Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 25-26, 2012

Technical Measurement of Small Fission Gas Inventory in Fuel Rod with Laser Puncturing System

Heemoon Kim [*], Sung Ryul Kim [a], Byoung-Oon Lee, Yong-Sik Yang, Sang Ryul Baek, Ung-Sup Song
Korea Atomic Energy Research Institute, Yuseong, Daejeon, 305-353 Rep. of Korea
[a]Dept. of Physics, Chungbuk Univ., Chongju, Chungbuk, Rep. of Korea
[*]Corresponding author: hkim1211@kaeri.re.kr

1. Introduction

The fission gas release cause degradation of fuel rod. It influences fuel temperature and internal pressure due to low thermal conductivity. Therefore, fission gas released to internal void of fuel rod must be measured with burnup. To measure amount of fission gas, fuel rod must be punctured by a steel needle in a closed chamber. Ideal gas law(PV=nRT) is applied to obtain atomic concentration(mole). Steel needle type is good for large amount of fission gas such as commercial spent fuel rod. But, some cases with small fuel rig in research reactor for R/D program are not available to use needle type because of large chamber volume. The laser puncturing technique was developed to solve measurement of small amount of fission gas. This system was very rare equipment in other countries. fine pressure gage and strong vacuum system were installed, and the chamber volume was reduced at least. Fiber laser was used for easy operation.

Fig. 1 Laser puncturing system

Fig.2 Chamber with quarz tube(left) and laser system(right)

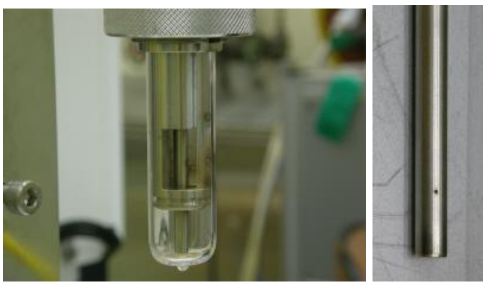

Fig. 3 Quartz tube with fuel rod for laser shot and punctured hole on surface

2. Experimental

2.1 Apparatus

The laser puncturing system consists of three parts: one is vacuum device, second is puncturing chamber and third is laser device as shown in Fig.1. Rotary pump and turbo pump were installed to keep the chamber as ~10^{-6} torr. The chamber was made stainless steel and quartz tube was installed to chamber for laser shot on fuel rod, and fine pressure gauge(1~1,000 Torr) and thermocouple were installed as shown in Fig. 2. Pulse type of laser was good for puncture with 1.5 kW as one shot. Fig.3 showed quartz tube with fuel rod after laser shot. Generally, puncturing point on rod surface was set up by guide laser(red light) and it is moved by XYZ laser bench. After laser shot, small fine chips sticked to inner surface of quartz tube.

Table. I Properties of tube samples

Tube samples	*Length(mm)*	*O.D(mm)*	*I.D(mm)*	*End -plug*		*Effective Volume(cc)*
				Length(mm)	*O.D(mm)*	
T92	127	5.5	4.6	5.1	4.5	2.0295
Zry-4	167.23	9.5	8.35	5.13	8.3	8.8799
Zry-4	166.7	9.5	8.35	40	8.3	6.9642
SUS-316	167.1	6.33	5.3	5.08	5.27	3.5757
SUS-316	167	6.33	5.3	40	5.28	2.8085
SUS-316	167.76	6.33	5.3	80	5.28	1.94944

2.2 Sample preparations

Pressure measurement test was performed with six tube samples. Tube samples were made with T92, SUS-316 and Zry-4 tubes.

Dimension of tubes were measured to obtain internal volume as shown in Fig.4 and table. I. All tubes were filled with the air of which concentration in each sample tube was measured by temperature and fine gauge(1~1,000 torr). Thus, various material, thickness and amounts of air were prepared to verify ability of puncture and gauge sensitivity.

Fig.4 Tube Samples

Fiber laser was activated with 1.5kW of pulse power and shot on the surface of tube through a quartz tube with 10 msec of duration time and 0.1mm of laser point.

3. Results

Before puncturing of fuel rod and measurement of fission gas, damage of quartz tube and reliability of pressure gauge must be tested. Quartz tube was not damaged and kept still vacuum state after laser shot. All tubes were punctured completely with optimized laser condition. Even 2mm of thickness was punctured with one laser shot without damage of quartz tube.

Six tube samples were punctured by laser and measured pressure of chamber. Ideal gas law was applied to obtain air concentration. Table II showed results of all tubes.

Table. II Summary of puncturing results

Tube samples	*Air contents(mol.)*	*Measuring contents(mol.)*	*Error(%)*
T92	8.189×10^{-5}	7.681×10^{-5}	6.2
Zry-4	3.583×10^{-4}	3.456×10^{-4}	3.5
Zry-4	2.810×10^{-4}	2.708×10^{-4}	3.6
SUS-316	1.443×10^{-4}	1.395×10^{-4}	3.3
SUS-316	1.133×10^{-4}	1.084×10^{-4}	4.3
SUS-316	7.866×10^{-5}	7.683×10^{-5}	2.3

Air content and dimension of tubes had an a little error during sample preparation. Even air content error would be slightly high. Thus, the error of between air contents and measuring contents was reasonable and acceptable.

4. Conclusions

To measure small fission gas inventory in fuel rod, laser puncturing method was introduced. Laser penetration of quartz tube and metal tube puncture were tested to obtain optimized laser condition. Six tubes were prepared with different material and internal volume which was filled by air. After laser puncture, air contents were compared. All data were good agreement with below 5% of error.

The laser puncturing system will be performed with a SFR fuel and a large grained fuel rod after the chamber and the laser are installed into a hotcell.

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).