A model for mesoscale tensile strength of irradiated U-10Mo fuels considering irradiation creep damage

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In the in-pile irradiation environments, the U-10Mo fuel foil in monolithic UMo/Al fuel plates will undergo the deformations of thermal expansion, irradiation-induced creep and irradiation swelling. The total irradiation swelling includes the contributions of solid and gaseous fission products. The mechanism of fission-gas induced swelling is of complexity, which mainly results from the formed large grain boundary bubbles. Accumulation of these bubbles with the increase of fission density will make the fuel foil evolve into a porous configuration, with bubble pressure subjected to the fuel skeleton. The bubble volume fraction and bubble pressure will affect the actually endured stresses in the fuel skeleton. In addition, large irradiation creep strains will lead to creep damage in irradiated U-10Mo fuel skeleton to degrade its tensile strength. In order to establish a fracture criterion, it is necessary to develop a mesoscale stress model together with a model of mesoscale tensile strength for irradiated U-10Mo fuels.

In this work, based on the mesoscale normal stress model obtained with the U-10Mo fuels considered as a porous medium with gas bubbles and bearing bubble pressure and surface tension, a method is developed to correlate the mesoscale tensile strength of U-10Mo fuels with the experimental results for the macroscale bending strength of irradiated U-10Mo fuels. The bubble volume fraction, bubble size, bubble pressure at certain fission density are obtained through performing finite element simulation of the in-pile thermo-mechanical coupling behavior in the UMo/Al monolithic fuel plate. Meanwhile, the equivalent irradiation creep strains are also calculated out. According to the mesoscale normal stress model and the experimental results of the macroscale bending strength, the corresponding mesoscale tensile strength at certain fission density can be acquired with the effects of bubble volume fraction and bubble pressure and surface tension considered. Compared with the bending strength of un-irradiated U-10Mo, a damage factor is proposed to involve the creep damage effect on the mesoscale tensile strength for irradiated U-10Mo. In brief, a model for the mesoscale tensile strength of irradiated U-10Mo fuels is ultimately developed with irradiation creep damage taken into account, which correlates the tensile strength of un-irradiated U-10Mo and equivalent irradiation creep strain with the post-irradiation mesoscale tensile strength. This study lays a foundation for the development of a fracture criterion for U-10Mo monolithic fuels, and can help to analyze the mechanism of fuel fracture found in the irradiation experiments.

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