Development of Thermal Margin Method using Double Hot Channel

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1. Introduction

FAST code[1] was developed to calculate the DNBR value and thermal margin in the reactor core of SMART. In the thermal margin analysis of whole core of SMART using FAST, 4-channel lumping model is applied to evaluate the minimum DNBR in the hot channel. There are two kinds of hot channel in SMART which is typical and thimble type. These hot channels have a similar hydraulic diameter in contrast with 16 by 16 type hot channel(OPR-1000 reactor) which is the thimble channel with a large guide tube. In this reason, a separate calculation according to the hot channel type assembly should be required on thermal margin analysis of SMART fuel.

To reduce the time consuming process to look for the minimum DNBR value for a typical channel or a thimble channel, double channel method is suggested. The method is available to simultaneously calculate the minimum DNBR for two hot channels. As a result, single stage thermal margin calculation is available. Present study shows the double channel method and comparison results of MATRA-S thermal margin analysis.

2. Methods and Results

2.1 4-channel lumping model

Thermal margin model of FAST code has a total four thermal-hydraulic channels to model cross flow effect at the open-core. Figure 1 shows a typical layout of the 4-channel model. Channel 2 is quadrant of the hottest assembly in the core and Channel 1 is an assembly which represents the average coolant conditions for the remaining portion of the core. The lumped channel 2 includes channels 3 and 4. Channel 3 averages the subchannels adjacent to the hot channel 4. The location of the minimum DNBR channel is determined form a detailed MATRA-S code results of the 1/8 thermal margin model of SMART core[2].

FAST code adopted the transport coefficient model like CETOP-D code[3] to reduce the errors caused by lumping channel. In present 4-channel model, the transport coefficient is necessary only for the connection between channel 2 and channel 3 where channel size difference is the largest. The coefficient can be calculated only to know the enthalpy at the boundary channel like Eq. (1). Enthalpy at boundary channel 2' can be determined from the energy conservation of channel 2' in the assistant with the channel 2".

$$N_H = \frac{h_3 - h_2}{h_3 - h_{2'}} \qquad (1)$$

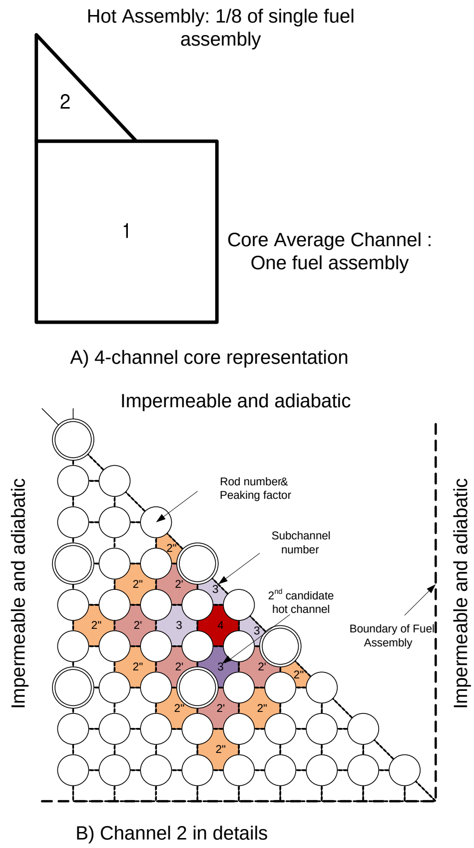
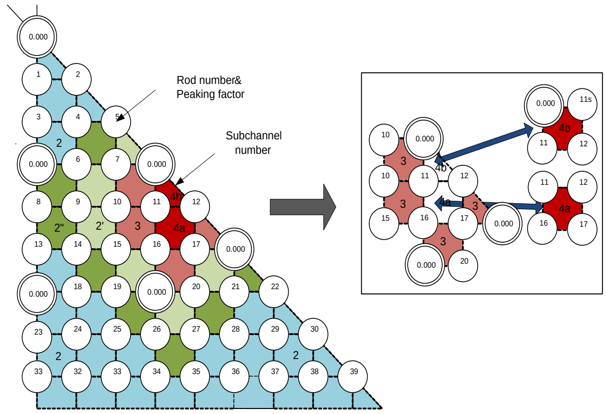


Fig. 1. Typical channel layout of 4-channel lumping model of FAST code.

