A Preliminary Validation and Sensitivity Analysis of FARO L-14 Experiment using Fuel-Coolant Interaction Module of CINEMA

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1. Introduction

CINEMA (Code for Integrated severe accident Evaluation and Management) is a comprehensive analysis code for severe accidents of nuclear power plant. It is composed of the three major modules based on the accident progress and phenomena: in-vessel/ex-vessel phase, and fission products. The ex-vessel module includes main functions that can evaluate hydrogen combustion and explosion, fuel-coolant interaction (FCI), and molten core-concrete interaction (MCCI).

In this study, the FARO L-14, a large-scale FCI experiment in the high-pressure condition, was analyzed using the FCI module of CINEMA [1-4]. Heat transfer between the particle and water is one of the most important factors to determine the pressure and temperature after the experiment.

2. Methodology

2.1 FARO L-14 test [5]

FARO experiment is a series of large scale FCI experiment which used about 100 kg scale UO2. Among the series of experiments, FARO L-14 test is an OECD/CSNI international standard problem (ISP-39), and widely used to validate the FCI codes.

FARO L-14 is a non-energetic FCI test with about 125 kg of a mixture melt (UO_2+ZrO_2). The mixture is melted in the FARO furnace and transferred to the release vessel which is designed to hold the melt, and release it into the main vessel. The melt is released by gravity, and the release height is about 3.085 m. In the main vessel, the height of saturated water pool is a 2.05m, and the system pressure is about 5.1 MPa. The volume of main vessel is about 2.45 m^3.

2.2 CINEMA input for FARO test

As mentioned in the introduction, the FCI module of CINEMA was used to evaluate FARO test. The input for the ex-vessel module, SACAP, was developed, and it mainly consisted of geometry (LVol), cavity (CAVITY), melt jet (MassFlowRate), FCI (StmExp). The reference input data in this study is listed in Table I.

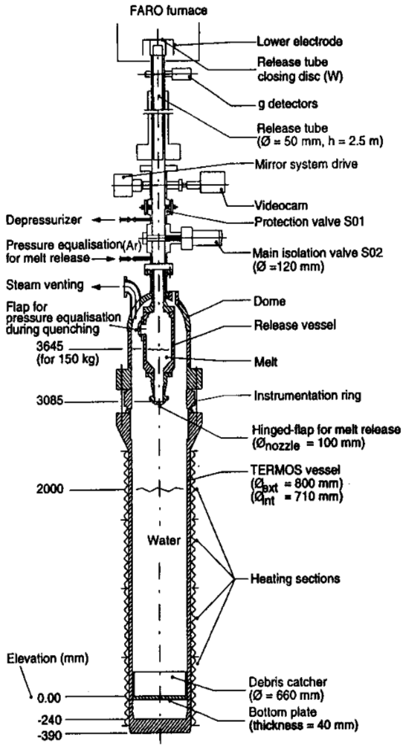

Fig. 1. FARO test facility

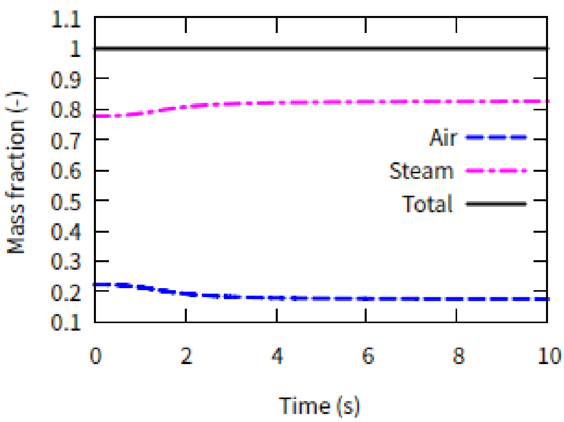

Fig. 2. Mass fraction of FARO L-14 test

Table I. FARO L-14 experiment input data for CINEMA

Parameter		Value
Vessel	Volume (m^3)	2.45
	Diameter (m)	0.71
	Height (m)	4.0
	Pressure (MPa)	5.1
	Temperature (K)	537
	Water height (m)	2.05
Melt jet	UO_2-ZrO_2 (-)	80w%-20w%
	Decay heat	-
	Mass (kg)	125
	Temperature (K)	3123
	Release diameter (m)	0.0048
	Velocity (m/s)	1
Model parameter	chtc (-) *	0.1
	diam (mm) **	4.8

**: Factor for heat transfer coefficient between jet and coolant.*
***: Mass median diameter of particle during the jet breakup. The value is based on the experimental result.*

During the FCI, it is important to investigate the heat transfer between particles and the coolant. Thus, both particle heat transfer coefficient and diameter model are directly related to the result. Heat transfer of particles in CINEMA is calculated with film boiling correlation and radiation. In here, the constant particle model was selected to give the same particle diameter condition in both code, CINEMA and COOLAP-II. There are model parameters to adjust uncertainty of correlation and model. In the Table I, 'chtc' and 'diam' are listed, which refers the factor of heat transfer coefficient between jet and coolant and particle diameter during the jet breakup, respectively.

