Assessment of the Thermal Hydraulic Models in THALES

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1. Introduction

THALES (Thermal Hydraulic AnaLyzer for Enhanced Simulation of core) [1,2] developed by KEPCO Nuclear Fuel is a subchannel analysis code on the basis of the single-stage core analysis model. THALES calculates the local fluid conditions and DNBR in the PWR (Pressurized Water Reactor) core. Currently, THALES is limited to the licensed type of the nuclear power plant because the thermal hydraulic models and CHF (Critical Heat Flux) correlations for OPR1000 and APR1400 are only licensed. KEPCO NF intends to apply THALES to WH typed nuclear power plants in Korea. To expand the applicable types of the nuclear power plants, the existing thermal hydraulic models were modified and new thermal hydraulic models were added to THALES. In this study, the thermal hydraulic models tested and added in THALES are reviewed and a preliminary calculation is performed.

2. Methods and Results

2.1 Expansion of the Thermal Hydraulic Models in THALES

THALES is able to calculate the flow and enthalpy distribution in the core using subchannels. Since THALES was developed for the core thermal hydraulic design of OPR1000 and APR1400, it only has the thermal hydraulic models that are optimized for the OPR1000 and APR1400. To evaluate possibility of the expansion of the applicable types of the nuclear power plants, new thermal hydraulic models like the void model were added in THALES and some of the existing thermal hydraulic models, such as the turbulent mixing, transverse pressure loss coefficient, are modified. First, the boiling curve is shown in Fig. 1.

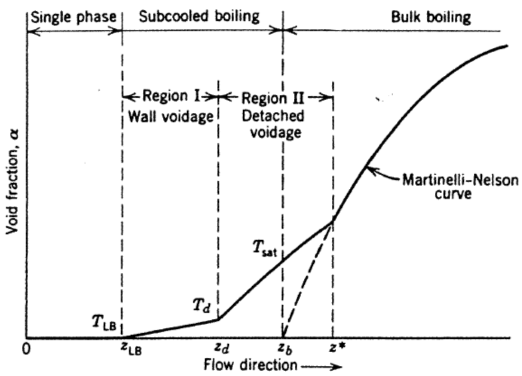


Fig. 1. Void fraction in subcooled and bulk boiling region [3]

In Region I where the degree of subcooling is high, the void fraction can be calculated using the following correlation suggested by Maurer [4];

$$\alpha = \frac{q_b'' k_L Pr_L}{1.07h^2(T_{sat} - T_b)}$$

In Region II where the degree of subcooling is reduced and the void fraction increases, the void fraction can be obtained from the void model correlation suggested by Bowring [5]. The point where boiling curve in Region I was intersected with that in Region II can be predicted by Griffith et al. [6]. Finally, the void fraction in the bulk boiling region is calculated from the homogeneous model or the Martinelli-Nelson curve. The intersecting point between the boiling curves in Region II and bulk boiling curve is the point where $\Delta T = T_{sat} - T_{bulk} = 0$.

Second, the turbulent mixing and the transverse pressure loss coefficient are modified. The turbulent mixing between channels is calculated as follows;

$$w' = \beta \cdot s \cdot \bar{G}$$

where β is TDC (Thermal Diffusion Coefficient) and s is the gap between the channels shown in Fig. 2. $\bar{G}$ is the average mass flux of adjacent channels.

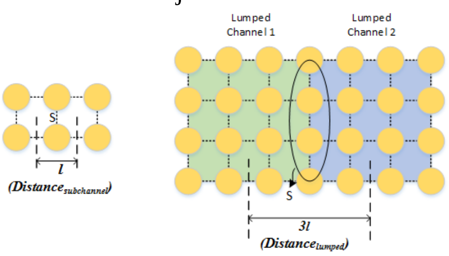


Fig. 2. Concept of the gap (s) and centroid distance (l)

The turbulent mixing is considered between the subchannels. In case of the turbulent mixing between the subchannel and the lumped channel, the following equation is used to consider the centroid distance in the some subchannel analysis codes like COBRA [7];

$$w' = \beta \cdot \left(\frac{Distance_{subchannel}}{Distance_{lumped}}\right) \cdot s \cdot \bar{G}$$

This concept is also applied to the transverse pressure loss coefficient (K_G). K_G is based on the single gap between the subchannels as shown in Fig. 3.

