CANDU PHTS Ageing Effect on the Fission Product Inventory

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1. Introduction

Fission products play a significant role in determining fuel element performance during normal operation or transient after the postulated accident as follows. First, fission products provide a corrosive environment inside the fuel sheath and can promote stress corrosion cracking. Second, the release of significant quantities of diffusion gas can result in high internal gas pressures within the element, possibly leading to increased sheath stresses. Third, from a safety perspective, the distribution of fission products within the fuel element also plays a major role in determining possible doses to the public after postulated accidents have occurred [1].

Fission products are uniformly generated throughout the pellet at rates proportional to the local fission rate. However, fission products may move over time because of the diffusion, changes in the granular structure of the UO_2. Gap fission products accumulated between the pellet and sheath can be promptly released following the sheath failure. Therefore, the amount of gap fission product is very important because it may affect the initial dose to public.

Nuclear power plant undergoes degradations, so called ageing, with their operation time [2]. Because of the ageing of HTS, the thermal-hydraulic conditions can vary and it is evident that the changed thermal-hydraulic conditions affect the distribution of fission product inventory such as gap fission product.

Accordingly, in this paper, the HTS ageing effect of CANDU reactor on the fission product inventory was investigated during the normal operation. From the thermal-hydraulic analysis for the fresh and 11 EFPY aged core model by using the CATHENA code [3], the initial coolant conditions were derived and they were provided to the input of fuel analysis by using the ELESTRES code [4].

2. Initial Thermal-Hydraulic Conditions

Primary heat transport system (PHTS) and coolant flow of typical CANDU-6 is shown in Fig. 1. Ageing of each HTS component may cause some changes to the primary HTS characteristics and these changes also affect operational and safety margins of CANDU reactor. The main ageing mechanisms include pressure tube diametral creep, magnetite deposition, and feeder orifice degradation, etc. Based on these ageing mechanisms, the thermo-hydraulic model for 11 EFPY aged core was developed [5] by considering the ageing effects of the following hydraulic parameters: inlet and outlet feeder roughness, inlet feeder orifice loss coefficient, inlet end fitting roughness, fuel channel roughness (independent of pressure tube creep), pressure tube diametral creep, fuel channel flow area, hydraulic diameter, and coolant volume for crept pressure tube, and boiler tube roughness.

Initial thermal-hydraulic conditions of coolant temperature, pressure, and heat transfer coefficient were derived at the O6_mod limiting channel by CATHENA simulations for both fresh and 11 EFPY aged cores. Fig. 2 ~ 4 show the coolant pressure, temperature, and heat transfer coefficients at each bundle position of O6_mod channel for both fresh and 11 EFPY aged core. As shown in these figures, the pressure difference between the inlet and outlet headers for the aged core more decreased compared to the fresh core. Also, the inlet coolant temperature of aged core is higher and the heat transfer coefficients for the aged core are lower. From the thermal-hydraulic simulation, it is evident that the coolant conditions seem to be worse for the aged core because of the various ageing effect of HTS components.

