a heat transfer coefficient of 31.2 $kW/m^2/K$ on the fuel outer surface. The heat generation of the fuel is approx. 1.71 MW/m^3.

Fig.3 shows the fuel temperature with transverse power distributions. With the uniform heat distribution, the maximum fuel temperature is found in the middle of the fuel. As the power near the side ends of the fuel increases, the maximum fuel temperature is found near the side ends. However, the maximum fuel temperature is not found where the maximum transverse power is. This is because the high power locally released from the edge of the fuel is laterally conducted to the cladding. It can be clearly seen in Fig.4 that the temperature change on the fuel outer surface is not noticeable for the segment number higher than 6. In addition, the maximum wall temperature with 18 segments is slightly lower than that with 12 segments.

4. Discussions

In the present study, the effect of the transverse power distribution on the fuel temperature is investigated. The transverse power distributions with variation of fuel segment number are evaluated. The maximum power peaking with 12 segments is higher than that with 4 segments. Based on the calculation, 6-order polynomial is generated to express the transverse power distributions. The maximum power peaking factor increases with segments. The averaged power peaking is 2.10, and the maximum power peaking with 18 segments is 2.80. With the uniform power distribution, the maximum fuel temperature is found in the middle of the fuel. As the power near the side ends of the fuel increases, the maximum fuel temperature is found near the side ends. However, the maximum fuel temperature is not found where the maximum transverse power is. This is because the high power locally released from the edge of the fuel is laterally conducted to the cladding. As a result of the present study, it can be concluded that the effect of the high power peaking at the edge of the fuel on the fuel outer wall temperature is not significant.

REFERENCES

[1] E.H. Wilson, F.E. Dunn, T.H. Newton Jr., L. Hu, Safety analysis of the MIT nuclear reactor for conversion to LEU fuel. 5th International Symposium of Material Testing Reactors, October 22-25, 2012, Columbia, MO USA.

[2] C.G. Seo, Comparative study on fuel material for KIJANG research reactor (under review).