Influence of the High Burnup Structure Modelling on the Fuel Rod Failure Simulation
Narakhan Khunsrimek1, Alexey Cherezov2, Somboon Rassame1, Deokjung Lee2
1 Chulalongkorn University, 2 Ulsan National Institute of Science and Technology

Abstract

The fuel burnup is a key factor influencing the energy production of a nuclear power plant. In order to improve the economic efficiency of a power plant, increase of fuel burnup is needed. This research aim study the effect of HBS on fuel rod behavior. The IFA-432 benchmark has been calculated by the FRAPCON fuel performance code. There are two built-in gas release models in the code: the Massih model and FRAPFGR model that includes the influence of HBS effects. The calculations are conducted for each model. The calculation results show a large difference of the total fission gas release between two models. However, this is not affect to fuel damage in rang of beginning of life.

Fission gas release

Irradiated nuclear fuels cause fission gases. These gases are low solubility in Uranium dioxide affect bubbles on grain of fuel. The fission gases were trapped by bubble makes size of bubble increase. Then each bubble move to grain boundary. When the number of gas in bubble is saturate lead to interconnect each other of bubble and became tunnel network to free surface as show at figure 1. This cause fission gases in fuel leakage to outside. The fission gas release which accumulated in gap became layer between fuel and cladding affect heat transfer in gap decrease and leads to increase temperature in fuel and pressure in the gap. This shown that fission gas is important factor may lead to fuel rod damage. Thus behavior of fission gas was studies by FRAPCON code.

FRAPCON code

FRAPCON code is analysis tool for reactor safety research. The code was used to studied fuel rod behavior in light water reactor (LWR) when power and boundary condition is steady-state. This research uses this code to study behavior of fission gas in normal case and high burn-up structure case using two models in FRAPCON code which detail as follow:

Massih model
Massih model is model for calculation of fission gas release in general grain. The model assumes that gas production rate is constant and grain in fuel is spherical grain. When the number of gas in the grain is saturate all gases diffuse to shall of grain. Meanwhile, when gas in shall saturate them release to outside at shown in figure 2.

FRAPFGR model
The FRAPFGR has two functions that difference Massih model. The first function is grain grow model that grain size is explan along temperature and time. Another function is high burnup rim thickness.

Input data

IFA-432 is fuel rod assembly that was test in Halden heavy boiling-water reactor (HBWR). The experiment is intended to test the long-term steady-state performance of BWR-6 type fuel rods in case power plant operated at power levels that were at the upper bound for full-length commercial fuel rods. Fuel rods were design overall length, outer-diameter of cladding and high of each pellet approximately 580 mm, 10.67 mm and 13.00 mm respectively. Type of cladding and fuel is Zirvoloy 2 and Uranium dioxide. The experiment was conducted for 9 years. The results from experiment were used to create input data for FRAPCON code.

Results

The analysis result shown that the number of gas releasing from fuel pellet in case high burnup structure occur in grain during beginning of life is lower than general grain. This cause heat conductance in gap is high and lead to easily transfer the heats in fuel to cladding. Moreover, the pressure in gap is lower than general case. Therefore, the high burnup structure in rage of beginning of life is not impact to fuel rod.

Conclusion

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Acknowledgement

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Methodology

IFA-432 benchmark data were used as input data for simulation in FRAPCON code using Massih model and FRAPFGR model to calculate fission gas release in general case and high burnup structure occur respectively. The results from simulation of both models were compared to study effect of high burnup structure.

Reference