# Assessment of Flow Regime and Friction Modules in the SPACE code

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## 1. Introduction

Since 2007, the SPACE code has been developed by several companies and research institutes, with the aim of analyzing thermal-hydraulic behaviors of PWR power plants in the light of safety. KAERI has been in charge of thermal-hydrodynamic models and correlations. At present, the trial version of the code is on the edge of release. For this reason, a variety of evaluations have been made for checking that the integrated correlation package works as designed. The package is composed of correlation modules of flow regime maps, interfacial/wall friction, interfacial/wall heat transfer, and droplet entrainment/ de-entrainment. This paper provides some results showing the verification of correlation modules for flow regime maps and interfacial/wall frictions.

## 2. Models and Correlations

Through an intensive literature survey, we selected models and correlations of the vertical flow regime map and interfacial/wall frictions to be incorporated into the SPACE code. They are summarized in Table I and II. Due to the limitation of paper length, pre-CHF vertical cases are considered in the present study. Detailed information on the references can be found in the reference [1].

Table I: Selected literature for vertical flow regime map

| Flow regime | Selections |
|---|---|
| Bubbly Cap/Slug | Titel (1980) for void fraction<br>Choe (1976) for mass flux |
| Cap/Slug Transition | Mishima & Ishii (1984) |
| Transition Annular-mist | McQuillin & Whalley (1983, 1985) |
| Stratified | Ishii (1979) |

Table II: Selected literature for interfacial/wall frictions

| Flow regime | Selections |
|---|---|
| Bubbly Cap/Slug (interfacial friction) | - Ishii & Chawla (1979) (Drag coefficient model)<br>-RELAP5/Mod3.3 (Drift-flux model) |
| Annular-mist (interfacial friction) | Wallis (1970) |
| Droplet (interfacial friction) | Ishii & Chawla (1979) |
| Total pressure drop (wall friction) | Claxton et al. (1972)<br>Churchill (1977) |

## 3. Test conditions

Figure 1 illustrates test conditions for a vertical pipe with three cells. Water and steam are injected from the bottom inlet. A pressure boundary condition is imposed on the top outlet. At the inlet, the velocity of water is fixed at 6m/s, however, the velocity of steam is set to a value ranging from 2 to 50m/s and void fraction at the inlet is adjusted from 0.05 to 0.95.

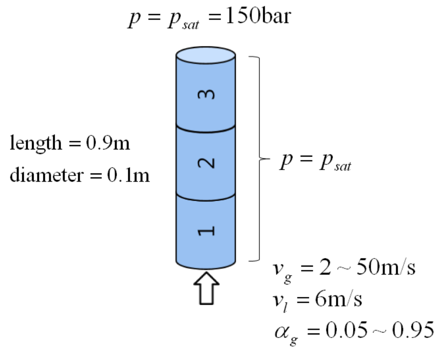


Fig. 1. Schematic diagram of a vertical test

## 3. Result

### *3.1 Flow regime map*

The test result of a vertical flow regime map is given in Fig. 2. The dash lines indicate the boundaries between flow regimes, according to Table I. In this figure, the liquid velocities($v_l$) are all 6m/s, but the gas velocities ($v_g$) are 2, 4, 6.5, 8, 10, 15, 20, 25, 30, 40, 50m/s in order from the lowest line, respectively. The drag coefficient models are utilized in this result.

