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Non-destructive test for irradiated fuels using X-ray CT system in hot-laboratory

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1. Introduction

To inspect inside of irradiated fuel rod for PIE in hotcell, neutron beam and X-ray have been used. Many hot laboratories in the world have shown the results for NDT by 2-D film data. Currently, computed image processing technology instead of film has been developed and CT was applied to the X-ray and neutron beam system. In this trend, our facility needed to set up X-ray system for irradiated fuel inspection and installed in hotcell with consideration of radiation damage.

In this study, X-ray system was tested to be operated with radioactive samples and was performed to inspect fuel rods and observe internal damage and dimensional change.

After system-check, the PIE for several fuel plates and VHTR rods were tested and produced the results with 2-D and 3-D images and dimensional measurement.

2. Experimental

2.1 Samples

After calibration and alignment of X-ray system, 8 fuel plates and 2 VHTR rods were prepared as sample. Fuel plate was U-Mo dispersed Aluminum plate as shown in Fig. 1 and each VHTR rod contained 5 fuel compacts and 9 fuel compacts, respectively as shown in Fig. 2[1,2]. Each burnup was about 60%-U235 for fuel plates and 40,000 MWd/t-U for VHTR rods, respectively. Radiation dose for fuel plates and VHTR rods were measured at distance of 1 m and those results were about 450~500 mSv/h for fuel plates and 92~95 mSv/h for 2 VHTR rods.

2.2 Apparatus

An X-ray system consists of an X-ray tube, sample bench, and LDA (Line Detector Array). The system was made by YXLON Co. in Germany. The specifications of the X-ray tube are 450 kV, 15 mA, and 0.4/1.0 mm in focus size. LDA has a 254 μm pitch and 1,984 elements with a CdWO4 scintillator. Its collimator is 1.0 mm gap with tungsten. It took 1 year to make all system including installation[3]. Two PCs with two programs were supplied; one was X-ray scan program to produce profiles of object and the other was 3-D image processing program. Especially, GOST algorithm is applied to X-ray scan program for gamma noise reduction[4]. Additionally, dimensional measurement of sample was possible in 3-D program. All system was shown in Fig. 3 and Fig. 4.

2.3 Results

It took about 10~12 hours for CT test of each fuel sample and total exposure time to X-ray system was 200 hours including 2-D scan and calibration/alignment, etc.

Identification of fuel plates were carried out by comparing fuel plates with before/after meat shape using 2-D scan as shown in Fig. 5. Dimensional measurement of plate size using CT tests were performed and showed in Fig. 6.

X-ray 2-D scan and CT for VHTR rods were inspected to observe defects and dimensional change. CT tests of 2 rods showed good results as shown in Fig. 7.

3. Conclusions

450kV X-ray CT system was installed in hotcell with modification and tested to check image resolution and radiation damage. The image data were analyzed by 3-D computer software. 8 fuel plates and VHTR rods were inspected and measured internal shape and dimension. The results were good and the system showed good condition until now without radiation damage but concern about radiation damage still not free for LDA, encoder and electronics, etc.

REFERENCES

[1] Project of PIE of fuel plates for KJRR
[2] Project of PIE of fuel particle for VHTR
[3] The X-ray system, Y.CT Customized., YXLON, Co., Germany
[4] GOST program in YXLON, Co., Germany
[5] H.Kim, et al. “Development of Non-Destructive Test for Fuel Rods using X-ray CT in Hotcell”, Autumn meeting, Transactions of the Korea Nuclear Society.(2014)

