A Parametric Study to Improve Steam Explosion Models by Using a TROI Test

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1. Introduction

The overall objective of the OECD programme SERENA (Steam Explosion Resolution for Nuclear Applications) is to consolidate the understanding on FCI phenomenology and assess a method for reliable estimation of the magnitude of loadings for realistic reactor conditions, in order to bring about an understanding and predictability of FCI energetic to desirable levels for a risk management. Main conclusion of phase 1 is that in the absence of pre-existing loads, an in-vessel steam explosion would not challenge the integrity of the vessel, and damage to the cavity is to be expected for an ex-vessel explosion because the level of the loads cannot be predicted due to a large scattering of the results. One major uncertainty that does not allow for a convergence towards consistent predictions is that there is no data on the component distribution in a pre-mixture at the time of the explosion, especially the level of a void. Global void fraction is only available from level-swell measurements. The other major uncertainty is the explosion behavior of corium melts[1].

SERENA phase 2 project which has been conducted since 1st Oct. 2007 is aimed a resolution of the uncertainties on the void fraction and the melt composition effect by performing a limited number of well-designed tests with advanced instrumentations to clarify the nature of a prototypic material with mild steam explosion characteristics and to provide innovative experimental data for a computer code validation. An analytical working group (AWG) is established with the aim of increasing the capabilities the FCI models/codes for use in reactor analyses by complementing the work performed in Phase-1. The main tasks of the group are: 1) performing pre-, post-test calculations, 2) improving the common understanding of those key phenomena such as breakup, void fraction, and fragmentation, 3) addressing the scaling effect and application to the reactor case,

In this paper, the pre- and post-test calculation for the first TROI test, called TS-1, were presented. The main goal of the pre- and post-test calculations is to provide a basis for the assumed analysis of major phenomena to be modeled and respective uncertainties to be solved in order to reach a modeling status fitting for purpose of reactor safety analyses. This means to continue checking major differences in analytical approaches in order to reach convergence in understanding and modeling key effects. All the calculations are conducted by using MC3D[2].

2. Input Model

The configuration of the geometrical condition are presented in Figure 1, in which the axi-symmetric cylindrical coordinate was adapted to the TROI test facilities[3]. Two kind of pouring mode are calculated. A test condition by considering the prototypical severe accident condition and the limitation of the TROI test facilities was set up: pressure of 0.2 MPa, liquid temperature of 333.15 K, fuel temperature of 3100 K, jet temperature of 3100 K, water depth and diameter of 1 m and 60 cm, melt free fall of 1m, melt mass of 15 kg

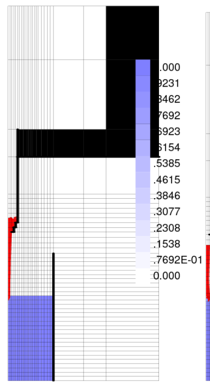

Fig. 1. Calculated explosion pressure for various materials.

3. Sensitivity Study

3.1 Sensitivity Study for Fragmentation Rate

The sensitivity study on the fragmentation rate was conducted by using 15kg pouring mode of the intermediate melt catcher. The 30% fragmentation rate give us the proper explosion impulse and the fragments mass comparing the TS1 experiments.

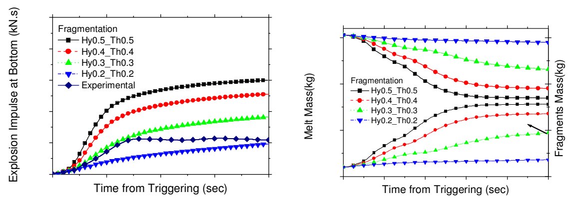

Fig. 2. Calculated impulse and fragments mass.

3.2 Sensitivity Study for Melt Pouring

The melt jet progression is presented as the time-dependent position from the bottom and the mixture behavior at 0.8215 sec in Figure 2. The injection mode with 2.0 m/s can simulate the fuel progression better than the injection mode from intermediate melt catcher. The global void fractions for various pouring modes are presented in Figure 3. The global void fractions are nearly the same to each other. We must note that the void distributions are quite different for the various times even though the global void fractions are nearly the same,

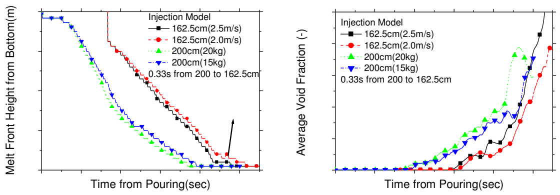

Fig.3 Melt progression for various pouring modes.

4. Final Calculation

Above sensitivity calculations indicates that the proper pouring and fragmentation rate result in the reasonable estimation of explosion work. The mixing calculation with the melt injection with 2.0m/s estimate the similar melt progression(Figure 3). Figure 4 shows that the spatial distribution is quite different for the time progression. The void fraction was not in the bottom region at the triggering time of 0.94s, which is very similar to the experimental data.

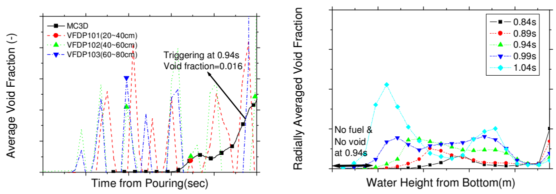

Fig. 4 Global and local void fraction

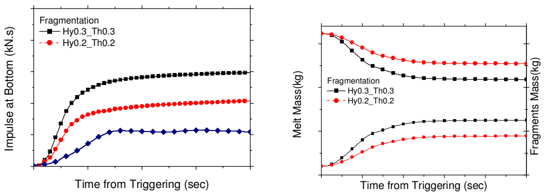

Fig. 5 Explosion impulse and fragments mass.

5. Conclusion

Parametric steam explosion calculations were conducted for various pouring and fragmentation rates. Melt jet breakup, film boiling model, minimum bubble diameter for a condensation model are fixed during these calculations[4]. As the void fraction distribution is related to the melt progression and the explosion efficiency is determined by the fragmentation rate, the more accurate melt pouring and fragmentation rate are needed. With the current approach, the explosion pressure and the explosion impulse can't be adjusted simultaneously to the TS-1 data. This is resulted from the difference pressure profiles. In the TS-1, the explosion peak pressure is high and the explosion pressure decay is too fast. The explosion pressure decay is slower in the calculations.

ACKNOWLEDGMENTS

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