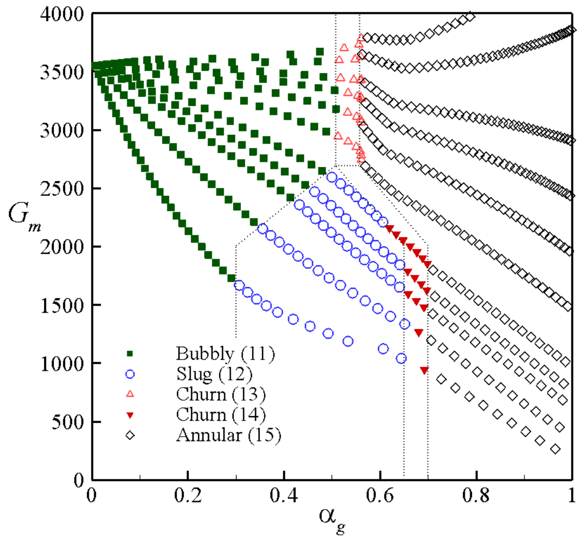


Fig. 2. Flow regime map

### *3.2 Interfacial/wall frictions*

A line of $v_g$=10m/s and $v_l$=6m/s is chosen for the interfacial/wall friction tests since it passes through a few flow regimes, as shown in Fig. 2. Figure 3 and 4 show the interfacial and wall friction coefficients:

$$F_{gk} = \frac{F_{ik}}{(v_g - v_k)},\ F_{wk} = \frac{F_{wk}}{v_k} \quad (1)$$

Here, $F_{ik}$ and $F_{wk}$ are the interfacial and wall friction forces of phase $k$ per the unit volume [N/m$^3$], the phase symbol $k=l$ and $d$ stand for liquid and droplet, respectively.

We can see from Figs. 3~4 that the friction modules work as designed, based on the several observations. First, their curves change smoothly across the flow regimes. Second, the interfacial friction between gas and droplet phases appears at the beginning of annular flow($\alpha_g \geq 0.75$), which is due to the occurrence of droplets. Third, the wall friction against gas increases with void fraction, however, the wall friction against liquid decreases gradually. As for the droplets, the friction remains nearly zero. Above observations are physically correct and imply the normal operation of the correlation modules for flow regime maps, interfacial area, interfacial/wall frictions.

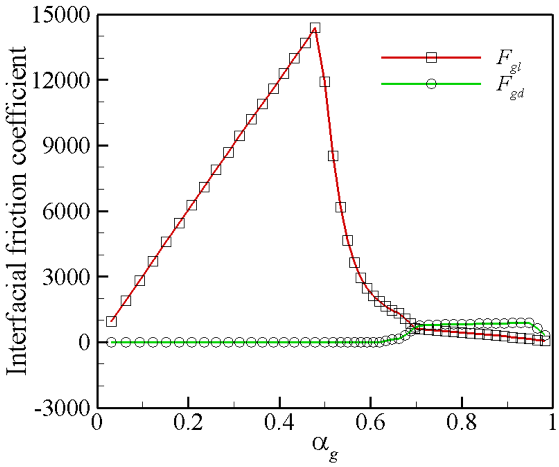


Fig. 3. Interfacial friction coefficient variation with $\alpha_g$

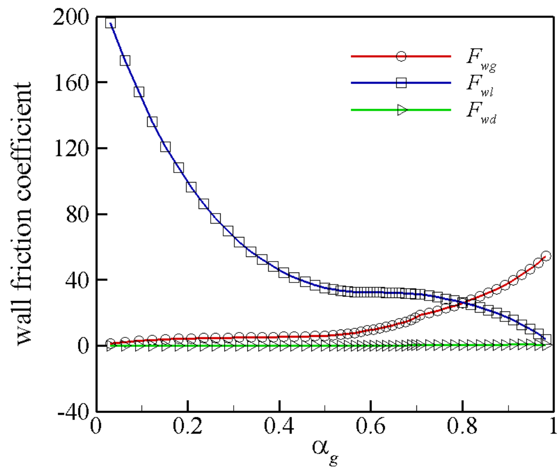


Fig. 4. Wall friction coefficient variation with void fraction

## 4. Conclusion

Before releasement the trial version of the SPACE code, many evaluations have been being performed to test the integrated correlation modules. As a part of assessment, this paper ascertains the normal operation of the correlation modules for flow regime maps, interfacial area, interfacial/wall frictions.

## Acknowledgments

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## REFERENCES

[1] K. D. Kim, S. W. Lee, S. W. Bae, S. K. Moon, S. Y. Kim, Y. H. Lee, Thermal-Hydraulic Models and Correlations for the SPACE code, May 18-20,. 2009, Jeju, Korea