A study for development of a material irradiation capsule in the OR holes of HANARO

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1. Introduction

This paper focuses on the design of a capsule for a material irradiation that is supposed to be loaded in an OR test hole in the HANARO. Through a technical analysis of the HANARO test holes, a new capsule for an irradiation of medium and high temperature materials in an OR test hole was designed and fabricated. A test for a pressure drop and a vibration of this capsule was performed before manufacturing a material capsule suitable for an OR hole in HANARO. The conceptual design of a capsule was performed to design a capsule to irradiate materials at the hole. The capsule is fixed by using a clamp device by pressing a stopper onto the protection tube. It was concluded before the test, that the diameter of a capsule for an OR holes should be more than 49mm by an evaluation of a flow rate and pressure drop in theory. Based on the out-pile test results, an irradiation capsule with a diameter of 56mm was finally fabricated and irradiated successfully in the HANARO.

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2. Pressure drop Test

The pressure drop test for a material capsule to be irradiated in the OR holes was performed in the single channel test loop of the HANARO out-pile test facilities. Before the test, it was estimated that the diameter of a capsule for the OR holes should be more than 49mm by a theoretical estimation[1, 2]. According to the theoretical estimation, the 3 kinds of mock-up capsules with diameter of 52, 54, 56mm were made and used for a pressure drop test. A protection tube of the capsule was commonly connected to the 3 different sizes of main bodies as in Fig. 1. The results for a pressure drop test were indicated in the Fig. 1. The data for a pressure drops of a dummy fuel and a fuel capsule, which are installed alternatively in the same OR hole, was included as reference data for a comparison with the test results for the OR capsule. According to the results, the 3 kinds of mock-up capsules with diameter of 52, 54, 56mm were confirmed to satisfy the requirement for a pressure and flow rate in HANARO.

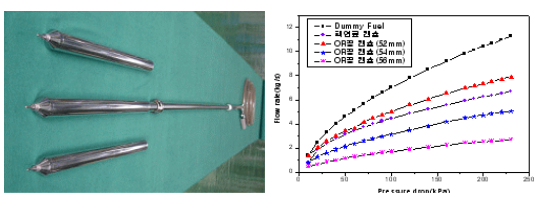

Fig. 1 The mock-up capsules and the pressure drop test

3. Vibration test

The capsules with diameters of 54, 56mm were used in a vibration test taking consideration into a receptive capacity of specimens. The test was performed in the HANARO out-pile test facilities. The 6 sets of accelerometers were installed at 3 places on the protection and the capsule. As the aspect ratio of a capsule is very big, a bending vibration in the lateral direction is apt to occur more than a longitudinal vibration in the axial direction. A bending vibration might occur greatly at a part of the protection tube over the OR clamp because the upper part of the protection tube is supported by the OR clamp when loading a capsule. Therefore, two underwater accelerometers were installed in the perpendicular direction to measure the horizontal vibration at a part of the protection over the OR clamp.

As an upper part of the protection tube is supported by the OR clamp when loading a capsule and the lower part can be considered to be fixed on the top of the reflector tank in a lateral direction, the greatest position of a lateral vibration might be a central part of the protection. Accordingly, a central position of the protection tube under the OR clamp was designated as a point of the vibration measurement because a bending vibration is expected to occur greatly there and two underwater accelerometers were installed in the perpendicular direction by using an attachment jig. And two small 2-axis accelerometer were installed at a lower part inside the capsule to measure a vibration of the main body of the capsule. A direction of this accelerometer points toward the branch of the protection tube.

The analyses for a time-region and a frequency-region were performed for the vibration signals measured from the accelerometers installed on the protection and in the capsule. The sampling frequency is 4096Hz, and the time for obtaining the data is more than 120 seconds, and the displacements were calculated by integrating the acceleration signals two times.

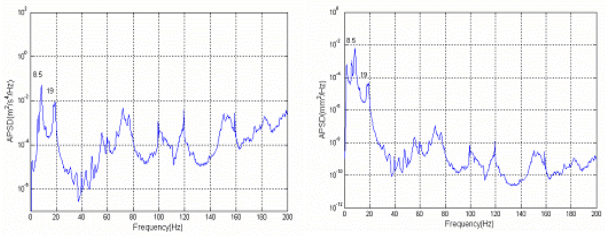

Fig. 2 Self spectrum density function of the vibration signal(acceleration and displacement at A1 position)

In the analysis for a time-region, the RMS(root mean

square) and the maximum amplitude were obtained. In the analysis for a frequency-region, the frequency components were obtained in detail and the co-relations between the measured signals were analyzed. Fig. 2 shows the self spectrum density function of the vibration signal at the upper position.

