Coolant Condition Effect on the Fission Gas Release for CANDU Fuel

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1. Introduction

The amount of fission product inventory produced during the normal operation is affected by the thermal-hydraulic condition of the irradiated fuel channel. Fission product inventory which is cumulated within the fuel during the normal operation can be released from the fuel if the fuel fails after a postulated accident such as feeder stagnation break. The released fission gas from the fuel is provided as a source term for the following dose calculation in the safety analysis.

In this study, the effect of coolant thermal-hydraulic condition on the fission product inventory and fission gas release was investigated. Two cases of coolant conditions were considered, one is for the coolant condition of 11 EFPY fuel channel state, which means that the coolant condition includes the effect of pressure tube radial expansion, and the other is for the initial fuel channel state of Wolsong 2 NPP, which means that there is not pressure tube radial expansion. The first coolant data of temperature, pressure and heat transfer coefficient were calculated from the thermal-hydraulic simulation by using CATHENA code [1], and the second coolant data for Wolsong 2 NPP were obtained from the Reference [2]. These thermal-hydraulic data were provided as input data for a fuel analysis by using the ELESTRES code [3]. Through the fuel analysis, the fission product inventory during the normal operation was calculated and fission gas release following stagnation feeder break was evaluated based on the fission product inventory and transient thermal-hydraulic condition by using Gehl's correlation [4].

2. Evaluation of Fission Product Inventory

For the conservative fission product inventory analysis, a limiting channel, which is called O6_mod channel, was assumed. This limiting channel has a channel power of 7.3 MW and the two central bundles at 935 kW. Here, 7.3 MW and 935 kW are the LCO (Limiting Condition for Operation) power values for a fuel channel and a fuel bundle, respectively.

2.1 Results of Thermal-Hydraulic Simulation

A thermal-hydraulic simulation was carried out for the 11 EFPY fuel channel state. Creep data for this 11 EFPY pressure tube at 12 bundle positions are shown in Fig. 1. Through the thermal-hydraulic simulation by using the CATHENA code, the steady state conditions of coolant temperature, coolant pressure and heat transfer coefficient were obtained. Fig. 2 shows the coolant temperatures at each bundle position for refurbished wolsong 1 and wolsong 2. Coolant temperature of Wolsong 2 is a little bit higher than that of Wolsong 1. Fig. 3 shows the coolant pressures at each bundle positions for 2 cases. Also, coolant pressure for Wolsong 2 is higher than that of Wolsong 1. Fig. 4 displays the heat transfer coefficients for each ring of Wolsong 1 and Wolsong 2 at each bundle position. From this, it can be known the overall heat transfer coefficient for Wolsong 2 is higher than that of Wolsong 1.

