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Non-destructive test for VHTR fuel using 160kV X-ray system in Hotcell

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1. Introduction

The research for VHTR which is one of the next generation reactor has been actively carried out. As a part of the research for VHTR, an irradiation examination for the VHTR fuel was performed to cofirm an in-pile behavior in HANARO [1]. Also, the post irradiation examination(PIE) was performed in IMEF.

The non-destructive test for the irradiated fuel is very important to understand the in-pile behavior of the fuel. Especially, the X-ray system is useful to observe the fuel shape without destruction. A dimensional change and defect of the fuel can be confirmed thorugh the X-ray system. Also, using the 3-D software and CT techonology, the fuel shape can be intuitionally observed.

The 450kV and 160kV X-ray system were installed and operated in IMEF hotcell [2]. The 160kV X-ray system relatively using a low voltage is suitable to a smallscale sample. And high resolution images can be obtained.

In this study, the non-destructive test for the unirradiated and irradiated VHTR fuel were performed using the 160kV X-ray system. Through thses test, the possibility for the X-ray inspection of irradiated fuel was confirmed.

2. Experimental

2.1 Samples

The un-irradiated fuel compact and coated particle fuel were prepared as sample. Also, the irradiated coated particle fuel was prepared. The irradiated fuel burnup was about 40,000 MWd/tU. The coated particle fuels were separated from the fuel compact through a heating test. In case of the irradiated fuel, the X-ray inspection of the coated particle fuel was only performed to reduce the radiation damage of the X-ray system and researcher.

2.2 Apparatus

The 160kV X-ray system is Cheetah model produced by YXLON in Germany. A voltage and current of X-ray tube are 160kV and 10mA, respectively. A target material is tungsten. And a maximum detectability of system is 1μm. A detailed specification of 160kV X-ray system is shown in Table 1. The 160kV X-ray system and sample loaded in system are shown in Fig.1 and Fig.2, respectively.

Table 1. Specification of 160kV X-ray system

X-ray Tube	Tube type	Open microfocus tube
	Target material	Tungsten
	Voltage range	25 – 160 kV
	Current range	0.01 – 10 mA
	Detectability	< 1 μm
Image Chain	Detector type	Panel 1313 high speed
	Number of pixel	1,004 x 1,004 pixel
	Pixel size	127 μm
	Total magnification	17,000x

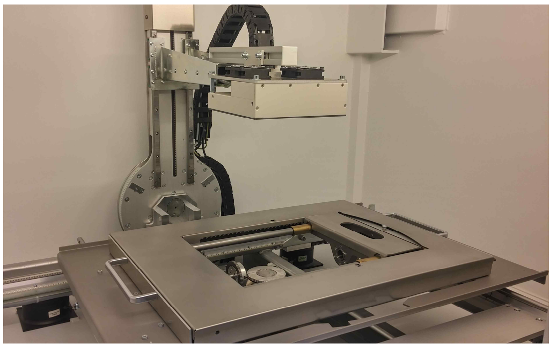

Fig. 1. 160kV X-ray system

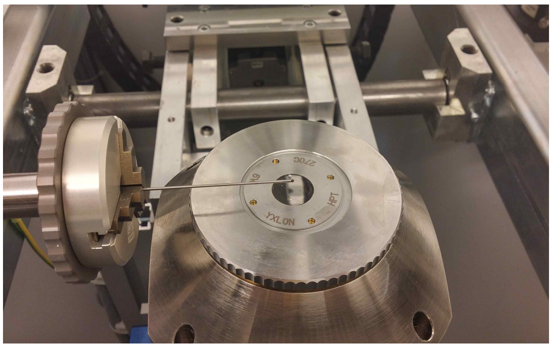

Fig. 2. X-ray tube and sample loaded in system

2.3 Test condition

A transmission rate is different according to a material density. Also, the transmission rate is related to the voltage and current of X-ray tube. These difference of transmission rate is expressed as brightness at the X-ray image. The X-ray inspection was peformed at 70kV, 0.7μA conditions both the unirradiated and irradiated samples. All of the fuel composition could be confirmed under these voltage and current conditions.

3. Results

The X-ray image of the unirradiated fuel compact is shown in Fig. 3. The graphite wich is structure material of fuel compact had relatively bright color because of a low density. Also, it was confirmed that the coated particle fuels were evenly distrbuited in a graphite.

Fig 4. Shows the X-ray image of unirradiated coated fuel. Althogh density of a buffer and IPyC is little different, the OPyC, SiC, Buffer, IPyC and Kernel could be distinguished under these test conditions.

