Preliminary Test for Constitutive Models of CAP

Yeon Joon Choo*, Soon Joon Hong[a], Su Hyun Hwang[a], Keo Hyung Lee[a], Min Ki Kim[a], Byung Chul Lee[a], Sang Jun Ha[b], Hoon Choi[b]
[a] *FNC Tech., SNU 135-308, Daehak-Dong, Kwanak-Gu, Seoul, 151-742, S. Korea*
[b] *Korea Electric Power Research Institute, 65 Moonjiro, Yuseonggu, Daejeon, 305-380 , S. Korea*
**Corresponding author: yjchoo@fnctech.com*

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. As a part of this project, CAP (Containment Analysis Package) code has been developing for the containment safety and performance analysis side by side with SPACE. The CAP code treats three fields (vapor, continuous liquid and dispersed drop) for the assessment of containment specific phenomena, and is featured by assessment capabilities in multi-dimensional and lumped parameter thermal hydraulic cell. Thermal hydraulics solver was developed and has a significant progress now [1]. Implementation of the well proven constitutive models and correlations are essential in other for a containment code to be used with the generalized or optimized purposes.

Generally, constitutive equations are composed of interfacial and wall transport models and correlations. These equations are included in the source terms of the governing field equations. In order to develop the best model and correlation package of the CAP code, various models currently used in major containment analysis codes, such as GOTHIC[2], CONTAIN2.0[3] and CONTEMPT-LT [4] are reviewed. Several models and correlations were incorporated for the preliminary test of CAP's performance and test results and future plans to improve the level of execution besides will be discussed in this paper.

2. Constitutive models in Containment Phenomena

Two major transport phenomena in containment occur 1) between two fields through an interface and 2) between each field and wall which is the solid surface of heat structure. Typical interfaces are between 1) pool and atmosphere and 2) dispersed drop and atmosphere 3) pool and dispersed drop. Transport phenomena through interface and wall could include

- Convective (sensible) heat transfer
- Condensation/ Evaporation (latent) mass transfer base on the steam partial pressure
- Spray gravitational settling on the continuous liquid interfacial surface.
- Shear stress (drag force) between fields and between each field and wall

All models presented in this paper were tested for the lumped parameter cells only.

3. Interfacial Transport Model

Up to now CAP has pool-drop flow regime only. Three interfaces among three fields are considered; vapor-liquid, liquid-drop and drop-vapor. Fig. 1 shows schematically the typical flow pattern and three interfaces. First interface is formed on the free surface of pool which bounds between atmosphere filled with gas mixture and pool filled with continuous liquid. Vapor field consists of steam and a number of noncondensible species, which have the same local temperature and velocity. Reference temperature of heat transfer from interface toward each phase is the saturation temperature based on the steam partial pressure during condensation and evaporation. Mass transfer between two fields through interface results from energy surplus and deficit of interfacial heat transfer mentioned above. Same processes could occur on interfacial heat/mass transfer between drop and vapor. Interaction between steam and liquid/drop field includes both the sensible heat transfer and latent heat transfer, whereas between noncondensible gas and liquid/drop only sensible heat transfer. Interfacial drag occurs between fields except for liquid-drop interface and embeded in the momentum source term.

Interfacial area model, interfacial heat/mass transport model, and interfacial momentum transport model are summarized in Table I and Table II, respectively.

4. Wall Transport Model

Typical wall heat transfer patterns are shown in Fig. 2. The heat transfers address convective (free convection and forced convection) and condensational (direct condensation and blowdown condensation). Mass transfer between steam and wall is accounted by

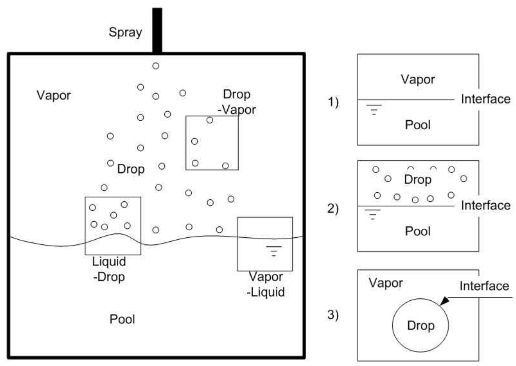

Fig. 1. Typical flow pattern and interface in CAP

condensation only. These wall heat transfer rate are used as boundary conditions to solve the conduction equation of heat structure. Summation of friction and minor loss drag was included in momentum source terms also. Wall constitutive models implemented in CAP are summarized in Table III.

