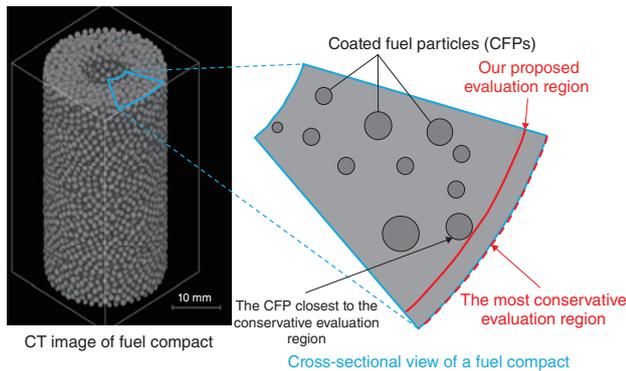


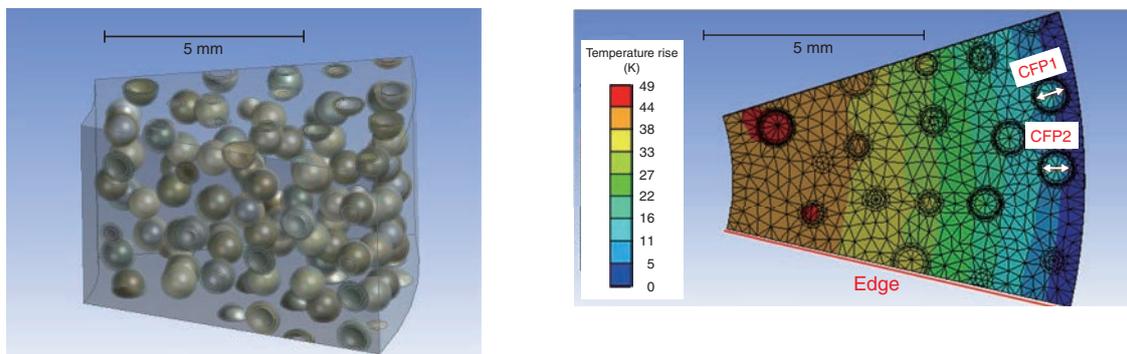
# 1-3 Evaluation of the Fuel Integrity of High Temperature Gas-Cooled Reactor to Maximize the Performance

— Improvement of the Failure Assessment Method of Tristructural Isotropic Fuel Performance for High Temperature Gas-Cooled Reactor —



**Fig.1 X-ray computed tomography (CT) image of the distribution of coated fuel particles in a fuel compact**

We obtained an X-ray CT image of a fuel compact fabricated by the method called the overcoat method, which is the same as the method used to synthesize HTTR fuel. As we approach the outer surface of the fuel compact, the temperature gradient becomes larger and the fuel nucleus migration becomes more severe. From these images, the location of the coated fuel particle (CFP) closest to the outer surface of the fuel compact is identified to determine the evaluation point of our proposed method.



**Fig.2 Computational model for thermal conduction evaluation in a fuel compact reproducing the actual heterogeneous CFP distribution (left) and the calculation results of temperature-rise distribution across the fuel compact (right)**

The left figure shows a model extracted from the fuel compact at a height of 5 mm and an angle of 30°. The right figure shows the results of the temperature-rise distribution evaluation. The temperature gradient is especially large near the outer surface of the fuel compact (CFP1 and CFP2 in the figure), which results in the largest fuel kernel migration in this region.

High Temperature Gas-cooled Reactor use coated fuel particles (CFPs) that comprise fuel kernels of uranium dioxide coated with multiple layers of pyrolytic carbon and silicon carbide. As the core burnup progresses, the carbon in the coating reacts with the free oxygen from the fuel kernel, vaporizes on the hot side, and precipitates and accumulates on the cold side. The formation of carbon monoxide may cause migration of the fuel nucleus, a phenomenon in which the fuel nucleus is pushed out of the gap created on the hot side. Therefore, the fuel kernel migration rate (KMR) during the operation period is evaluated in the core design to confirm that the fuel kernels do not come into direct contact with the coating at the end of the burnup period.

In a previous study, KMR was evaluated for particles located on the outer surface of the fuel compact, where the temperature gradient was the largest. However, such an overestimation limits the core performance. Therefore, we proposed a method that can reasonably evaluate the KMR by considering the inhomogeneous CFP distribution in the fuel compact, while maintaining the conservatism of the evaluation results.

Specifically, we proposed a method for selecting the evaluation point of the KMR to the outermost region where the CFP exists (Fig.1, right) based on a CT image of a fuel compact (Fig.1, left). In the case of the HTTR fuel, an evaluation point is set to 0.20 mm inside from the outer surface of the fuel compact.

According to our evaluation, using the proposed method, the KMR can be reduced by approximately 8% compared with the conventional method.

To confirm that our proposed method is sufficiently conservative, the KMR obtained by the proposed approach was compared with a reference case in which the KMR was estimated from the temperature distribution (Fig.2, right) in the fuel compact. This distribution was obtained via a thermal conduction evaluation using a computational model to reproduce an actual heterogeneous CFP distribution (Fig.2, left). First, the Monte Carlo neutron transport calculation code MVP was used to calculate the fission reaction rate, namely, the heat generation rate, by dividing the fuel compact into eight radial regions for each CFP packing fraction.

Second, the temperature distribution in the fuel compact was calculated from the heat generation rate using the finite element analysis code, ANSYS. The results of the comparative study show that the KMR in the reference case is smaller than that obtained using the proposed method.

This finding led us to conclude that the proposed approach provides a conservative evaluation of the KMR. This outcome may contribute to improving the core performance, for example, by enabling longer burnups.

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## Reference

Fukaya, Y., Okita, S. et al., Study on Evaluation Method of Kernel Migration of TRISO Fuel for High Temperature Gas-Cooled Reactor, Nuclear Engineering and Design, vol.399, 2022, 112033, 9p.