An Evaluation of Triggering Timing for the TROI Tests

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1. Introduction

In the postulated reactor severe accident, the molten corium can be poured into the remained reactor coolant of the lower pressure vessel or the reactor cavity. This might severely threaten the containment integrity, and thus, the experimental and analytical efforts have been done to reveal this risk. It is generally received by the steam explosion experts that the in-vessel steam explosion steam explosion would not challenge the integrity of the vessel and the containment [1].

The ex-vessel explosion, however, cannot be excluded from the factor to threaten the integrity of the cavity and more the reactor vessel. The worse thing of ex-vessel situation is that water is subcooled under a relative low pressure. The results of steam explosion experiments indicate that the subcooled water under a low pressure might be a good environment to make a strong steam explosion [2]. Furthermore, the calculation results for evaluating ex-vessel steam explosion work are too scattered each other [1]. Thus, the conversion ratio of ex-vessel explosion is still remained as a resolved issue.

SERENA phase 2 project which has been conducted since 1st Oct. 2007 is aimed a resolution of the uncertainties on the void fraction, the solidification, 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.

The steam explosion results such as explosion pressure, conversion ratio, and the debris configuration are strongly affected by the initial conditions. Meanwhile, some events like triggering magnitude might not be important for the steam explosion results. The initial conditions of the steam explosion, called premixture, are determined by three factors: first one is melt and water condition, second one is a mixing process, and the other is the triggering timing. The mixing process is a part of physical phenomena. The melt and water conditions, and the triggering timing are a parametric part. They should be carefully selected for evaluating conversion ratios considering the worst case. The computational work can help this selection, saving expense from too many experiments. In this study, the pre-test calculation for the TROI tests with specific melt and water condition are discussed in terms of triggering time. All the calculations are conducted by using MC3D [3], in which the initial conditions and the model parameters are set up by reference [4, 5].

2. Input Model and Mixture

The configuration of the geometrical condition and the premixture conditions are presented in Figure 1, in which the axi-symmetric cylindrical coordinate was adapted to the TROI test facilities [4]. 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 (saturated at 393.38 K), liquid temperature of 333.15 K (60^{o} subcooled), fuel temperature of 3100 K, jet temperature of 3100 K, water depth and diameter of 1 m and 60 cm, melt free fall of 1 m, melt mass of 15 kg.

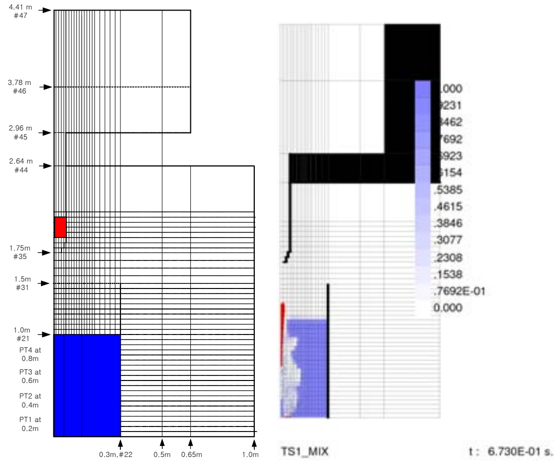

Fig. 1 Initial Condition and Premixure at 0.9 s after Mixing.

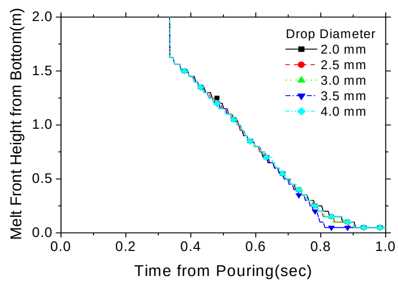

Fig. 2 Melt Front Height for Various Drop Diameter.

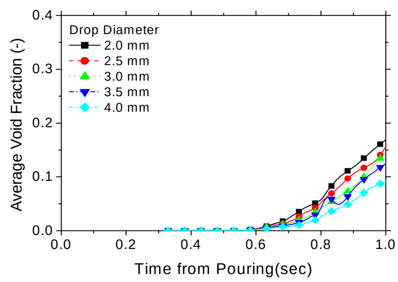

Fig. 3 Void Fractions for Various Drop Diameter.

