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Results of the Irradiation Test for a creep capsule with a Single Specimen

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1. Introduction

A creep capsule was irradiated at the IR2 test hole of the HANARO 34-1 operation cycle in 2004. During the irradiation test, the temperature of the components and the displacement of the specimen were measured and analyzed. The temperature of the specimen during the test was 650±5℃ over the whole irradiation period[1]. The measured temperature of the components showed differences of not more than 50℃ when compared with the design values and this indicates the error range to be within 10% when compared with the design values.

2. Irradiation Test

2.1 The results for the irradiation test

The temperatures of the capsule components and the displacement at the specimen were measured through the irradiation test. The target temperature of the specimen in this capsule was 600℃(±10%)[2]. As a result of the irradiation, the temperature of the specimen was 650±5℃ over the whole irradiation period. The irradiation test was performed at this temperature by a gamma heating without using a heater. The stress on the specimen was started at 150MPa first and then it was increased to180MPa for the last 3 days of the test. An abnormal signal in the displacement occurred for the first few days of the irradiation.

1) The internal temperature of the capsule

To investigate the temperature dependency on the degree of the vacuum, the temperatures of the capsule components were measured by changing the degree of the vacuum inside the capsule at 24MW. The degree of the vacuum can reach up to 80 torr in the present capsule control unit, and so the temperatures were measured at a vacuum of 80~730 torr. The temperature changes depending on the degree of vacuum are shown in Fig. 1. A drastic change of temperature was not shown in the data when the vacuum is descending from 570 to 80 torr. The part showing the drastic change of the temperature depending on the degree of the vacuum seems to appear at a vacuum lower than 80 torr.

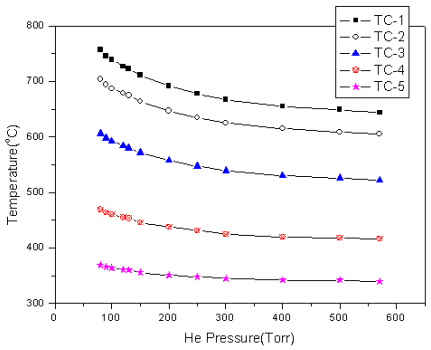

Figure 1. Changes of the temperatures depending on the vacuum(24MW)

2) The displacement of the specimen

The signal of the LVDT during the irradiation test is shown in Fig. 2 with the data of the temperature and the stress. The LVDT installed in this capsule is able to measure a displacement in the range of ±15mm. The signal of a displacement disappeared in the first few days during the irradiation test as shown in Fig. 2. However, after that, the signal shows a tension of 2mm from +7.1mm to +5.1mm in the direction of the stress[3]. The centerline in Fig.2 is the line of the displacement by the LVDT, and this indicates that its signal disappeared for about 5 days.

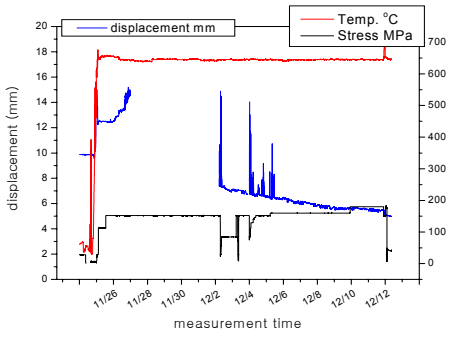

Figure 2. The irradiation history for the displacement, temperature and stress

2.2 The analysis of the results

1) The estimation of the temperatures depending on the reactor power

The temperatures at a HANARO power higher than 24MW can be estimated by using the measured temperature. The function obtained by a graph fitting using the temperature data measured depending on the HANARO power is

$$Y=90.573+28.6624X-0.24953X^2 \quad (1)$$

where X is the power of HANARO and Y is the temperature of the specimen.

The temperature of the specimen calculated at a 30MW power using this function is 726℃. This temperature is too high for a specimen in the creep test. In the next creep test for the 03S-07K, the creep capsule will be irradiated at a 30MW power of HANARO, and the target temperature of the specimen is 550℃. Therefore, it is necessary to reduce the size of the gap to lower the temperature of the specimen to 550℃.

2) Comparison between the design and measured temperature

Fig. 3 shows the design and the measured temperatures for the specimen and the components of the 02S-08K creep capsule. For the temperature of the specimen, the measured value shows an error of 12.2~14.8% depending on the degree of vacuum when compared with the design temperature. The temperature calculated before the irradiation test was estimated as lower than 100℃ when compared with the measured one. The gap between the thermal media and the outer tube, which was established for controlling the temperature of the specimen, is 0.4mm. This shows that there is an error of 25℃ per 0.1mm gap between the design and measured temperature.

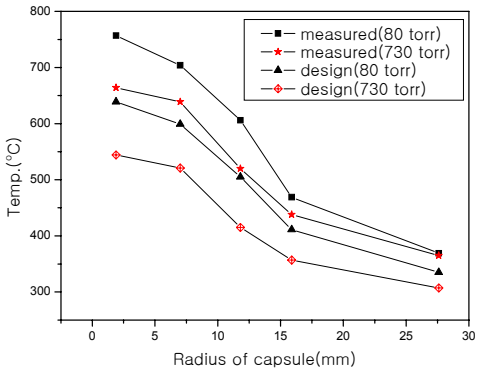

Figure 3. Design and measured temperatures of the specimen

3) Creep rate

To obtain the creep rate using the result of the measurement for the displacement during the irradiation test, the creep strain was estimated for the period where the stress of 150MPa was imposed. The average temperature of the specimen during this period is 650℃, and the deviation is in the range of ±5℃. As a result for the displacement, there was a little disturbance in the early stage of the displacement signal, however the general trend of the displacement shows an extension in the direction of the stress as expected. The whole time period of the irradiation test is 432hours, which corresponds to 28 EFPD(Effective Full Power Day), and the time period where the stress of 150MPa was imposed was 160 hours. During the period of the irradiation test, a rupture did not occur by a creep extension. The creep rate($d\varepsilon/dt$) during this period is estimated to be 9.5×10^{-8} $s^{-1.}$

3. Conclusion

During the irradiation test, the temperature of the specimen was 650±5℃ over the whole irradiation period without using a heater. As for a strain, there is some disturbance for the signal of the LVDT, but the LVDT shows the general trend of a creep strain well, which was expanded in the direction of the stress by 2mm. The measured temperature of the specimen was estimated at no less than 100℃ when compared with the design value and this is shown to be in the error range of 12.2~14.8% of the design value.

ACKNOWLEDGEMENT

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