2.2 Double hot channel model

Previous 4-channel method required separate two times calculation according to the hot channel type. Double hot channel method is possible to reduce the process to the single time process using the double hot channel in Fig. 2. Double hot channel model is assumed to be capable of not specifying the hot channel between typical and thimble channels because these channels have a same probability to be the hot channel.

As shown in Fig. 2, 4-channel lumping model is used to evaluate the thermal margin. Only difference with previous model is that two hot channels 4a, 4b was lumped as a single lumped hot channel 4. To evaluate the minimum DNBR of each hot channels in the lumped channel 4, additional energy conservation is derived in Eq (2).



Double hot channel model

4-Hot assembly channel (Ch2) in detail

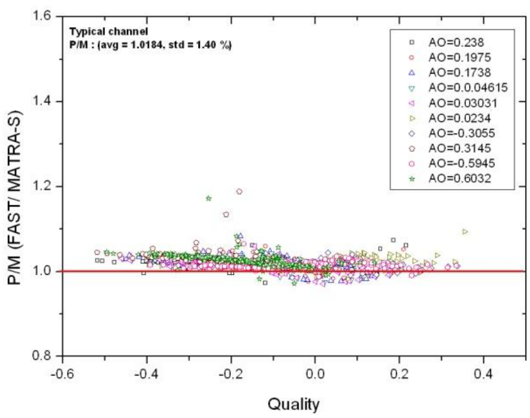
Fig. 2. Lumping model and hot channel treatment of double hot channel model

$$h_{4a,J} = \frac{m_{4,J}\dfrac{AR_1}{\Delta x}h_{4a,J-1} + w'_{3,4}SR_1 \cdot h_{3,J} + q'_4 QR_1}{m_{4,J}\dfrac{AR_1}{\Delta x} + w'_{3,4}SR_1} \qquad (2)$$

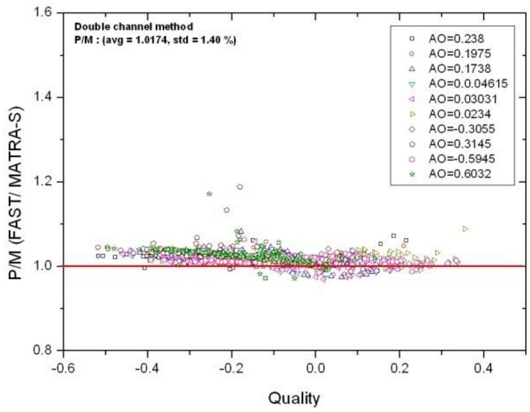
,where AR1 is area ratio of channel 4 and channel 4a or 4b, SR1 is gap ratio of the gap between channel 4 and channel 3 and the gap between channel 4a or 4b and channel 3, and QR1 is linear heat ratio of channel 4 and channel 4a or 4b.

2.3 Comparison results with MATRA-S

Double channel model and single channel model are compared with the minimum DNBR result of MATRA-S thermal margin. Calculation conditions are 1680 cases with combination of operating variables such as mass flux, heat flux, pressure, and inlet temperatures. As shown in Fig. 3, double channel method is slightly more accurate than the single channel method with 1.0 % on the P/M value. However, calculation efficiency is 2 times faster than single channel method.



a) single hot channel method results for the typical channel



b) double hot channel method results

Fig. 3. Comparisons of two 4-channel models with the minimum DNBR of MATRA-S code

3. Conclusions

Double hot channel method is developed to evaluate the thermal margin on the SMART type 17 by 17 fuel assembly. The method is possible to calculate the minimum DNBR of two hot channels, simultaneously. Double hot channel method is an efficient and accurate 4-channel lumping model in the comparison with the previous 4-channel lumping model.

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