

## **In-pile Creep Machine of HANARO**

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### **Abstract**

An in-pile creep machine of HANARO was designed and fabricated for the measurement of uniaxial deformation of zirconium cladding tube working at the conditions of  $<400^{\circ}\text{C}$ , and  $2\text{ kg/mm}^2$ . The creep machine mainly made of 304 stainless steel consists of bellows assembly, grips, yokes, a push rod, heater and bearing. The creep machine heater has two sections which heating element is silicon carbide with aluminium oxide insulator. Thermocouples are attached to specimen and heater for the temperature monitoring and controls. Inner temperature of the creep capsule is also controlled by gas flowing into the main chamber of the creep machine. The bellows assembly is isolated to the main chamber and controlled by an external gas pressure. The load and displacement of the zirconium specimen was determined by a pressure gauge and a linear voltage differential transformer, respectively. The load-displacement relationship was automatically converted into stress-strain curve by a computerized machine. The performance test of the creep machine in out-of pile conditions showed that the resultant stress-strain curve was well agreement with the results determined by a standard tensile test machine.

### **1. Introduction**

Irradiation creep of zirconium alloys have been widely studied to understand their degradation mechanism and to develop a high performance cladding materials.[1] An in-pile creep machine should be designed and fabricated for the study of the irradiation behaviors of the zirconium cladding tubes.[2] Various types of in-pile creep machines were made for well installation in each test reactor.[3-4] The creep machines were basically composed of a load transfer part, displacement monitoring part and an external controlling part. For example, the in-pile creep machine of JAERI has characteristics as follows : lower end of a specimen for creep testing is fixed to the outer tube of the capsule and the tensile force is loaded on its upper end. The pressurized bellows by

helium gas tube pull the specimen through the yoke. The creep strain is obtained by the buffer and LVDT.[4] The creep machine used in UKAEA has gas gauge devices containing a needle type of helium micrometers.[5] The creep rig developed by CEA is suitable for the diameter measurement of tubing with the aid of a system of three balls placed at 120 ° around the specimen.[6] Recently, KAERI successfully developed a non-instrumented capsule for material irradiation tests in a domestic research reactor, HANARO.[7] This results in strongly stimulating and accelerating irradiation tests of nuclear reactor materials in domestic industry and research fields. This study was initiated by the necessity of a special capsule to study irradiation creep behaviors of zirconium alloys in HANARO. Although many studies have appeared in literature about fabrication of a creep capsule, no systematic investigation of the creep capsule for HANARO has been completely studied.[8] Hence, the objectives of the present work were to design and fabricate in-pile creep capsule of HANARO, carry out its performance in out-of pile conditions and finally obtain the design and fabrication technologies of the special creep capsule.

## 2. Experimental method

An in-pile creep machine was designed to apply uniform stress to a test specimen in HANARO and to measure continuously the deformation of the specimen. Basic design technology was obtained by the fabrication and performance tests of the mock-up of the creep capsule.[7] Figure 1 is the schematic drawing of the mock-up of creep capsule used in this study. Specimen was made by machining zirconium cladding tubing. The displacement of the specimen with applied pressure was determined with a LVDT and a pressure gauge, respectively. The load-displacement relationship was automatically determined by a computerized machine.

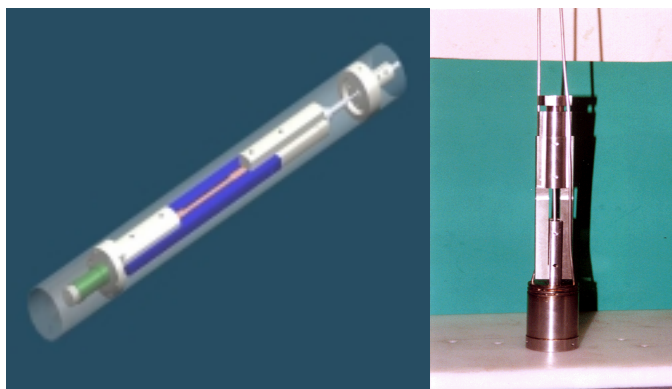


Fig. 1. Schematic drawing (left) and photo (right) of the inside of the mock-up used for the design of in-pile creep capsule.

