Sensitivity Analysis of Ex-Vessel Steam Explosion using TEXAS-V code for APR1400

Sung Chu Song *, Yong Jin Cho, Bok-ki Min, Taesuk Hwang
Korea Institute of Nuclear Safety, 34 Gwahak-ro, Yuseong, Daejon, 305-338, Korea
**E-mail : scsong@kins.re.kr*

1. Introduction

A steam explosion can occur when a hot corium is mixed with a coolant, more volatile liquid. In severe accidents, the corium can come into contact with coolant either when it flows to the bottom of the reactor vessel and encounters the reactor coolant, or when it breaches the reactor vessel and flows into the reactor containment. A steam explosion could then weaken the containment structures, such as the reactor vessel or the concrete walls of the containment building.

The purpose of this study is to calculate using TEXAS-V code for ex-vessel steam explosion for a flooded reactor cavity of APR1400.

2. Methods and Results

TEXAS computational models are one of the simplified tools for simulations of fuel-coolant interaction during mixing, triggering and explosion phase.[1,2] TEXAS-V has simplified computational model to analyze the steam explosion phenomena. The calculation of TEXAS-V code consists of two steps; mixing and explosion.

After performing base calculation, we focus on parameter sensitivity in this paper.

2.1 Steam Explosion Calculation for Flooded Reactor Cavity

The developed input[1] for the flooded reactor cavity of APR1400 has 35 nodes for simulation of flooded cavity: 28 nodes(0.4m) are for the vessel and 7 nodes(1m) are to cover the upper vapor region. The void fraction and melt fraction in each region are initialized to match the test configuration and condition. Coherent jet of uniform melt is released to the cavity in 17^{th} node(6.41m). The released location of melt jet is selected over the node boundary due to the error of TEXAS-V[3]. The initial condition of fluid temperature and vapor pressure are 304K and 0.2MPa for reactor cavity. The initial properties of ceramic melt jet when small localized opening exist for the base case calculation are summarized in Table 1.[1]

The surface area and mean diameter of jet particle after mixing calculation can be seen in Figure 1. The melt jet from node 17 is reached 4m height from the reactor cavity floor about 0.86sec after. Jet velocity is slower as the jet approaches the bottom area of the vessel because the larger trailing particles are catching up on the smaller leading particles.[1]

Table 1. Properties of melt jet

Thermal Properties	Unit	Value
Melting Temperature	K	2850
Density	kg/m^3	8450
Thermal conductivity	W/m-K	5.3
Specific heat	kJ/kg-K	0.51
Viscosity	mPa-s	5.3
Surface tension	N/m	0.45
Emissivity	-	0.86
Velocity	m/s	5

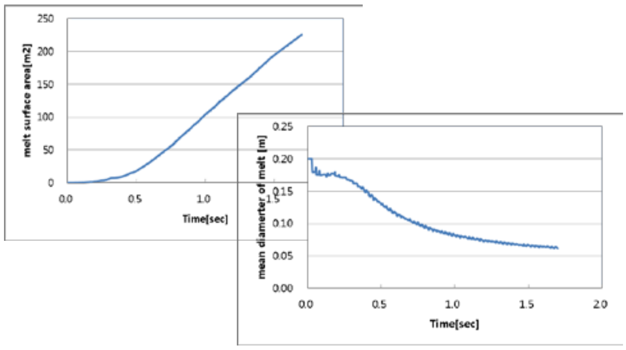


Figure 1. Surface area and mean diameter of melt jet

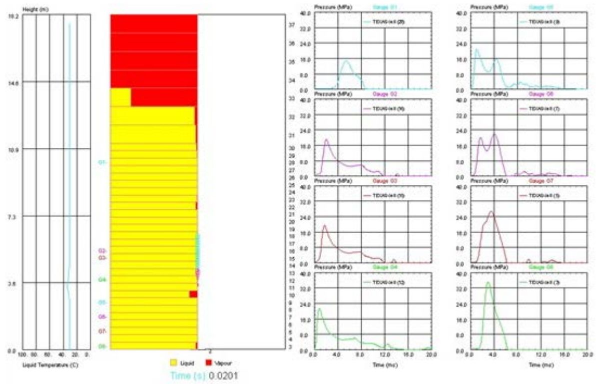


Figure 2. Nodalization and pressure load of base case

2.2 Sensitivity Analysis

There is a need to determine how different values of an independent variable will impact a particular dependent variable under a given set of assumptions. In order to achieve a better comprehension of complex steam explosion phenomena, a parametric study has been partially performed on simulating the APR1400 reactor scale. Using these parametric test, this study provides an insight on how a change in one variable has an influence on the target variable. The created sets for calculation presented in Table 2. 1.