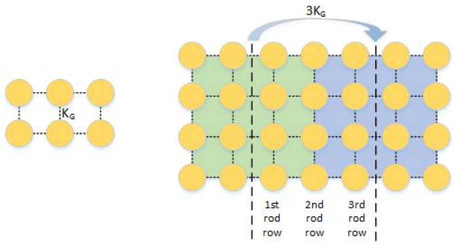


Fig. 3. Correction of K_G between lumped channels

When applying K_G between lumped channels, K_G is multiplied by N if there are N rows between the centers of the lumped channels. Fig. 3 is an example in case that N=3. The turbulent mixing and K_G modified are implemented in THALES.

2.2 Core Analysis Model

To conduct the subchannel analysis using THALES, the single stage core analysis model is developed based on the 1/8th symmetry core. The core analysis model is composed of the hot node and lumped channels. The hot node consists of 45 subchannels and 39 fuel rods as shown in Fig. 4. Yellow circles mean the fuel rod and gray circles mean the guide tube. Since the outer subchannels (channel # 37~45) meet lumped channels directly, the turbulent mixing and K_G between the outer subchannels and the lumped channels are carefully considered as mentioned in above. The fuel assemblies surrounding the hot nodes are distributed as the lumped channels.

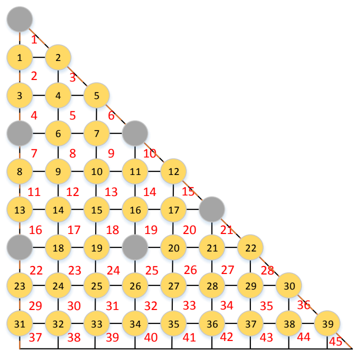
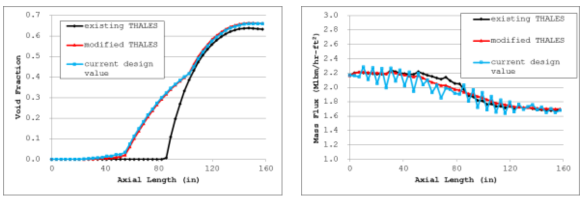


Fig. 4. Arrangement of subchannels and fuel rods in the hot node

2.3 Preliminary Calculation

The preliminary calculation is conducted using the current THALES and the modified THALES under high pressure and high power condition of Kori 3&4 nuclear power plant. The results are shown in Fig. 5.



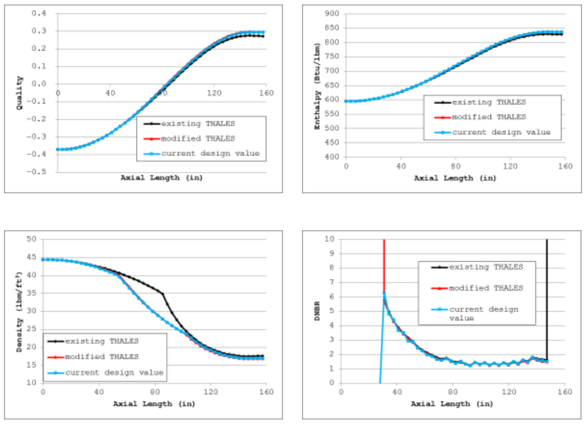


Fig. 5. Comparison between the current and modified THALES

Fig. 5 shows that the modified THALES is well following the current design results comparing to the existing THALES. Through this calculation, it is shown that the existing thermal hydraulic models are properly modified and the void model is well implemented in THALES.

3. Conclusions

KEPCO NF intends to apply THALES to various typed nuclear power plants in Korea. So, the existing thermal hydraulic models implemented in THALES are modified and the void model which are generally used in the subchannel analysis code is added. Through the preliminary calculation, it is confirmed that the thermal hydraulic models are properly modified and implemented in THALES, which shows the possibility to apply THALES in various typed nuclear power plants in Korea.

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