### 3. Results and Discussion

An in-pile creep capsule for HANARO was designed and fabricated based on the technologies obtained by conceptual design of the creep capsule.[7] Figure 2 is a drawing of the creep capsule which contained bellows assembly, grips, yokes, a push rod, heater and bearing. 304 stainless steel bellows had a dimension of 25 mm in diameter and 30 mm in extension. The bellows was installed in an autoclave type chamber connected two gas in and outlets to avoid the buckling instability of the bellows. The internal pressure of the chamber provided by gas pressure resultantly tended to shorten the bellows by applying externally to the bellows.

Figure 3 is a photograph of the inside assembly of the in-pile creep capsule and a standard tensile specimen which showed the positions of grips, yoke and gas feed lines. The grips, yoke and a push rod were made with stainless steel by electron discharge machining. The grips consist of two separate parts, upper and lower grips. The lower grip was attached on the top of the pressure chamber and the upper grip was connected to a rectangular yoke, respectively. Specimen was placed between two grips. Figure 4 is photographs of the creep machine heater and bearing. The creep machine heater was located around the gauge length part of the specimen. The heater separated as two sections which heating element was silicon carbide with aluminium oxide insulate. Thermocouples were attached to the specimen and the heater for the temperature monitoring and controls. The temperature was also able to be controlled by gas flows into the main chamber of the creep machine. A push rod was on the top of the rectangular yoke, which was connected to a linear voltage differential transformer. The push rod was supported by a bearing with graphite sliding. As shown in figure 4, the center of the bearing contained a graphite o-ring through which the push rod was able to move back and forth smoothly. The load was transferred to the specimen by the working mechanisms in which the contraction of bellows by gas pressure moves a yoke and an upper grip connected to a specimen, simultaneously. Figure 5 is a photograph of the in-pile creep capsule in which flanges around the outer capsule were used for the alignment of the parts such as a LVDT and a push rod. The flanges were detached after assembling the capsule.

Figure 6 is the stress-strain curve determined based on load-displacement measurement by the in-pile creep capsule at room temperature. As shown in figure 6, the displacement was well determined by applied gas pressure. The resultant ultimate tensile strength was 712 MPa, which value was almost similar to the value of 728 MPa determined by standard test method. This supports that the in-pile creep capsule designed and fabricated domestically was well working in the test conditions.

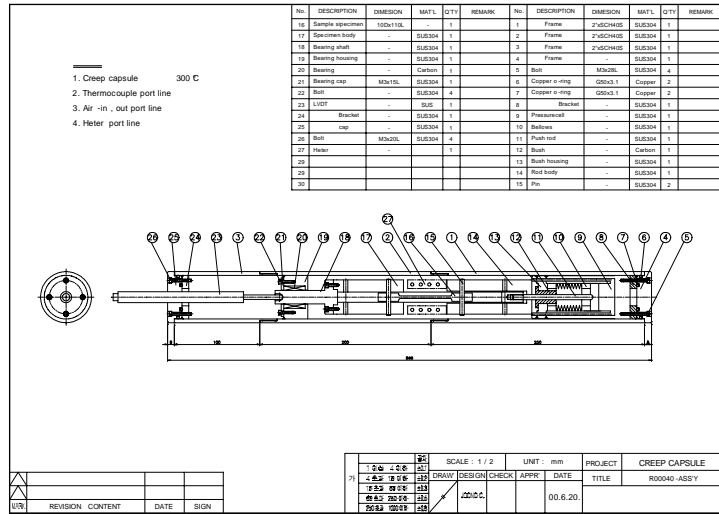


Fig. 2. A drawing of in-pile creep capsule for HANARO.

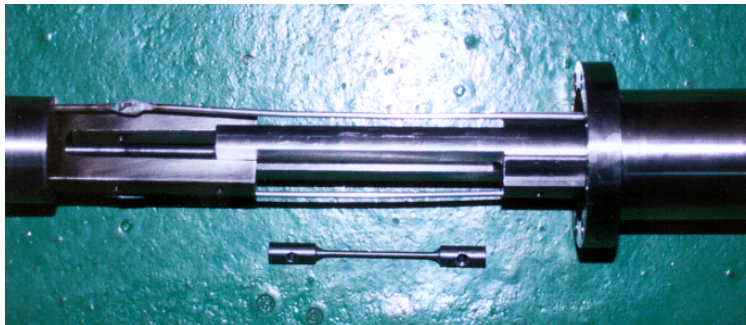


Fig. 3. Inside view of in-pile creep capsule for HANARO.

