§96. Evaluation of Low-Temperature Swelling in Austenitic Stainless Steels

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It is well known that austenitic stainless steels suffer large swelling typically at around 773K under fast breeder reactor (FBR) core environments. Phenomenology of such swelling which occurs at relatively high temperatures, or high temperature swelling, has been extensively studied, and mechanistic studies and modeling have been performed as well. At lower temperatures, namely about 673K or below, formation of voids and/or bubbles still occurs in austenitic steels irradiated in FBRs or in mixed spectrum reactors, although swelling there has never be catastrophic as observed at higher temperatures, until damage levels of at least several tens of displacement per atom (dpa).

However, since the material response to neutron bombardments is significantly affected by irradiation conditions such as displacement damage rate, helium production rate and neutron energy spectrum, swelling data obtained from above-mentioned experiments do not necessarily guarantee that irradiation-induced dimensional changes at low temperatures may not exceed certain limits under various environments. As predicted by a simple theory of the influences of temperature and damage rate on swelling, especially a combination of low temperature and small damage rate may results in significant swelling. Some components, like radiation / thermal shields, of blanket structures in future fusion devices and some of the pressurized water reactor core components are among the examples in which low temperature swelling is anticipated. Therefore, in this work it was intended to study the influences of irradiation environment, including displacement damage rate and helium production rate, on low temperature swelling behavior of austenitic stainless steels, to aid the assessments of dimensional instability of materials for fusion and fission reactor applications.

The results from intensive study by computer simulation based on advanced rate theory modeling on the influences of irradiation environment, including displacement damage rate and helium production rate, on low temperature swelling behavior of austenitic stainless steels are summarized as follows.

(1) There found noticeable characteristics of low temperature swelling which are not common for medium-to-high temperature swelling.
(2) Cascade-produced vacancy clusters (CVC), when produced, play a major role in determining microstructural evolution at low temperatures. The effectiveness of CVC production to swelling suppression becomes pronounced at a lower temperatures even when damage rate is selected so that the largest swelling occurs for the temperature.
(3) Low temperature swelling of detectable levels may occur at temperatures within a very narrow range under CVC-producing conditions. The amount of swelling will simply be increased with the increasing helium production rate.

Reference

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