Preliminary Evaluation of PCI resistance Fuel in Commercial Reactor

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1. Introduction

Development of Accident Tolerant Fuel is being carried out globally. In Korea, several concepts of nuclear fuel and cladding are being developed. Among them, PCI resistance fuel pellet seems to be able to reduce the damage due to PCI during accident conditions. Until now, the performance of fuel PCI resistance fuel pellet has not been qualitatively evaluated. This is because the most of 1-dimensional fuel rod performance analysis code that we have been using so far simulates a fuel pellet as a rigid body. However, rigid body assumption does not work for PCI resistance fuel pellet. Therefore, it is required to evaluate the advantages of PCI resistance fuel especially in the view point of mechanical interaction. In this paper, qualitative evaluation of the fuel pellet due to enhanced creep were presented.

2. Methods and Results

In this paper, we evaluate fuel creep behavior by using Finite Element Method. In addition to this, rigid body-based code is used as a reference and to derive clad stress behavior during normal operation.

The behavior of the fuel pellet was evaluated using the conditions of the commercial reactor as shown in Table I. Cladding is conventional Zircaloy-4 and the chamfer and dish were assumed to be the same as the conventional fuel pellet.

Table I: As-built Fuel Rod Data of Commercial Reactor

Data	Input Value
Pellet Outer Diameter	0.323 inch
Clad Outer Diameter	0.374 inch
Gap Thickness	0.003 inch
Clad Material	Zircaloy-4

2.1 Nuclear Design Assumptions

The core conditions were evaluated using the conservative fuel rod power history and the axial power distribution of the commercial reactor core. It is assumed that small amount of additives does not significantly change the power.

2.2 Material Properties Assumptions

Since there is no significant difference in composition between the PCI resistance fuel and the conventional UO_2 fuel pellet, it can be assumed that there is no significant difference in physical properties such as thermal conductivity, thermal expansion except fuel creep. The material to be developed is expected to improve creep, so its mechanical property change should be considered. If the fuel pellet creep occurs well, the stress applied to the cladding can be reduced when the power transient occurs, thereby improving the cladding integrity.

In the case of the code using the rigid body model, only the thermal expansion of the fuel pellet was often considered. However, in order to consider fuel creep, factors such as the elasticity of the fuel pellet, the Poisson's ratio, and the creep model should be included. In this evaluation, the mechanical properties are referred to the MATPRO manual [1].

2.3 Conventional UO_2 Fuel

Fig. 1 shows the clad hoop stress change according to burnup and local power. As the burnup increases, the temperature gradient becomes worse and the thermal expansion becomes larger due to the degraded fuel thermal conductivity. It can be seen that as the degree of burnup increases, the stress applied to the cladding increases due to irradiation hardening. Note that if rigid body assumption is used, displacement of cladding inside diameter will give conservative results in cladding hoop stress. Therefore, it is expected that a smaller stress will be applied to the PCI resistance fuel.

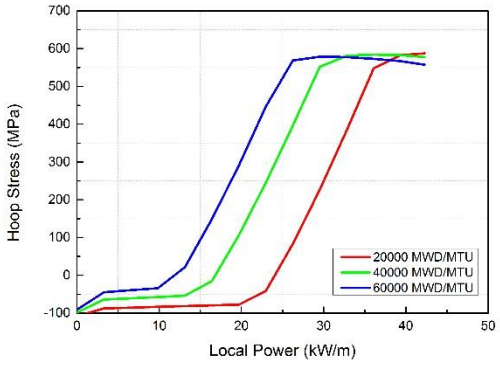

Fig. 1. Clad Hoop Stress change with Burnup and Local Power Level

2.4 PCI resistance fuel

As shown in Fig. 2, it was confirmed that the stress applied to the cladding was significantly reduced in medium and high burnup region. Considering that the

clad hoop stress at the same power level became higher when burnup increases, this result suggests that PCI resistance fuel can prevent PCI damage during normal operation especially in high burnup.

Also, decrease of pressure on the grain boundary bubble may lower the threshold value which is mostly determined by pellet boundary pressure and increase fission gas release amount. That is, contact pressure decrease due to PCI resistance fuel may result lower fission gas release compared to traditional fuel. Although there is a difference, it doesn't show significant change in rod internal pressure at the end of life as shown in Fig. 3.

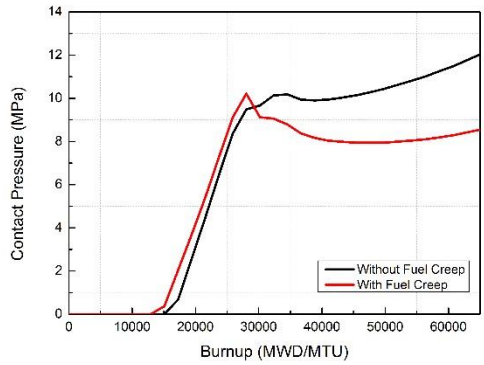

Fig. 2. Fuel Creep Effect on Fuel-Clad Contact Pressure

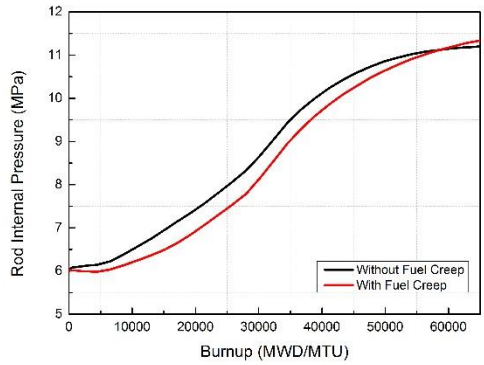

Fig. 3. Fuel Creep Effect on Rod Internal Pressure

3. Conclusions

In this paper, we evaluate the performance of PCI resistance fuel pellet. For the evaluation, rigid body-based fuel performance code and Finite Element Method are used. In conclusion, the use of PCI resistance fuel can reduce contact pressure during normal operation especially in high burnup region.

REFERENCES

[1] NUREG-1005, MATPRO-09, A Handbook of Materials Properties for Use in the Analysis of Light Water Reactor Fuel Behavior, 1976.