Three-point Bending Test of Irradiated Fuel Cladding in Hot Cell

Y. G. Jin*, S. J. Baik, B. O. Yoo, S. Y. Baek, H. M. Kim
Korea Atomic Energy Research Institute, 989-111 Daedeok-daero, Yuseong-gu, Daejeon 34057, Korea
**Corresponding author: ygjin@kaeri.re.kr*

1. Introduction

Mechanical properties of a fuel rod, which is a long and flexible structure, are of great importance for fuel assembly reliability during operation inside the nuclear reactor and transportation for spent fuel storage. Bending is one of the loading modes for fuel rod as a part of PWR (Pressurized light Water Reactor) fuel assemblies. The bending fracture could be a safety concern because of shock and vibration caused by a spacer grid or fuel rod interaction.

In the present study, a three-point bending test of a cladding was conducted to investigate the characteristics of deformation behavior and the change in structural strength of an irradiated cladding in a hot cell at IMEF (Irradiated Materials Examination Facility) of KAERI.

Fig. 1. Cutting of the irradiated cladding using the micro-cutting machine in a hot cell.

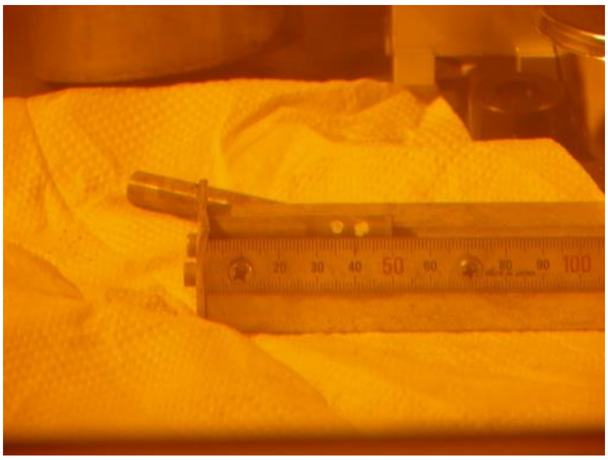

Fig. 2. Dimensional measurement of the length of the irradiated cladding in a hot cell.

2. Methods and Results

This paper presents the results of a three-point bending test aimed at measuring the mechanical properties of an irradiated zirlo cladding. The bending test specimens were fabricated using the micro-cutting machine in a hot cell as shown in Fig. 1.

Fig. 2 shows the dimensional measurement of the length of the cutting tubes in a hot cell. The values of the length and diameter of the irradiated cladding were 50 and 9.5 mm, respectively. The accuracy of the cutting length was not so critical and the cutting length and quality were acceptable in a three-point bending test because the support span is the most important parameter to evaluate the mechanical properties of the testing tube [1].

As the structural material including a fuel rod is irradiated by neutrons in the core of a reactor, it could be a highly radioactive substance during operation. Therefore the examination and measurement apparatus must be designed to control it remotely from the operation area of the hot cell facility.

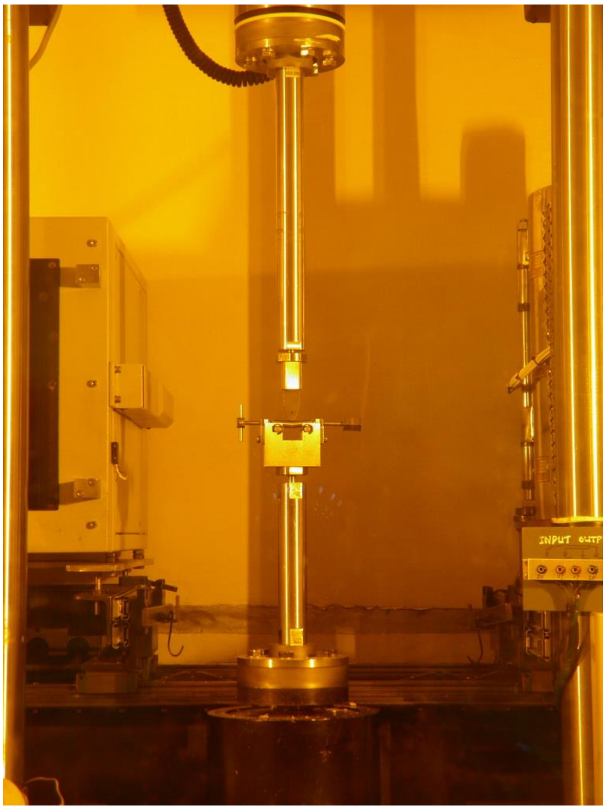

Fig. 3. Experimental set-up for the three-point bending test of the cladding using a universal testing machine in a hot cell.

Fig. 3 shows the experimental set-up of the bending test. A modified Instron 8562, which is a universal test machine as shown in Fig. 1, was used for a bend testing. Control components were designed separately from the test frame and located outside of the hot cell. The specimens for the bending test were tested using a 50 kN-capacity calibrated load cell and newly designed flexure test fixtures was customized for a hot cell testing.