The allowable value for an amplitude of an acceleration in HANATO is 18.99m/s^2[3]. The maximum amplitude of an acceleration when a diameter of a capsule is 56mm is in the range of 10.40~12.14m/s^2, and this is less than the allowable value in HANARO. As the displacement of this capsule is 0.41~0.47mm and less than the gap between the OR flow tube and the capsule, this capsule does not bump into the wall of an OR flow tube.

A capsule of a diameter 56mm satisfies the requirement for an allowable limit of a vibration acceleration applied in HANARO and its maximum amplitude of a displacement is less than the gap (2mm) between the flow tube and the capsule. Therefore, a capsule with a diameter 56mm would maintain a structural integrity by a vibration and not interfere with the adjacent structures.

4. Analysis for a Heat Transfer and a Surface Temperature

If the dimensions of a capsule are determined, a heat transfer coefficient should be calculated and then the temperature on a surface of the capsule should be evaluated to confirm it is less than the ONB temperature. When a diameter of a capsule is 56mm, the flow rate was 2.57kg/s at a pressure difference of 209kPa according to the results of the test. The heat transfer coefficient was evaluated as 33,011 W/m^2 ℃.

A boiling should not occur on the surface of a capsule installed in HANARO. The temperature on a surface of a capsule should be less than 124℃ to meet this requirement. The heating rate of an OR capsule is 17,418W on the basis of that of the 07M-21K capsule. The surface temperature of the OR capsule with a diameter of 56mm is evaluated as 43.7°C, and this is less than the ONB temperature.

5. Thermal performance test

Based on the previous technical examination and on the out-pile test results by using a mock-up capsule, a capsule for a thermal performance test for high temperature materials was finally designed and fabricated. The capsule with a diameter of 56mm is composed of five stages with a separated thermal medium, specimens and an electric heater at each stage. The thermal medium contained has 4-holes to contain the specimens of STS 304 material with a dimension of 10x10x100mmL. Other thermal media like Al, Fe, Zr, Ti and Mo were used. These materials are candidate ones to be used as a substitute of Al thermal media for an irradiation of high temperature materials in the future. The length of the main body is 813mm and the total length including the main body and the protection body is 4934mm.

The thermal performance test was applied at the heater power of 1800 and 2850W in a He environment of 760 and 100 torr. The results are indicated in Fig. 3. The temperature of the specimens in the Fe thermal medium at the 2nd stage was 400°C at a 760 torr, and 527°C at a 100 torr. The temperatures were distributed in the order of a high temperature at Fe, Ti, Mo, Zr and Al. The temperatures are inversely proportional to the values of the thermal conductance.

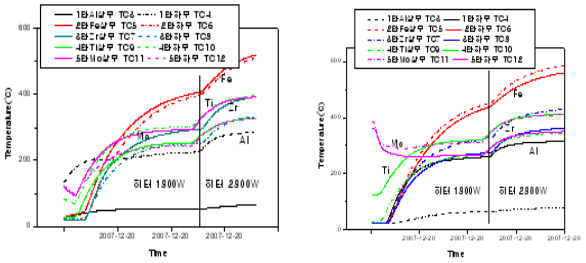

Fig. 3 Temperatures in heater powers

6. Conclusions

A performance test was used for a pressure drop and a vibration to determine the size of a capsule for a material irradiation in the OR holes of HANARO. In the pressure drop test, all three kinds of the capsules satisfied the conditions for a pressure and a flow rate required in HANARO. The two capsules with a diameter of 54 and 56mm out of them were put in a vibration test by taking into consideration a receptive capacity of the specimens. A capsule with a diameter of 56mm satisfied the requirement for an allowable limit of the vibration acceleration applied in HANARO. The capsule with a diameter of 56mm was selected and finally fabricated as a capsule for a materials irradiation in the OR holes of HANARO. After a thermal performance test for this mock-up capsule, the first capsule to be utilized for an irradiation test of a high temperature material at the OR holes will be designed, fabricated and irradiated in 2008.

References

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[3] R. R. Bonder, “KMRR shut-off unit test report, TR-37-31730-001, Rev. 0, 1993