Effects of the microstructure and thickness of porous carbon buffer layer on the thermo-mechanical behavior of an FCM fuel pellet

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The application of fully ceramic microencapsulated (FCM) fuels to light water reactors (LWRs) has attracted increasing attention. FCM fuel pellets are composite fuels, in which the tri-structural isotropic (TRISO) fuel particles are embedded in the SiC matrix. To guarantee the safety and obtain the greatest fissile loading, it is necessary to perform the optimal design for functional coatings in TRISO particles.

As the main storage space for fission products in FCM fuels, the microstructure and thickness of porous carbon buffer layer should be optimally designed. Under irradiation environments, the buffer layer experiences a complex thermo-mechanical coupling behavior and strong kernel-buffer-IPyC mechanical interaction. Irradiation swelling of kernel squeezes the buffer layer. The buffer layer also shrinks due to neutron irradiation. In addition, fission gases and other gases are released into the buffer layer, which results in expansion of the buffer layer and variation of thermal conductivity. The buffer layer will be restrained by anisotropic IPyC. Also of importance, the microstructure and thickness of porous carbon buffer layer evolves with fast neutron fluence, which affects the thermo-mechanical behavior of FCM fuel pellets. To date, the related analysis is relatively scarce. The kernel-buffer-IPyC mechanical interactions are ignored because of the lack of knowledge concerning buffer properties. For optimal design of the buffer layer, more accurate and comprehensive analysis needs to be conducted, which considers the kernel-buffer-IPyC mechanical interaction and above physical mechanisms.

In this study, based on the established thermo-mechanical constitutive relationship for the buffer layer, three-dimensional finite element analysis for the thermo-mechanical behavior in an FCM fuel pellet is performed involving kernel-buffer-IPyC mechanical interaction and main physical mechanisms. The effects of the microstructure and thickness of porous carbon buffer layer on the thermo-mechanical behavior is investigated, including the effects on the distribution and evolution of temperature, deformations, stresses within the fuel pellet and the interfacial stresses at the kernel/ buffer buffer/IPyC interfaces. Suggestions on the optimal design are proposed for the buffer layer in FCM pellets.

References

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