

# ODS Cladding Burst test using DIMAT and Transient Analysis with FRAPTRAN-KATF

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## 1. Introduction

Oxide dispersion strengthened Zircaloy-4 (Zry-4) cladding has been studied as one of the candidates for accident tolerant fuel (ATF) in Korea Atomic Energy Research Institute (KAERI) [1, 2]. To achieve ODS layer on the surface of the Zry-4 cladding, a laser beam scanning (LBS) has been employed. It is the effective way to increase the strength of the Zry-4 cladding [3]. Measuring properties of each layers separately is impossible by using conventional tensile test.

DIMAT (Deformation In-situ Measurement Apparatus by image-analysis Technique) was developed with an IR furnace controlled by a thermocouple measurement regulation loop to control the temperature. DIMAT consists of a pressurizing apparatus, the IR heating furnace, and an image capture part as shown in Fig. 1 [4]. Steady-state creep test with constant temperature and tube burst test with variable temperature can be performed depending on the purpose of the experiment.

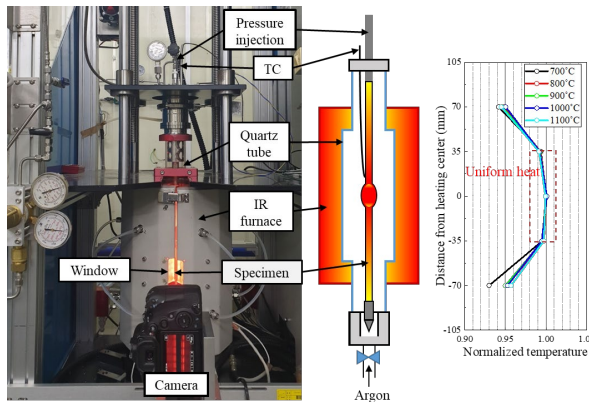


Fig. 1 DIMAT composition, schematic drawing and temperature distribution of a specimen

In the case of a LOCA accident in a nuclear reactor, the cladding tube fractured after large deformation such as ballooning due to the pressure difference between the fuel rod and the external steam. Some studies based on creep strain were performed to evaluate the cladding large deformation, and it assumed that the creep strain rate was described in the form of the Arrhenius equation. Therefore, in order to derive the coefficients necessary for the Arrhenius equation, experiments were performed to measure the creep strain of the specimen under constant temperature and load conditions.

In this paper, creep strain for ODS ATF cladding is measured using DIMAT and derived creep coefficients.

These coefficients are applied to FRAPTRAN with creep-based large deformation module and compared with ODS ATF burst test results.

## 2. 2. Burst tests using DIMAT

### 2.1 experimental conditions

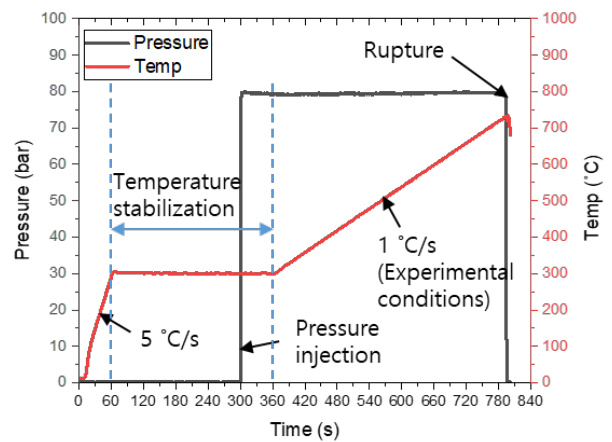


Fig. 2 Tube burst test experimental control procedure (80bar, 1°C/sec)

As shown in Fig. 2, the cladding is heated at 5°C/sec to the normal operating temperature of the PWR (about 300°C) and held for stabilization for 300 seconds. The internal pressure is applied 60 seconds before overheating, and after temperature stabilization, overheating proceeds according to the experimental conditions shown in Table 1.

Table 1 ODS specimen burst test conditions

Pressure [bar]	Heating rate [°C /s]	Burst temperature [°C]
80	1	789
	14	880
	28	885
60	1	845

### 2.2 Experiment results

Fig. 3 shows the relationship between the rupture temperature and the circumferential stress due to the internal pressure for each temperature increase rate. The solid line is the result for the Zry-4 cladding taken from the NUREG-0630 report [5]. Indicated with a star is the ODS test result, and the rupture occurs at a temperature about 1.075 times higher than that of Zry-4. Since

sufficient test results are not secured due to the limitation of the specimens, additional experiments are needed to confirm a clearer correlation.

Table 2 shows the estimation of the creep coefficients of the ODS cladding using the obtained real-time deformation data. This is estimated assuming isotropy, and it is the coefficients estimated using the transient condition test results. If sufficient specimens are secured, the creep coefficients in the alpha phase indicating anisotropy can be obtained through steady-state creep experiments.

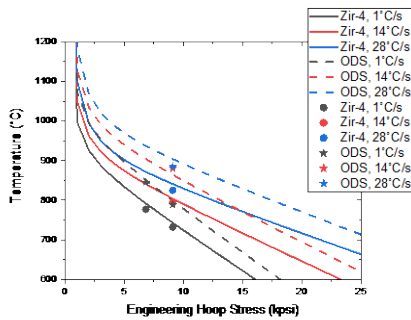


Fig. 3 Correlation between nominal circumferential stress and rupture temperature as a function of heating rate [6]

Table 2 ODS axial creep coefficients [6]

Material	$A_z$	$Q$	$n$
Zry-4	19400	320000	5.89
ODS	22900	373000	6.60

### 3. Analysis of ODS ATF burst test using FRAPTRAN-KATF

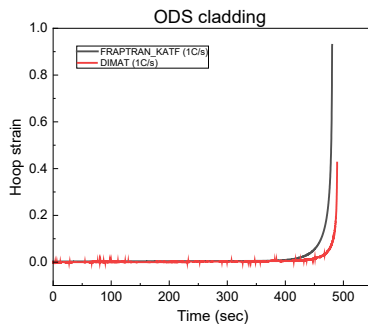


Fig. 4 Hoop strain versus time (80bar, 1 °C/sec)

The large deformation evaluation module based on the creep model is implemented in FRAPTRAN-2.0. This module is connected with FRACAS-I, which is small deformation module of the FRAPTRAN-2.0. This estimates with the original large deformation module, BALON2. By applying the creep-based large deformation model to FRAPTRAN, it is possible to derive a calculation result that is more consistent with

the physical phenomenon in the calculation of the rod internal pressure and the cladding stress [7].

In this study, FRATTRAN-KATF which reflects the mechanical properties and creep coefficients of ODS is used to evaluate the behavior of the ODS cladding at accident conditions. Fig. 4 shows the comparison between the results of 80 bar and 1 °C/sec ODS burst test and analysis results using FRAPTRAN-KATF.

## 4. Results and Discussion

DIMAT tests were performed to obtain the creep coefficients for ODS cladding. Through this experiment, the creep coefficients for ODS cladding were obtained. The obtained creep coefficients were used in FRAPTRAN-2.0 with creep-based large deformation module to perform ODS burst tests. As a result of the analysis, it is confirmed that the time of failure is delayed, but the strain according to time is well predicted. It is the reason that failure criteria of Zry-4 were used.

### Acknowledgement

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