Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 17-18, 2012

The Characteristics of Single Stage and Multi Stage Core DNBR Analysis Models

Younhwa Lee [a*], Joon Hyong Cho
KEPCO Nuclear Fuel Co. Ltd., Reactor Core Technology Dept, 989beon-gil242(Deokjin-dong), Daedeok-daero , Yuseong-gu, Daejeon, 305-353, Korea
[*] *Corresponding author:younhwa@knfc.co.kr*

1. Introduction

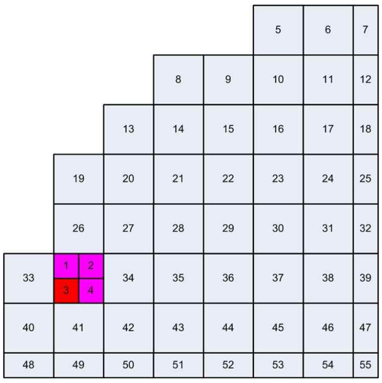
The multi stage analysis model has been applied to various core thermal hydraulic designs [1] and the fast processing analysis has benefited numerous analyses. However, the existing analysis method has been pointed out as multi stage model carries out two distinct calculations solving a single 1/4 assembly. In this paper, the single stage analysis model is proposed to solve subchannels of single 1/4 assembly and the difference between two models has been investigated. The subchannel analysis code, THALES (Thermal Hydraulic AnaLyzer for Enhanced Simulation of core) which will be applied to the core thermal hydraulic design of nuclear power plants is used [2].

2. Model descriptions

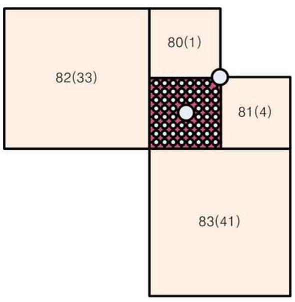
2.1 Multi stage analysis model

The multi stage analysis model is typically divided into two parts as shown in Fig.1.

The core-wide or Stage 1 analysis determines coolant



(a) Stage 1



(b) Stage 2

Fig. 1. Schematics of multi stage analysis model

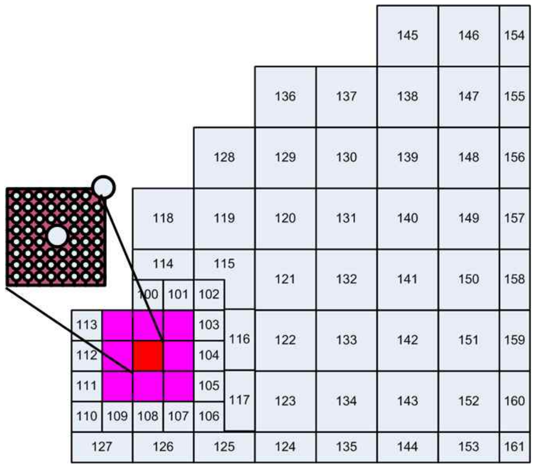


Fig. 2. Schematics of single stage analysis model

conditions throughout the core on a coarse mesh basis. A core quadrant is normally modeled, in which the smallest unit represented by a flow channel is a single fuel assembly in stage1. The local coolant conditions in the limiting subchannels are determined in Stage 2. The several variables, such as pressure, flow rates, enthalpy, etc, are calculated in Stage 1 and are provided to Stage 2 as boundary conditions.

2.2 Single stage analysis model

A core quadrant and the limiting subchannel are simultaneously calculated in the single stage analysis. The highest temperature assembly was analyzed by the units of each subchannels and the nearest channels of the surrounding 1/4 assembly were set to have lumped channel size of 2~3 subchannels. 1/4 assembly based subchannels were set to surround the boundary of lumped channels. The rest of the channels were analyzed as a unit of assembly. Fig. 2 shows the single stage analysis model which will be applied to next core thermal hydraulic design.

3. Results and Discussions

In order to compare the results of multi stage and single model, we chose representative thermal-hydraulic model and core operating condition as shown in Table I. Among various boundary conditions which affect the analysis difference between single stage model and multi stage model, mass flux is chosen as an example of influencing the analysis of minimum DNBR of limiting subchannels as shown in Fig. 3.

Table I: Operating conditions of core analysis model

Run assembly #	Pressure (psia)	Inlet Temp. (^oF)	Mass flux ($Mlbm/ft^2$-hr)	Core average heat flux ($MBtu/ft^2$-hr)
120	2415	595	2.0854	0.188251

As revealing the character of multi stage model, the boundary conditions around limiting subchannels are applied as fixed and uniform values, or largely lumped values. However, when the single stage model is used, the limiting subchannels and channels around limiting subchannels are simultaneously calculated providing more realistic boundary conditions. Consequently, the results of the DNBRs of limiting subchannels show difference between two models due to distinct local conditions as shown in Fig.4. For new thermal-hydraulic analysis model, single stage model can be a recommendable candidate as the model processes the calculation more similar to full-core analysis, and provides better accuracy over multi stage analysis model. The more minimum DNBR differences between two models were observable with pin power distribution examples of higher deviation. Totally three pin power distributions are investigated as shown in Fig. 5. 'Peak' pin power distribution has the maximum pin of 1.550 and local pin power gradually decreases from maximum pin to other locations of pins forming a contour line. 'Mid-peak' pin power distribution has the maximum pin of 1.400. 'Flat' pin power distribution has the same pin powers over the 1/4 assembly. The averages of each three distributions are identical to the value of 1.360. Pin to node factor (P2N) represents the value of maximum pin power divided by average pin power. 'Peak' pin power distribution can be considered as a distribution of high deviation, and on contrary, 'Flat' as low deviation distribution.

