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高温气冷堆反应堆压力容器在几种典型瞬态条件下的概率断裂力学分析

摘要

概率断裂力学（PFM）在轻水堆压力容器结构完整性评价中的应用越来越广泛。对于高温气冷堆（HTGR）来说，其压力容器的工作负荷在温度、压力、瞬态和快中子通量等方面都与轻水堆不同。此外，与压力容器相关的安全要求也存在差异。本文对 290MW 球床模块式高温堆的压力容器进行了几种典型瞬态工况下的概率断裂力学分析。为了模拟不同 ASME 规范下压力容器的制造条件，假设不同制造质量水平的压力容器具有不同的沿壁厚的缺陷分布。此外，还研究了压力容器中不同类型和不同区域的缺陷对条件启裂概率（CPI）和条件失效概率（CPF）的贡献。计算结果表明，即使在缺陷尺寸的保守假设下，由于快中子通量水平低和瞬态发展缓慢，高温气冷堆压力容器的失效概率也非常低。

关键词

高温气冷堆；反应堆压力容器；概率断裂力学

Abstract

Probabilistic fracture mechanics (PFM) has been increasingly used in the structural integrity evaluation of reactor pressure vessels (RPVs) in light water reactors (LWRs). For high temperature gas-cooled reactor (HTGR), the working load of its RPV is different from that of LWR in terms of temperature, pressure, transient and fast neutron fluence. In addition, there are differences in the safety requirements associated with RPV. In this paper, PFM analysis of RPV of a 290MWth pebble-bed modular HTGR under several typical transient conditions is carried out. To simulate the manufacturing conditions of RPVs under different ASME rules, it is assumed that the flaw information of RPV along the wall thickness has different levels of manufacturing quality. In addition, the contribution of different types and regions of flaws in RPV to the conditional probability of initiation (CPI) and the conditional probability of failure (CPF) is investigated. Numerical results indicate that due to the low level of fast neutron fluence and slow transient development, the CPF of the RPV of HTGR is extremely low even under conservative assumptions of flaw size.

Keywords

High temperature gas-cooled reactor; Reactor pressure vessel; Probabilistic fracture mechanics

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