Out-pile Test of Double Cladding Fuel Rod Mockups for a Nuclear Fuel Irradiation Test

Jaemin Sohn, Sungjae Park, Younghwan Kang, Harkrho Kim, Bonggoo Kim, Youngki Kim
Korea Atomic Energy Research Institute, 150 Deokjin-dong, Yuseong-gu, Daejeon 305-353, Korea
**Corresponding author: jmsohn@kaeri.re.kr*

1. Introduction

An instrumented capsule for a nuclear fuel irradiation test has been developed to measure fuel characteristics, such as a fuel temperature, internal pressure of a fuel rod, a fuel pellet elongation and a neutron flux during an irradiation test at HANARO. In the future, nuclear fuel irradiation tests under a high temperature condition are expected from users. To prepare for this request, we have continued developing the technology for a high temperature nuclear fuel irradiation test at HANARO.

The purpose of this paper is to verify the possibility that the temperature of a nuclear fuel can be controlled at a high temperature during an irradiation test. Therefore we designed and fabricated double cladding fuel rod mockups. And we performed out-pile tests using these mockups. The purposes of a out-pile test is to analyze an effect of a gap size, which is between an outer cladding and an inner cladding, on the temperature and the effect of a mixture ratio of helium gas and neon gas on the temperature.

This paper presents the design and fabrication of double cladding fuel rod mockups and the results of the out-pile test.

2. Design and Fabrication of Double Cladding Fuel Rod Mockups

2.1 Design of the Double Cladding Fuel Rod Mockups

To verify the effect of a gap size and a mixture ratio on the temperature, three typed double cladding fuel rod mockups were designed. Each mockup contains an inner cladding, an outer cladding, a thermocouple, a thermal media, a heater, a gas-in tube and a gas-out tube as shown in Fig.1. Three types of gaps between an outer cladding and an inner cladding were designed 0.1 mm, 0.2 mm, 0.3 mm.

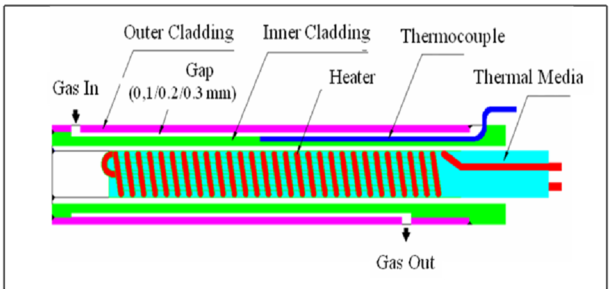


Fig. 1. Schematic Drawing of a Mockup

A K-type thermocouple was used to measure the temperature of an outside surface of an inner cladding. The mixed gas flows through the gap between an outer cladding and an inner cladding.

2.2 Fabrication of the Double Cladding Fuel Rod Mockups

An outer cladding is made of STS304 and it is 35 mm in outside diameter, 110.5 mm in length and 2 mm in thickness. An inner cladding is made of STS304 also and it is 28 mm in inside diameter, 120 mm in length and it has a groove to install a thermocouple. A thermal media is made of STS304 and it is 26 mm in outside diameter, 110 mm in length and it has a grooving to install a heater. A heater was wound on a thermal media. Three mockups are in an outer tube as shown in Fig. 2. An outer tube is made of STS304 and it is 56 mm in outside diameter, 727 mm in length and 2 mm in thickness.

3. Out-pile Test of Double Cladding Fuel Rod Mockups

Out-pile test was performed at a single channel test loop. The Gas Control System for a Fuel Capsule Irradiation(GSF-2002) was used to control the heater power, the mixture ratio of the helium and neon gas and the flow of mixed gas. And it was used to acquire the output signals. The mockups were installed in this loop for an out-pile test as shown in Fig. 3.

