Transactions of the Korean Nuclear Society Autumn Meeting
PyeongChang, Korea, October 25-26, 2007

An Investigation on the Mechanism of the Material Effects on Steam Explosions for the TROI Tests

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1. Introduction

The TROI[1,2] experiments were carried out to provide experimental data for a proper estimation of a steam explosion work. The explosion work can be characterized by the explosion pressure wave, and the mixture condition can be characterized by a particle size distribution. Thus, the TROI tests were analyzed in view of a particle size response for various types of fuel coolant explosions.

One of the findings from the 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, ZrO_2, Zr, Steel[3]. Prototypic corium generally used in the FCI experiments is a mixture of 80 % of UO_2 and 20% of ZrO_2. In the TROI experiments, a typical 80:20 corium was not apt to create spontaneous steam explosions, while 70:30 corium created spontaneous steam explosions probabilistically. 100 % ZrO_2 was almost apt to create a steam explosion if the water subcooling was enough. Even though just being conducted once, 87:13 corium and 49:51 corium did not induce spontaneous steam explosions

A comparison between the TROI experimental findings and the results of the sensitivity study might allow us to establish which parameter is important and which model is uncertain for steam explosions. Thus, a sensitivity study on the material effects on steam explosions was conducted in order to reveal whether the TEXAS-V model implements the material effects and what is the major parameter that controls the results of fuel coolant interaction. Then, the TROI tests were analyzed in view of this revealed parameter. This could provide an understanding about the relationship among the initial condition of a mixing and an explosion.

2. Sensitivity Study on Materials at Steam Explosions by Using TEXAS-V

Based upon a simulation of the TROI-13 test, a sensitivity study was implemented for the TROI experimental parameters such as the melt composition, water depth, and water area. The main criterion factor in the sensitivity study is the explosion pressure. In this sensitivity study, the initial conditions of TROI-13 were maintained as Table 1 except for the melt mass. The melt mass was changed from 2.26 kg to 10 kg in order to maintain a consistency at the various coolant depths. The model parameters of the TEXAS-V code were maintained as a TROI-13 simulation.

The steam explosion pressure profiles for the various melt compositions are presented in Figure 1. The composition effect in the TEXAS-V calculations agrees exactly with the TROI test results, in which the melt composition has an effect on the steam explosion occurrence probabilities and the steam explosion strength. This means that the composition effects were considered in the TEXAS-V code, which might be related to the melt jet breakup.

As shown in the Figure 2, the void fraction for the ZrO_2/water system is the lowest and the void fraction for the 80:20 corium/water system is the highest. This void fraction behavior might be induced from the fuel droplet diameter shown in Figure 3. A large diameter of the ZrO_2 /water system might result in a small void fraction and a strong steam explosion. A small diameter of the 80:20 corium/water system might result in a large void fraction and a weak steam explosion.

3. Analyses of Particle Size Distribution of TROI Tests

TEXAS-V sensitivity study indicated that the material effect on the results of the fuel coolant interactions seems to be driven by a different particle size and a different void fraction. An investigation on the particle size distribution of the TROI tests was required. Table 1 shows the TROI experimental results ordering by the composition; TROI-2, TROI-11, TROI-18, TROI-29., in which a steam explosion did not occur.

The difference in the particle size response between the ZrO_2 system and the corium system is a major group of the particles. The large sized particle group(above 6.35mm) occupies 36.3 % of the total particle mass in the ZrO_2 system (TROI-2), but the relatively small sized particle group of 2-4.75mm in diameter occupies 38%-52% in the corium system (TROI-11, 18, 29). Considering that the large sized particle group above 6.35mm in diameter is the major contributor to the steam explosion energy as mentioned above, the ZrO_2/water system seems to be more explosive than the corium/water system. This particle behavior accords with the TROI experimental results.

The difference in the particle size responses of 70:30 corium and the other corium compositions is a portion of the fine particle group below 0.71 mm. That is the fine particle group in the 70:30 corium system occupies only 0.9 % (TROI-11), which is nearly the same as the ZrO_2 system. The portions of the fine particle group in the 80:20, 50:50, 87:13 corium are 5.3 %, 17.6 %, 11.7 %, respectively.

This difference could be one fact why the probability of a steam explosion is higher in the ZrO_2, 70:30 corium system than in the 80:20 corium. The fine particle group seems to prevent a spontaneous steam explosion by raising the void fraction and/or by quenching the fuel melt mainly due to an increased heat transfer area.

4. Conclusions

The sensitivity study by using TEXAS-V indicated that the material effect on the steam explosions was caused by a void fraction difference, which was driven by the particle size difference. The particle size responses for the TROI parametric tests showed that a different material resulted in a different particle size distribution. An increase of the large particle portion and a decrease of the fine particle portion at the mixing stage could result in an explosion and its opposite could result in a mild quenching.

Though the material effect on the steam explosions was appeared in the TROI tests and the TEXAS-V calculation, the size of the effect is clearly different from each other. We note that 80:20 corium did not cause any steam explosion in the TROI tests, but in the TEXAS-V simulation there was a steam explosion. This point should be properly considered in a steam explosion model during a reactor safety analysis.

ACKNOWLEDGMENTS

This study has been carried out under the nuclear R&D program by the Korean Ministry of Science and Technology.

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Table 1. Composition Effect On Particle Size

	TROI test number			
	2	11	18	29
UO2/ZrO2[w/o]	0/100	70/30	78/22	50/50
Total[kg]	5.50	9.23	9.055	11.51
>6.35mm[%]	36.3	16.1	18.4	7.9
4.75~6.35[%]	12	14.8	15.6	10.3
2.0~4.75[%]	12	52.0	38.2	38
1.0~2.0[%]	5	13.6	17.6	19.5
0.71~1.0[%]	5	2.6	4.9	6.7
.425~.71[%]	0.7	0.4	4.5	8.9
<0.425[%]	0.7	0.5	0.8	8.7
Shell[%]	46	0	0	0

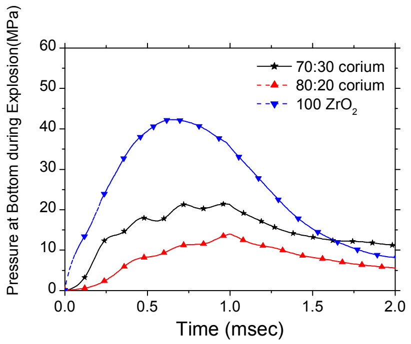

Fig. 1 Explosion Pressure For Different Materials

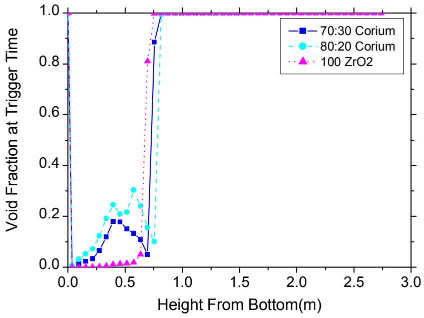

Fig. 2 Vapor Fraction For Different Materials

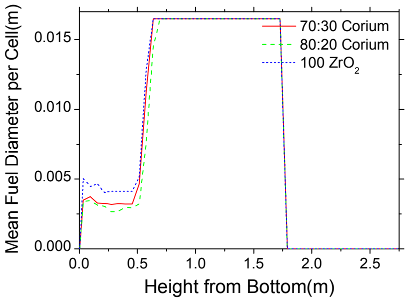

Fig. 3 Quenched Particle Size at Different Material