RECENT EXPERIMENTAL RESULTS ON NEUTRON-INDUCED VOID SWELLING OF AISI 304 STAINLESS STEEL CONCERNING ITS INTERACTIVE DEPENDENCE ON TEMPERATURE AND DISPLACEMENT RATE—F. A. Garner (Pacific Northwest National Laboratory), B. J. Makenas (Fluor Hanford Company)

OBJECTIVE

The objective of this effort is to explore the response of austenitic steels in diverse nuclear environments. Since light water reactors generate helium/dpa levels comparable to fusion devices, there is considerable overlap in relevance. In addition, the focus on AISI 304, while not of direct application to fusion devices, is useful because this simple steel does not have a very complicated phase evolution, allowing study of radiation-induced microstructural evolution without the complications associated with precipitation.

SUMMARY

Almost all data on the void swelling of AISI 304 stainless steel relevant to PWR applications were derived from examination of structural components or experimental assemblies irradiated in the EBR-II fast reactor. However, many more components and assemblies were not fully analyzed and often were not published as the fast reactor program moved to research on more swelling-resistant alloys. In this paper a number of these lost opportunities have been rescued and examined with an eye toward their relevance to predicting behavior of AISI 304 in PWRs.

Swelling of annealed AISI 304 stainless steel initially proceeds at a rate of ~0.07%/dpa in the range of 370–390ºC and then begins to accelerate toward a rate of ~1%/dpa, with the breakaway dose dependent on dpa rate, temperature, temperature gradient and stress in roughly that order. The interactive effects of dpa rate and temperature are very strong and produce “loops” which allow visualization of the conditions under which swelling will be the strongest. These conditions are lower dpa rate and higher temperatures, but temperature gradients and stresses can also accelerate the onset of swelling. While no additional data are available below 370ºC, the insight acquired will allow better extrapolation down into the full range of PWR-relevant temperatures.

PROGRESS AND STATUS

Introduction

The major portions of baffle-former assemblies of PWRs are constructed from annealed AISI 304 stainless steel. This steel is known to swell rather easily compared to other steels such as cold-worked AISI 316 frequently used for baffle bolts [1,2]. Swelling in AISI 304 is known to increase monotonically as the temperature rises above 370ºC [1]. Relatively small isolated volumes of the baffle-former assembly at reentrant corners may therefore experience significant amounts of void swelling that arise due to localized higher temperatures generated by gamma-heating in thick plates, especially at reentrant corners [3].

Essentially all data on the swelling of AISI 304 was generated in the now-decommissioned EBR-II fast reactor. The data base suffers from three significant deficiencies. First, there are no data available below 370ºC which was the inlet cooling temperature. Most of the PWR baffle-former assembly will experience temperatures less than 350–360ºC. Second, irradiation in the EBR-II core proceeded at dpa rates on the order of 0.5 to 1.0×10^{-6} dpa/sec, fully an order of magnitude higher than the maximum dpa rate experienced by those portions of the baffle-former assembly that are closest to the PWR core. Third, most data were derived from components that spanned a range of temperatures and dpa rates, thus making it difficult to separate the simultaneous and synergistic effects of these two variables. Additionally, some of the examined components were subject to either constant or time-dependent stresses, and stress is the third most important variable in determining the onset of void swelling in austenitic steels [2].