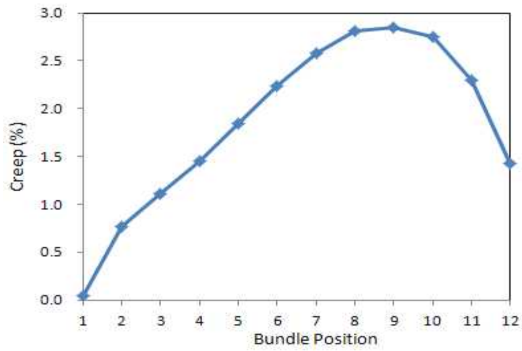

Fig. 1 Creep (%) data for 11 EFPY pressure tube

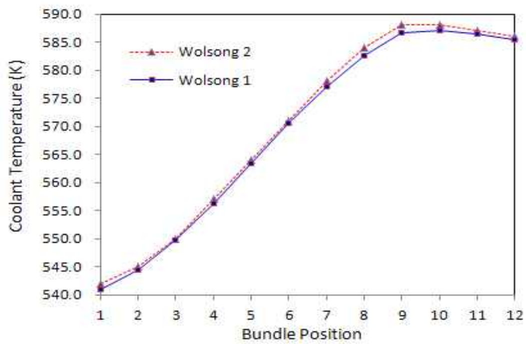

Fig. 2 Coolant temperature for two cases

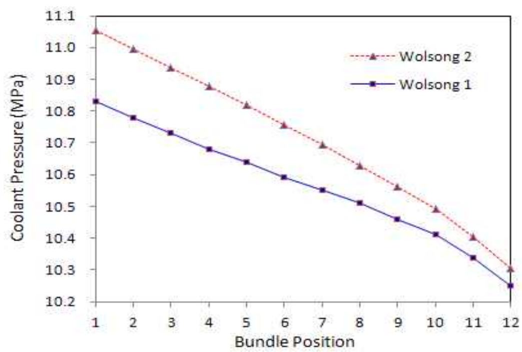

Fig. 3 Coolant pressure for two cases

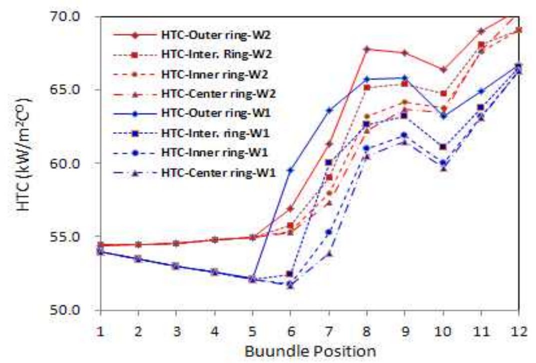

Fig. 4 Heat transfer coefficient for two cases

2.2 Results of Fission Product Inventory

Calculated coolant temperature and pressure were provided as input data to the fuel analysis by using the ELESTRES code.

Fig. 5 shows the results of gap FP (fission product) inventory for Wolsong 1 and Wolsong 2 at each bundle position. Fission product gap inventory for Wolsong 2 was a little bit higher than that of Wolsong 1. This result seems to be reasonable because of the higher coolant temperature of Wolsong 2.

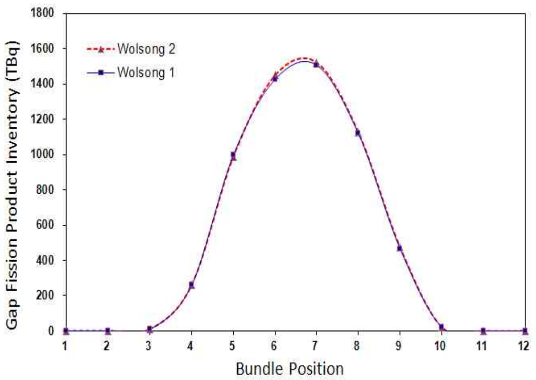

Fig. 5 Gap fission product inventory for two cases

3. Evaluation of Fission Gas Release

For calculation of fission gas release during stagnation feeder break, it was assumed that all fuel sheaths in the channel are failed and the entire gap inventory is released instantaneously at the beginning of the accident. The additional calculation of the transient fission product release from the fuel grains and grain boundary following feeder stagnation break is performed by applying the Gehl's release model.

The channel is predicted to fail at 11.1 seconds based on the thermal hydraulic evaluation. To ensure that the releases are not under predicted, the transient releases were calculated until 13.1 seconds.

Fig. 6 shows the results of fission gas release for each case of Wolsong 1 and Wolsong 2 following the feeder stagnation break. Fig. 7 magnifies the fission gas release result at the time region around 13 second. As shown in this result, the fission gas release for Wolsong 2 NPP is slightly higher than that of Wolsong 1. This might be explained by the higher coolant temperature of Wolsong 2. Although the heat transfer coefficients for Wolsong 2 are higher than that of Wolsong 1, the coolant temperature affects more dominantly to the fission product inventory and fission gas release.

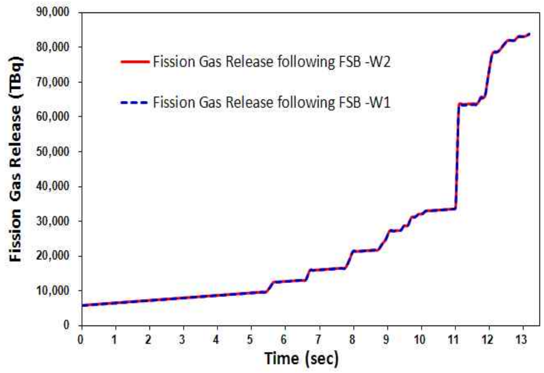

Fig. 6 Fission gas release following the feeder break

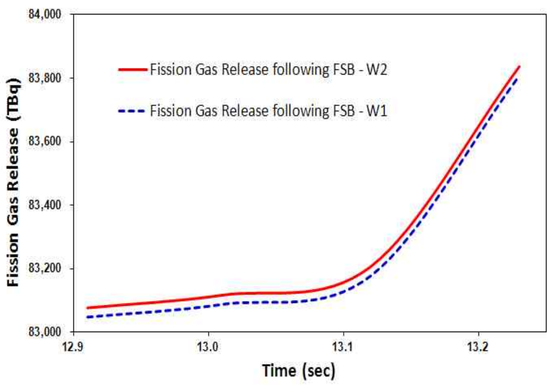

Fig. 7 Detailed fission gas release for two cases

4. Conclusions

The effect of coolant thermal-hydraulic condition on the fission product inventory and fission gas release for feeder stagnation break was investigated. Simulation results showed that the coolant temperature effect was more dominant to the gap fission product inventory and fission gas release following the feeder break accident.

REFERENCES

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