Clad Thickness Effect on the Fuel Behaviors for a CANDU Feeder Stagnation Break

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1. Introduction

Fission product inventory, which is cumulated within the fuel during normal operation, can be released from the fuel if the fuel fails after a postulated accident such as a 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. Thus, a conservative calculation of the initial fission product is requested in the safety analysis.

The initial fission product inventory is calculated using the ELESTRES-IST code [1] for a safety analysis of a postulated accident in a CANDU reactor. The conservative calculation of the initial fission product inventory can be performed by applying conservative input values for the code. The clad or sheath thickness is one of the controlled input variables for the ELESTRES-IST code.

Accordingly, in this study, the effect of clad thickness on the fission gas release for a feeder stagnation break was investigated. The clad thickness is one of the ELESTRES code input variables and can be selected as a control variable. Based on the design drawing [2] and fuel design manual [3] of the CANDU 37 element fuel, the clad thickness can be varied from a minimum of 0.38 mm to a maximum of 0.65 mm. Since the heat produced inside the fuel by irradiation is transferred to the coolant through the sheath, the clad thickness can be a important variable to evaluate the fuel behavior for a safety analysis. This study simulated a CANDU feeder stagnation break accident by applying four cases of clad thickness of 0.38 mm, 0.45 mm, 0.55 mm, and 0.65 mm. For the four cases of clad thickness, fuel behaviors under normal operation condition such as fuel temperature, sheath deformation, and fission product inventory were evaluated and the fission gas release following a feeder stagnation break was also investigated.

2. Fuel Behavior Results during Normal Operation

For a conservative evaluation of the feeder stagnation break, a limiting 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. The ELESTRES-IST code was used for the evaluation of fuel behavior during normal operation. Fig. 1 shows the results of fuel centerline temperature of bundle 6 outer elements for four cases of fuel clad thickness. As shown in the figure, the fuel temperatures of the thicker clad fuel were higher than the thinner clad fuel. Fig. 2 shows the temperature results of the bundle 6 center elements for four cases of clad thickness, and a similar behavior was shown for the outer element.

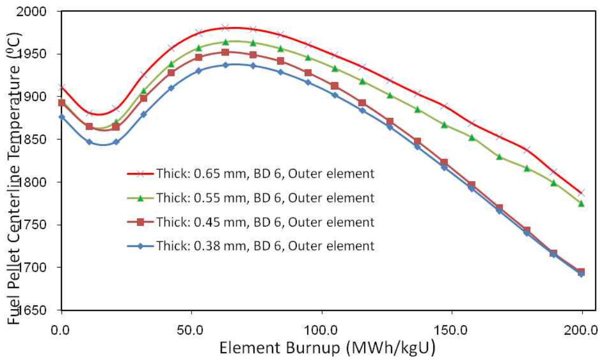

Fig. 1 Fuel centerline temperatures for outer elements

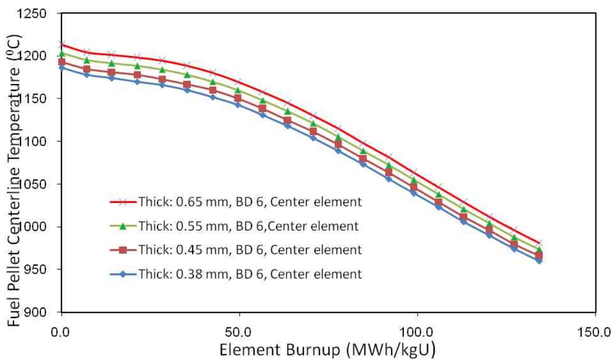

Fig. 2 Fuel centerline temperatures for center elements

The fission product inventory is produced initially within the UO_2 matrix. It can migrate by thermal or irradiation diffusion processes. This redistributes the fission gases within the grains of the fuel pellet. Some of the fission gas atoms migrate to the grain boundaries. The fission products at the grain boundaries can also migrate out of the fuel pellet to the gap between the UO_2 fuel pellets and the sheath, as well as to the cracks within the fuel pellets. Fig. 3 shows the results of the gap fission product inventory for each bundle position and each clad thickness. As expected, the FP gap inventories at the middle bundle were higher, and a thicker clad fuel produced more gap inventory.

As shown in Fig. 4, the total channel gap inventory increase as the clad thickness increases. The total channel gap inventory for a clad thickness of 0.38 mm is 5,804.97 TBq, and for a clad thickness of 0.65 mm is 6,299.65 TBq. The gap inventory can be released promptly following the fuel element failure, and the amount of gap inventory is very important as a fission gas source term.

