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High-temperature creep properties of NIFS-HEAT-2 high-purity low-activation vanadium alloy

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The National Institute for Fusion Science (NIFS) developed the NIFS-HEAT in collaboration with Japanese universities. Previous heats exhibited brittle fracture of weld joints and cracking during tubing fabrication at room temperature, due to ductility loss caused by interstitial impurities, such as C, N and O. The total of interstitial impurity level of NH2 is almost half that of the US heat. As a result, weldabilty and workability were successfully improved because of enhanced ductility. Although many properties were improved by the purification, possible degradation of high-temperature strength due to purification softening was a concern. Therefore, the present study evaluated the high-temperature creep properties of NH2, which were expected to be sensitive to impurity levels.

Creep rupture time of NH2 in the lower applied stress region (≤ 100 MPa) was comparable to the US heat at 800℃, although in the higher stress region, the rupture time was shorter than that for US data. The creep activation energy of the US heat was 320 kJ molˆ-1 in average, and consistent with 270 kJ molˆ-1 for self-diffusion energy in pure vanadium. This indicates that climb-assisted dislocation motion is the predominant process for creep. NH2 showed higher activation energy, 640 kJ molˆ-1, suggesting additional deformation process. Since the applied stress in the creep tests, 150 to 200 MPa, was close to the yield stress (195 MPa) of NH2, thermally activated dislocation glide was thought to be induced and thus enhanced creep.

The creep data were converted by time-temperature equivalence scaling using the Larson-Miller parameter. Some of the parameters for NH2 are smaller than those for the US heat, however are still superior to fusion-grade steels. As mentioned above, creep properties were not degraded by the purification at stress levels ≤ 100 MPa. This means that the purification requires no change in design stress for blanket, because the thermal stress would be less than this level, assuming the first wall consists of a simple edge-constraint plate with heat flux and wall thickness of less than 1 MW mˆ-2 and 5 mm, respectively.

In conclusion, the purification for NH2 improved many properties, such as weldability and workability, and raised no negative effect on high-temperature creep properties under the projected blanket service stresses.

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