Development of a MELCOR Input for Hydrogen Experiments in the SPARC Test Facility

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1. Introduction

The Korea Atomic Energy Research Institute (KAERI) has built up a large-sized test facility, called SPARC (SPray-Aerosol-Recombiner-Combustion) [1] for an experimental simulation of hydrogen stratification phenomenon affected by Passive Auto-catalytic Recombiners (PAR) activation [2]. In parallel to the experimental study, an analytical study for a numerical simulation of the hydrogen stratification induced by PARs are being conducted [3]. We are using a lumped-parameter (LP) analysis code such as MELCOR [4] as well as a 3-dimensional analysis code, to take advantage of each kind of codes. Especially, the MELCOR ESF Package models the phenomena for the various engineered safety features (ESFs) in a nuclear power plant. The PAR package constitutes a sub-package within the ESF package, and calculates the removal of hydrogen from the atmosphere due to the operation of passive hydrogen reaction devises.

An integral severe accident code MELCOR has been widely used and intensively verified against many international benchmark problems or experiments, but it is the first time to apply this code to analysis of SPARC experiment. As part of our efforts to establish a confident analysis environment both with a lumped and 3-dimensional codes we are going to develop the input models of MELCOR for PAR experiments which are undergoing in the SPARC test facility.

In this study, modelling of the control volumes and flow paths for SPARC test vessel is automated by Excel sheet to avoid user mistakes and saving time for simple recurring tasks. The steady-state input for MELCOR is also tested by a simple benchmark problem.

2. Development of MELCOR Code Input

In the stage of development of basic MELCOR input, most of efforts has been made to calculate the geometric data for modelling of control volumes and flow paths.

2.1 Geometrical data of SPARC

The exact dimensions of SPARC configuration in detail can be obtained from the 3-D CAD data. Fig. 1 shows the configuration of the SPARC test facility and its vessel. The main input parameters for control volume and flow path of MELCOR input should be prepared. This task includes calculation of data such as hydraulic volume, flow area, path length, hydraulic diameter and etc., which was automated with Excel sheet.

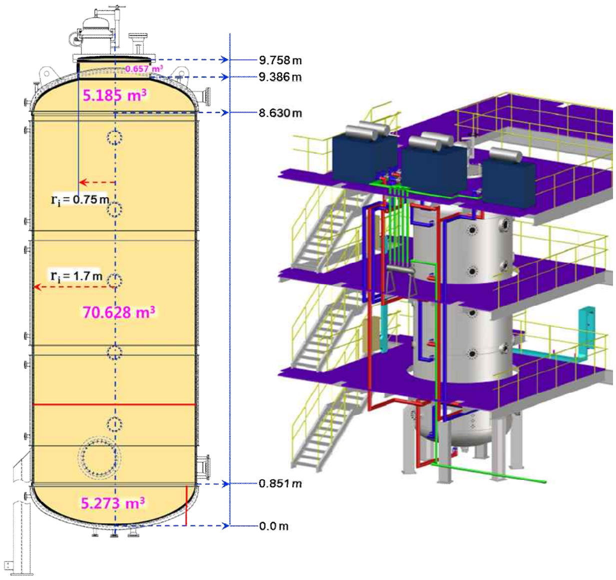

Fig. 1. SPARC test facility and dimension of vessel.

2.2 Modeling for MELCOR Code

MELCOR 1.8.6 was used for the analysis of SPARC test. The geometry of test facility was modeled with 82 control volumes (CVs). Fig. 2 shows the conceptual diagram for structure of CVs in this work.

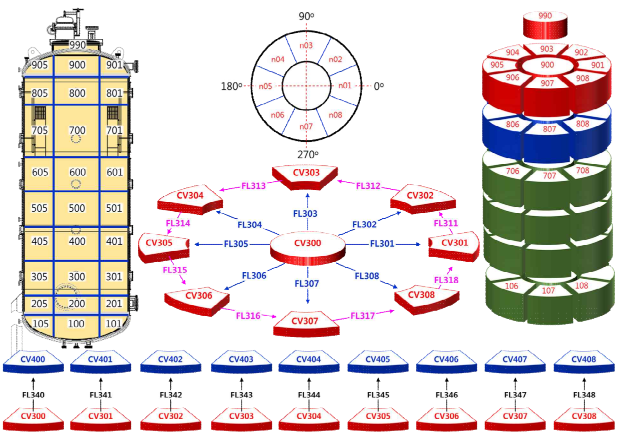

Fig. 2. MELCOR modeling of SPARC test facility.

Since most of measurement devices within test vessel are arranged with 8 circumferential segments, we divided 8 circumferential segments with one core volume in the center for each axial positions. Test vessel was divided into 9 levels by elevation. However we can adjust its elevation from sensitivity study in the future. The change of nodalization can be efficiently performed by an automation process using Excel sheet.

