The effect of a CANDU fuel bundle geometry on dryout power

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1. Introduction

The thermal performance of a fuel channel is largely affected by the configuration of a rod bundle in a pressure tube. With a view to designing the advanced fuel channel having a larger safety margin, it is important to reveal the effect of the geometric configuration on the thermalhydraulic characteristics of a fuel channel. The subchannel technique is known to be very useful for investigating the thermal behavior of fuel assembly in a nuclear power reactor. In the present study, the subchannel analysis for a horizontal flow has been performed with a variation of the geometric configuration of a rod bundle. The objective of this study is to examine the thermalhydraulic characteristics in a fuel channel having the different geometric configuration of a rod bundle and to scrutinize the effect of the modification of element size on the thermal performance of a horizontal fuel channel.

2. Numerical methods

In this study, the ASSERT-IV code [1] was used for the subchannel analysis of the standard and modified fuel channel. In subchannel analysis, the complex geometry of the rod bundle is divided into smaller sections. Since gravity is perpendicular to the direction of channel flow in CANDU reactors, at least half of the bundle should be modeled for the subchannel analysis. Figure 1 shows the subchannel models for the standard fuel bundles, together with the element and subchannel numbers. The subchanel model for the standard fuel bundle includes 19 powered elements and 34 subchannels.

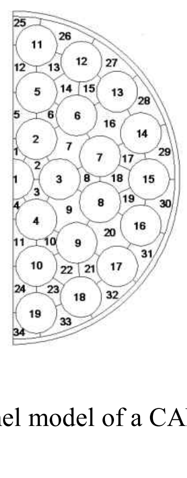

Fig. 1 Subchannel model of a CANDU standard fuel bundle

The conservation equations of mass, momentum and energy are solved for each subchannel while taking into accout the intersubchannel interactions as source terms. The detailed explanations for numerical method are described in ref [2]. The calculation was performed under the normal operating condition with an inlet fluid temperature of 256°C, an outlet header pressure of 10.0 Mpa and mass flux of 20.0 kg/s.

3. Results

Figure 2 shows the dryout power of each ring for a modified fuel bundle. The open and solid symbol denotes the value for a standard and a modified fuel bundle, respectively. As the basic case of a modified fuel bundle, the element diameter in center ring was changed to 11.0mm from the original value of 13.08mm, while the element sizes of other rings remained. From the figure, it is revealed that, by the modification of element diameter, the dryout power of each ring is substantially affected and the location of ring where the first dryout occurs is also changed. It is noted that the flow rate in the subchannels near the center ring is increased, which results in the increase of dryout power at the elements in the center and inner ring. As the element diameter of the center ring is modified, the dryout power in a fuel bundle is improved by about 11.0% for both the uncrept and 5.1% crept channels, compared with a standard fuel bundle.

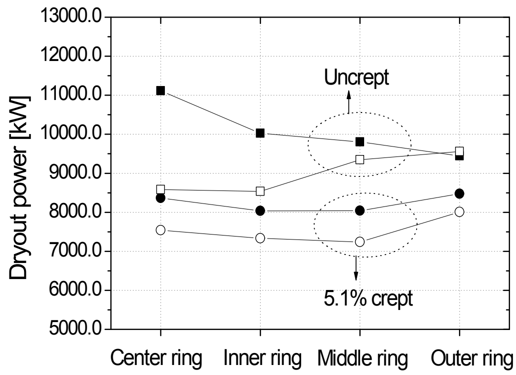

Fig.2 Dryout power at each ring of modified fuel Bundle

Figure 3 shows the dryout powers of the elements on a vertical centerline in a standard and modified fuel bundles. It is revealed from the figure that, in an uncrept channel, the elements in the center ring and upper inner ring have an enourmous increase of dryout power by the modification of the center ring. The effect of the modification of the center ring is transferred towards the physically higher elements due to the buoyancy drift effect. Hence, the effect of modification of the center ring is more pronounced at the elements in the upper region of a bundle rather than at the elements in the lower region of a bundle as shown in Fig. 3. Especially, in a 5.1% crept channel, the dryout power of elements in the upper half region of a bundle are significantly affected by the modification of the center ring.

