Development of Fuel Rod Puncturing and Fission Gas Collection System for Post Irradiation Examination in Hotcell

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1. Introduction

A fission gas release is related to the fuel rod sustainability during reactor operation. Many fuel rods were punctured to measure the amount of fission gas with burnup. Generally, commercial fuel rods, PWR, were punctured by a steel needle with a large chamber to measure a large amount of gas.

However, after a fuel pin and small fuel rig for R/D were irradiated in a research reactor, a small amount of the fission gas exists into the internal void in a pin and a rig. A steel needle was not useful for these small fuel rods. Alternatively, the laser puncturing technique was developed to solve the measurement of a small amount of fission gas. This system is considered very rare equipment in other countries. A fine pressure gauge and strong vacuum system were installed, and the chamber volume was reduced as small as possible. A fiber laser was used for easy operation.

2. Experimental

2.1 Apparatus

A laser puncturing system consists of three parts: a vacuum device, a puncturing chamber, and a laser device, as shown in Fig. 1. A rotary pump and turbo pump were installed to keep the chamber at ~10^{-6} torr. The chamber was made of stainless steel and a quartz tube was installed in the chamber for a laser shot on the fuel rod, and a fine pressure gauge(1~1,000 Torr) and thermocouple were installed. A pulse type laser is good for puncturing with 1.5 kW in one shot[3].

2.2 Sample preparations

To check the reliability of a pressure gauge in the system, 4 sampling bottles were made as shown in Fig. 2, and measured each volume with the pressure gauge in the system.

Argon filled sampling bottles with different pressure were connected to a fuel rod chamber in a hotcell to measure each gas content, as shown in Table. I.

Fig. 1 Laser puncturing system in IMEF

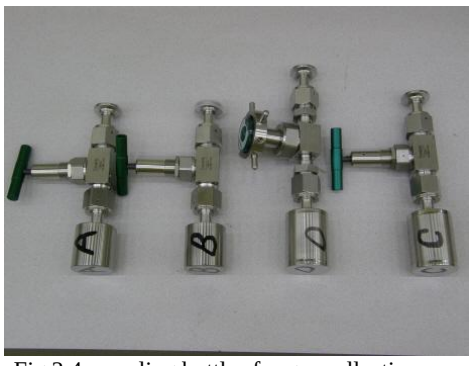

Fig.2 4 sampling bottles for gas collection

Table. I Pressure test of sampling bottles

Sampling Bottles	*Volume(cc)*	*Filled Pressure(torr)*	*Chamber total Vol.(cc)*	*Measured Pressure(torr)*	*Error(%)*
A	35.7	600.1	140.1	153.7	0.48
B	35.72	400.4	140.0	102.7	0.52
C	52.86	200.4	157.1	68.2	1.14
D	54.81	100.4	160.2	34.4	0.141

Those data were shown to have good agreement. In Fig. 3, we prepared 6 sample rods with different pressure, which were made by a gas injection system in another facility to compare the pressure gauges as well as to check the laser capacity for a puncture.

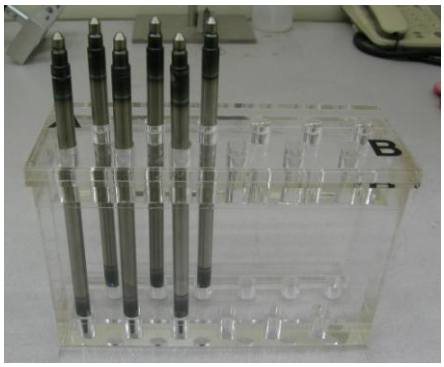

Fig. 3 Six sample rods for laser capability and pressure measurement.

3. Results

Based on the pressure gauge test with sampling bottles, the gauge showed consistence with an error of 1%, as shown in Table. I. In the sample rod test, laser power was enough to penetrate the metal tube as shown in Fig. 4. It could be possible to make a hole up to a thickness of 2 mm.

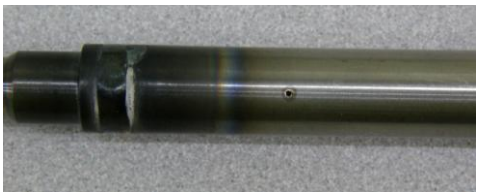

Fig.4 Samples rod with laser hole

The result of a sample rod test was shown in Table II. The difference of pressure was found because different gauges were used.

The measured pressure in this system showed lower than filled pressure in rod preparation, and we assumed that rods(R-5,7) would be failed by leakage on welding spot after the sample preparations due to the lowest pressure.

Table. II Summary of puncturing results

Tubes	*filled P(bar)*	*Measured P(bar)*	*Error(%)*
R-1	2.1	1.759	16.2
R-3	4.2	3.537	15.7
R-5	3.5	0.7554	Failed
R-6	4.1	3.563	13.1
R-7	4.3	0.7	Failed
R-10	4.1	3.1	24.4

Rods(R-3,6) showed a consistent gap, even with an error of 20%. It needs to check the specifications and mechanical differences of two pressure gauges.

4. Conclusions

To measure the small fission gas inventory in a fuel rod, a laser puncturing method was introduced. The reliability of the pressure measurement was found to have an error of 1% after a test of four sample bottles with different pressures. In the test of six sample rods, an under estimation was found because of a different pressure gauge was used in the rod preparation. However, there was consistency between the results of some rods. We need to check the properties and mechanical differences of each gauge.

REFERENCES

[1] Presentation material in collaboration meeting of metallic fuel(INL-KAERI), Laser puncturing system in INL hot-laboratory.
[2] Advice of Laser welding company(IPG Photonics).
[3] “Technical measurement of small fission gas inventory in a fuel rod with a laser puncturing system”, Transactions in spring meeting, Korean Nuclear Society(2012).