LONG-TERM STABILITY OF AUSTENITIC ODS STEEL

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One of the major goals in nuclear materials research is to develop steel grades applicable under extreme operating conditions. Ferritic oxide dispersion strengthened (ODS) steels have been successfully developed and proven their capabilities at temperatures higher than 600 °C. However, one of the major drawbacks of available ferritic ODS steels is the decreased toughness in the high temperature regime. The stable high temperature phase of iron, the austenitic phase, could deliver the necessary long term high temperature stability due to its enhanced creep and fatigue behavior at elevated temperatures. Another benefit is the paramagnetism of austenitic steels, which could make it an ideal candidate for applications in magnetic fields like in the Tokamak.

A reason for the major focus on the development of ferritic/martensitic instead of austenitic steels was originated in the lower heat conductivity and the inferior behavior of austenitic steels under irradiation. However, the efforts to develop an austenitic ODS steel able to overcome these disadvantages have been successfully conducted over the period of the last 10 years and has led to an ascertainable mitigation of the swelling behavior under irradiation up to at least 80 dpa. An increased ductility combined with a high temperature toughness comparable to ferritic steels and the prospect of a longer lifetime are promising features.

This publication targets three issues related to austenitic ODS steels and are described and discussed in detail:

(1) To address the mechanical alloying of austenitic steels and the fact that due to its increased ductility the powder is more susceptible to stick to the container walls and milling balls. This leads to a change in the chemical composition and a low powder production yield. To prevent this, the addition of a process control agent (PCA) can change the surface properties and the ratio of work hardening and fracture of powder particles. The influence of an induced PCA as well as the change in the microstructure and production yield were investigated with respect to the applied milling energy by examining the chemical composition of powder particles after different milling conditions using energy dispersive X-ray spectroscopy (EDX) in a scanning electron microscope (SEM).

(2) The second goal was to investigate the long-term high temperature stability of oxide particles and grain sizes of an austenitic ODS steel by examining the microstructure using TEM, APT and SEM EBSD techniques after annealing for 750, 1000, 1250 and 1500 hours at three different temperatures. The results have been used to calculate the activation energy and to determine the maximum operation temperature. The evolution of hardness was compared to the microstructure to figure out the main strengthening mechanism.

(3) The effects of the contamination by a carbon containing PCA were analyzed in respect to the annealing time and temperature to reveal the capabilities of this novel production process for austenitic ODS steels.

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