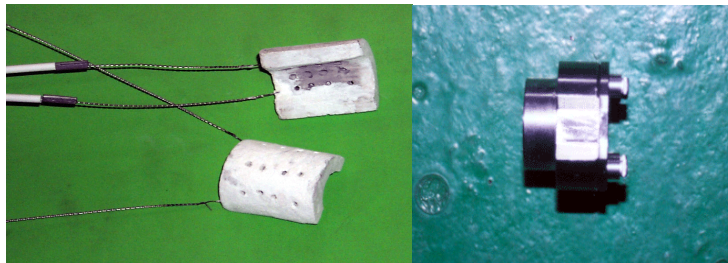


Fig. 4. Creep machine heater (left) and bearing (right).

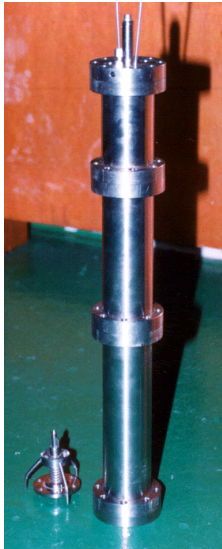


Fig. 5. A photograph of the in-pile creep capsule.

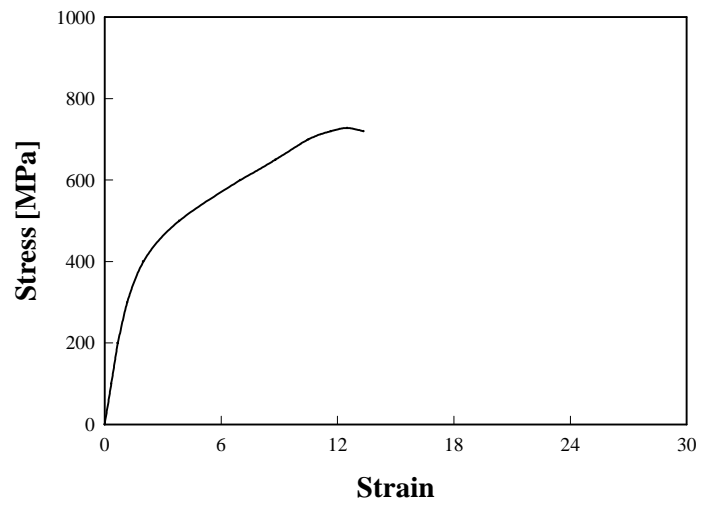


Fig. 6. Stress-strain curve determined by in-pile creep capsule.

#### 4. Summary

An in-pile creep capsule for HANARO was designed and fabricated. The creep machine mainly made of 304 stainless steel consists of bellows assembly, grips, yokes, a push rod, heater and bearing. The creep machine heater has two sections which heating element is silicon carbide with aluminium oxide insulate. The creep capsule demonstrated that the modified tensile specimen made by machining zirconium cladding tube was well deformed through the shrinkage of bellows in a pressure vessel by externally applied gas pressure. Stress-strain curve was automatically determined by monitoring load-displacement relationship. The resultant ultimate tensile strength was 712 MPa, which value was almost similar to the value of 728 MPa determined by standard test method. This supports that the in-pile creep capsule designed and fabricated domestically was well working in the test conditions.

#### 5. Acknowledgement

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#### 6. References

- [1] Y. Choi, B. Friching and H. Gazaroli, "Evaluation of Irradiation Clad Creep", B21/87/2 070 R&D 924287, Erlangen, Germany, 1987.
- [2] F. Scott, "The Dounreay First-reactor Uniaxial Creep-Measuring Machine", Journal of Nuclear Materials, vol. 65 pp. 313-328, 1977.
- [3] JMTR Irradiation Handbook, 1995.
- [4] Massaki Yokai, Toshin Kogyo Co. unpublished paper, 1999.
- [5] D. S. Wood, "Zircaloy-2 Irradiation Creep Strain Measurement Techniques", Journal of Nuclear Materials, vol. 65 pp. 329-335, 1977.
- [6] M. Masson, "In-pile Creep Measuring Rigs for Metallic Specimen", Journal of Nuclear Materials, vol. 65, pp. 307-312, 1977.
- [7] Y. H. Kang et al., "Capsule Development and Utilization for Material Irradiation Tests", KAERI/RR-2038/99.
- [8] Y. Choi, B. G. Kim and Y. H. Kang, "Manufacturing and Performance Tests of In-pile Creep Measuring Machine of Zirconium Alloy", Proceedings of the Korean Nuclear Society spring meeting, May 1999.