A Steam Explosion Experiment with a Narrow Interaction Vessel in the TROI Facility

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1. Introduction

A steam explosion experiment (TROI-54) was performed in the TROI facility with a narrow (0.3 m in diameter) interaction vessel at an elevated ambient pressure. TROI-54 was performed with 70 : 30 (UO_2 : ZrO_2) corium at 0.205 MPa and at room temperature.

This test resulted in a triggered steam explosion in a narrow interaction vessel in contrast with previous tests [1]. Analyses of the dynamic pressure, load and debris size distribution inferred that they induced this result.

2. Experimental Results

The experimental facility for TROI-54 is shown in Fig.1 and the instrumentations are described in Ref. 2. Two similar pyrometers were used to measure the melt temperatures during a melting and a melt delivery. The glass effect observed during a melt temperature measurement in the previous tests [2] was compensated for by using a quartz window.

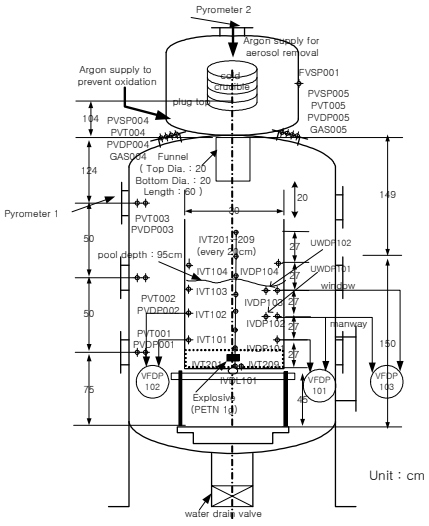

Figure 1. Schematic diagram of TROI-54.

This test was carried out to induce a triggered steam explosion with 70 : 30 corium interacting with a 0.67 m deep water pool in a 0.3 m wide interaction vessel at 0.205 MPa and at room temperature. Previous tests showed that 70 : 30 corium did not lead to a steam explosion when the interaction vessel was narrow (30 cm in diameter) [1].

A mixture of UO_2 and ZrO_2 at a 70 : 30 weight percent was charged into the crucible. Then the mixture was melted and the molten corium was delivered into the water in the narrow interaction vessel.

During a melting, the melt temperature was measured through a quartz window, and it is presented in Fig.2. The measured temperature through the quartz window was observed to be almost the same, when setting the emissivity ratio at 0.996, as the standard reference temperature measured from a calibration test performed at KRISS. The maximum melt temperature reached 2990 K just before a melt delivery.

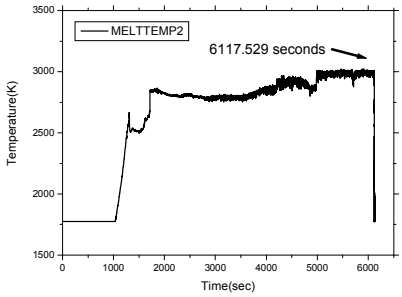

Figure 2. Melt temperature during a melting in TROI-54.

When the melt jet penetrated the water in the interaction vessel, an external trigger (PETN, 1 g) exploded at 1.30 seconds after the initiation of the melt delivery which is the time of a puncher action.

Figs.3 and 4 show the dynamic pressures in the water measured by the wall-mounted pressure sensors and by the under-water sensors, respectively. Fig.3 shows pressure peaks of 22 MPa in magnitude with a long duration from 1.3427 seconds to about 1.346 seconds. Fig.4 also shows pressure peaks of 5.5 MPa with a long duration from 1.3428 seconds to about 1.3465 seconds. UWDP102 went wrong during an explosion. The UWDP101 was hung in the water in the interaction vessel so it was easily moved by an explosion so as to measure an attenuated pressure. The remarkable thing is that the duration of the pressure peak is about 8 times longer than that from a calibration test performed with only an external trigger without a melt delivery. The pressure peak from the calibration test is shown in Fig.5 and its duration is about 0.4 ms. It is difficult to determine the occurrence of a triggered steam explosion in this test.

Fig.6 shows the dynamic load on the bottom of the interaction vessel. The maximum value was 310 kN. From this figure, the external triggering was initiated at 1.3427 seconds from the puncher action. The duration of the explosion was 11 ms which is similar to the previous steam explosion tests.

