Development of Vacuum System for High-Temperature Heating Test in Hot Cell

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1. Introduction

Sodium-cooled Fast Reactor (SFR) which has an advantage of enhanced reactor safety, fuel cycle economy, and environmental protection has developed in KAERI. Post-irradiation examination was performed to evaluate performance of an irradiated metallic fuel in IMEF. As a part of the post-irradiated test, high-temperature heating tests for the irradiated U-10Zr and U-10Zr-5Ce with T92 cladding fuel were conducted to confirm the eutectic reaction between the metallic fuel and the Fe based cladding [1]. Additionally, high-temperature heating tests will be performed for the irradiated U-10Zr and U-10Zr-5Ce with HT9 and FC92 cladding in order to compare differences of microstructure and eutectic penetration rate according to cladding types.

At the first heating test, helium gas and Zircaloy-4 sheet act as O_2 getter were used to prevent oxidation of the metallic fuel. However, development of vacuum system and jig were necessary for effectively preventing the oxidation. Therefore the vacuum heating system was developed to prevent the oxidation during the high-temperature heating test and also vacuum storage was made to prevent the oxidation before the test. In addition, jig was developed to test various types of cladding at the same time.

After the development, performance tests of the vacuum heating system and preliminary tests using a misch metal composed of Lanthanum and Cerium were completed.

2. Methods and Results

2.1 Specimen

The jig shown in Fig. 1 was developed to reduce the fuel oxidation and to test various types of the cladding at the same time. The jig is made symmetrically, however, one side is made of FC92 and the other side is made of HT9.

In the preliminary test, the misch metal composed of the Lanthanum and Cerium was used to confirm the performance of the vacuum heating system.

2.2 Apparatus

The vacuum furnace and vacuum storage installed in hot cell are shown in Fig. 2. The temperature was controlled by one heating zone furnace, and it measured the temperature of the furnace and inside of the vacuum

Fig. 1. Misch metal and jig for preliminary test

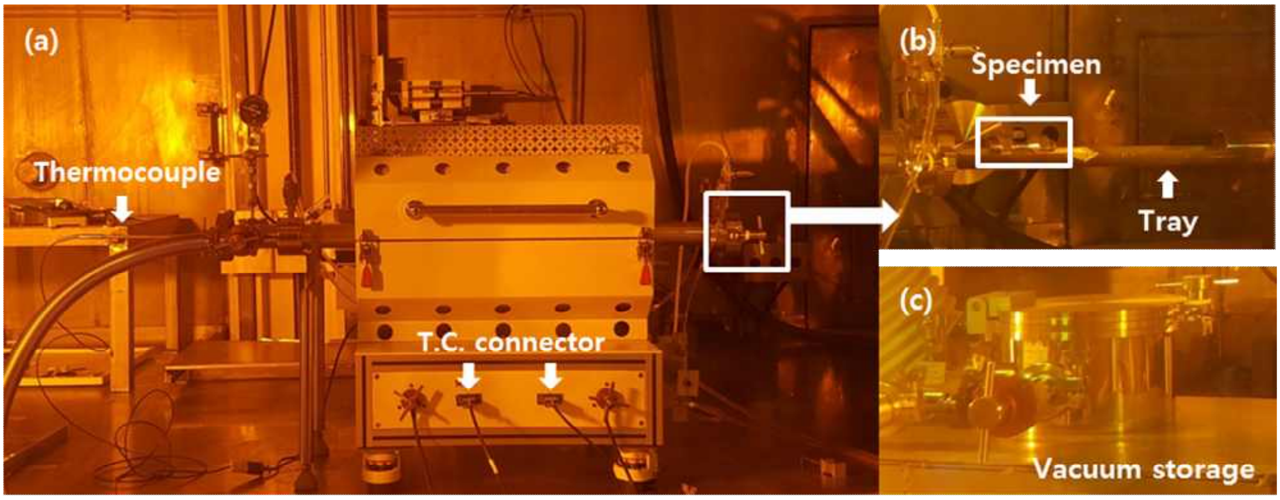

Fig. 2. Experimental set-up of (a) Vacuum furnace, (b) specimen and tray, and (c) vacuum storage installed in hot cell

tube by two thermocouples. Also, there are thermocouple connectors at the furnace for easily connecting with the furnace controller and the indicator installed in operating area. As shown in Fig. 2(b), specimen can be installed and removed using the tray. Rotary and diffusion pump connected with vacuum furnace and vacuum storage to achieve high vacuum environment. By using the vacuum system, the oxidation of the specimen can be prevented during and before the heating test. The furnace controller, chiller, vacuum pump, and vacuum gauge were installed in operating area for ease of maintenance.

2.3 Performance test

Before the preliminary test, the performance test of the vacuum furnace was carried out. It could be possible to achieve and maintain high vacuum environment up to 10^{-5} Torr. Temperature deviation was maintain within ±1℃ at the test temperature thorough repetitive test. The lateral deviation from 3 cm based on the center was about 2℃. The lateral deviation from 1 cm based on the center was within 1℃. It is reasonable temperature distribution results because the specimen length is about 6 cm and the fuel length is only 5 mm.

The preliminary tests were performed. Fig. 3 is one of the preliminary test results. The specimen was heated up to 750℃ and then maintained during 1 hour. After heating test was ended, the specimen was air-cooled. The specimen was cut and mounted for observing a microstructure using OM and SEM. And also, component analysis using EPMA was performed. At the results, the reaction area occurred between misch metal and cladding was successfully observed. Expected component analysis results were also obtained.

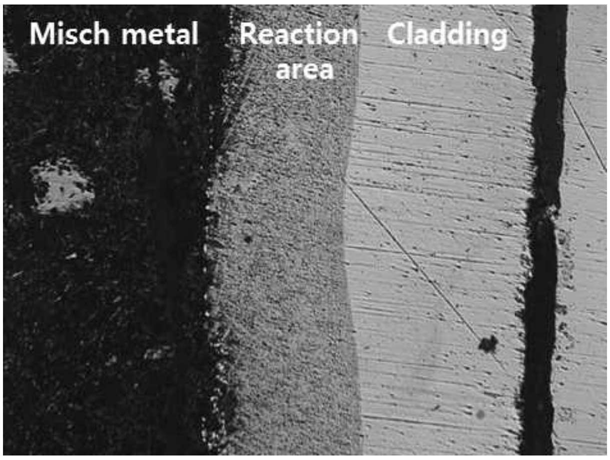

Fig. 3. Preliminary test results (750℃, 1h)

3. Conclusions

The second high-temperature heating test will be performed to confirm the eutectic reaction between the metallic fuel and Fe based claddings in IMEF. The vacuum heating system was developed to effectively prevent the oxidation more than the first heating test. And also, the jig was developed to test various types of the cladding at the same time. Before heating test of the irradiated fuel test, performance test of the vacuum furnace and preliminary test were performed. At the results, enough reasonable test results were obtained and test procedure could be set up.

Based on this test results, high temperature heating tests of the irradiated U-10Zr and U-10Zr-5Ce with T92, FC92, and HT9 will be performed. It is expected to successfully obtain results of microstructure and eutectic penetration rate according to cladding types.

REFERENCES

[1] June-Hyung Kim, Jin-Sik Cheon, Byoung-Oon Lee, Jun-Hwan Kim, Hee-Moon Kim, Boung-Ok Yoo, Yang-Hong Jung, Sang-Bok Ahn, and Chan-Bock Lee, Results of High-Temperature Heating Test for Irradiated U-10Zr(-5Ce) with T92 Cladding Fuel, Metals, Vol.6, No.278, 2016.