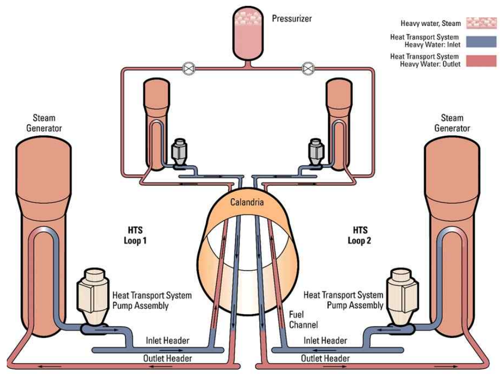

Fig. 1 CANDU-6 Primary Heat Transport System

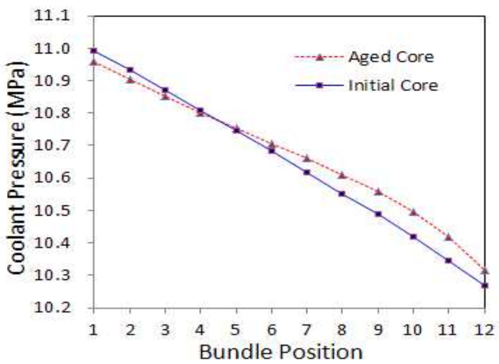

Fig. 2 Coolant Pressure Conditions for Both Cores

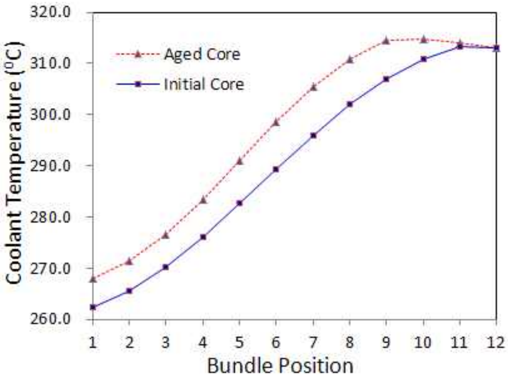

Fig. 3 Coolant Temperature Conditions for Both Cores

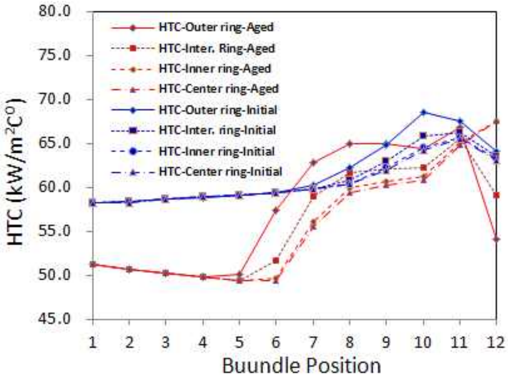

Fig. 4 Heat Transfer Coefficients of Each Ring

3. Evaluation of Fission Product Inventory

Fig. 5 shows the results of gap FP (fission product) inventory for the fresh and 11 EFPY aged core at each bundle position of a limiting channel. Gap inventories for the aged core were a little bit higher than that of the fresh core. This result seems to be reasonable because of the higher coolant temperature and lower heat transfer coefficient of the aged core. For the FP inventory at grain boundary within the pellet, the inventory of the aged core is higher as shown in Fig. 6. This means that produced fission gas is more actively diffused to the grain boundary from the in-grain for the aged core because of the hot condition. However, since the total amount of the FP is dependent on the fission rate, FP inventory within grain for the aged core is lower than that for the fresh core as shown in Fig. 7.

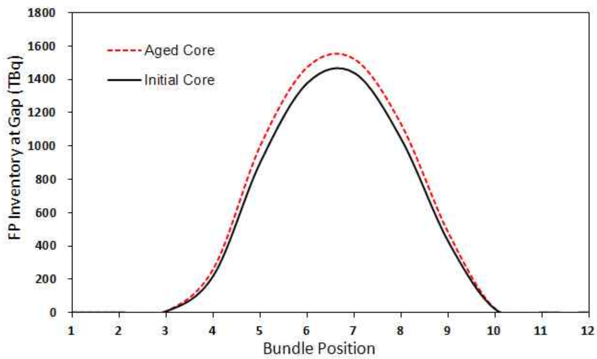

Fig. 5 Fission Product Inventory at Gap

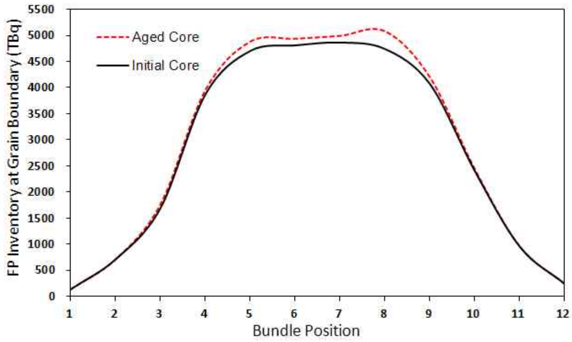

Fig. 6 Fission Product Inventory at Grain Boundary

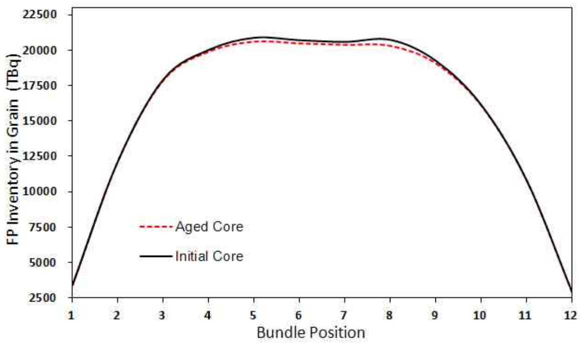

Fig. 7 Fission Product Inventory within Grain

4. Conclusions

The CANDU PHTS ageing effect on the fission product inventory during normal operation was investigated through the thermal-hydraulic analysis and fission product analysis for the fresh core and 11 EFPY aged core states. The gap and grain boundary inventories which are promptly released following the sheath failure were higher for 11 EFPY aged core than those of the fresh core. From this result, it was found that the 11 EFPY aged core is more conservative than the fresh core for the safety perspective.

REFERENCES

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