Simulated Transient Behavior of Fuel Cladding of SFR

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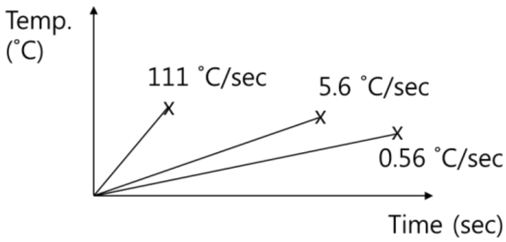
1. Introduction

The tempered-martensitic steel such as HT9 was investigated for advanced cladding in sodium-cooled fast reactors. It is promising alloy because of its high resistance to swelling, good resistance to irradiation creep, and low thermal expansion coefficient [1,2]. Nowadays, in Korea, advanced cladding such as FC92 is developed and its transient behaviors are required for the safety analysis of SFR. Design and safety analyses of sodium-cooled fast reactor (SFR) require understanding fuel pin responses to a wide range of off-normal events. In a loss-of-flow (LOF) or transient over-power (TOP), the temperature of the cladding is rapidly increased above its steady-state service temperature. Transient tests have been performed in sections of fuel pin cladding and a large data base has been established for austenitic stainless steel such as 20% cold-worked 316 SS [3-6] and feriritc/martensitic steels such as HT9 [7-9]. In the FCTT system in the U.S., the ramp test condition which simulates a typical TOP event and the ramp and hold test condition which simulates LOF event were introduced as shown in Fig. 1. The concept and general approach of transient testing of fuel cladding specimens was to define the failure stress and strain for fuel cladding in the temperature up to 1400℃ at transient heating rates of 0.56, 5.6 and 111℃/sec [7,8]. Results obtained for FC92 and HT9 cladding in a variety of simulated transients using the facility in KAERI will be further presented.

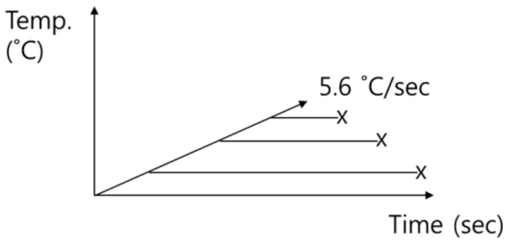
2. Experiments and Results

2.1 Experimental procedure

Transient tests are being conducted on FC92 and HT9 claddings in KAERI. Tests were conducted by pressurizing the specimen to a predetermined value and then increasing the temperature at a fixed heating rate (0.56, 5.6, and 20℃/sec) until rupture occurred. Specimen heating was achieved with a radiant heating until its failure. Vertical type of infrared heating system was adopted to give a stable temperature along the axial direction of cladding. This heating system gives temperature stability on cladding especially under the ramp and hold test. Tests were conducted at heating rates of 0.56, 5.6 and 20℃/sec, where 20℃/sec is reported to be enough to simulate fast ramp condition from the previous LWR operation [9]. The schematic of transient test facility is shown in Fig. 2. The diameter of claddings was measured using micro-meter at near the breach region after failure occurred. Data obtained included failure temperature, strain, and hoop stress calculated from the internal pressure and initial specimen geometry. After tests finishes, a general description of the correlation of FC92 for the ramp test will be developed. Detailed test conditions for ramp test are summarized in Table I.



(a)



(b)

Fig. 1. Typical transient test conditions; (a) ramp test and (b) ramp and hold test.

Fig. 2. Transient test facility in KAERI.

Table I: Test matrix for ramp test

Material	FC92B, FC92N, HT9
Heating rate	0.56℃/sec, 5.6℃/sec, 20℃/sec
Hoop stress	500 MPa to 50 MPa

The ramp test has been carrying out in present status. As shown in Fig. 3, the temperature data log during the ramp test has been recoded. The heating rate of the ramp test is controlled by the spotted welded T/C on the cladding tube for the PID control with 0.56℃/sec and the square root value is unity which means the temperature control is accurate. As the test results, hoop stress versus failure temperature data has been plotted as shown in Fig. 4 (a). HT9 cladding tubes showed relatively conservative values at this test condition with compared to WHC data [7,8]. The strain of the failed tube shown in Fig. 4 (b), without failed region has been also measured. The ramp and hold test is also planned to carry out after ramp test. Using the test results, a development of a general description of the cumulative damage fraction (CDF) correlation of FC92 and HT9 cladding for the ramp test as well as ramp and hold test are carrying out.

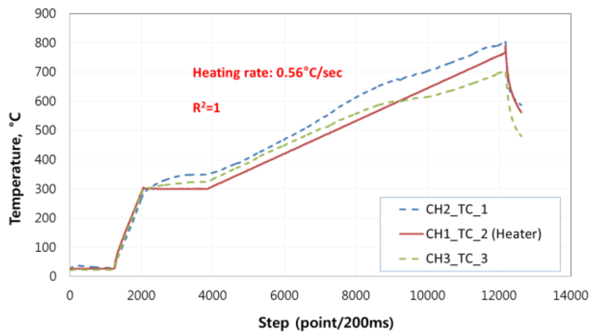
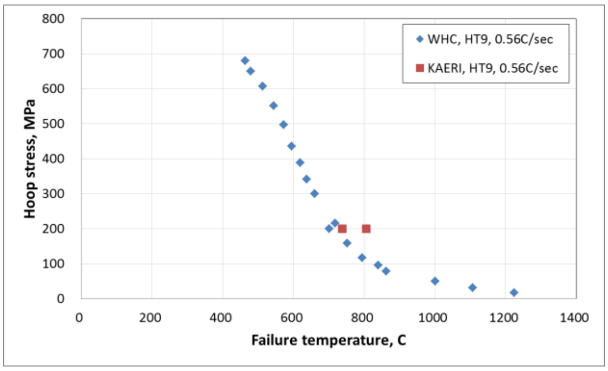
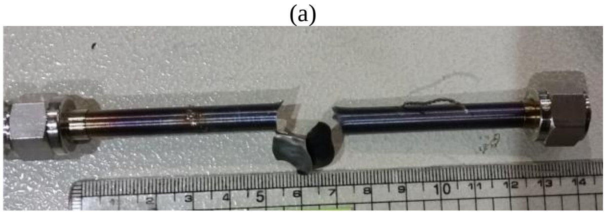


Fig. 3. Temperature data log during ramp test with heating rate of 0.56℃/sec.



(a)



(b)

Fig. 4. (a) Hoop stress versus failure temperature results for HT9 cladding with 0.56℃/sec transient heating rate of the ramp test with WHC data [7,8] and (b) HT9 cladding tube ruptured at hoop stress of 200 MPa.

3. Conclusions

For the safety analyses in SFR in Korea, simulated transient tests with newly developed FC92 as well as HT9 cladding are being carried out. A development of a general description of the cumulative damage fraction (CDF) correlation of FC92 and HT9 cladding for the ramp test as well as ramp and hold test are carrying out.

Acknowledgement

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