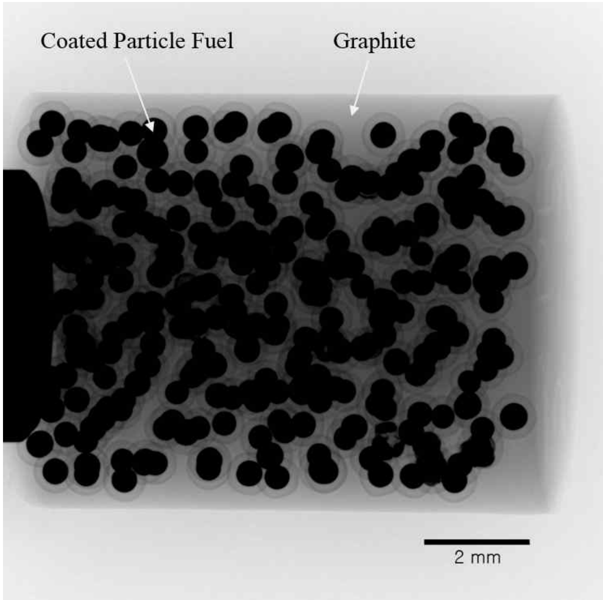

Fig. 3. Unirradiated fuel compact

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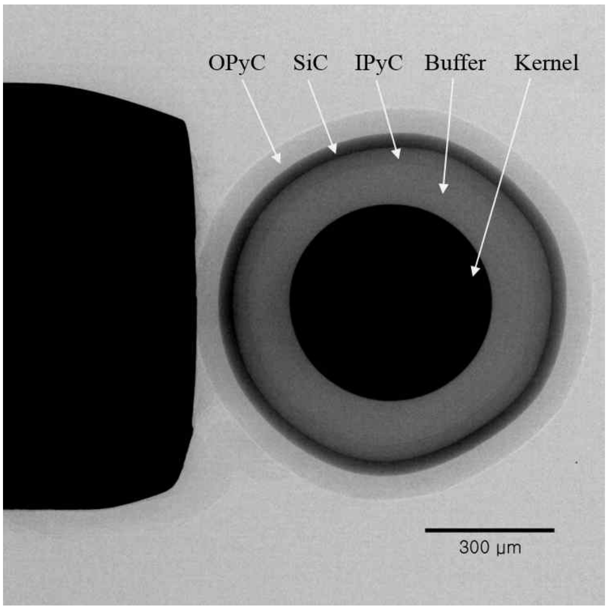

Fig. 4. Unirradiated coated particle fuel

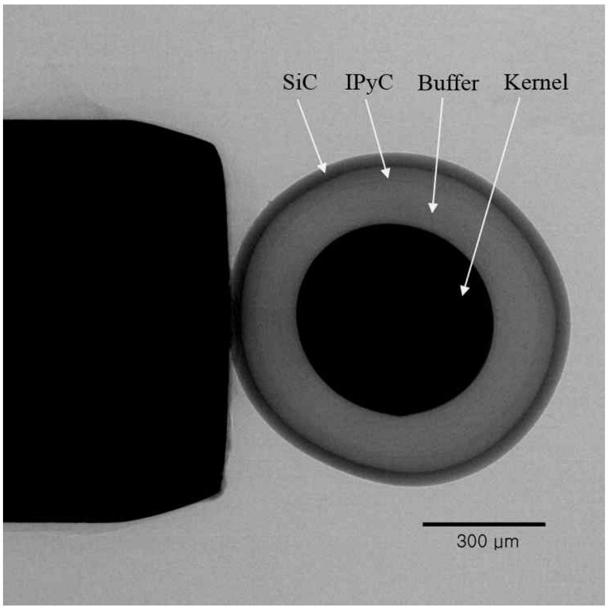

Fig. 5. Irradiated coated particle fuel

As shown in Fig.5, the clear X-ray image of the irradiated coated particle fuel was obtained without the radiation damage. In case of the irradiated fuel, the OPyC couldn`t be observed because the OPyC was removed during the heating test.

4. Conclusions

The non-destructive test for the unirradiated and irradiated VHTR fuel were performed using the 160kV X-ray system. Through these test, the possibility for the X-ray inspection of the irradiated fuel was confirmed. The clear images of the irradiated coated particle were produced without the radiation damage during the X-ray inspection. The X-ray images of the VHTR fuel will be utilized as the in-pile performance validation data.

REFERENCES

[1] B.G.Kim et al, Irradiation Test Plan of Coated Particle Fuel at HANARO, KAERI/TR-4875/2013.
[2] H.M.Kim et al, Development of X-ray radiography using image processing system for high burnup fuel, KAERI/RR-3972/2014.