Evaluation of the Thermal-Hydraulic System Analysis Code for SMART-P

Yong Won Choi,a Dong Ju Jang,a Chang Hwan Park,a Un Chul Lee,a Young Dong Hwang,b Kyu Hyung Lee,b Hee Chul Kim b

a Dept. Nuclear Engr. Seoul Nat'l Univ., Shillim-dong, Kwanak-gu, Seoul, 151-744, Korea, changga@snu.ac.kr

b Korea Atomic Energy Research Institute P.O.Box 105, Yuseong, Daejeon, 305-600, KOREA, ydhwang@kaeri.re.kr

1. Introduction

In this study, the basic equations set and several special models of TASS/SMR were reviewed and there were a process of selection of basic problems for V&V of TASS/SMR. Then, evaluation work has been performed properly for each problem considering the objective of the validation contents. This study is on the first stage for V&V of TASS/SMR, where it is evaluated with basic conceptual and analytical problems.

In the 2nd stage, TASS/SMR will be evaluated by comparing with the experimental results of high pressure & high temperature experimental facility

2. Selection of Basic Problems for Verification of TASS/SMR

2.1 Basic equation of TASS/SMR

The Basic equations of TASS/SMR are composed of five basic conservation equations and one conservation equation of incompressible gas.

- Mixture's mass conservation equation:

$$A\frac{\partial}{\partial t}(\rho_m)+\frac{\partial}{\partial x}(W_x)=0 \tag{1}$$

- Liquid mass conservation equation:

$$A\frac{\partial}{\partial t}[(1-\alpha)\rho_l]+\frac{\partial}{\partial x}[(1-\alpha)\frac{\rho_l}{\rho_m}W_x]-\frac{\partial}{\partial x}[\frac{\alpha\rho_g(1-\alpha)\rho_l}{\rho_m}V_r A]=-\Gamma_g \tag{2}$$

- Mixture's momentum conservation equation:

$$\frac{\partial}{\partial t}(W_m)+\frac{\partial}{\partial x}(\frac{W_m^2}{\rho_m A})+\frac{\partial}{\partial x}[\frac{\alpha\rho_g(1-\alpha)\rho_l}{\rho_m}V_r^2 A]=-A\frac{\partial P}{\partial x}-K\Phi^2\frac{W_m|W_m|}{2\rho_m A}+\rho g h \tag{3}$$

- Mixture's energy conservation equation:

$$A\frac{\partial}{\partial t}(\rho_m e_m)+\frac{\partial}{\partial x}(h_m W_m)+\frac{\partial}{\partial x}[\frac{\alpha\rho_g(1-\alpha)\rho_l}{\rho_m}(h_g-h_l)V_r A]=q'_w \tag{4}$$

- Vapor enthalpy conservation equation:

$$A\frac{\partial}{\partial t}(\alpha\rho_g h_g)+\frac{\partial}{\partial x}(h_g\frac{\alpha\rho_g}{\rho_m}W_m)+\frac{\partial}{\partial x}[\frac{\alpha\rho_g(1-\alpha)\rho_l}{\rho_m}h_g V_r A]=\Gamma_g\cdot h_{sg}+q'_{wg}+q'_{ig} \tag{5}$$

- Incompressible gas mass conservation equation:

$$A\frac{\partial}{\partial t}(\alpha\rho_N)+\frac{\partial}{\partial x}(\frac{\rho_N}{\rho_g}\frac{\alpha\rho_g}{\rho_m}W_m)+\frac{\partial}{\partial x}[\frac{\alpha\rho_N(1-\alpha)\rho_l}{\rho_m}V_r A]=0 \tag{6}$$

2.2 Selection of Basic Problems

Table 1. Selection of Basic Problems

No.	Selected Problem	Relative Verification Object
1	Mass & Energy conservation	-mass/energy error -mass/energy convection
2	Nine Volume	-gravity -phase interface boundary
3	Pressure Gradient by Local Loss	-local losses -geometrical variation
4	Pressure Gradient by Compound Channel	-local losses -gravity / frictional loss
5	Manomatric Oscillation	-mass convection / gravity -momentum flux -oscillatory frequency
6	Natural Circulation	-mass/energy convection -direct energy input -natural convection flow rate
7	Donor Void Fraction & Downflow Rate	-donor void fraction & downflow rate
8	Temperature Gradient of Heated Channel	-energy convection -mass convection -energy conservation
9	Stratified Flow	-void fraction wave propagation -phase interface boundary
10	Control System Logic	-control logic simulation

3. Results: example – Manomatric Oscillation

3.1 Concept

This Problem is for calculating fluid oscillation by gravity in half full of water manometer, supposed by Ransom (1992). The initial fluid velocity in manometer is not zero to make the condition for oscillation.

