OXIDE DISPERSION-STRENGTHENED STEELS: A COMPARISON OF EXPERIMENTAL AND COMMERCIAL STEELS—R. L. Klueh, J. P. Shingledecker, R. W. Swindeman, and D. T. Hoelzer (Oak Ridge National Laboratory)

OBJECTIVE

This work is carried out to develop an understanding of the mechanical properties and microstructures of experimental and commercial oxide dispersion-strengthened steels that are considered possible candidate materials for fusion applications.

SUMMARY

Oxide dispersion-strengthened (ODS) steels are being developed and investigated for nuclear fission and nuclear fusion applications in Japan, Europe, and the United States. In addition, commercial ODS products are available and have been used in niche applications. Microstructural and mechanical properties studies have been conducted at Oak Ridge National Laboratory and elsewhere on various commercial and experimental ODS steels. Tensile and creep properties have been obtained and collected from literature and commercial sources. These data are compared to show the differences and similarities of different ODS steels, and observations are explained in terms of the microstructures of the steels.

PROGRESS AND STATUS

Introduction

If the conventional high-chromium ferritic/martensitic steels, such as modified 9Cr-1Mo and Sandvik HT9, or the reduced-activation steels, such as F82H, ORNL 9Cr-2WVTa, EUROFER, and JLF-1, were used for a fusion power plant first wall and blanket structure, the upper operating temperature would be limited to 550-600°C.

One way suggested to increase this limit to higher temperatures and maintain the advantages inherent in ferritic/martensitic steels (i.e. high thermal conductivity and low swelling) is to use oxide dispersion-strengthened (ODS) steels. Elevated temperature strength in these steels is obtained through microstructures that contain a high density of small Y_2O_3 and/or TiO_2 particles dispersed in a ferrite matrix.

ODS steels are being developed and investigated for nuclear fission and fusion applications in Japan [1,2], Europe [3,4], and the United States [5]. Some commercial ODS products are available and are being used in limited quantities; commercial alloys include MA 956 and PM 2000 from Special Metals Corporation in the United States and Metallwerk Plansee GmbH in Germany, respectively. Microstructural and mechanical properties studies have been conducted at Oak Ridge National Laboratory (ORNL) on various commercial and experimental ODS steels. Results obtained at ORNL and elsewhere will be presented, compared, and discussed to show the differences and similarities of the different steels.

In previous work at ORNL, the microstructures and tensile and creep properties of two experimental ODS steels with nominal compositions of Fe-12Cr-0.25Y_2O_3 (designated 12Y1), manufactured by Sumitomo Metal Industries Ltd., and Fe-12Cr-2.5W-0.4Ti-0.25Y_2O_3 (designated 12YWT), manufactured by Kobe Special Tube Co. Ltd., were investigated [6]. Optical microscopy, transmission electron microscopy (TEM) [7], and atom probe field ion microscopy [8,9] studies indicated that the 12Y1 microstructures were very different from those of 12YWT (Fig. 1). For 12Y1 [Fig. 1(a)], particles were estimated to be 10-40 nm in diameter at a number density of 10^{20}-10^{21} m^{-3}; the dislocation density was estimated at $\approx 10^{15}$ m^{-2}. Diffraction studies indicated the particles were essentially pure, crystalline Y_2O_3. For 12YWT [Fig. 1(b)], dislocation density, particle size, and particle number density were estimated at 10^{15}-10^{16} m^{-2}, 3-5 nm diameter, and 1-2 x 10^{23} m^{-3}, respectively. For this alloy, three-dimensional atom probe analysis revealed