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Results of an Irradiation Test for a Creep Capsule with Four Specimens

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1. Introduction

This paper includes an analysis of the irradiation test results of a creep capsule with 4 specimens. An irradiation test for this capsule was performed for the 45th HANARO period operated during June, 2006. The fatigue test was performed at a specimen temperature of 600℃ and a specimen stress of 253MPa. The temperature changes measured during an increase of the HANARO power are reported and analyzed with the design values. Also a temperature change according to the state of a vacuum in the capsule is described. The displacements were measured and analyzed separately for 4 specimen modules containing a stress loading unit and the LVDT, and the cause for an abnormal signal which occurred at some of the LVDTs was analyzed to devise a proper measure.

2. Irradiation Test

2.1 The results for the irradiation test

The target temperatures of the specimens in this capsule were 600℃(±10%)[1]. As a result of the irradiation test, the temperatures of the upper and lower specimens were respectively 367~378℃ and 546~567℃ at a HANARO power of 30MW and a capsule internal pressure of 1 bar. The temperature of the specimen was maintained at 600±5 ℃, which is the target temperature, by a control of the He pressure and the heater power. As for the temperature change depending on the degree of a vacuum, the temperature of the specimen was changed suddenly at a pressure lower than 50torr when the pressure in the capsule dropped from 760 to 10torr. This was measured for 10, 20, 30MW of the HANARO power, and the same phenomena were presented in all three cases. As a result, the conductivity in a He environment turned out to be very low at a pressure lower than 50torr when the vacuum was decreasing. By the measurement for a temperature of the specimens, there was a deviation of 8~52% when compared with the design ones. The temperatures at the lower specimen revealed a big difference between the design and measured value. It is because the gamma heat generation rate level was assumed to be much less.

1) The internal temperature of the capsule

The result for the temperatures of the capsule components measured depending on the HANARO power is shown in the Fig. 1. In the irradiation test, the temperatures of the upper and lower specimens were respectively 367~378℃ and 546~567℃ at 760torr of the internal pressure of the capsule. The temperatures of the specimen at 70 and 30torr were respectively 427~439℃, 514~526℃ at the upper specimens and 657~674℃, 742~746℃ at the lower specimens. The temperatures at the lower specimens are over the range of the target temperatures. So, the internal pressure of the capsule should not be lower than 70torr.

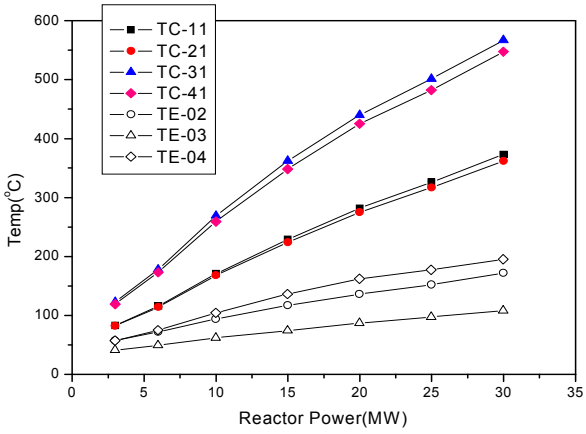

Figure 1 A temperature distribution depending on the power of HANARO

2) The displacement of the specimen

These displacement signals at 4 LVDTs during an increase of the HANARO power are considered as abnormal except for that of LVDT 11. The displacement signal of LVDT 11 increased normally with an increase of the HANARO power, and was 0.111mm when the power of HANARO reached 30MW. This is in the range of the displacement estimated in the out-pile performance test. The displacement signals of LVDT 31 and 41 were over the measured range. The direction at the displacement of LVDT 21 was the same as that of an expansion of the specimen, but a volume of the expansion was much bigger than the predicted one, so it turned out to be unreliable. LVDT 21 and 31 revealed a signal over the measured range from the early stage of an irradiation, and the signal of LVDT 41 was recovered after some days, but it could not be considered as normal because the displacement was too big.

2.2 An analysis of the results

1) A change of the temperatures depending to the degree of a vacuum

To investigate the temperature dependency on the degree of a vacuum, the temperature of the capsule components was measured by changing the degree of a vacuum inside the capsule at 30MW. The degree of a

vacuum can reach up to 5torr in the present capsule control unit, and so the temperatures were measured in the range of a vacuum of 10~760torr. A change of the temperatures depending on the degree of a vacuum is shown in Fig. 2. An abrupt rise of the temperature appeared in the range lower than 50torr when the vacuum was descending from 760 to 10torr.