In the right figure of Figure 1, the mixture radius is about 10 cm and the jet breakup length is about 40 cm. Considering the melt front location and average void fraction of Figure 2 and Figure 3, The melt bottom contact time is 0.9 s, and the void fraction at 0.9 s is 0.05 ~ 0.15 which is the same to 0.45 ~ 1.0 at mixture.

3. Sensitivity Study for Triggering Time

The time-dependent mixture conditions are obtained during the mixing calculation. The mixture condition at a certain specific time, called triggering time, is used for the initial mixture condition of the explosion calculation. The triggering time affects on the steam explosion results because it determines the mixture conditions such as the phasic volume fraction and the phasic area concentration. The explosion calculations were done for five triggering times of 0.83 s, 0.88 s, 0.93 s, 0.98s, 1.03 s which means five different premixtures. The explosion pressures at PT1 (20cm from bottom) and PT4 (80cm from bottom) of Figure 1 are presented at Figure 5 and Figure 6. The explosion pressures of three early triggering calculations are bigger than those of two later triggering. The fragmented mass of 3 early triggered cases increase more rapidly than those of 2 later triggered explosions.

4. Conclusion

Parametric steam explosion calculations were conducted for various triggering times. The initial condition of this calculation is based on TROI geometry with 0.2 MPa and 333.15 K water. The melt arrived at the bottom at 0.9s after pouring, and the void fraction of the water chamber is about 0.05 ~ 0.15. The later triggering after 0.94 s results in the weak explosion and the early triggering time before 0.94 s is recommended in order to measure the explosion potential in this steam explosion. The later triggering event results in a weak explosion mainly due to the larger void fraction of the mixture. The water of 0.2 MPa and 333.15 K seems to be a worse condition to trigger an explosion than the water of 0.1 MPa and 293 K, which is common experimental condition of TROI. Thus, the triggering time as well as initial water and melt condition is an effective parameter on the steam explosion behavior. The conversion ratio through the experiment can be carefully determined considering this triggering time.

ACKNOWLEDGMENTS

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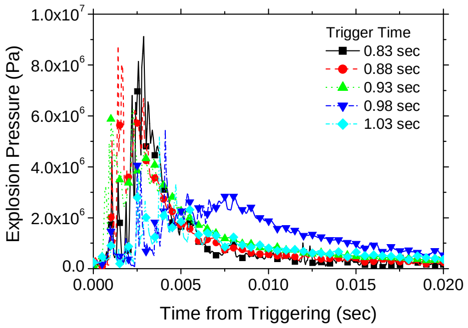

Fig. 5 Explosion Pressure at PT1.

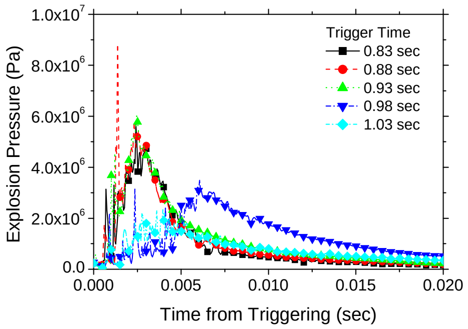

Fig. 6 Explosion Pressure at PT4 .

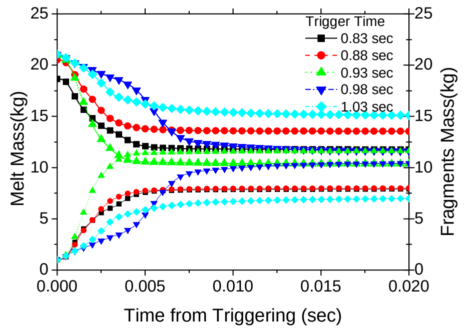

Fig. 7 Unfragmented and Fragmented Masses.