Comparison between the Findings from the TROI Experiments and the Sensitivity Studies by Using the TEXAS-V Code

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1. Introduction

Since a steam explosion may breach the integrity of a reactor vessel and containment [1], it is one of the most important severe accident issues. So, a lot of experimental and analytical researches on steam explosions have been performed[2,3]. Although many findings from the steam explosion researches have been obtained, there still exist unsolved issues such as the explosivity of the real core material(corium) and the conversion ratio from the thermal energy to the mechanical energy [4]. TROI experiments were carried out to provide the experimental data for these issues. The TROI experiments were performed with a prototypic material such as ZrO2 melt and a mixture of ZrO2 and UO2 melt (corium). Several steam explosion codes[5] including TEXAS-V had been developed by considering the findings in the past steam explosion experiments. However, some unique findings on steam explosions have been obtained from a series of TROI experiments. These findings should be considered in the application to a reactor safety analysis by using a computational code. In this paper, several findings from TROI experiments are discussed and the sensitivity studies on the TROI experimental parameters were conducted by using TEXAS-V code and TROI-13 test. The comparison between the TROI experimental findings and the results of the sensitivity study might allow us to know which parameter is important and which model is uncertain for steam explosions.

2. Findings in TROI Experiments

One of the findings from TROI experiments is that the results of the fuel coolant interaction are strongly dependent on the composition of the corium, which is composed of UO_2, Zr O_2, Zr, Steel [6]. Prototypic corium generally used in FCI experiments is mixture of 80% U O_2 and 20% ZrO_2. In the TROI experiments, typical 80:20 corium was not apt to make steam explosions, while 70:30 corium created a steam explosion probabilistically. 100% ZrO^2 was almost apt to make a steam explosion. Even though just being conducted one time, 87:13 corium and 49:51 corium did not induce steam explosions.

Another finding from the TROI experiments is that the result of the fuel coolant interaction is changed as the initial water depth is changed [7]. Steam explosions would occur with 67 cm in water depth, while steam explosions would not occur with 95 cm and 130cm. Merely, three tries to make triggered steam explosion resulted in just one mild steam explosion with 130 cm water. Water area effect in the TROI experiments [8] is not clear because tests under 0.071 m^2 in water area, 67cm in water depth, 70:30 corium were not conducted. Obvious thing is that 0.071 m^2 in a water area does not increase a steam explosion work to more than 0.283 m^2 when comparing the tests under 95 cm, 130 cm in water depth. We note that the steam explosion was not apt to occur under 95 cm and 130 cm depths.

3. Sensitivity Study by Using TEXAS-V code

Based upon a simulation of the TROI-13 test, a sensitivity study was done for the TROI experimental parameters such as melt composition, water depth, water area, free fall, pressure. 3500 K, 70:30 corium was poured into 292 K, 0.67 m, 0.283 m^2 water in the TROI-13 test. After 1.223 second from puncher actuation, the spontaneous steam explosion occurred and the 7 MPa explosion pressure is measured. The criterion factor in the sensitivity study is the explosion pressure. The steam explosion pressure profiles for the various melt composition are presented in Figure 1. The composition effect in the TEXAS-V calculations does not exist mainly because the material properties being considered in the steam explosion model are not largely changed by changing the corium composition. This result is quite different from that of the TROI experiments, in which the melt composition has an effect on the steam explosion occurrence probabilities and the steam explosion strength as mentioned in Chapter 2. The eutectic of 70:30 corium is one reason for the melt composition effect because the solidification temperature around the eutectic point is low, the melt is likely to maintain its liquid state at the time of a triggering so as to trigger an explosive phenomenon.

The steam explosion pressure profiles for various water depths are presented in Figure 2. In the TEXAS-V calculatins, the explosion pressure seems to increase as the water depth increases because the mixture, in which the explosion can propagate, is deeper. This result is not harmonious to that of the TROI experiments, in which the steam explosions were apt to be prevented by a deeper water chamber of 1.3 m in depth. The large void fraction and weaker bottom contact are reasons for a lesser steam explosion in a small water area.

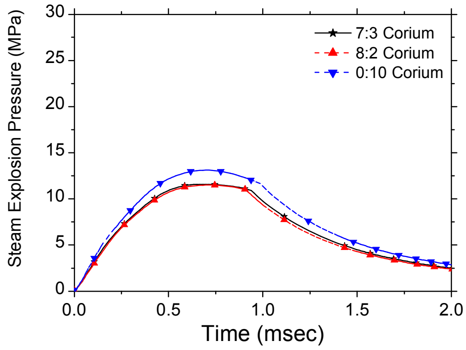

Figure 1. Melt composition effect on steam explosions

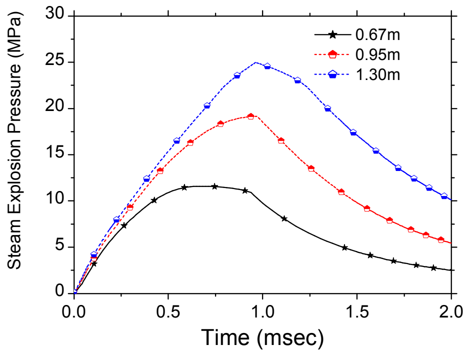

Figure 2. Water depth effect on steam explosions

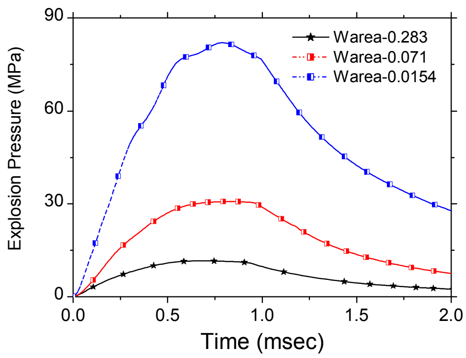

Figure 3. Water area effect on steam explosions

The steam explosion pressure profiles for various water areas are presented in Figure 3. The water area effect in TEXAS-V calculations seems to be completely opposite to that in the TROI experiments, in which steam explosions were not induced with a narrower water chamber even though a external triggering device was used. In Figure 3, the steam explosion pressure in TEXAS-V calculations increases when the water area becomes smaller. This is induced because the fuel fraction in the water increases as the water area decreases but the void fraction does not increase enough. The low void fraction might be different from the TROI experimental results. The difference between the TROI experimental results and the TEXAS-V calculations could be caused by the difference between the breakup model and the breakup mechanism of the TROI experiments.

4. Conclusion

We discuss three finding from the TROI experiments and compare them to the TEXAS-V calculations. The composition effect is strong in the TROI experiments, but it is weak in the TEXAS-V calculation. The water depth effect is not the same. The water area effect between the TROI experiments and the TEXAS-V calculations is completely opposite mainly due to the low void fraction in the TEXAS-V calculation. The current breakup model and the TROI breakup mechanism seems to be different in some way. Thus, the parametric responses of the TROI experiments and the TEXAS-V are different form each other and revealing the reason for this difference will be very helpful work for increasing the reliability of a nuclear power plant safety analyses.

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