Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 22, 2009

The Development of a Material Capsule(07M-09K) for an Irradiation at the HANARO Out-core Region

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1. Introduction

To meet the various requirements of the users for the neutron fluence and the temperatures of the specimens, an irradiation capsule for a utilization of the out-core region at HANARO was designed, fabricated and performance tested. The test for a pressure drop and a vibration was performed to see if the hydraulic and vibration conditions required in the HAHARO are satisfied. The mass of the capsule and the electric resistances of the heaters and the thermocouples were measured, and the thermal performances of the capsule were investigated. The thermal performances test for Fe, Zr, Ti, Mo materials, which will be used as the thermal media of a high temperature irradiation capsule, were tested.

2. Design and fabrication

Based on the previous technical examination and the performance tests[1], the capsule(07M-09K) for an out-pile test was finally designed and fabricated. The shape of the capsule is as shown in Fig. 1. The external tube is made of STS316L with the outer and inner diameter 56 and 52mm, and the protection tube is made of STS304 with a diameter of 42.7mm for a utilization of the existing OR clamp. The specimens are the modified RPV steel of 9Mo-1Cr RPV and 40 pieces of Charpy ones. The irradiation temperatures of the specimens are 350~400℃. The target of the irradiation is 2.1×10^{19} n/cm^2 (E>1.0 MeV) at OR5 hole.

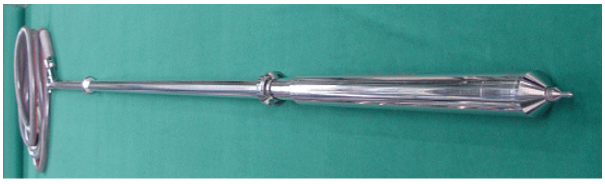

Fig. 1 07M-09K capsule

The capsule is composed of five stages with a separated thermal medium, the specimens and an electric heater at each stage. The thermal medium has 4-holes to contain the specimens of STS 304 material with a dimension of 10x10x100mmL as in Fig. 2. The various thermal media of Al, Fe, Zr, Ti and Mo material were used for an irradiation of a high temperature. These materials are candidate ones to be used as substitutes 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.

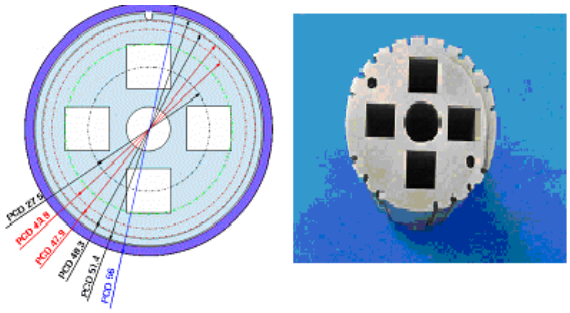

Fig. 2 Thermal medium

3. Analysis for a heat transfer and a surface temperature

The heat transfer coefficient of the capsule was calculated and the temperature on the surface was evaluated to confirm it is less than the ONB temperature[2]. The flow rate was 5.25kg/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 the 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 previous capsule. The surface temperature of this capsule is evaluated as 43.7°C, and this is less than the ONB temperature.

4. Out-pile tests

At the out-pile test facility, the mass, the He leak rates, the flow and the pressure drop and the electric resistances were measured. The loading and the unloading tests were done to review the possibility of a vibration during the operation. And, the thermal performances were tested for the various thermal media to check the highest temperatures of the specimen to be reached at each thermal medium.

The mass of the capsule is 44.25 kg containing the guide tube of the polyvinyl and the 10 pieces of the signal cables. In the leak test, the capsule was pressurized at 8kg/cm^2 by He gas for 30 minutes and it was confirmed not to be leaked. The flow rate was measured as 5.25kg/s at the pressure drop of 209kPa, while it was 2.57kg/s in the theoretical analysis. It satisfies the requirement that the flow rate should be less than 12.7kg/s. The electric resistances of the signal cables were measured to confirm the normality, and it was confirmed that the cables were well insulated and connected.

5. The thermal performance test

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 media have 4-holes to contain the specimens of STS 304 material with a dimension of 10x10x100mmL. The thermal media of Al, Fe, Zr, Ti and Mo material 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. To measure the maximum temperatures of the specimens to be attained by using the various thermal media, the maximum powers of the heaters were first measured. The maximum temperatures were measured at 90~95% powers of the heaters to prevent them from breaking.

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 593°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.

Comparing with the temperatures at the various thermal media, they were higher in the order of Fe, Ti, Mo, Zr and Al. The temperature at Fe thermal medium was the highest because the gap was biggest as 1mm while they were 0.3mm at other thermal media.

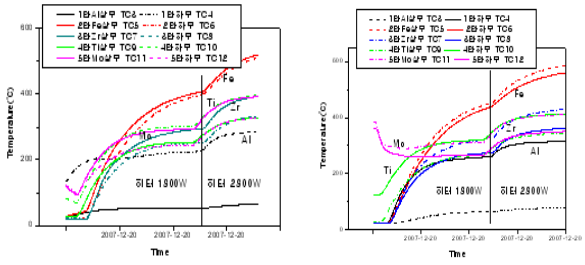

Fig. 3 Temperatures vs. heater powers

The maximum temperatures were measured at a 90~95% heater power at the atmosphere of 36 torr. The maximum temperature was 669°C at 2nd stage with the Fe thermal medium.

6. Breakage of the heaters

During measuring the temperatures at 36 torr, the heaters of the second to fifth stages were broken. It was occurred 2 minutes after changing the internal pressure to 36 torr. The relation between the temperature and the heater powers were shown in the Fig. 3 and the maximum temperatures were found there. To find where the breakage was started, the graph for the temperatures and the time was shown at the figure 4. The heater at the 1st stage was not broken until the end, those at the 2~5 stages were all broken. By the Fig. 4, the breakage of the heaters was started from the 3rd stage, and next in the order of 4, 5 and 3 stage. The 4th heater was broken after 4 seconds, the 5th after 7 seconds and the 2nd after 43 seconds from the breakage of the 3rd stage heater[3].

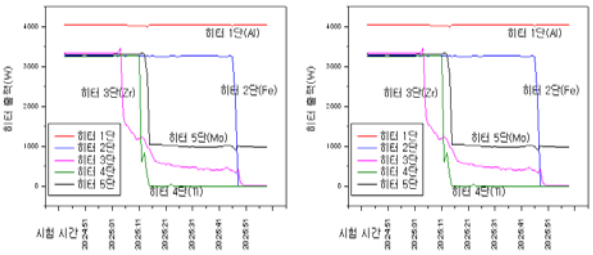

Fig 4. Temperature on the breakage of the heaters

7. Conclusions

To meet the various requirements of the users for the neutron fluence and the temperatures of the specimens, an irradiation capsule for a utilization of the out-core region at HANARO was designed, fabricated and performance tested. The pressure drop test showed to meet the requirement for a flow and pressure drop at HANARO. The thermal performances test for Fe, Zr, Ti, Mo materials, which will be used as the thermal media of a high temperature irradiation capsule, were tested. It is ascertained that the temperature of the specimens can be raised up to 700˚C by using the thermal media such as Fe, Zr, Ti, Mo instead of Al.

Acknowledgements

The authors would like to express their appreciation to Korea Science and Engineering Foundation (KOSEF) and the Ministry of Education, Science and Technology (MEST) of the Republic of Korea for the support of this work through the Nuclear R&D Project.

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