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高温气冷堆甲烷蒸汽重整系统中氚渗透行为研究

摘要

高温气冷堆（HTGR）甲烷蒸汽重整（MSR）制氢是中短期内最有希望实现的核能制氢技术。由反应堆产生的氚的渗透行为在系统安全分析时极为重要。目前有两种方法可以将核反应堆与氢气生产系统连接起来：直接耦合或通过中间热交换器（IHX）间接耦合。为了分析两种耦合方式的氚渗透差异，比较不同 IHX 合金和运行条件下氚渗透行为，本研究考虑放射性元素氚不同源项的产生速率、释放分数，以及衰变减少等情况，分析了氚浓度、分压、温度和不同合金等参数，建立了氚在 IHX 发生渗透的计算模型。结果表明，氚的渗透速率主要受到 IHX 合金指前因子的限制，并且受温度变化影响较大，稳定状态下温度由 750℃ 增加为 950℃ 时，氚的渗透速率可增大近 3 倍。核能制氢系统通过中间换热器间接耦合，使得二回路中氚的分压较一回路下降约 90%。这些结果将有助于设计一个有效和安全的高温气冷堆甲烷蒸汽重整制氢系统，并为核能制氢系统的安全和高效运行提供宝贵的信息。

关键词

高温气冷堆，核能制氢，氚，氚渗透，系统安全性分析

Abstract

Hydrogen production system by Methane Steam Reforming (MSR) using High Temperature Gas Cooled Reactor (HTGR) is the most promising technology for nuclear hydrogen production in the near future. The tritium permeation behavior produced by the reactor is extremely important when analyzing the system safety. It is currently possible to connect a nuclear reactor to a hydrogen production system by direct coupling or indirect coupling through an intermediate heat exchanger (IHX). In this study, parameters such as partial pressure, temperature and different alloys were analyzed in steady state and unsteady state. Then a calculational model for the permeation of tritium occurring at the IHX is established. The results show that the permeation rate of tritium can increase nearly two times as the temperature increases from 750 to 950℃ in the steady state. The nuclear hydrogen production system is indirectly coupled through an intermediate heat exchanger, which results in an approximately 90% decrease in the partial pressure of tritium in the second circuit compared to the first circuit. These works will contribute to the design of an efficient and safe nuclear hydrogen production system by MSR using HTGR.

Keywords

High-Temperature gas-cooled reactor, Hydrogen production using nuclear energy, Tritium, Tritium permeation, System safety

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