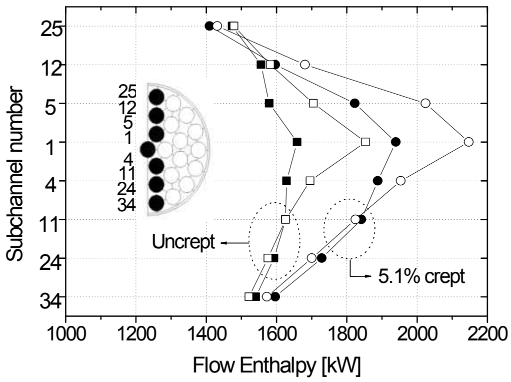

Fig.3 Comparison of dryout power at central-positioned rods.

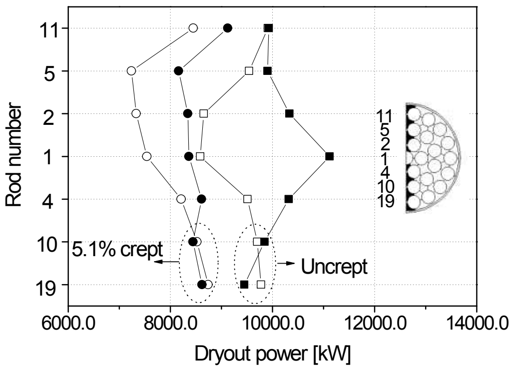

Fig.4 Flow enthalpy at central positioned subchannels of modified fuel bundle

Figure 4 shows the flow enthalpy distribution at the subchannels on the vertical centerline for a modified fuel bundle. The decrease of enthalpy is the largest at the upper center subchannel by the increased flow rate in this region, which is in line with the result of dryout power variation. Although the enthalpy at the subchannels in the upper half region in a fuel bundle is decreased by the modification of the center ring for both the uncrept and 5.1% crept channels, the enthalpy decrease in the upper half region is more defnitely shown in a 5.1% crept channel, which reflects the pronounced buoyancy effect in a 5.1% crept channel.

A series of computations were made by altering the size of the elements in each ring, and the results are shown in Fig. 5. For the considered size of element diameter, the dryout power of a fuel bundle has a tendency to increase as the size of the element diameter decreases. However, an inspection of Fig. 5 reveals that, as the element diameter is further decreased beyond a certain value, the increase rate of dryout power in a fuel bundle is decreased. In actual, in the case where the center ring is modified, the dryout power of a bundle shows the negligible change for the further decrease of the element diameter below 11mm.

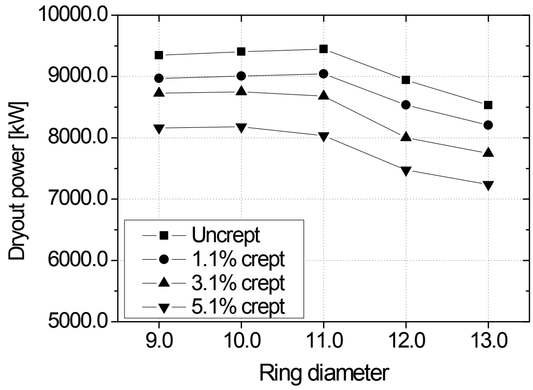

Fig.5 The effect of diameter of modified fuel bundle on the dryout power

4. Conclusions

The dryout power of a fuel bundle is increased by the modification of an element size. For an uncrept channel, the dryout power is largely increased for the elements near the modified ring. In a 5.1% crept channel, the increase of dryout power by the modificaiton is noticeable for the elements in the upper region of a bundle. The dryout power of a fuel bundle has a tendency to increase as the size of the element diameter decreases. However, as the size of the element diameter is further decreased beyond a certain value, the increase rate of dryout power in a fuel bundle is reduced.

REFERENCES

[1] Carver M.B., Kiteley J.C. “Validation of the ASSERT subchannel code”, Nuclear Technology, 299-314, 1995

[2] Bae J.H., Park J.H. “A subchannel analysis of CANDU fuel bundle in a crept channel”. Transactions of the Korean Nuclear Society Autumn Meeting, 2010