Introduction of VESTA Facility and Melting Test Results

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1. Introduction

An ex-vessel corium cooling system, such as an external core catcher, should be required for retaining and cooling the molten corium outside the reactor vessel, if retention of the molten core debris inside the reactor vessel is not assured during a postulated severe accident. In the year of 2010, the VESTA (Verification of Ex-vessel corium STAbilization) test facility was designed and constructed at KAERI to perform the verification tests for the development of a core catcher under the APR+ project. The test facility was designed to have the capability of passively injecting the coolant and gas from below the ex-vessel corium. Not only the simulant tests but also the reactor material tests are accommodated in the test facility. The test facility can also be used for performing various verification tests to resolve some severe accident issues related to molten corium interactions with some modifications. This paper deals with the introduction of the VESTA facility and results of the melting test.

2. Description of the VESTA Facility

The schematic diagram of the facility is shown in Fig. 2. 1. The facility is composed of a furnace vessel, a corium melting system including an intermediate melt catcher and a power supply for an induction heating, a melt delivery system, a coolant supply system, an auxiliary system, and instrumentation and control system.

The furnace vessel protects the melting crucible in which stimulant melt and corium melt are generated by a cold crucible induction heating technology. When the molten corium is sufficiently formed inside the crucible and the molten corium approaches a sufficiently high temperature above the melting point, a plug installed underneath the crucible is removed and a puncher is remotely actuated to perforate the sintered bottom layer for the melt delivery. A cone-shaped intermediate melt catcher is mounted between the furnace vessel and the test section in order to collect the melt temporarily and then to deliver a melt jet into the test section. The power supply system was designed to supply electrical power for the generation of melt in the crucible. The induction heating method with an induction heater of 450 kW in power and 100 kHz in frequency was used. It is expected that up to 400 kg of corium melt can be generated with the power supply system. The coolant supply system is composed of an intermediate cooler and a cooling tower to remove the heat generated in the induction heater, the induction coil, the cold crucible and the plug. The design pressure of the current test section is 1.0 MPa. The design temperature of the upper test section and lower test section are 600 ℃ and 800 ℃. A MgO coating with a thickness of 0.025 m and 0.1 m is provided at the upper and lower test sections. The water injection tank is provided to cool down the melt in the test section. The condensate tank is provided to condense the steam flowing from the test section.

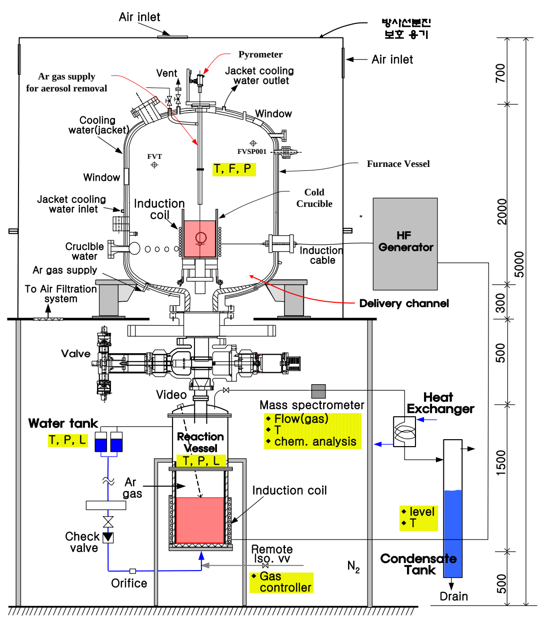

Fig. 2.1 Schematic of VESTA facility

VESTA experimental data include melt temperatures, coolant temperatures and flow rates, gas temperature, vessel pressures, and water levels in the tanks etc. The melt temperatures generated by the furnace vessel are measured by two infrared thermometers (3R-35C15-0000, MODLINE 3, IRCON).

Each thermometer has two sensors with spectral ranges of 0.7-1.08 μm (wide range sensor) and 1.08 μm (narrow range sensor), a useful temperature range of 1773 – 3773 K, a response time of 0.01 to 60 sec., an accuracy of within 0.6%, and a controllable spectral e-slope range of 0.850 to 1.150. All measured data are collected and controlled by using a data acquisition system (DAS, PXI, National Instruments). The DAS system for VESTA experiment is capable of 32-DC signal input channels with 2 MS/s single-channel sampling rate (NI PXIe-6363) and 64-thermocouple signal channels with 80 S/s sampling rates and 24-bit resolutions (NI PXIe-4353). The DAS is controlled by LabVIEW program in a personal computer.

3. Melting Test Results

Fig. 3.1 shows the charging of ZrO_2 in the cold crucible. The total charged mass of ZrO_2 (crushed ingot and powdered ZrO_2) was 151 kg. An initiator made of a ZrO_2 ring was placed at 1/3 height from the bottom of the cold crucible. Three holes were provided inside the charged ZrO_2, two holes for the venting of the gases, one hole for the temperature measurement by the pyrometer.
Power was continuously supplied from the generator with a stepwise increment until the end of the melting process. The maximum power to the crucible was about 300 kW. It took about 160 min. for the complete melting. If the water outlet temperature of the plug increases a lot during the melting process, we can judge that melting is completed. Then we remove the plug and actuate the puncher. Fig. 3.2 shows the surface of the melt. Fig. 3.3 shows the surface temperature of the melt measured by the infrared thermometer installed at the upper furnace vessel. The maximum temperature was about 2860 ^{o}C. As time went, the surface temperature dropped below 2000 ^{o}C, because the hole provided for the temperature measurement by the infrared thermometer collapsed and the surface crust was formed. But, maximum temperature inside the melt is sure to be maintained at about 2860 ^{o}C.

Fig. 3.2 Charging of ZrO_2

Fig. 3.3 Surface of melt

After the complete melting, we removed the plug from the bottom of the cold crucible and actuated the puncher system. The melt was temporarily contained in the melt catcher and dropped into the test section through an orifice with an inner diameter of 50 mm. The melt delivery process was videotaped. The melt delivery duration was about 13 sec. Investigation of the cold crucible and the test section showed that the melting of the ZrO_2 was successful and most of the melt was delivered to the test section. Fig. 3.4 shows the surface crust in the crucible after the test.

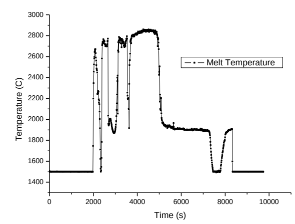

Fig. 3.3 Melt temperature

Fig. 3.4 ZrO_2 crust

4. Conclusions

VESTA test facility, which was designed and constructed at KAERI to perform the verification tests for the development of a core catcher, was represented. The major characteristic of the facility is that up to 400 kg of corium melt can be generated with the cold crucible melting technique. Melting test with 151 kg of ZrO_2 was performed. Investigation of the cold crucible and the test section showed that the melting of the ZrO_2 was successful and most of the melt was delivered to the test section. Two categories of the test are planned until the end of 2012, that is, the melt jet impingement test and the long-term interaction test between the melt and the sacrificial material. The tests will be performed with some modifications of the VESTA facility.

ACKNOWLEDGEMENTS

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