MARS 3D Calculation for OECD-PANDA Benchmark

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1. Introduction

As an enhancement effort for the analysis capability of containment thermal-hydraulics, a series of PANDA [1] Tests has been scheduled in OECD SETH Project. This program is motivated from the increasing needs of adequate experimental data for the 3D distribution of the relevant variables like the temperature, velocity and steam-air concentrations that are measured with sufficient resolution and accuracy. PANDA facility consists of 2 main large vessels and 1 connection pipe. Within the large vessels, steam injection nozzle and outlet vent are arranged for each test cases. With the different steam injection velocity and locations, 24 test cases will be performed. These tests are categorized to 3 modes, i.e. the high momentum, near wall plume, and free plume tests. The test case 17 in the near wall plume mode was selected and modeled by MARS.

2. Multi Dimensional Capability of MARS

MARS has been developed as an integrated system safety analysis code based upon RELAP5 and COBRA-TF [2]. In different to conventional 1D system codes, MARS code has the multi-dimension equation by extending the convection terms and adding an extra diffusion terms in momentum equations. The extended convection terms and diffusion terms in Cartesian coordinates are represented as follows, respectively.

$$\vec{V} \bullet \nabla \vec{V} = \begin{cases} u\dfrac{\partial u}{\partial x} + v\dfrac{\partial u}{\partial y} + w\dfrac{\partial u}{\partial z} \\ u\dfrac{\partial v}{\partial x} + v\dfrac{\partial v}{\partial y} + w\dfrac{\partial v}{\partial z} \\ u\dfrac{\partial w}{\partial x} + v\dfrac{\partial w}{\partial y} + w\dfrac{\partial w}{\partial z} \end{cases} \quad (1)$$

$$\nabla \underline{\underline{\tau}} = \begin{cases} \mu'\left[\dfrac{\partial^2 u}{\partial y^2} + \dfrac{\partial^2 u}{\partial z^2}\right] \\ \mu'\left[\dfrac{\partial^2 v}{\partial x^2} + \dfrac{\partial^2 v}{\partial z^2}\right] \\ \mu'\left[\dfrac{\partial^2 w}{\partial x^2} + \dfrac{\partial^2 w}{\partial y^2}\right] \end{cases} \quad (2)$$

where the viscosity μ' is the sum of the dynamic viscosity and turbulent viscosity.

In addition to the modifications in momentum equation, a multidimensional turbulent conduction term is added in the energy equation.

Up to now, the multi-dimensional convection terms and the diffusion terms have been verified and the obtained results were reasonably acceptable [3].

3. Modeling of PANDA Facility

The vertical two vessels of PANDA facility have the dimensions of 4.0 m diameter and 8.0 m height. The drywell 2 (DW2) has the injection nozzle inside and drywell 1 (DW1) has been installed the outlet vent at the top roof of itself. The 0.156 m diameter injection nozzle is horizontally located at the 1.8 m from the bottom of DW2. The whole volume of vessel is initially filled with 380 K air and 410 K steam is injected into DW2 at 4.926 m/s. The system pressure is maintained at 1.3 bar.

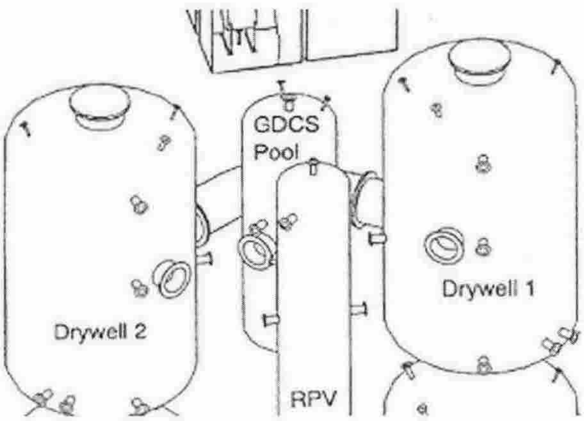

Figure 1. The schematic view of the PANDA Test facility.

In order to model the vessels, the DW2 vessel is modeled as 2,420 volumes. Although the vessels have cylindrical shapes, the modeling is conducted in the Cartesian coordinates for the convenience of modeling of the injection nozzle. The unused volumes that lie at the edge of the square shaped nodalizations are cut away from the calculation domain so that the simulated vessel volume is maintained as the designed value. The grid size is adjusted so that the mesh is fine enough to catch the plume jet near the injection nozzle.

The vent vessel, DW1, is modeled as 945 volumes. The edge unused volumes are also cut off and the total simulated volume is equal to the design value. The connection pipe, which is 5.0 m long and 1.0 m diameter, is modeled as 50 volumes. The total number of volume, 3415 is allocated to simulate the whole test facility.

4. Results

It is planned that the results of test 17 are revealed and discussed at the OECD-SETH meeting. The main measurement parameter is the local temperature inside the vessels and connection pipe. Additional measurements are local gas concentration and velocity profile near the steam injection nozzle.

A pre-test calculation is performed using MARS with PC of 1.8GHz CPU. Total calculation CPU time is about 90,000 seconds for 2,000 second simulation time. The calculated temperature field at 2,000 second for DW2 is represented at Figure 2. As shown, the temperature field represents the jet and buoyancy effect in the plume formation.

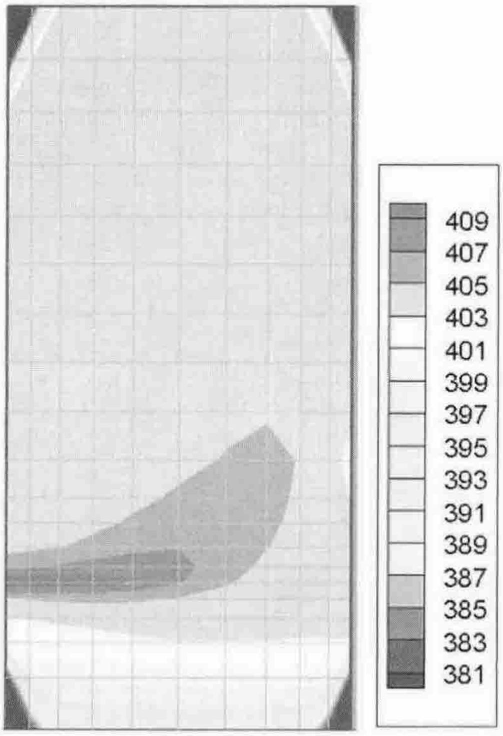

Figure 2. The temperature field in the vertical middle cross-section of DW1 at 2,000 second.

5. Conclusion

A pre-test calculation of OECD-PANDA Test number 17 has been carried out using the multi-dimensional component of MARS code. Although the number of volume is not enough to represent the CFD turbulent effect and boundary layer, the calculation results show the spatial distribution can be obtained within the reasonable computing time. The results will be compared with other detail CFD calculations and experimental data at the OECD SETH benchmark meeting

Acknowledgement

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