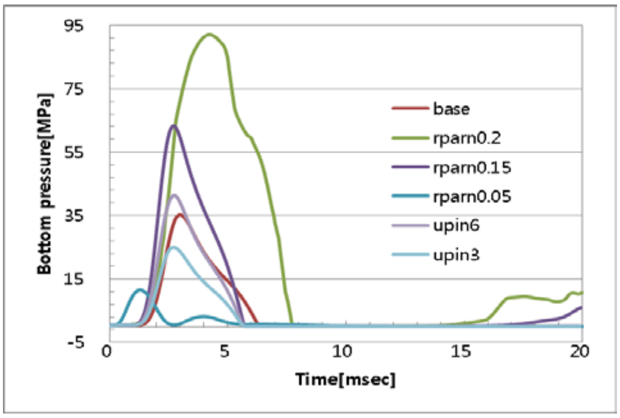
The main parameter to compare the steam explosion calculations is the pressure load and impulse. These values give a direct insight on the loads whether the structure of reactor cavity and containment building has integrity or not. Therefore, we choose the melt velocity and ejected melt diameter for spectrum analysis due to these parameters comparison of the other variables influence on the results more.

2.3 performing sensitivity tests

The sensitivity calculation results are summarized in Table 2 and Figure 3 shows a series of computed pressure distributions for the simulation at reactor cavity floor. High pressure in reactor leads to high velocity of corium when the reactor vessel is failed. Therefore pressure and impulse are higher because higher velocity enforces the premixing. Vessel breach size means released melt jet diameter and bigger diameter of corium is, the stronger the explosion is. As similar reason we could expect that, the more the melt mass, the stronger the explosion. The amount of energy that will be transferred by the droplets of melt to the water of cavity depends on the total available energy, which is connected to the released melt mass. Partially superposing the various interacting pressure waves obviously leads to the creation of peaks and troughs due to the released thermal energy.

Table 2. Sensitivity set and results

Parameters		Pressure	Impulse
Melt velocity m/s	3	25.0	53.7
	5	35.2	83.0
	6	41.4	89.5
Vessel breach size(diameter) m	0.1	11.6	19.3
	0.2	35.2	83.0
	0.3	63.3	150.9
	0.4	92.1	209.6



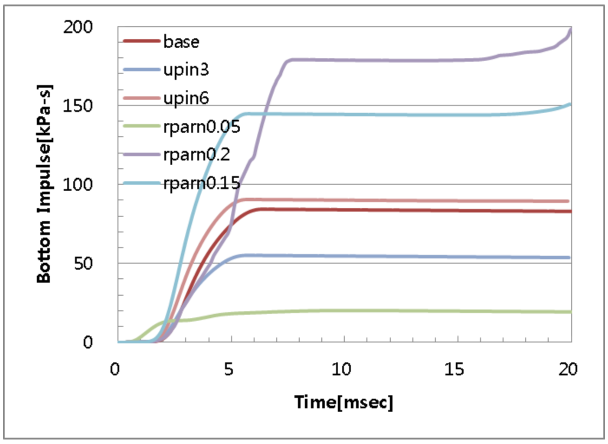


Figure 3. Sensitivity results for pressure and Impulse of cavity floor

3. Conclusions

TEXAS-V code to analyze and predict the ex-vessel steam explosion for a reactor scale is used. This study conducted the influence of melt velocity and melt diameter on the steam explosion calculation. There was strong influence of the jet diameter and velocity on the explosion. If there is the maximum pressure at the walls, the steam explosion loads can be too high to resist on the cavity wall.

In the future study, TEXAS-V code will be used to evaluate the impact of various uncertainties to provide a conservative envelope for the steam explosion.

ACKNOWLEDGMENTS

The present research is supported by NSSC, under the Research Program for Nuclear Safety Regulation.

REFERENCES

[1] S.C. Song et al., Preliminary Analysis of Ex-Vessel Steam Explosion using TEXAS-V code for APR1400, KNS, 2013.10.
[2] TEXAS code manual, University of Wisconsin, 1999.
[3] M.L. Corradini et al. Fuel-coolant interaction analyses with TEXAS-V vapor explosion model, University of Wisconsin, 1999