*Transactions of the Korean Nuclear Society Spring Meeting*
*Taebaek, Korea, May 26-27, 2011*

# Burst behavior and mechanical characterization of Zr-based alloys claddings LOCA conditions in PWRs

Dong Jun Park*, Jeong Yong Park, Byoung Kwon Choi
*LWR fuel Technology Division, Korea Atomic Energy Research Institute, 1045 Daedeok-daero, Yuseong-gu, Daejeon 305-353, Korea*
**Corresponding author: pdj@kaeri.re.kr*

## 1. Introduction

Although the pressurized cladding tubes have been used in case of pressurized water reactors (PWRs), current loss-of-coolant accident (LOCA) criteria is based on the results obtained from non pressurized claddings specimens under LOCA conditions. However, integrity of fuel claddings can be significantly affected by balloons that occur in the cladding under PWR LOCA conditions. Balloons may cause the fuel relocation or fuel dispersal due to its rupture opening during accidents. In addition, wall thickness of cladding can be reduced and local regions would become heavily oxidized and hydrided [1]. Phenomena in fuel cladding under LOCA condition in PWRs mentioned above may result in significant ductility loss in fuel cladding containing balloon region.

In this study, burst behavior of several kinds of zirconium based alloys was investigated by integral LOCA test and their post-quench ductility was also measured by four-points bending test.

## 2. Methods and Results

In this section some of the techniques and experimental apparatus used to simulate the LOCA situation are described. Then, the highlight data will be shown with detailed explanation.

### *2.1 Experimental Procedure*

Figure 1 shows the schematic illustration of integral LOCA test apparatus used in this study. For integral LOCA tests, 400 mm long cladding sample was used and filled with 10 mm-long alumina pellets to simulate the heat capacity of the fuel. The stack length of these pellets was about 360 mm long. The pressure was injected through stainless tube at the top and the cladding specimen was supported at the top to minimize specimen bowing. The Specimen temperature was measured by type-R thermocouple located near the sample center and the quartz tube provides an enclosed volume for steam flow and water quench, both of which are introduced through the bottom. Steam flow was initiated at a test chamber temperature of ≈30ºC. Following introduction of steam into the chamber, furnace heating started for a pre-test hold temperature of 300℃. Steam flow and 300℃ of sample temperature were stabilized within 180 s. Heating rate was 28 ℃ /s from 300℃ to 1200℃. After oxidation at 1200℃ with hold time of 300s, the tube was cooled slowly and quenched at ≈800°C by bottom flooding. Representative temperature and pressure profiles from several LOCA tests were shown in Fig.2.