As an initial condition of experiment, the mass fraction of steam in the main vessel is about 77%, and Fig. 2 shows the calculated mass fraction during the simulation. In this study, heat conductor, junction, other facilities (pump, valve, spray, etc.), hydrogen related model, etc. are neglected.

3. Results and Conclusion

Fig. 3 shows the CINEMA calculation result compared with experimental data. Black dotted line refers the experimental data in Fig. 3 (a) and (b). During the melt pouring, the system pressure rises steeply, and reaches about 8 MPa. The reference case follows the overall trend, however, the peak value of pressure is underestimated. The calculated gas temperature, generally, well matched with experimental data in Fig. 3 (b). Fig. 3 (c) and (d) represent the overall behavior of volume and melt mass on the cavity. The total mass of melt jet is well calculated during the simulation.

After the calculation of reference case, two sensitivity analyses are conducted to investigate the impact of model parameter as shown in Fig. 4 and Fig. 5. Two parameters are 'chtc' and 'diam' which are directly related to the heat transfer phenomena during the jet breakup. The top and bottom row represent pressure and temperature, respectively. From the result, pressure and temperature are affected significantly by those model parameters.

As a future work, the results of CINEMA will be compared with other similar system code, e.g. COOLAP-II, etc. FARO L-28 and 31, which are relatively low-pressure cases with two vessels will be simulated to validate the FCI module of the CINEMA code.

ACKNOWLEDGEMENTS

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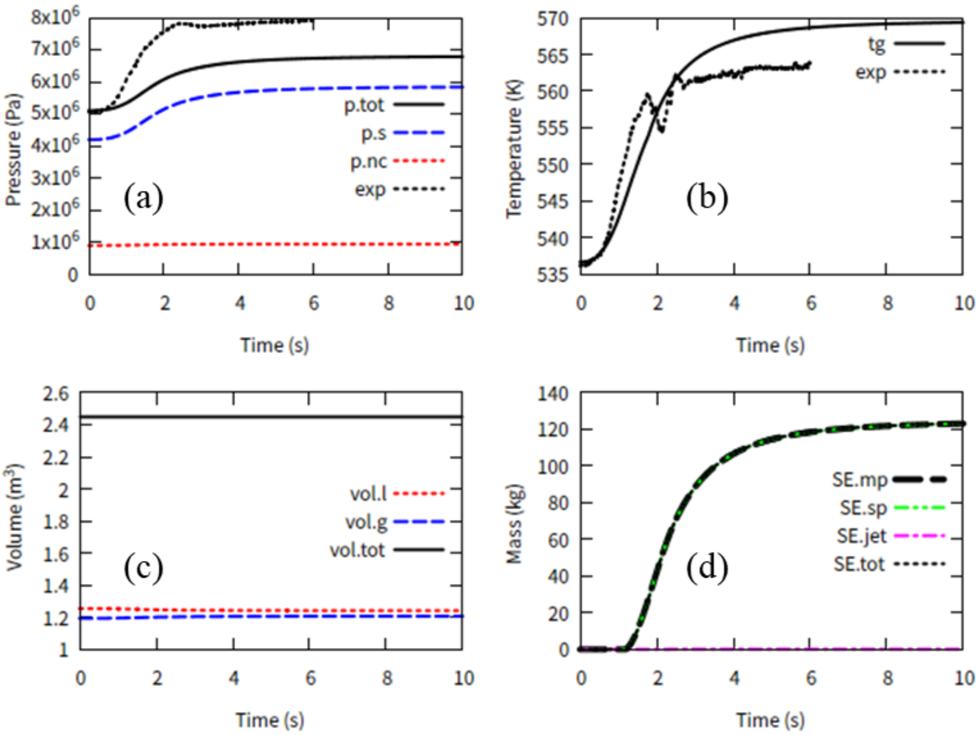

Fig. 3. CINEMA calculation result for L-14: (a) pressure, (b) temperature, (c) volume and (d) melt mass on the cavity.

