Atom probe tomography of 15KhMFT Cr-Mo-V steel surveillance specimens

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A combined atom probe tomography and atom probe field ion microscopy study has been performed on low copper Cr-Mo-V steel surveillance specimens from a VVER-440/213C reactor. These powerful microanalytical tools permit the solute distribution in these complex materials to be characterized at the atomic level. This information may be used to investigate the mechanisms that produce embrittlement during service in low copper materials.

Both base and weld surveillance specimens were characterized. The composition of the base metal was Fe- 0.07 wt. % Cu, 2.9% Cr, 0.31% V, 0.46% Mn, 0.66% Mo, 0.07% Ni, 0.17% Si, 0.16% C, 0.014% P, and 0.016% S. This material was characterized after neutron irradiation for 10 years to a fluence of 9.96×10^{24} n m^{-2} ($E > 0.5$ MeV) at a temperature of 275°C and also after thermal aging for 10 years at 275°C. The composition of the 15KhMFT weld metal was Fe- 0.06 wt. % Cu, 1.4% Cr, 0.20% V, 1.10% Mn, 0.50% Mo, 0.59% Si, 0.037% C, 0.012% P, and 0.017% S. The weld material was examined after tempering for 18 h at 690°C and a simulated multi-step stress relief treatment for a total of 43.5 h at 680°C. The weld was also characterized after neutron irradiation for 5 years to a fluence of 5.2×10^{24} n m^{-2} ($E > 0.5$ MeV) at a temperature of 275°C and also after thermal aging for 5 years at 275°C.

The ductile-to-brittle transition temperatures of the base metal were determined to be –49, -70 and 141°C, for the unirradiated, thermally aged and neutron irradiated materials, respectively. The ductile-to-brittle transition temperatures of the weld metal were 7, 11 and 125°C, for the unirradiated, thermally aged and neutron irradiated materials, respectively.

The microstructure of these materials was a dispersion of fine V(C,N) precipitates in the matrix. A high number density of ultrafine phosphorus-enriched regions was observed in the matrix of the neutron irradiated materials. Phosphorus segregation was observed at the V(C,N) precipitate-matrix interface and at grain boundaries. The solute distribution in the matrix and the composition of the fine V(C,N) precipitates will also be described.

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