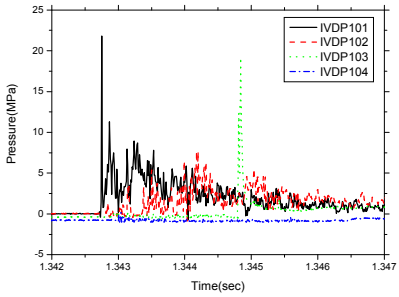

Figure 3. Dynamic pressures from the wall-mounted sensors in TROI-54.

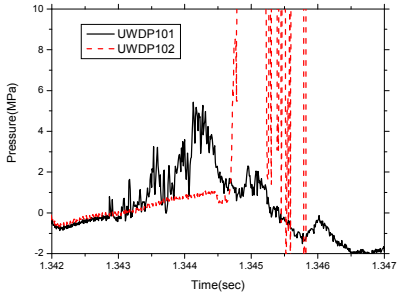

Figure 4. Dynamic pressures from the under-water sensors in TROI-54.

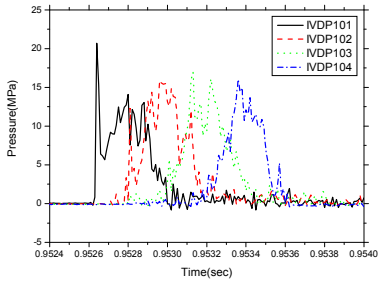

Figure 5. Dynamic pressures from the wall-mounted sensors for the calibration test.

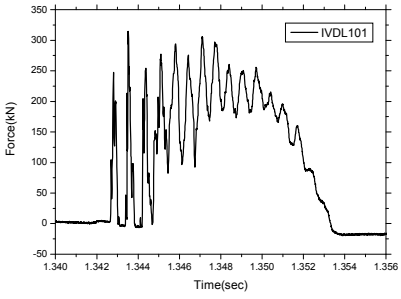

Figure 6. Dynamic load in TROI-54.

Figs.7 and 8 show the debris size distribution after the TROI-54 test. This figure shows that the mass fraction of the fine particles smaller than 0.425 mm is 47.3 %. This is a big amount when compared with non-explosive tests (less than 15 %) [1,2]. Furthermore, the mass mean diameter is as small as 0.46 mm, when compared to non-explosive tests (~ 2 mm). This denotes that a steam explosion occurred in this test.

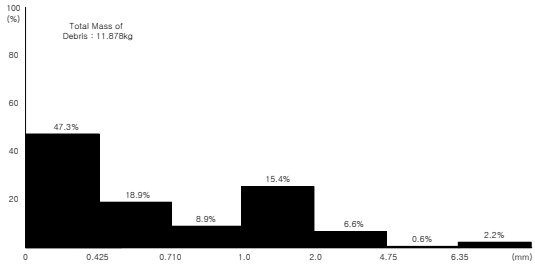

Figure 7. Debris size distribution in TROI-54.

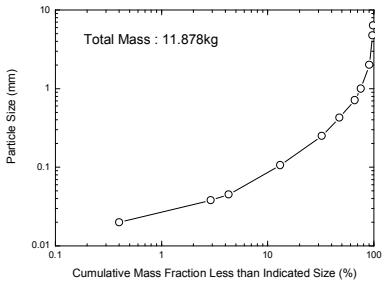

Figure 8. Cumulative debris size distribution.

3. Conclusion

A TROI steam explosion test has been performed with 70 : 30 corium in a narrow interaction vessel of 0.3 m in diameter. This test led to a triggered steam explosion, while no steam explosions had been triggered in previous tests with a narrow interaction vessel [1]. Fine fragmentations occurred at an elevated pressure of 0.205 MPa. It is deduced that the melt can be vigorously fragmented at a mildly elevated pressure to produce a stronger steam explosion than at an atmospheric pressure, when a steam explosion is triggered.

ACKNOWLEDGEMENTS

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REFERENCES

[1] J. H. Kim, I. K. Park, B. T. Min, S. W. Hong, S. H. Hong, J. H. Song and H. D. Kim,, Results of the Triggered TROI Steam Explosion Experiments with a Narrow Interaction Vessel, ICAPP-06, Reno, NV USA, June 4-8, 2006.
[2] J. H. Kim, B. T. Min, S. W. Hong, S. H. Hong, I. K. Park, J. H. Song and H. D. Kim, Layer Inversion Tests with Metal-added Corium in the TROI Experiment, ICAPP-07, Nice, France, May 13-18, 2007.