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PROCEEDINGS

The CDM-Based Modelling of the Multi-Field Coupling Delayed Hydride Cracking Behaviors of Zirconium Alloys

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ABSTRACT

Zirconium alloys have high strength, high corrosion resistance and low neutron absorption cross section, widely served as the nuclear cladding tubes or some other structural components. During the storage stage of spent fuels or in the lower-temperature reactor-core locations, the hydrogen atoms within the zirconium alloy components would diffuse to the crack tip owing to stress concentration, possibly initiating delayed hydride cracking (DHC) and posing a potential threat to nuclear safety. In this study, the CDM (continuum damage mechanics)-based multi-field coupling computational models are developed, with the hydride-induced hardening and embrittlement, hydride orientation contributions and irradiation effects involved in a three-dimensional damage mechanical constitutive model, damage evolution model and the critical damage factor model. Based on the derived equivalent integral weak forms of concerned multi-fields, all the finite element procedures are generated. The efficient numerical implementation for reproducing the dynamic cracking process is realized, obtaining the field variables of temperature, stress, damage factor, hydrogen concentration, hydride volume fraction, and hydride average orientation as a function of time. The predicted DHC velocities and subcritical cracking traits are in good agreement with the experimental results, validating the effectiveness of the newly developed models. The influencing mechanisms for delayed hydride cracking are deeply revealed, according to the spatial distribution and evolution of multi-physics results. This developed new numerical methods are more advanced than the previously used cohesive models, because the cracking directions are not restricted.

KEYWORDS

Hydride-embrittlement; delayed hydride cracking; damage mechanics; damage evolution model; zirconium alloy tubes

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