§13. Irradiation Creep Behavior of Vanadium Alloys during FBR Irradiation

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The advanced vanadium alloy is expected as a structural material for an advanced fusion reactor in the points of high temperature performance and high radiation-resistance. The coolant of advanced blanket system using vanadium alloys will be liquid metal (Li, Na, Pb-Li), and the problem of the material degradation in liquid metal environment such as surface wear by erosion and changes of mechanical properties due to the impurity mass transfer should be important in order to maintain the system integrity of blanket system.

Creep and creep-fatigue behaviors during neutron irradiation are critical issues for high temperature performance and the effect of impurity mass transfer for creep properties is one of important factors for estimating the life-time in operation, but there are many unsolved questions.

In order to investigate the high temperature performance during neutron irradiation, pressurized creep tubes (PCTs) of highly purified vanadium alloys, NIFS-Heat alloys were manufactured to examine the irradiation creep behavior under the liquid metal environment. Irradiation experiments for creep tests in pile under liquid Na environment in Joyo were developed in corporation with JAEA-Oarai.

In this study, the effect of impurity mass transfer from liquid Na for irradiation creep behavior is investigated and correlation of the irradiation creep behavior with thermal creep behavior in the vacuum and liquid Na environment are obtained and the irradiation effect for creep properties will be extracted for life-time evaluation of creep behavior on high temperature performance under neutron irradiation.

The V-4Cr-4Ti alloy used in this study was produced by NIFS and Taiyo Koko Co. [1]. Tube processing of NIFS-Heat alloy was successfully done by NIFS and Daido Co. and the PCT fabrication was done by JAEA and IMR/Tohoku Univ. The final heat treatment of PCT was done at 1000°C for 2 hrs in vacuum of $<1\times10^{-4}$ Pa. The detailed tubing process and fabrication process of PCT have been reported [2].

The irradiation was performed in Joyo. The online thermometry could not be adopted, but the maximum temperature measurement was used by TED (thermal expansion pyrometer). The irradiation temperature was 458°C and 598°C. The neutron doses were 6.7×10^{25} n/m^2 (E>0.1MeV) at 458C and 2.4×10^{25} n/m^2 at 598°C. The damage level at 458°C and 598°C corresponding to pure vanadium was estimated about 1.8dpa and 5.0dpa, respectively.

Followed by the cooling the radiation decay heat of irradiated specimens in FMF in JAEA-Oarai center after neutron irradiation, dismantling of irradiation capsule and inventory of irradiation sample were performed in MMF in the JAEA-Oarai. The cleaning and the measurement of dimensional change of PCTs were done in the Oarai center, IMR/Tohoku Univ. Dimensional changes of PCTs were measured with a precision laser profilometer at five axial and 18 azimuthal locations to an accuracy of 1μm for the outer diameter measurement.

Figure shows plots of the effective irradiation creep strain as a function of applied stress for highly purified NIFS-Heat alloys. It was apparent that the irradiation creep strain of the annealed NIFS-Heat alloys increased proportionally to the applied stress. It is assumed that the applied stress dependence of irradiation creep strain obey the equation, $\dot{\varepsilon} \propto \sigma^n$, where n is a creep stress factor, and the value of n, creep stress factor was estimated. The values of n for the annealed V-4Cr-4Ti alloys were 1.7±0.3 for the 458°C irradiation and 1.1±0.2 for the 598°C irradiation. Cold worked V-4Cr-4Ti alloys had larger irradiation creep strain than annealed ones. The tendency of the behavior of irradiation creep deformation in V-4Cr-4Ti alloys was different from that of thermal creep deformation at the point of the deformation processing.

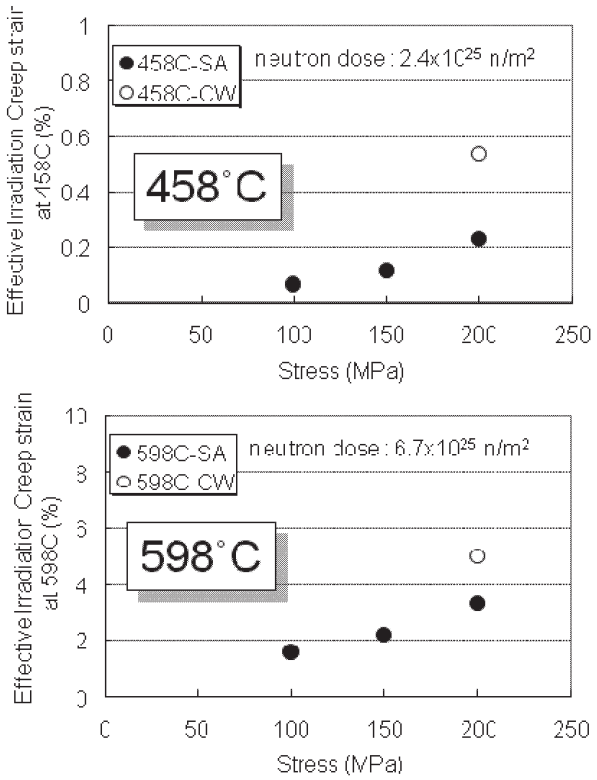

Fig. Plots of the effective irradiation creep strain as a function of applied stress for highly purified V-4Cr-4Ti alloys irradiated at 458°C (upper one) and at 598°C (bottom one).

Reference

1) Muroga,T., et al., J. Nucl. Mater. 283-287 (2000) 711
2) Fukumoto, K., et al., J. Nucl. Mater. 335 (2004) 103