In the SPARC-PAR experiment, two KNT small PAR, KPAR40, are installed at an elevation of 6 m from the bottom of the SPARC vessel, so two PARs will be located at the CV701 and CV705, respectively. Furthermore these two control volumes can be subdivided according to the detailed configuration of the PARS in the future work.

The open boundaries of each CV were modeled with 219 flow paths to the adjacent CVs along radial, circumferential, and axial (vertical) directions.

2.3 Pre-simulation for steady-state condition

A benchmark test calculation with steady-state condition is performed to check the working of the present MELCOR input. The minimum and the maximum time step used are 0.001 second and 0.3 second, respectively. Non-equilibrium option was used for the control volumes. A PAR package model of MELCOR is not used, which will be remained for future work.

As a test condition, hydrogen is released for 4,000 seconds at a rate of 0.296 g/s through a CV100. From a conventional test conditions of SPARC-PAR experiment, atmospheric air with temperature of 80°C is initially filled in the test vessel. After stopping a cold hydrogen (30°C) injection, it is expected that stratification of hydrogen in the test vessel and thermal hydraulic properties of hydrogen gas will be in the steady-state.

Fig. 3 shows the distribution of hydrogen mass concentration along the elevation. As we expected the hydrogen is vertically stratified in the more dense gas of air. It is also shown that this distribution of mass concentrations becomes stabilized after 4,000 seconds when injection stops.

Since the venting system from the test vessel is closed during the simulation, the gas pressure in the test vessel is increased as the gas is injected. Fig. 4 shows the pressure increase during hydrogen injection and approach to the steady-state condition after injection stop. The gas temperature was also predicted as shown in Fig. 5. The increase of the gas pressure in the constant volume results in increase of the temperature following the ideal gas law.

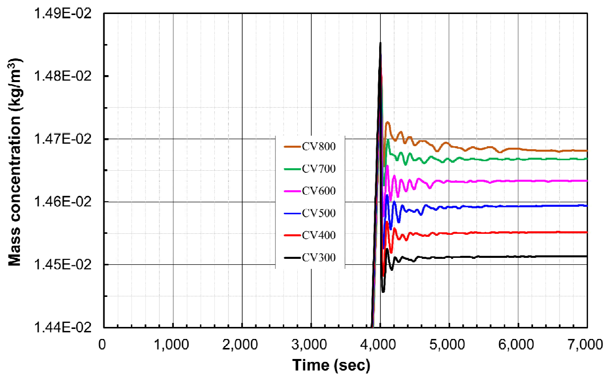

Fig. 3. Hydrogen mass concentration along the elevation.

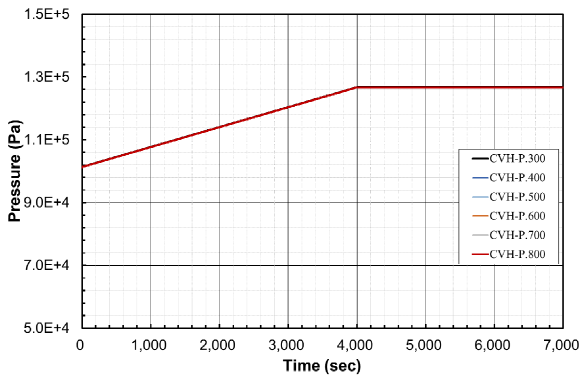

Fig. 4. Steady-state calculation results for gas pressure in the test vessel.

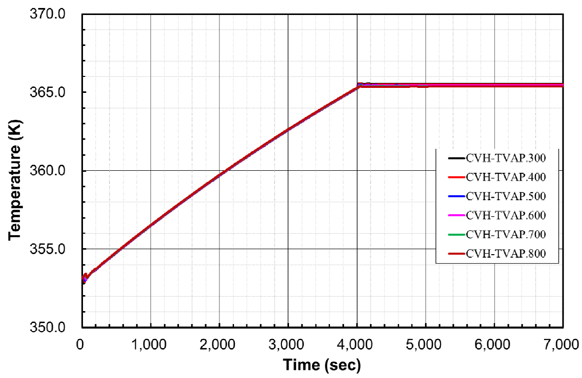

Fig. 5. Steady-state calculation results for gas temperature in the test vessel.

3. Conclusions

A MELCOR code input for SPARC test facility was developed. It is shown that the present input works well from the test calculation for steady-state condition. We will update this input model by adopting the appropriate PAR models provided by MELCOR code. While the PAR experiments in the SPARC test facility are undergoing the blind calculation will be performed and finally prediction of PAR performance test with various PAR models can be assessed against experimental data.

ACKNOWLEDGMENTS

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