Validation of CAP with SETH-PANDA Test-9

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1. Introduction

As part of the project of the development of domestic design codes, the CAP(Containment Analysis Package) code has been under development and an evaluation version was released for verification and validation at the end of 2011. To validate the gas mixing and stratification simulation ability of the CAP code, the SETH-PANDA test 9 was chosen. The results of test 9 show the 3-dimensional gas distribution in the test facility and were used to verify the simulation capabilities of the CFD codes. Though the CAP code doesn't have a 3-D calculation module yet, gas mixing simulation has been attempted by dividing into many lumped parameter volumes.

2. SETH-PANDA test 9

In this section a general description of the test facility and the conditions of the SETH-PANDA test 9 was given.

2.1 General description of PANDA facility

Design and scaling of the facility was originally based on the 670 MWe Simplified Boiling Water Reactor (SBWR) design from General Electric (GE). Fig.1 shows how the relevant compartments and components of the SBWR are represented in the PANDA facility. Full vertical heights are preserved in PANDA and the volume scaling is 1:25. The maximum power is 1.5 MW, also scaled to 1:25[1].

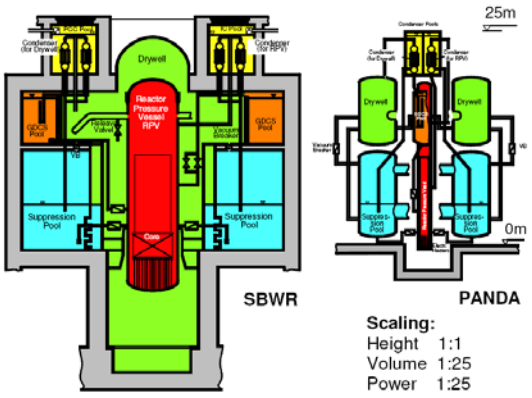

Fig.1. Schematics of SBWR(left) and PANDA facility(right) (identical colors indicate volumes with identical functions)

The complex containment volumes and the Reactor Pressure Vessel (RPV) are simulated in PANDA by six cylindrical pressure vessels. In PANDA Drywell (DW) and Wetwell (WW) are both subdivided into two vessels, in order to account for the multi-compartment character of a real reactor containment. A large Interconnecting Pipe (IP) connects the two DW vessels DW1 and DW2 at about mid-height. WW1 and WW2 are connected by two IPs, one in the water space and one in the gas space[1].

2.2 SETH Experimental Configuration

For the fulfillment of the requirements of the SETH-PANDA experiments major hardware modifications and implementations were done. The major parts of the experimental setup are :

- The multi-compartment test volume, consisting of the two PANDA vessels DW1 and DW2 plus their interconnecting pipe IP.
- The steam/helium injection system used to generate and control the steam or steam/helium mixture being injected into DW1 during each test to produce the jets or plumes and the internal piping that will allow the injecting of the gas mixture at different locations as specified for the individual tests.
- The venting system that corresponds to the lines used to expel and measure the fluid being vented out of the DWs during each test.
- The preconditioning systems needed to establish the initial and boundary conditions of the test.
- The instrumentation with specific adaptations and extensions.

The experimental configuration for the SETH-PANDA test 9 is shown in Fig. 2[1].

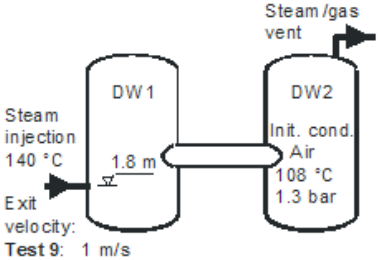

Fig.2. Experimental configuration for test 9

2.3 Initial and Boundary Condition

For test 9, the inside wall temperature of the DW1 and DW2 was maintained at 108 ℃ and kept constant throughout the test so as not to allow condensation. DW1 and DW2 were filled with dry air at a temperature of 108 ℃. Steam at 140 ℃ was injected at an exit velocity of 1 m/s into the DW1 through the nozzle at an elevation of 1.8 m above the bottom of the DW1. By steam and gas venting in the DW2, the pressure of both the DW1 and the DW2 was kept at 1.3 bar throughout the test. Test conditions are also shown in Fig.2.

3. CAP Modeling

The CAP code is still under development so it does not have a 3-dimensional nodalization scheme yet. By dividing each DW into 60 lumped parameter volume nodes a 3-dimensional effect was mimicked. According to the axial elevation of each gas concentration measurement, each DW was divided into 12 sectors and each sector was divided into 5 nodes. Every node was linked with its adjacent node by 208 junctions.

4. Calculation Results

The simulation was performed for 5,500 seconds and the simulated steam molar fractions (gas concentrations) of DW1 at 1,250 seconds, 2,900 seconds and 5,500 seconds were compared with experimental measurements and MARS calculation results [2]. Fig. 3 shows the steam molar fraction along the axis of the DW1 with varying of the elevation at 1,250 seconds after steam injection. Fig. 4 shows the results at 2,900 seconds and Fig. 5 shows the results at 5,500 seconds.

5. Conclusions

The SETH-PANDA test 9 was selected for the validation of the gas mixing and stratification simulation ability of CAP code. The test facility was modeled with lots of lumped parameter nodes and junctions to simulate 3-dimensional configuration. The steam molar fraction simulated by the CAP code is smaller than the experimental measurement in the early part of the test (See Fig.3). As time passed, the simulated results of CAP code became close to the test results (See Fig. 4 and 5). Meanwhile, though the experimental measurements and the results of MARS show that the steam molar fraction varied with elevation, those of the CAP do not. The steam molar fractions are almost the same except for those measured below the steam injection point. This means that the lumped model of CAP calculates the diffusion phenomenon more slowly than the real situation and has some limitations in terms of properly simulating the gas mixing and concentration. 3-D calculation capacity should be enabled in order to analyze the hydrogen distribution problem with the CAP code.

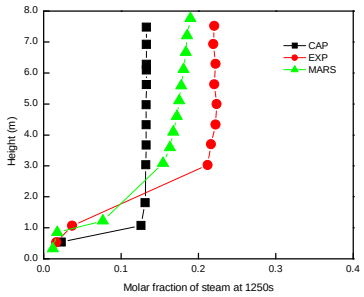

Fig. 3. Steam molar fraction in DW1 at 1,250 seconds

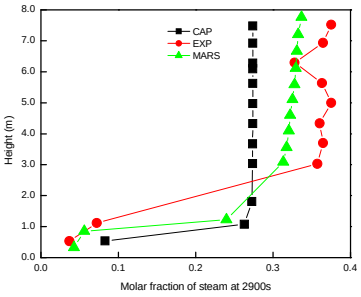

Fig. 4. Steam molar fraction in DW1 at 2,900 seconds

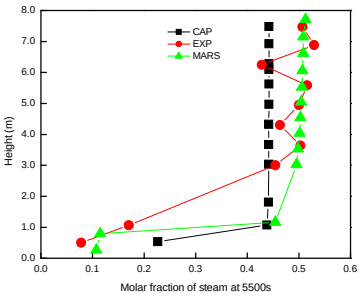

Fig. 5. Steam molar fraction in DW1 at 5,500 seconds

Acknowledgements

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