The fixtures for the bend test was designed and fabricated to satisfy various requirements of use in a hot cell testing. The support span of the fixture was 39 mm. The nominal bearings for the support of the cladding and for the application of load have diameters of 10 mm.

The alumina pellets were prepared and inserted into the tube. Specimens with alumina pellets were placed and aligned on the three-point bend fixture. The testing machine crosshead was manually positioned to provide the preload (15 N) to the specimens. Bluehill software for Instron testing machine was commanded to execute a test procedure to run the bend test as a constant crosshead speed of 0.5 mm/min at room temperature.

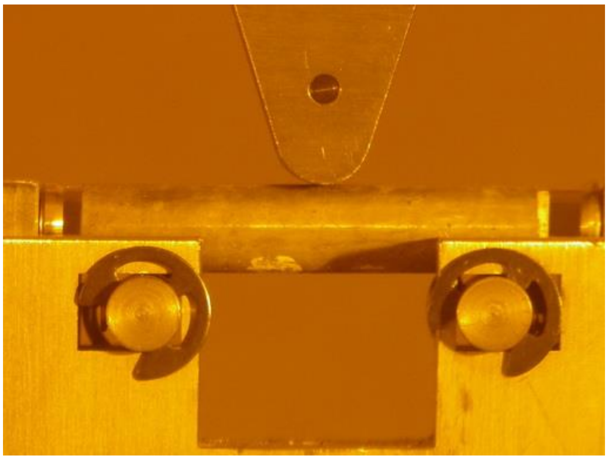

Fig. 4. Placement and alignment of the irradiated cladding with alumina pellets for the three-point bending test in a hot cell.

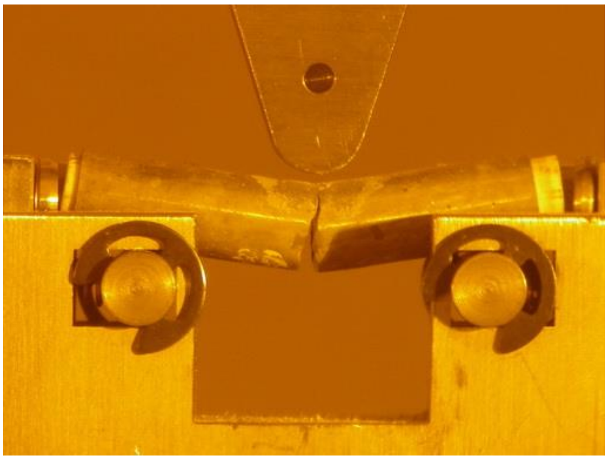

Fig.5. Fractured behavior of the irradiated cladding for the three-point bending test with alumina pellets in a hot cell.

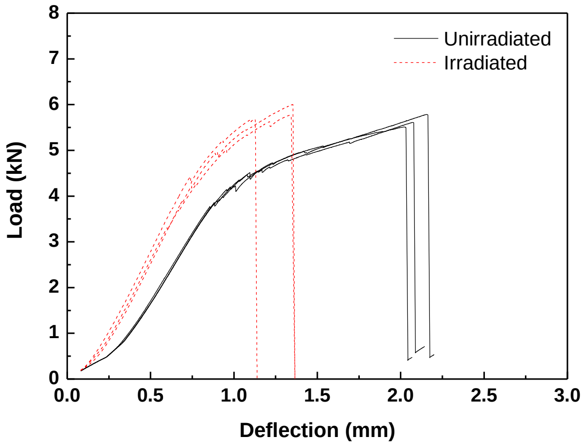

Fig.6. Load-deflection curves obtained from the three-point bending test of the irradiated and unirradiated fuel rods in a hot cell.

The elapsed time, displacement and load were collected during the test and the data acquisition rate was 5 Hz to ensure any small transient events were captured.

Irradiated specimens were fractured as shown in Fig. 5. Fig. 6 shows load-displacement curves from the bending tests. These curves show that the irradiated specimens show slightly increased maximum load, but the ductility of the irradiated specimens decreased comparing to the unirradiated specimens.

3. Conclusions

In order to evaluate the bending performance of an irradiated cladding, hot cell tests were carried out at IMEF of KAERI. Bending tests were conducted on the fuel rods with alumina pellets. Irradiated and unirradiated claddings were tested and the results were compared. It was shown that there was a degradation of ductility in the irradiated cladding. An understanding about the bending behavior caused by irradiation embrittlement is helpful for prediction of the fuel rod performance during the nuclear reactor and transportation for the spent fuel storage.

REFERENCES

[1] ASTM C1161, Standard Test Method for Flexural Strength of Advanced Ceramics at Ambient Temperature, ASTM International, 2013.