§10. Development of a Uniaxial Creep Testing Machine for Small Specimens of Low Activation Fusion Reactor Materials

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For fusion structural materials development, small specimen technique is essential for efficient use of irradiation volume. Vanadium alloys are known as the most sensitive material to test atmosphere among the candidate materials. It has been reported that their creep properties were significantly affected by impurity (C, N and O) pick-up from the vacuum during the test. The level of oxygen impurity in vanadium alloys was 200-2000 mass ppm up to year 1990s. Recently, high purity reference alloys designated as NIFS-HEATs (NH) with 130-180 mass ppm oxygen has been developed and shown further oxygen reduction to several 10 mass ppm level by an exposure to liquid lithium (coolant in fusion blanket). In such low oxygen condition, oxygen effect was relatively larger compared with the previous high oxygen alloys. Therefore more precise management of impurity contamination is required to estimate their creep properties. In the present study, a high vacuum and high temperature creep testing machine for small specimens was developed to estimate high temperature performance of fusion structural materials.

SSJ type tensile specimen with a gauge size of 5.0 x 1.2 x 0.25 mm was chosen in the present study, because it has been utilized in major irradiation test projects for fusion reactor materials development. Loading is of the simple suspension type, which leads to enhanced load stability and reduced cost. Creep strain was measured by double linear variable differential transformer (LVDTs), which are connected to molybdenum specimen holders. The specimen was surrounded by zirconium getter foil without contact with each other as shown in Fig. 1. Heater power and maximum test temperature was 1200 W and 1073 K, respectively. Vacuum system consists of a turbo molecular pump and an oil-free scroll pump. All the vacuum seal are copper metal gasket.

A creep test was conducted on 0.25 mm-thick sheet of NIFS-HEAT-2 (NH2) at 1073 K under load of 63 N, which is equivalent to the stress of 210 MPa. Vacuum during the creep test was 1 x 10^{-5} Pa, which is one order better than 1~5 x 10^{-4} Pa for conventional creep test machine. Time-strain curve in the creep test is drawn in Fig. 2. Fig. 3 shows the minimum creep rate in comparison with previous data on uniaxial and biaxial creep tests.

In the case of US832665, uniaxial creep data were consistent with the biaxial data. Contrarily, uniaxial creep data for NIFS-HEATs were considerably lower than biaxial ones. Present data are relatively close to biaxial data compared with the previous data on NH1 and NH2. Possible explanation is as follows. For NH alloys, strengthening due to oxygen pick-up might occurr to the similar oxygen level to US832665 (700-1100 mass ppm). Lower stress (150 MPa) took longer time for creep tests, therefore the difference was larger. The present data was close to biaxial data, because oxygen pickup was small. Further acquisition of the uniaxial test data is necessary and planned in both lower and higher stress region to understand creep behavior of vanadium alloys. Lower stress creep tests with longer time require more precise control of oxygen contamination. High vacuum and zirconium getter system in the present study would become effective for longer time tests with further improvement of procedure, i. e. an increase in the amount of zirconium getter and slower heating to the test temperature for high vacuum management.

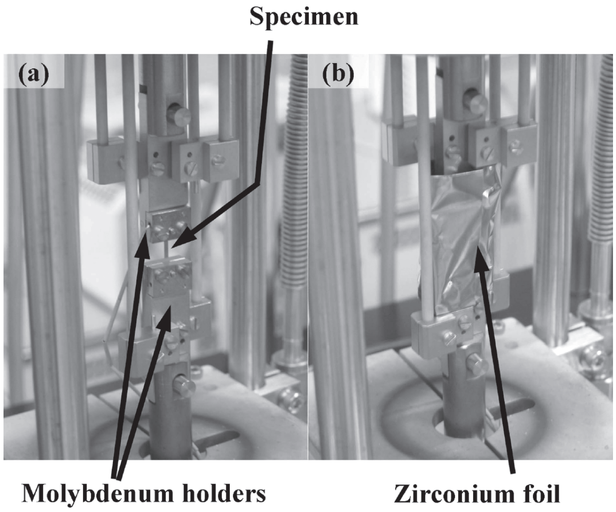

Fig. 1 Specimen surroundings (a) before and (b) after zirconium wrapping.

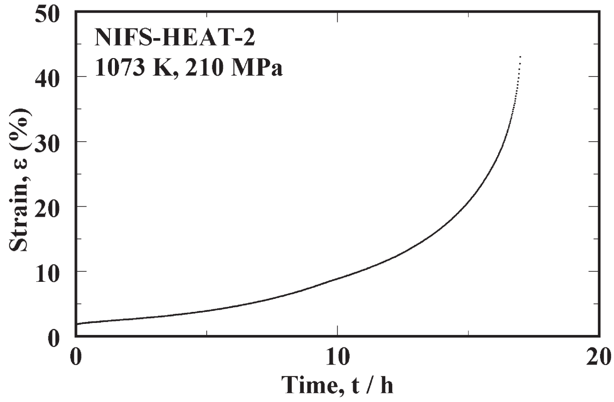

Fig. 2 Time-strain curve for under 210 MPa at 1073 K.

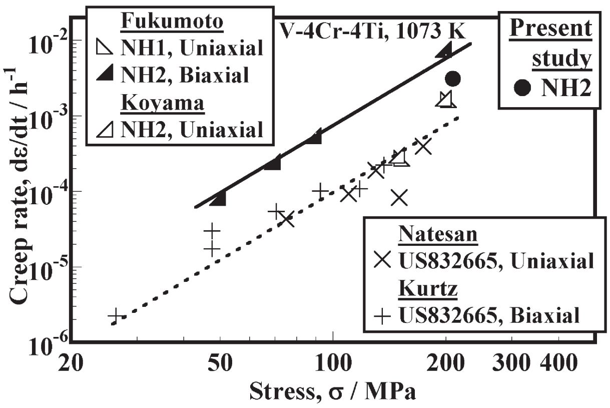

Fig. 3 Creep rate versus applied stress for V-4Cr-4Ti alloys.