Comparative study of Thermal Hydraulic Analysis Codes for Pressurized Water Reactors

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1. Introduction

Various codes are used for the thermal hydraulic analysis of nuclear reactors. For example, RELAP5, TRAC, COBRA-TRAC, CATHARE, ATHLET, DINAMIKA, SMABRE, APROS, TUF, RETRAN, CATHENA and etc. are used for the simulation of the system behavior and the codes like CONTEMPT, CONTAIN, GOTHIC, JERICHO, RALOC and COCOSYS those are used for the containment analysis [1]. There are two domestic development codes, SPACE and MARS. The use of some codes among these is limited by user and some codes are not even open to general person. Thus, the use of alternative code is considered for some analysis.

In this study, simple thermal hydraulic behaviors are analyzed using three codes to show that alternative codes are possible for the analysis of nuclear reactors. We established three models of the simple u-tube manometer using three different codes. RELAP5 (Reactor Excursion and Leak Analysis Program) [2], SPACE (Safety and Performance Analysis CodE for nuclear power Plants) [3], GOTHIC (Generation of Thermal Hydraulic Information for Containments) [4] are selected for this analysis. RELAP5 is widely used codes for the analysis of system behavior of PWRs. SPACE has been developed based on RELAP5 for the analysis of system behavior of PWRs and licensing of the code is in progress. And GOTHIC code also has been widely used for the analysis of thermal hydraulic behavior in the containment system.

2. Methods and Results

2.1 Analysis method

Fig. 1 shows the nodalization of the simple u-tube manometer.

The manometer is composed of two vertical pipes, which are separated 6 nodes, respectively. It is filled with water in node 2~6 of left side pipe and with nitrogen gas in node 1 of left side pipe and entire nodes of the right side pipe. Two vertical pipes are connected by a trip valve, J350. C200 and C500 are modeled as boundary conditions.

The model is assumed including the initial and boundary conditions summarized in Table 1.

If the trip valve, J350, is assumed to be opened after 10 seconds, the water begins to flow from pipe C300 to pipe C400 at the valve opening time and would be slowly stabilized through the transient period.

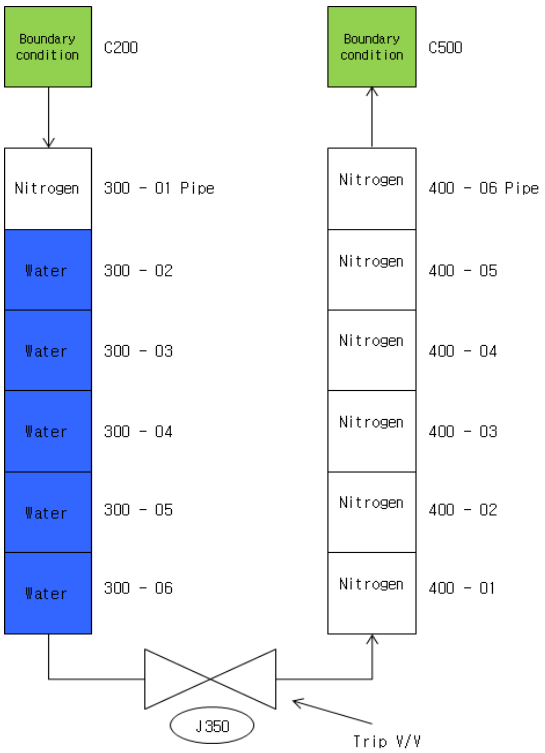
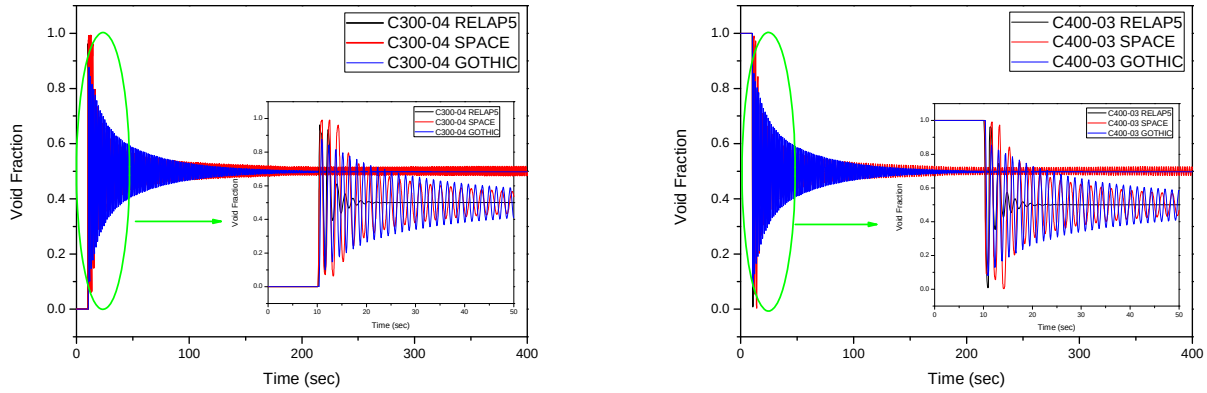


Fig. 1. Nodalization of u-tube manometer

Table 1 Model assumptions

Variable		Value
Initial condition of Gas and Water	Temperature (K)	330.3722
	Pressure (kPa)	101.325
Boundary condition	Temperature (K)	330.3722
	Pressure (kPa)	101.325
Cross-sectional Area (m^2)	Pipe (C300, C400)	0.007851597
	Valve (C350)	0.007851597
node length of Pipe C300 and C400 (m)		0.2
Opening time of valve J350 (sec)		10.0



(a) node 300-04 (b) node 400-03

Fig. 2. Void volume fraction of each Node

2.2 Analysis results

We analyzed the final stabilized time and void volume fraction of each node using RELAP5, SPACE and GOTHIC codes. Fig. 2 shows the void volume fraction of node 300-04 and 400-03. Shown in the Fig. 2, the transient phenomenon stops at about 27 seconds and the maximum peak of initial void volume fraction in the transient period rise up to 0.95 from initial 0.0 in RELAP5 and about 200 seconds and 0.87 in GOTHIC analysis result, where about 190 seconds and 0.98 in SPACE.

The general transient behavior analyzed by SPACE was similar to the transient behavior analyzed by RELAP5 and GOTHIC. However, the final stabilized time was significantly difference.

The difference of RELAP5 and GOTHIC would result from each code characteristic because RELAP5 specialized in thermal-hydraulic analysis for the rupture leakage of reactor, where GOTHIC was developed in specialized in the containment. The previous study reports that the difference between RELAP5 and GOTHIC is attributed to differences in spatial discretization and to different physical model used in the two codes [5]. Another study reports "the GOTHIC simulations show a better agreement with the experimental results than the RELAP5 and COPTA and this study also reports that it was not clarified if the difference was due to an error in the input data, absence of water resources in the model or in the capability of the programs to predict the superheated steam" [6].

The difference of RELAP5 and SPACE would result from applying the different governing equations. RELAP5 modeled by 2 fields and 7 governing equations, where SPACE modeled by 3 fields and 10 equations. GOTHIC also solves the multi-phase flow. Therefore, more persuasive analysis should be revealed later for the different results due to the different governing equations.

3. Conclusions

The internal behavior of u-tube manometer was analyzed by RELAP5, SPACE and GOTHIC codes. The general transient behavior was similar among 3 codes. However, the stabilized status of the transient period analyzed by REPAP5 was different from the other codes. It would be resulted from the different physical models used in the other codes, which is specialized for the multi-phase thermal hydraulic behavior analysis.

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