As a result, high deviation pin power, 'Peak', produced the largest difference of 3.25% between multi-stage analysis and single-stage analysis.

	2.0151	2.0151	2.0151	2.0151	2.0151	2.0151	2.0151	2.0151	2.0151	
2.1663	2.1356	1.9596	1.9116	1.8836	1.8606	1.8425	1.8295	1.7146		1.7931
2.1663	2.1358	1.9526	1.9107	1.8850	1.8629	1.8450	1.8321	1.8093	1.7158	1.7931
2.1663	2.1291	1.9510	1.9106	1.8858	1.8598	1.8412	1.8270	1.8176	1.8091	1.7931
2.1663	2.1221	1.9498	1.9117	1.8758	1.7406	1.8208	1.8225	1.8116	1.8067	1.7931
2.1663	2.1134	1.9461	1.9092	1.7709		1.7125	1.8155	1.8078	1.8038	1.7931
2.1663	2.1027	1.9418	1.9070	1.8738	1.7424	1.8231	1.8209	1.8092	1.8060	1.7931
2.1663	2.0914	1.9381	1.9039	1.8823	1.8604	1.8426	1.8261	1.8145	1.8127	1.7931
2.1663	2.0837	1.9425	1.9091	1.8874	1.8684	1.8523	1.8382	1.8294	1.8267	1.7931
2.1663	2.1135	2.0234	1.9904	1.9681	1.9492	1.9323	1.9192	1.9108	1.9021	1.7931
	1.7633	1.7633	1.7633	1.7633	1.7633	1.7633	1.7633	1.7633	1.7633	

(a) Multi stage

	2.0998	2.0998	2.0998	1.8677	1.8677	1.8677	1.8139	1.8139	1.8139	
2.0864	2.1857	2.0549	2.0319	1.9162	1.8743	1.8528	1.8298	1.6889		1.7656
2.0864	2.1900	2.0485	1.9994	1.9206	1.8749	1.8463	1.8244	1.7939	1.6610	1.7656
2.0864	2.1891	2.0452	1.9887	1.9227	1.8759	1.8420	1.8183	1.8004	1.7839	1.7656
2.0804	2.1880	2.0427	1.9880	1.9171	1.7450	1.8213	1.8122	1.7921	1.7729	1.7521
2.0804	2.1863	2.0413	1.9860	1.8014		1.6967	1.8053	1.7884	1.7696	1.7521
2.0804	2.1848	2.0396	1.9805	1.9083	1.7448	1.8223	1.8120	1.7930	1.7758	1.7521
2.1212	2.1842	2.0371	1.9769	1.9170	1.8729	1.8428	1.8199	1.8046	1.7999	1.8495
2.1212	2.1837	2.0394	1.9858	1.9199	1.8783	1.8511	1.8306	1.8185	1.8141	1.8495
2.1212	2.2804	2.1624	2.1246	2.0213	1.9758	1.9486	1.9247	1.9132	1.9068	1.8495
	2.0186	2.0186	2.0186	1.7877	1.7877	1.7877	1.7508	1.7508	1.7508	

(b) Single stage

Fig. 3. Exit mass flux distributions

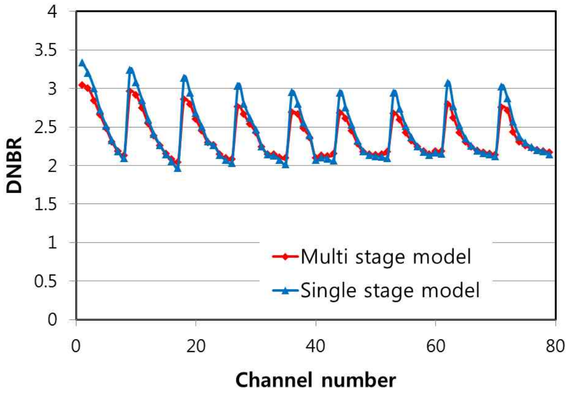
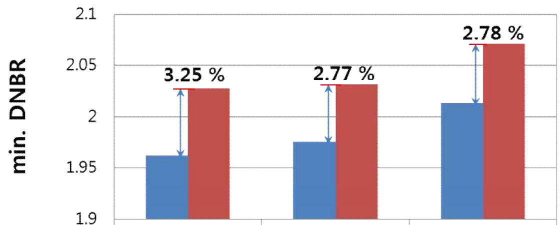


Fig. 4. Comparison of the DNBR results



	Peak	Mid-peak	Flat
multi-TH	1.9617	1.9752	2.0132
single-TH	2.0275	2.0315	2.0708
P2N	1.140	1.030	1.000

Fig. 5. Minimum DNBR from three distributions using single stage and multi stage model

The lowest deviation pin power 'Flat' produced the smallest difference of 2.78% between two analyses.

4. Conclusions

In this study, the single stage analysis model is proposed to improve calculation accuracy of multi stage analysis model. Based on the results, it could be concluded as single stage model conveying more reasonable accuracy due to the fact that lumped boundary conditions are replaced by individually realistic boundary conditions for analysis of local subchannels. In addition, the higher pin power distribution deviations are, the more minimum DNBR differences are founded.

REFERENCES

[1] User's Manual for TORC, CE-NPSD-628-P Rev. 12, Westinghouse Electric Company, June 2001.

[2] K.Y. Nahm, J.S. Lim, C.K. Chun, S.K. Park, S.C. Song, "Development Status of THALES Code", Korea Nuclear Fuel Co., Ltd., *Transactions of the Korean Nuclear Society Autumn Meeting*, Oct. 30, 2008.