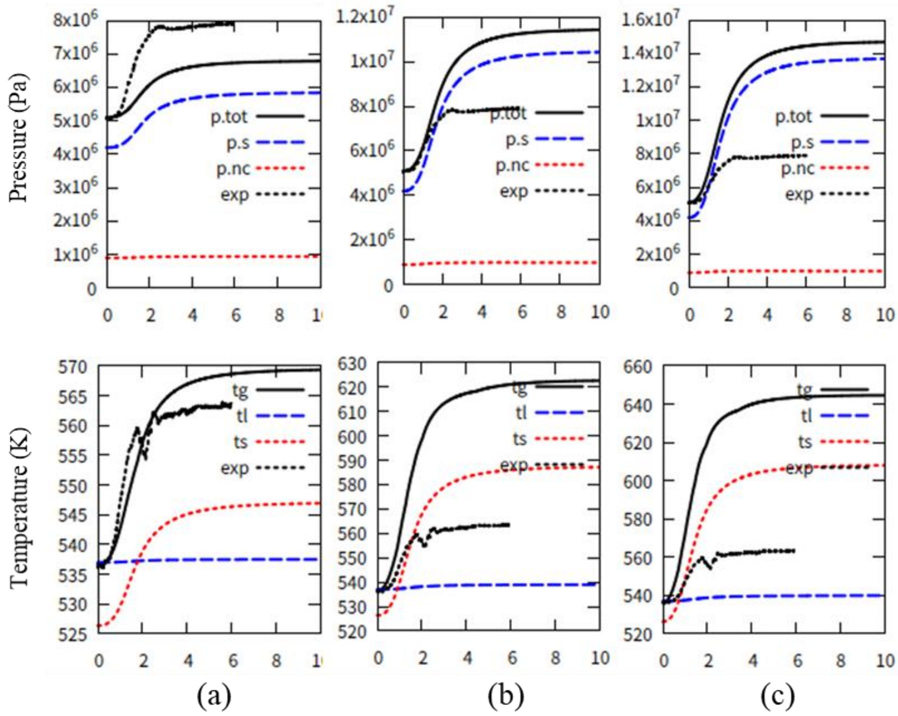

Fig. 4. Sensitivity analysis result with factor for heat transfer coefficient between particle and water: (top) pressure and (bottom) temperature; (a) 0.1(ref.), (b) 0.5 and (c) 1.0.

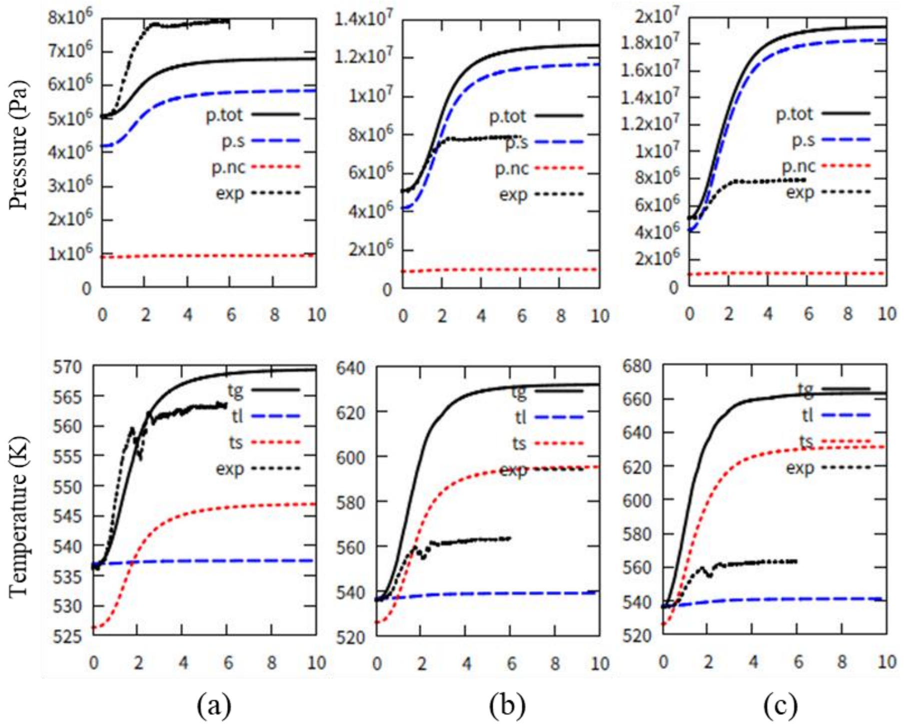

Fig. 5. Sensitivity analysis result with particle diameter during the jet breakup: (top) pressure and (bottom) temperature; (a) 4.8 (ref), (b) 2.0 and (c) 1.0.