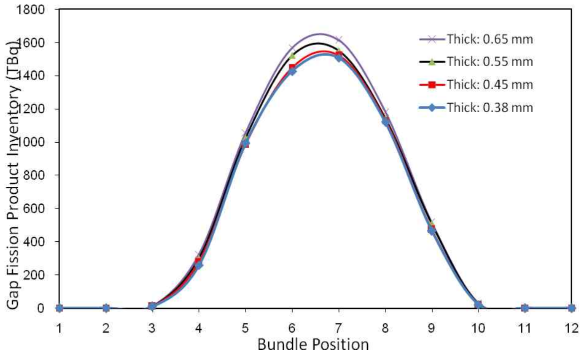

Fig. 3 Gap fission product inventory for each bundle

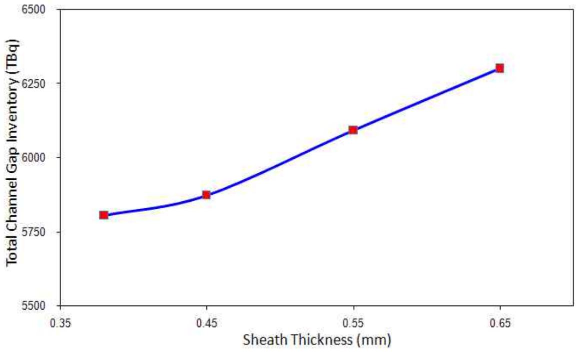

Fig. 4 Channel gap inventories for the clad thickness

Fig. 5 shows the sheath deformation results for each clad thickness. The sheath deformation increases as the clad thickness decreases.

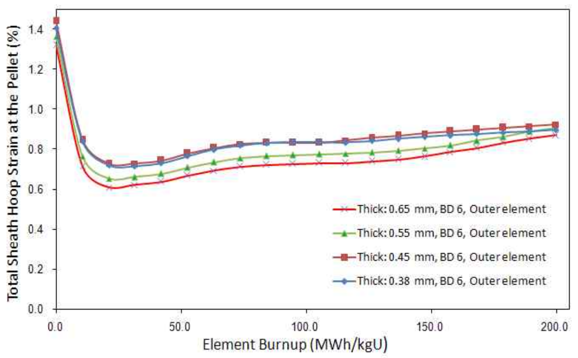

Fig. 5 Sheath hoop strain results for each thickness

3. Fission Gas Release Following Feeder Break

For calculation of the fission gas release during a stagnation feeder break, it is assumed that all fuel sheaths in the channel are failed and the entire gap inventory is released instantaneously at the beginning of the accident. An additional calculation of the transient fission product release from the fuel grains and grain boundary following feeder stagnation break is performed by applying Gehl's release model [4].

The channel is predicted to fail at 11.1 seconds based on the thermal hydraulic evaluation. Fig. 6 shows the results of fission gas release for each clad thickness following the feeder stagnation break. As shown in Fig. 7, fission gas release for a clad thickness of 0.65 mm is about 1.6% greater than the result for the 0.38 mm thickness.

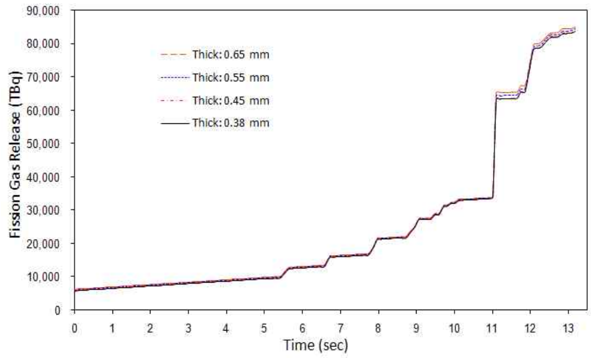

Fig. 6 Fission gas release following the feeder break

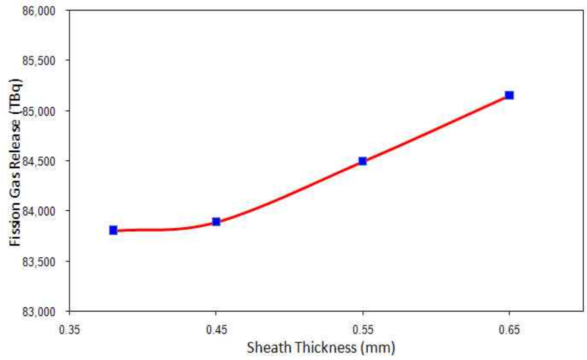

Fig. 7 Total fission gas release for the clad thickness

4. Conclusions

The effect of clad thickness on the fission gas release for a feeder stagnation break was investigated. Simulation results showed that the thicker clad thickness was more conservative in terms of the fuel temperature and fission gas release. However, sheath deformation was more conservative in the case of a thinner clad thickness. Thus, it is difficult to judge which is more conservative to evaluate the fuel safety.

Acknowledgement

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