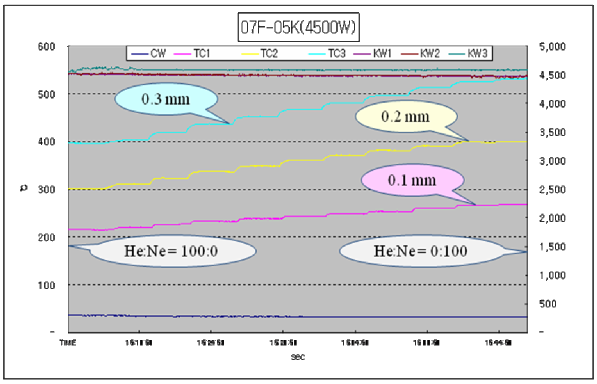
Fig. 2. Three double cladding fuel rod mockups and an outer tube(left)

Fig. 3. Out-pile test at a single channel test loop(right)

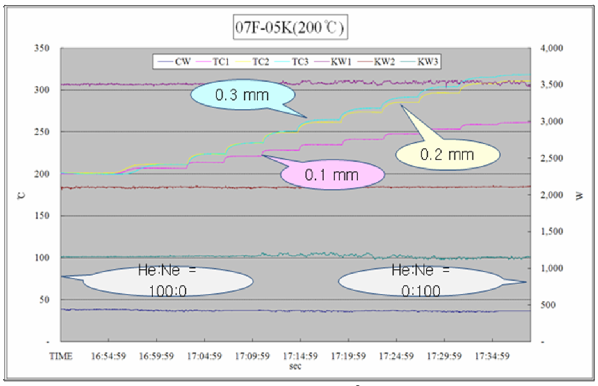
The out-pile test was conducted under a condition close to the OR5 experimental hole conditions of HANARO. Therefore, in a single channel loop, the temperature of the cooling water was set at 40 ℃, the flow of the cooling water was set at 12.7 Kg/s (△P 209 KPa). The flow of the mixed gas of helium and neon was fixed at 50 cc/sec. Because the flux of the mixed gas has only a little effect on temperature[1][2].

During the out-pile test, data for the following measurements was acquired; three thermocouple signals for the outside surface temperature of the inner cladding, heater power signals for the heat source, and a thermocouple signal for the temperature of the cooling water. This data has been collected over 1-second intervals.

In the first out-pile test, we fixed the heater powers(KW) of the three mockups at the same level and the neon gas ratio was varied in 10 % increments from 0 % to 100 %. And we monitored the temperatures of an outside surface of the inner cladding of the three mockups. This test was repeated under variable heater powers. The heater powers of the three mockups were varied in 500 KW increments from 500 KW to 4,500 KW. Figure 4(a) shows the typical measured data of the out-pile test at a 4,500 KW heater power.



(a) Result of a out-pile test at a 4,500KW heater power



(b) Result of a out-pile test at a 200 ℃ initial temperature

Fig. 4. Out-pile test data of mockups

In the second out-pile test, we fixed the initial temperatures of the outside surface of the inner cladding of the three typed mockups at the same level and the neon gas ratio was varied in 10 % increments from 0 % to 100 %. And we monitored the temperatures of the outside surface of the inner cladding of the three mockups. This test was repeated under variable initial temperatures. Figure 4(b) shows the typical measured data of the out-pile test at a 200 ℃ initial temperature. The measured maximum temperature was 531 ℃ at a 4,500 KW heat power and 0.3 mm gap.

The results may be summarized as follows: The larger the gap size is, the higher temperature is. A gap size and a temperature are in proportion to each other. And the higher the neon ratio of the mixed gas is, the higher the temperature is. A neon ratio of a mixed gas and a temperature are in proportion to each other.

4. Conclusions

Through the results of the study, the effects of a gap size and a gas mixture ratio on the temperature were verified. The results obtained in this study can be useful for the design of double cladding fuel rods for an irradiation test under a high temperature condition.

Acknowledgement

This study was supported by Korea Science and Engineering Foundation(KOSEF) and Ministry of Science & Technology(MOST), Korean government, through its National Nuclear Technology Program.

REFERENCES

[1] Y.H.Kang, "Out-pile characteristics of basic designed capsule mockup", Korea Nuclear Society, 2002.5.
[2] Y.H.Kang, "Performance Test of the I&C System(GSF-2002) for the Irradiation Tests using a Fuel Capsule", KAERI/TR-2875/2004, Korea Atomic Energy Research Institute, 2004.12.