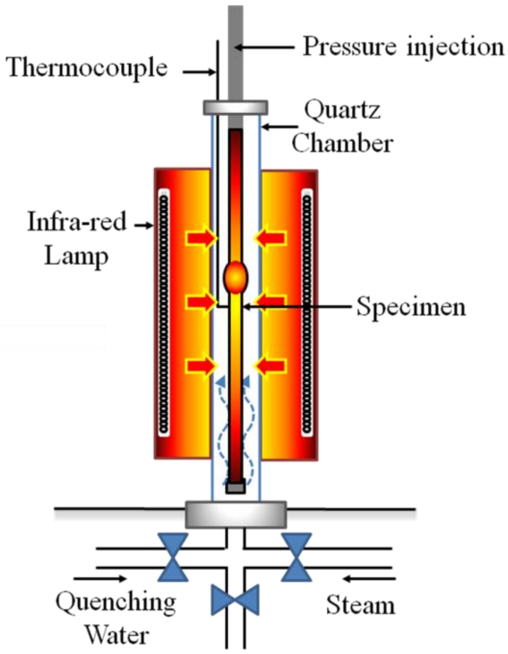


Fig.1. Schematic illustration for the integral LOCA facility

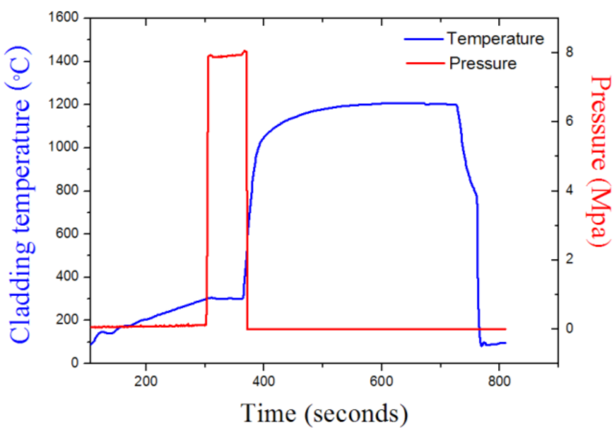


Fig.2. Typical temperature and pressure profiles of integral LOCA test

*2.2 Results*

Fig.3(a) shows images of the test samples of HANA4 alloy with stress relieved (SR) heat treatment, HANA6 alloy with SR heat treatment, HANA6 alloy with partial recrystallization(PRX) heat treatment, and Zircaloy-4 alloy with SR heat treatment after heating in argon to burst. Fig. 3(b) and 3(c) shows higher magnification of frontal view of burst opening of HANA6 alloy with PRX and Zircaloy-4 SR, respectively. Burst center relative to specimen midplane varied with alloy type. However, cause of these different burst centers is not clear. Zirclaoy-4 showed the largest rupture size in balloon region that means the largest fuel dispersal through rupture opening.

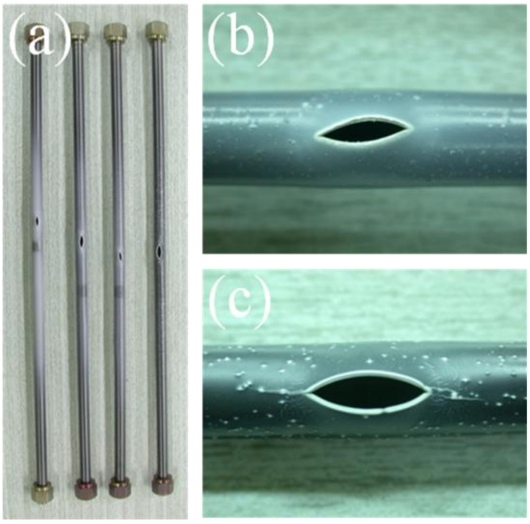


Fig.3. Images of integral LOCA test sample after heating in argon to burst and cooling: (a) low magnification of view of samples and higher magnification of frontal view of burst opening of HANA6 PRX and Zircaloy-4 SR cladding.

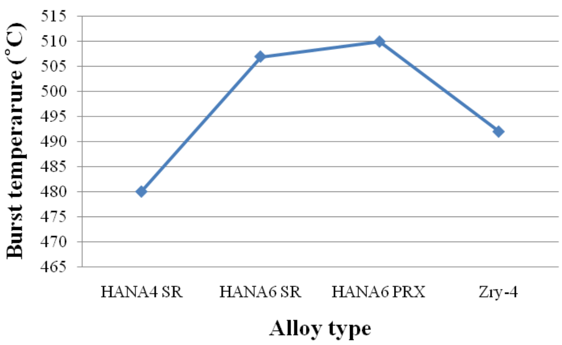


Fig.4. Burst temperature of test samples after integral LOCA test

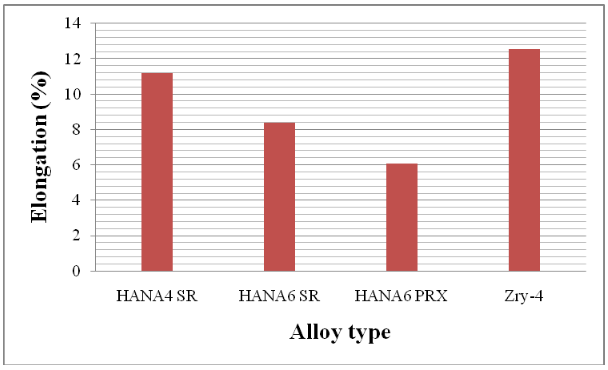


Fig.5. Elongation of test samples after integral LOCA test

HANA6 PRX alloy shows the highest burst temperature and the lowest elongation in the samples examined in this study (figs. 4 and 5). These results indicate superior fuel behavior of HANA6 cladding under integral LOCA test condition.

## 3. Conclusions

In order to investigate the effects of internal pressure on rupture behavior during the integral LOCA test, zirconium based alloys with different composition were examined. It is observed that HANA alloys show superior properties to the commercial Zircaloy-4 cladding under simulated LOCA condition in PWR

## REFERENCES

[1] M. Billone, Y. Yan, T. Burtseva, and R. Daum, Cladding Embrittlement during Postulated Loss-of-Coolant Accidents, NUREG/CR-6967, 2008 (available online in NRC ADAMS as ML082130389 at http://www.nrc.gov/NRC/reading-rm/adams.html)