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兆瓦级车载移动式热管冷却反应堆核能系统特性分析

摘要

热管冷却反应堆（Heat pipe cooled reactor, HPR）具有体积小、安全性高的特点，可用于车载移动等特殊应用场景。本文选择基于 HPR 的移动核电系统 MNPS-1000 进行研究和分析，该系统旨在产生输出 1MWe。根据设计，建立了一个完整的系统模型，包括反应堆模型、高温热管模型、热管换热器模型和能量转换系统模型等。利用 MATLAB/SIMULINK，搭建了适用于该核电系统的分析平台。基于该平台，对系统的稳态和瞬态性能进行了仿真。在稳态分析中，模型关键节点的模拟值与参数匹配的计算值基本一致，最大相对误差不超过 6%，验证了基于所建平台开展系统分析的有效性。在瞬态分析中，分别对典型的反应堆系统事故和能量转换系统事故进行了模拟和分析。这些事故中燃料组件的最高温度不超过 1550K，低于选定的材料温度安全限值，讨论了该系统的固有安全特性。

关键词

热管冷却反应堆，联合循环，车载移动，系统分析

Abstract

Heat pipe cooled reactor (HPR) has the characteristics of small size and high safety, and can be used in special application scenarios such as vehicle-mounted mobility. In this paper, the Mobile Nuclear Power System based on HPR named MNPS-1000, which is designed to generate 1MWe, is selected for research and analysis. Ac cording to the design, a whole system model is established, which includes the reactor model, high-temperature heat pipe model, heat pipe heat exchanger model and energy conversion system model, etc. Using MATLAB/ SIMULINK, the analysis platform suitable for this nuclear power system is built. Based on this platform, the steady state and transient performance of the system are characterized. In the steady state analysis, the simulated values of key nodes of the model are in general agreement with the calculated values of parameter matching, and the maximum relative error does not exceed 6 %. The effectiveness of characteristic analysis based on the built platform is verified. In the transient analysis, typical reactor system accidents and energy conversion system accident are simulated and analyzed respectively. The maximum temperature of the fuel assemblies in these accidents does not exceed 1550 K, which is lower than the selected material temperature safety limit. The inherent safety feature of the system is discussed.

Keywords

Heat pipe cooled reactor, Combined cycle, Vehicle-mounted mobile, System analysis

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