SOME ASPECTS OF THE USE OF ZIRCALOY AND STAINLESS STEEL AS CLAD FOR PWR FUEL RODS

A.T. SILVA, J.A. PERROTTA
Instituto de Pesquisas Energéticas
e Nucleares (IPEN),
Comissão Nacional de Energia
Nuclear (CNEN),
São Paulo, Brazil

Zircaloy replaced stainless steel as the primary PWR cladding material in the early 1970s. The principal advantages of using Zircaloy are its lower thermal neutron absorption cross-section and its higher melting temperature relative to stainless steel. In spite of the factors listed above, there are several advantages to using stainless steel clad fuel in PWRs. Stainless steel is stronger than Zircaloy and is, therefore, more resistant to pellet–cladding mechanical interaction damage and it is not susceptible to iodine stress corrosion cracking. In addition, it offers greater integrity than Zircaloy during large loss of coolant accidents in which cladding temperatures remain below 1200°C [1].

To check the behaviour of Zircaloy and stainless steel as clad for PWR fuel rods, the fuel performance computer code FRAPCON-1 [2] was changed to analyse PWR stainless steel clad fuel. FRAPCON-1 is a FORTRAN IV computer code which predicts the steady state, long term burnup response of Zircaloy clad PWR fuel rods.

During FRAPCON-1 stainless steel construction, the Zircaloy material properties and the thermal-mechanical models of FRAPCON-1 were replaced with material properties and models developed for stainless steel. Then the FRAPCON-1 stainless steel was benchmarked against one rod (WCAP-2923) of the fuels data [3]. Finally, an additional check on the stainless steel option was made by running both Zircaloy and stainless steel rods over the same power history. The objective was to verify that the differences in behaviour between these rods are all consistent with the known differences in material properties between the two cladding types.

A comparison of the stainless steel and Zircaloy cladding models used in the code led to the following conclusions:

(1) Stainless steel exhibits thermal expansion strains that are larger and in-reactor creep strains that are smaller than those of Zircaloy. The main result of these comparisons is that stainless steel clad rods maintain an open gap for a longer period than Zircaloy clad rods.
(2) The highest temperatures are observed in stainless steel clad rods due to wider gaps.
(3) During the pellet–cladding mechanical interaction, the magnitude of strain is smaller and the tensile stress larger in stainless steel rods. These effects result from the fact that stainless steel is stiffer than Zircaloy. Owing to its larger in-reactor creep strain, Zircaloy cladding strains further outwards than stainless steel cladding, thereby relieving the stress to a greater extent.

REFERENCES

[1] ADRIAN ROBERTS, J.T., Structural Materials in Nuclear Power Systems, Plenum Press, New York and London (1981).
[2] BERNA, L.A., et al., FRAPCON-1: A Computer Code for the Steady State Analysis of Oxide Fuel Rods, CDAP-TR-032-R1, Idaho National Engineering Laboratory, Idaho Falls (Nov. 1978).
[3] EG and G IDAHO, INC., Fuel Code Assessment Data Sample, Rep. EGG-CAAP-5114 (Feb. 1980).