§21. Creep Mechanism of NIFS-Heat2 Alloys by Using Pressurized Creep Tubes

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Vanadium alloys are candidate materials for fusion reactor blanket structural materials because of their potentially high operation temperatures. However the knowledge about mechanical properties of vanadium alloys at high temperatures is limited and there are uncertainties that may have influenced the results such as the interstitial impurity content of specimens. The National Institute for Fusion Science (NIFS), in collaboration with Japanese industry has initiated a program to fabricate a large ingot of highly purified V-4Cr-4Ti alloys [1]. A medium size (~160kg) ingot of V-4Cr-4Ti was fabricated by EB and VAR methods, which was designated as NIFS-Heat2. The impurity level for fabricating large V-Cr-Ti ingots was achieved as ~80wppm C, ~100ppm O. ~120wppm N and 1wppm or less of metallic elements. The objective of this study is to investigate the creep properties and microstructural changes of the high-purified V-4Cr-4Ti alloys, NIFS-HEAT2 by using pressurized creep tubes (PCTs), in order to prepare for in-pile creep tests.

The V-4Cr-4Ti alloy used in this study was produced by NIFS and Taiyo Koko Co. and designated as the NIFS-HEAT2 [1]. Tube processing of NIFS-Heat2 alloys was successfully done by NIFS and Daido Co. The tubes were cut into pieces of pipes with one-inch (25.4mm) length. The end plugs were fabricated from a rod by using a lathe, and a 0.6mmϕ / 0.25mmϕ hole was bored in the top end plug with electro-discharge machining. The circumferential plug-to-tube welds were made with an electron-beam (EB) welder in vacuum in a machine shop in Japan Atomic Energy Research Institute (JAERI), Tokai. The final heat treatment of PCTs was done at 1000°C for 2 hrs in vacuum of $<1\times10^{-4}$ Pa. A helium gas sealing was done in a helium gas enclosure at the Oarai branch of Japan Nuclear Cycle Development Institute (JNC), Oarai. The detailed tubing process and fabrication process of pressurized creep tubes have been reported in the ref [2]. The PCTs wrapped with Ta and Zr foils were enclosed in a quartz tube in vacuum. Thermal creep tests were done using the sealed quartz tubes in Muffle furnace at 600, 700, 750, 800 and 850°C. 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. After a creep strain exceeded 20% in a measurement, the creep test was finished and the TEM observation was performed for the specimen pieces cut out from PCTs.

A macroscopic examination of the welds indicated relatively smooth weld zones without any cracks, porosity, or other significant weld flaws. The incursion of impurities at the time of manufacturing PCTs was not accepted by a result of analysis of chemical composition before and after creep tests. The result of chemical analysis is shown in table 1.

Table1. Chemical analysis before and after creep test.

Condition	Oxygen conc. (wppm)	Nitrogen conc. (wppm)
Pre-creep test	370	80
850°C, 150MPa 120hrs (Ex.2times)	520	140
850°C, 200MPa 50hrs	330	110

From the results of dimensional changes, the activation energy of creep deformation in the NIFS-Heat2 alloys was about 180kJ/mol. This amount of creep activation energy of PCTs is very similar to that of uniaxial creep specimens of NIFS-Heat1 alloys in the previous study [3]. The creep strain rate of PCTs is several times larger than that of uniaxial specimens.

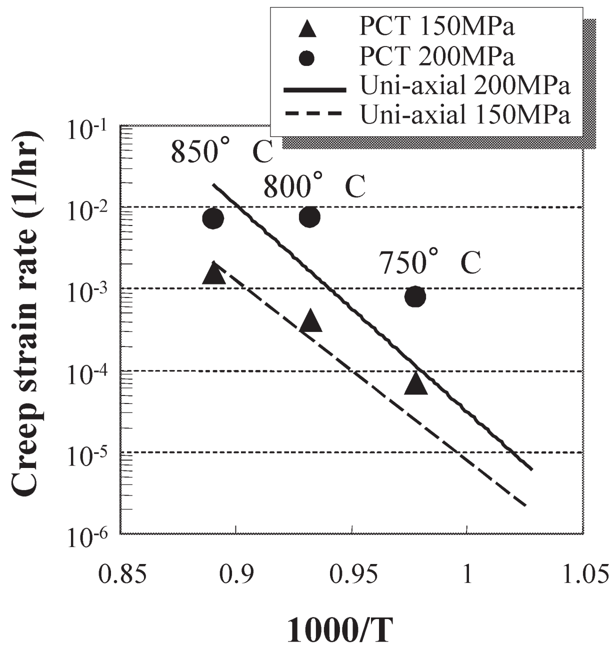

Fig. 1. An Arrhenius plot of creep strain rate examined by using PCTs and uniaxial tensile specimens.

The creep tests at 750 and 700°C are being continued. TEM microstructural analyses for fully deformed PCTs are also undergoing. The creep mechanism for NIFS-Heat2 alloys will be apparent by combining the information between the deformed microstructure after creep test, activation energy of apparent creep deformation and creep exponent for each creep temperature for NIFS-Heat2 in the future.

Reference
1) Muroga,T., et al., J. Nucl. Mater. 283-287 (2000) 711
2) Fukumoto, K., et al., J. Nucl. Mater. 335 (2004) 103
3) Fukumoto, K., et al., J. Nucl. Mater. 283-287 (2000) 535