TENSILE AND CREEP PROPERTIES OF AN OXIDE DISPERSION-STRENGTHEND FERRITIC STEEL—R. L. Klueh, P. J. Maziasz, D. T. Hoelzer, N. Hashimoto (Oak Ridge National Laboratory), I. S. Kim, and K. Miyahara (Nagoya University)

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Extended Abstract

For increased efficiency in a fusion plant, the operating temperature must be increased above the maximum temperature (550 to 600ºC) for the conventional 9-12% Cr ferritic/martensitic steels. One possibility for doing this and still maintaining the advantages of ferritic steels (enhanced swelling resistance and thermal properties) is the use of oxide dispersion-strengthened (ODS) steels.

Two ODS steels from Kobe Steel Company, Japan, were investigated at Oak Ridge National Laboratory and Nagoya University. Nominal compositions of the two ODS steels were Fe-12Cr-0.25Y_2O_3 (designated 12Y1) and Fe-12Cr-3W-0.4Ti-0.25Y_2O_3 (12YWT). Previous work, which included optical microscopy, transmission electron microscopy, and atom probe field ion microscopy studies, indicated that the 12YWT contained a high density of extremely fine Y-Ti-O clusters, compared to much larger oxide particles in 12Y1. Tensile and creep properties of the two steels were obtained for the steels to determine the effect of the different microstructures on properties.

Tensile behavior of the two steels was determined over the range of room temperature to 900ºC and compared to the reduced activation 9Cr-2WVTa steel for tests to 700ºC. The yield strength of the 12YWT was superior to that of the 12Y1 and the 9Cr-2WVTa over the entire temperature range, which is consistent with the difference in the microstructures (the high number density of small particles in the 12YWT). Because of the much larger and less evenly distributed oxide particles in the 12Y1, the yield stress of this steel is only higher than that of the 9Cr-2WVTa steel below 550ºC, while the 12YWT continues to show excellent strength well above this temperature. As expected from the relative yield stress behavior, the elongation of the weaker 12Y1 exceeds that of the 12YWT. However, despite the higher strength, the 12YWT still has good ductility.

Creep and creep-rupture tests were conducted at 600-850ºC. The creep strength of the 12YWT exceeded that of the 12Y1. Larson-Miller parameters for the 12YWT and 12Y1 steels were compared with parameters for MA956 and MA957, two commercial ODS ferritic steels, and the 12YWT had the best creep-rupture properties. For tests at 800ºC, the creep-rupture strength of the 12YWT is also superior to that of the V-4Cr-4Ti alloy, another potential material for fusion applications.

The microstructure of the 12YWT creep specimen that failed after 14,500 h at 850ºC was examined by TEM and SEM. The TEM showed a high density of dislocations along with a clear depiction of the elongated grain structure of the material that is developed by the processing. Observations by SEM on polished specimens further elucidated the elongated grain structure of the as-processed material. The crept specimen showed indications of the elongated grain structure, but in addition, indications of recrystallization were observed. Such evidence of recrystallization was still only apparent in isolated regions, indicating that recrystallization was in its initial stages for a specimen in creep at 850ºC for 14,500 h. No unstressed specimens have been thermally aged to determine the role of stress in the recrystallization

It must be emphasized that even though the 12YWT steel displays these excellent properties, ODS steels for fusion are still at an early development stage, similar to the vanadium alloys.

Neither of these materials is at a stage of development comparable to conventional and reduced-activation ferritic/martensitic steels, for which the technology (i.e., steel processing, final fabrication, welding, etc.) is advanced to the point that a fusion plant could be constructed. Some of the problems still to be solved for ODS steels include: the elimination of the elongated grain structure (deriving from the way the steels are processed) that produces anisotropic behavior in the mechanical properties, the production of large section sizes, and the joining of ODS steels in a large structure. Finally, there is the question of irradiation resistance, for which very little information is available.