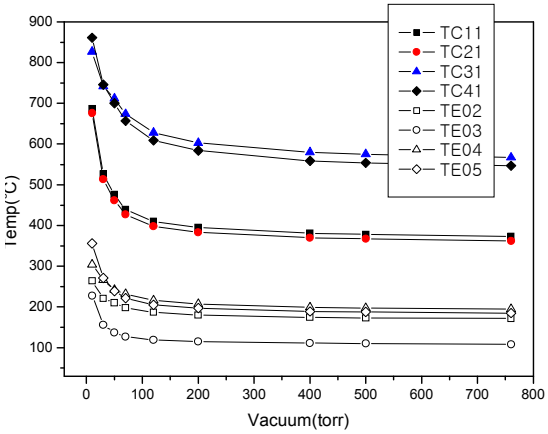

Figure 2 Change of the temperatures depending on the degree of a vacuum (30MW)

2) A Comparison between the design and measured temperature

Table 1 shows the design and measured temperatures for the specimen and components of the 04S-23K creep capsule. For the temperature of the specimen, the measured values show an error of 7~52% depending on the degree of a vacuum when compared with the design temperatures. The temperatures calculated before an irradiation test were estimated to be lower than the measured ones. Particularly, the temperature difference at the lower specimen was larger. This is because the heat generation rate at this location was estimated to be too low.

Table 1 Design and measured temperatures

	Location	760 torr	
		design	measured
TC-11	specimen 1	301	373
TC-41	specimen 4	360	547
TE-03	upper LVDT	95	108
TE-05	lower LVDT	213	195
TE-02	bellows surface	173	187

3) A relation between the temperatures and the LVDT signals

The displacement and temperatures of specimen 1 measured for a change of the power of HANARO are shown in the Figure 3. The displacement indicated a change to -1.590V from -1.678V and the temperature of the specimen arrived at 373℃ from 30℃ when the HANARO power rose to 30MW. The change of the voltage represents 0.111mm when calculated in terms of a length. This can be compared with the result in the out-pile test. The displacement in the out-pile test was 0.07mm when the temperature arrived at 373℃. There was a little difference between these two values. In the out-pile test only the specimen is heated, on the other hands all the components including the specimen, yoke, and thermal media are heated by the γ heat in the reactor core[2].

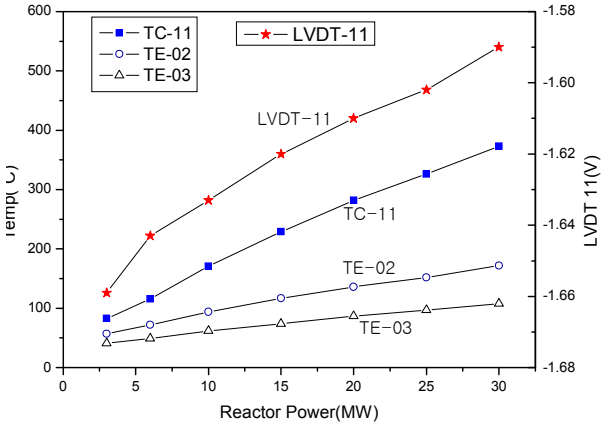

Figure 3 A displacement of the LVDT 11 depending on the HANARO power and a change of the temperatures

3. Conclusions

An irradiation test of the creep capsule having 4 specimens was performed in the IR2 hole in June, 2006. The temperatures and displacement measured during the irradiation test were analyzed and the cause of an abnormal signal from the LVDT was reviewed. During the irradiation test, the temperatures of the upper and lower specimens were respectively 439, 526℃ and 674, 746 at a HANARO power of 30MW. The temperatures of specimens were maintained at 600℃ during the whole irradiation period by a control of the He pressure and the heater power. When the pressure in the capsule drops from 760torr to 10torr, the temperature of the specimens rises suddenly at a pressure lower than 50torr. A high radiation was detected at the radiation monitors at the top of the pool by a backward flow of an air in the bellows due to a loss of the electric power supply in the capsule control unit. As a countermeasure, a purging of the bellows before an irradiation test is suggested.

ACKNOWLEDGEMENT

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REFERENCES

1. M. S. Cho, The Irradiation Test Plan of the Creep Capsule (04S-23K), KAERI/TR-3175/2006, 2006. 7
2. M. S. Cho, The Irradiation Test Results of the Creep Capsule (04S-23K), KAERI/TR-3329/2007, 2007. 2