The accuracy of calculation can be verified by comparing the TASS/SMR result of this problem with referential analytic solution.

This problem is to identify how well the gravitational effect is reflected in momentum equation of TASS/SMR and how well the interface between liquid and gas is maintained.

3.2 Verification system

3.2.1. Referential analytic solution

In Case of neglecting wall friction and inertia of vapor, period can be expressed as following expression.

$$\therefore \tau = \pi\sqrt{\frac{2L}{g}} \tag{7}$$

L : the water length
g : gravity

3.2.2. Nodalization

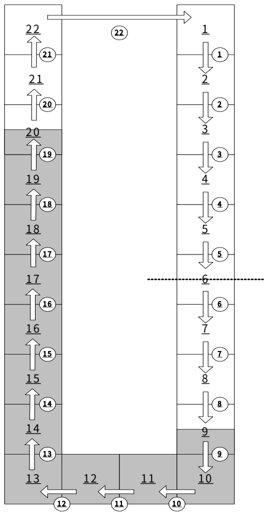

Figure 1. Manometric Oscillation Node Composition

3.3 Result and analysis

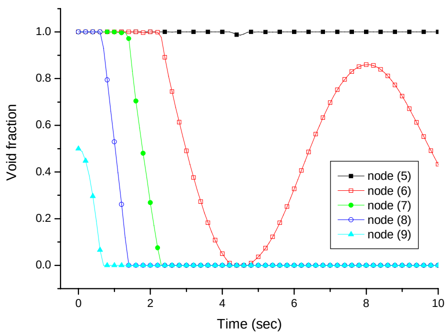

Figure 2. Behavior of void fraction

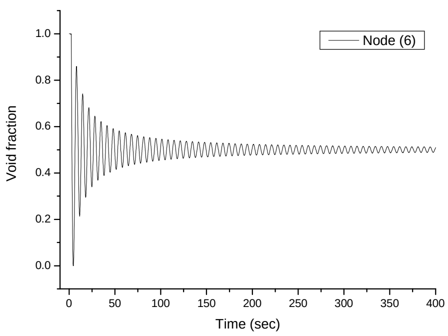

Figure 3. Behavior of void fraction Node six

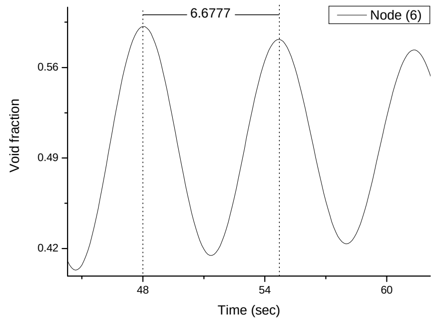

Figure 4. Period of oscillation

Table 2. Analysis of result

Analytical reference solution(sec)	TASS/SMR(sec)	Error
6.6568	6.6777	0.3140%

The oscillation behavior showed gravity effect quantitatively well and interface between fluid and gas was maintained well. And we could ascertain by oscillation period that there was a considerable confidence of calculation accuracy in TASS/SMR.

4. Conclusion

Through the process of validation of TASS/SMR, it is found that the error mass & energy has the degree of 10^{-6}. Generally, the result conservation law of mass and energy can be considered pertinent. The results of the evaluation of momentum equation lead to the conclusion that each term of momentum equation is reflected properly in the calculation. Gravitational effect is also shown well through the nine volume problem. The period of manometric oscillation is nearly same with the analytical solution and the interfacial boundary of each phase (liquid and steam) is kept well during whole calculation time. The result of the temperature gradient in unheated channel is found proper with respect to the energy conservation. And down flow rate from donor node has variance dependent on the void fraction of the donor node. In the stratified channel having different water level in the both side from the middle, the behavior of void fraction wave propagation is found out. Collectively, it can be concluded that TASS/SMR has appropriate ability related to numeric and basic equation of that is well-established.

REFERENCES

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[2] KAERI, " TASS- Governing Equations", 1999