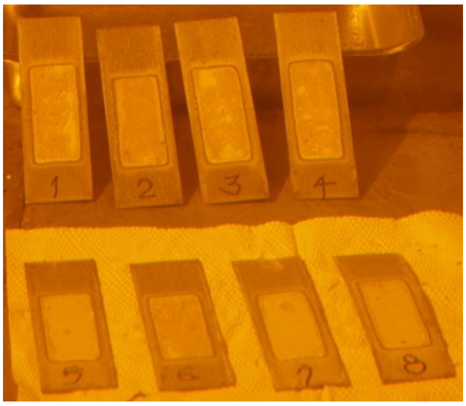

Fig. 1 8 Irradiated fuel plates after capsule dismantlement

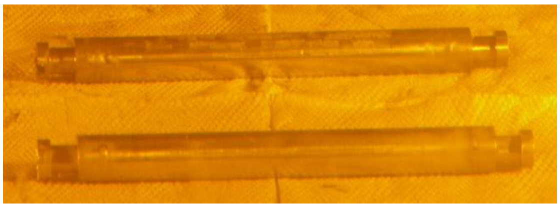

Fig. 2 2 Irradiated VHTR fuel rods after capsule dismantlement

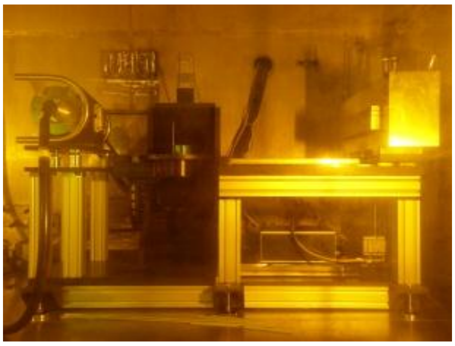

Fig. 3 450kV X-ray system in hotcell

Fig. 4 X-ray controller and PLC in operating area

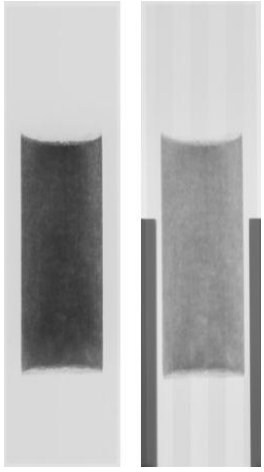

Fig. 5 Fuel meat shape before(left)/after(right) irradiation

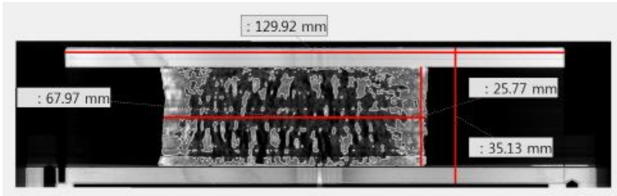

Fig. 6 Dimensional measurement of fuel plate by 3-D computer software

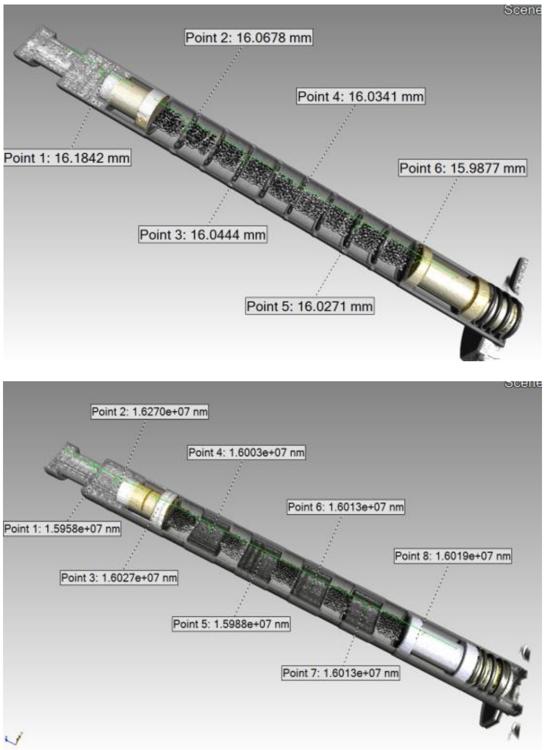

Fig. 7 Dimensional measurements of 2 VHTR rods by 3-D computer software