Table I: Interfacial heat/mass transport model

Case	Model	Comments
Pool-Vapor	Pool: Linehan (1972) Gas: Bankoff (1980)	-
Drop-Vapor	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)	Gravitational Settling, Impaction, Deposition, etc.

Table II: Interfacial drag model

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

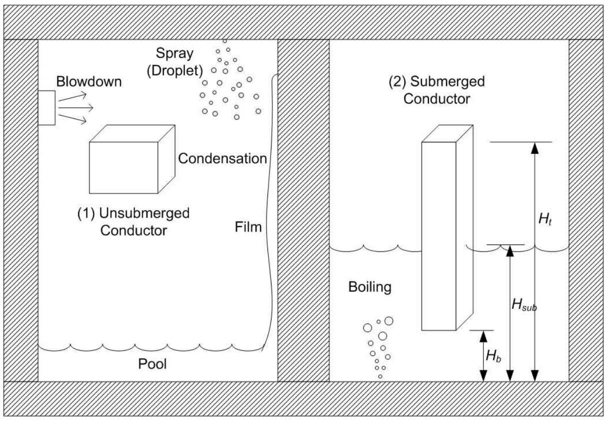

Fig. 2. Wall heat transfer pattern in CAP

Table III: Wall heat, mass 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
Condensation	Uchida Tagami Blowdown	Tagami model is for single volume model
Drag	Friction and Form Loss	-

5. Preliminary Test Result and Discussion

Figure 3 shows the preliminary test result. Constitutive models tested here include the interfacial hest transfer between vapor and pool, Uchida condensation model and convective heat transfer between vapor and wall. Test initial condition of cell is P= 1bar, T= 150^{o}C, pure steam (volume fraction = 0.9) and pool (volume fraction = 0.1) and heat structure is initially at 30^{o}C. Cell pressure is falling due to the condensational heat transfer with the subcooled wall by 100 sec. Volume fractions of vapor and liquid are decreased and increased before finishing condensation mode. After then, interfacial heat and mass transfer will be the dominant transport phenomena.

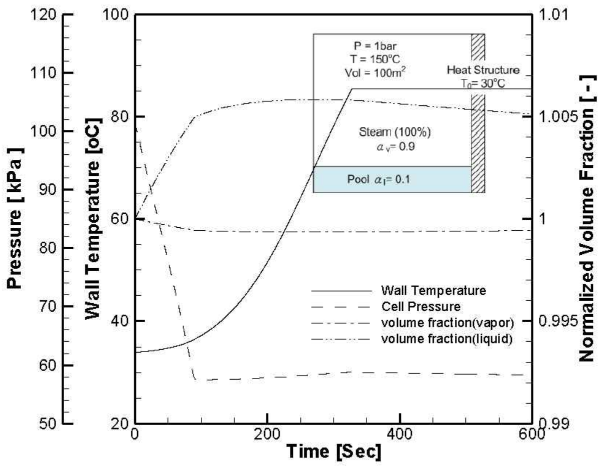

Fig. 3. Preliminary test result of constitutive model in CAP

6. Conclusion

This paper presented the interfacial and wall transport models of CAP code and preliminary test results on a simplified test problem were discussed.

REFERENCES

[1] S.J. Hong, et al., Development of CAP Thermal Hydraulic Solver, S06NX08-R-1-TR-26 Rev. 0, 2009

[2] F. Rahn, GOTHIC Containment Analysis Package Technical Manual Version 7.2, Electric Power Research Institute, Inc, 2004

[3] K.K. Murata, et al, Code Manual for CONTAIN 2.0: A Computer Code for Nuclear Reactor Containment Analysis, U.S. Nuclear Regulatory Commission, NUREG/CR-6533, SAND97-1735, 1997

[4] D. W. Hargroves, et al., CONTEMPT-LT/028, A Computer Program for Predicting Containment Pressure-Temperature Response to a Loss-Of-Coolant Accident, United State Nuclear Regulatory Commission, NUREG/CR-0255, 1979