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Interfacial and Wall Transport Models for SPACE-CAP Code

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1. Introduction

The development project for the domestic design code was launched to be used for the safety and performance analysis of pressurized light water reactors. And CAP (Containment Analysis Package) code has been also developed for the containment safety and performance analysis side by side with SPACE. The CAP code treats three fields (gas, continuous liquid, and dispersed drop) for the assessment of containment specific phenomena, and is featured by its multi-dimensional assessment capabilities. Thermal hydraulics solver was already developed and now under testing of its stability and soundness [1].

As a next step, interfacial and wall transport models was setup. In order to develop the best model and correlation package for the CAP code, various models currently used in major containment analysis codes, which are GOTHIC[2], CONTAIN2.0[3], and CONTEMPT-LT [4], have been reviewed. The origins of the selected models used in these codes have also been examined to find out if the models have not conflict with a proprietary right. In addition, a literature survey of the recent studies has been performed in order to incorporate the better models for the CAP code. The models and correlations of SPACE were also reviewed.

CAP models and correlations are composed of interfacial heat/mass, and momentum transport models, and wall heat/mass, and momentum transport models. This paper discusses on those transport models in the CAP code.

2. Review of the Major Phenomena in Containment

Major components inside containment are;

- Atmosphere
- Structure
- Pool

Interactions among them can be listed as follows;

- Heat/mass and momentum transfer of spray drop
- Pressure drop by friction or shape change
- Heat transfer by natural convection
- Heat transfer by forced convection
- Interfacial shear stress
- Condensation
- Evaporation or boiling
- Spray deposition

In summary the containment thermal hydraulic phenomena are combined interactions between vapor, continuous liquid, dispersed drop, and solid wall. Such interactions include heat/mass and momentum transfers. Besides them gas diffusion is also an important phenomenon.

3. Interfacial Transport Model

Through the intensive review of containment specific phenomena and well-known containment analysis code, simple but effective flow regime map was developed. Fig.1 shows the typical of pool/drop flow pattern.

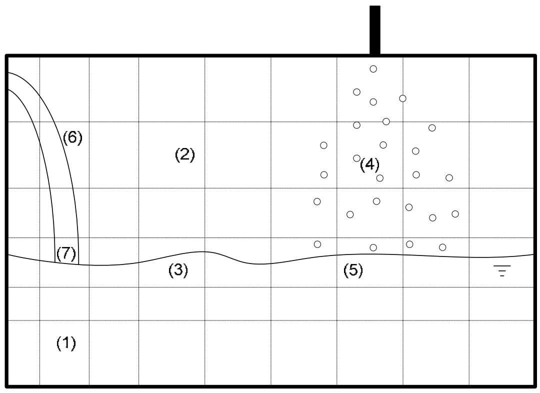

Fig. 1 Flow Pattern in CAP

In Fig. 1 the numbered cells have following features;

- Cell (1): is fill with only liquid and has no free surface
- Cell (2): is filled with only gas and has no free surface
- Cell (3): is composed of continuous liquid and gas at the same time and has a unique free surface
- Cell (4): is composed of dispersed drop and gas at the same time but has no free surface
- Cell (5): is composed of gas, continuous liquid, and dispersed drop at the same time and has a unique free surface
- Cell (6): has continuous liquid jet and has no free surface
- Cell (7): is the place at which the continuous liquid jet meets the free surface, free surface has no actual meaning. Actual free surface may exist at upper cell.

Location which has a free surface can be determined by comparison of void or liquid fractions at upper or lower cells. This pool/drop regime is commonly used in horizontal flow, lumped parameter model, and junction flow model.

Interfacial area model, interfacial heat/mass transport model, and interfacial momentum transport model are summarized in Table 1, in Table 2, and in Table 3, respectively.

Table 1 Interfacial Area Model

Case	Model	Comments
Pool-Gas	Cell horizontal area	Wave effect (Wallis, 1969)
Drop-Gas	IAC transport	-
Jet-Gas	Liquid fraction weighted cross-section and cell length	Max. or Min. Option

Table 2 Interfacial Heat/Mass Transport Model

Case	Model	Comments
Pool-Gas	Pool: Linehan (1972) Gas: Bankoff (1980)	-
Drop-Gas	Drop: Bird (2002) or Pasamehmetoglu and Nelson (1987) Gas: Ryskin (1987)	Drop: Max of the Two
Pool-Drop (Only Mass Transport)	Lopez (1998) Hinz (1982)	Pool Entrainment, Drip, Gravitational Settling, Impaction, Deposition, and so on
Jet-Gas	Pool: Linehan (1972) Gas: Bankoff (1980)	Same to Pool-Gas Case

Table 3 Interfacial Momentum Transport Model

Case	Model	Comments
Pool-Gas	Ohnuki (1987)	SPACE
Drop-Gas	Ishii-Mishima (1984)	SPACE
Jet-Gas	Ohnuki (1987)	-

4. Wall Transport Model

Typical wall heat transfer patterns are shown in Fig. 2. The heat transfers address convective heat transfer (free convection and forced convection), condensation heat transfer (direct condensation and blowdown condensation), and boiling heat transfer (nucleate heat transfer and subcooled boiling). Solid structure should be determined whether it is submerged or not, because the heat transfer is very different according to its submergence. And then the appropriate heat transfer mode is selected as shown in Fig. 3.

Table 4 shows summarized wall heat and momentum transfer models.

5. Conclusions

This paper presents interfacial and wall transport model in CAP code. In further study, actual tests will be conducted in order to check the model performance.

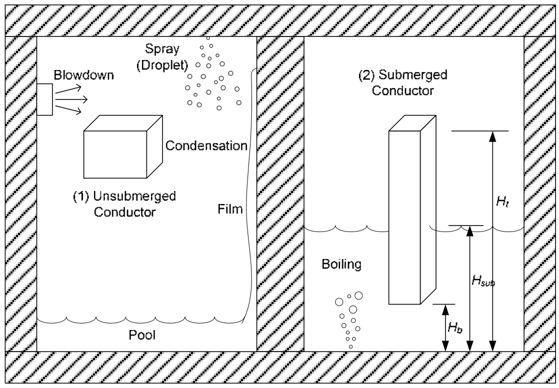

Fig. 2 Wall Heat Transfer Pattern in CAP

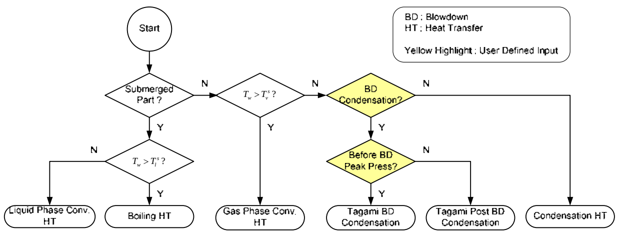

Fig. 3 Wall Heat Transfer Mode in CAP

Table 4 Wall Heat and Momentum Transport Model

Case	Model	Comments
Free Convection	Churchill-Chu, McAdams, Lloyd-Moran, Morgan, Bejan	Geometry Dependent
Forced Convection	Blassisus Solution Dittus-Boelter	Laminar or Turbulent
Boiling	Nucleate Boiling: Chen Subcooled Boiling: Chen	-
Condensation	Uchida Tagami Blowdown Tagami Post Blowdown	Tagami model is for single volume model
Drag	Friction and Form Loss	-

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