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Steam Explosion Experiments with Iron-added Corium in the TROI Facility

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1. Introduction

Although many studies have been performed worldwide on a steam explosion [1,2], there are only a few tests using real reactor materials. So the TROI steam explosion experiments have been carried out to evaluate the explosivity of corium. In the previous TROI tests, the effects of the water depth, corium composition and an external trigger were studied on the occurrence of a steam explosion in a 60 cm wide interaction vessel [3,4,5,6]. It turned out that a shallow water pool, eutectic or pure material and the use of an external trigger easily led to steam explosions. However, tests with metal added-corium are needed since the real core material contains iron and zirconium. In this paper, the results of two TROI tests (test No. 43 and 44) are presented using a mixture of spontaneously explosive eutectic corium (70 : 30 at weight percent of UO_2 : ZrO_2) and iron with or without applying an external trigger.

2. Test Facilities

The test facilities of the TROI-43 and 44 tests are almost the same as the previous TROI-36 test [6]. The aim of these tests is to observe the steam explosions using iron-added eutectic corium with or without applying an external trigger. An explosive (PETN 1 g) was used as the external trigger.

3. Test Results

The TROI-43 and TROI-44 tests have been performed with or without applying an external trigger with iron added-corium using a 60 cm wide interaction vessel. The initial conditions and test results are presented in Table 1. In both cases, no energetic steam explosions occurred. However, a weak steam spike occurred without applying an external trigger in the TROI-43 test.

3.1 TROI-43 Test

In the TROI-43 test, 17.000 kg of a mixture of 90% of eutectic corium (UO_2 : ZrO_2 = 70 : 30) and 10% of iron was charged into the crucible and melted. Then 10.220 kg of the melt at 2860K was delivered into a 95 cm deep water pool. The melt temperature was lower than that (> ~3000K) in the corium tests due iron addition. An external trigger was not applied in this test. In this test, a weak spontaneous steam spike occurred in this test. This can be deduced from the dynamic pressure and load signals as shown in Figures 1 and 2. Dynamic pressure was measured only by IVDP102 at 1.34 seconds. The peak pressure was 0.16 MPa and the duration was 27 ms. Since the maximum peak is lower and the duration is longer compared with those from a steam explosion which are a few hundreds MPa and ~ 1 ms, respectively, a steam spike seems to have occurred in this test. The dynamic load was 34 kN with duration of 18 ms

Table 1. Initial conditions and test results

	TROI test number	Unit	43	44
Melt	Initial Composition UO_2 / ZrO_2 /Fe	[w/o]	63/27/10	63/27/10
	Temperature	[K]	2860	2880
	Charged mass	[kg]	17.000	17.000
	Released mass	[kg]	10.220	10.770
	Initial jet diameter	[cm]	6.5	8.0
	Free fall in gas	[m]	3.55	3.55
Test Section	Water mass	[kg]	269	269
	Initial height	[cm]	95	95
	Final height	[cm]	78	93
	Initial temperature	[K]	296	295
	Sub-cooling	[K]	77	78
Pressure Vessel	Initial pressure(air)	[MPa]	0.109	0.110
	Initial temperature	[K]	296	294
	Free volume	[m3]	8.023	8.023
Results	Maximum PV pressurization	[MPa]	0.041	0.057
	Maximum PV heat-up	[K]	175	74
	Maximum water heat-up	[K]	17	14
	Steam explosion		SS*	NO
	Dynamic pressure peak	[MPa]	0.16	-
	Duration	msec	27	-
	Impulse	kN	34	-
	Duration	msec	18	-

Note : * Steam spike

3.2 TROI-44 Test

In the TROI-44 test, 10.770 kg of the same melt composition as TROI-43 at 2880K was delivered into a 95 cm deep water pool. An external trigger was exploded by the time of the melt–bottom contact (~1.50 seconds after the melt delivery). However, no triggered steam explosion occurred. This fact is deduced from the dynamic pressures shown in Figure 3. Compared with a calibration test (13 MPa) shown in Figure 4, the peak pressure was very small as 1.0 MPa. It is thought that the external trigger was unprecedentedly weak and no steam explosion occurred since the peak pressure was measured to be so low.

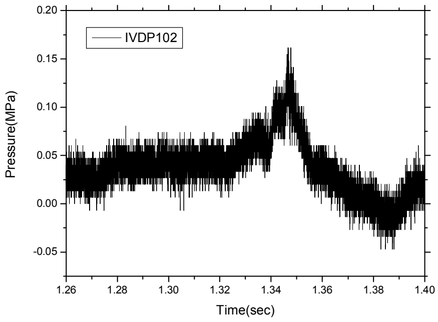

Figure 1. Dynamic pressures in the TROI-43 test

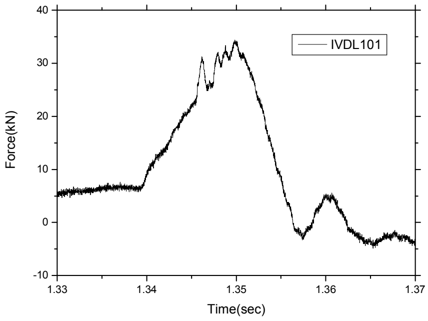

Figure 2. Dynamic load in the TROI-43 test

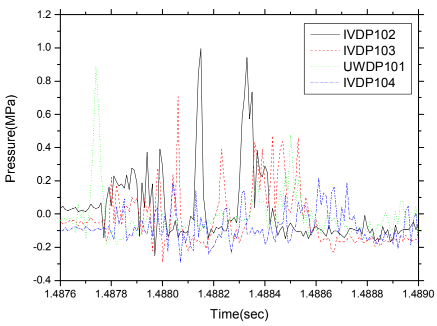

Figure 3. Dynamic pressures in the TROI-44 test

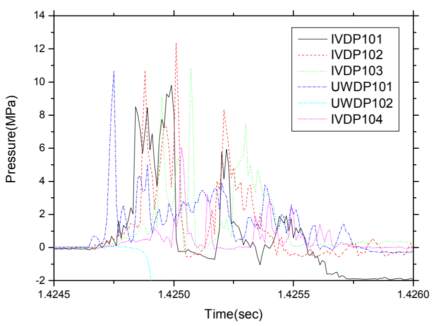

Figure 4. Dynamic pressures in the calibration test

4. Conclusion

Two steam explosion experiments have been performed using iron-added corium with or without applying an external trigger. In both cases, no energetic steam explosions occurred. The reason is thought to be that the relatively low melt temperature prevented a spontaneous steam explosion and that an unprecedentely weak external trigger failed to trigger a steam explosion. More steam explosion experiments with metal-added corium including zirconium metal need to be carried out with a proper external trigger to investigate the effect of metal in corium.

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