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颗粒床反应堆流动不稳定研究及缓解措施分析

摘要

颗粒床反应堆（PBR）具有功率密度高和堆芯压降低的优点，在核热推进（NTP）中具有很大的应用潜力。PBR 中氢气的流动路径不固定，物性变化剧烈，容易导致流动不稳定，使反应堆温度更加不均匀，甚至干涸。考虑到 NTP 的安全性，有必要对流动不稳定性及其缓解措施进行详细分析。本文采用计算流体力学方法分析了简化的二维颗粒床多孔介质模型的流动不稳定性，并通过证明不稳定性的存在，验证了该模型的适用性。计算了稳定边界，并与经典的水堆两相不稳定进行了比较，总结了流动不稳定的特征。此外，在颗粒床入口加入冷孔板，分析了不同情况下界面反向导热对缓解能力的影响。

关键词

颗粒床反应堆；流动不稳定性；缓解措施；反向导热

Abstract

With the advantages of high-power density and low reactor pressure drop, Particle Bed Reactor (PBR) has great application potential in Nuclear Thermal Propulsion (NTP). Flow path in PBR is no fixed and the physical properties of hydrogen change dramatically, so it is easy to lead to flow instability, causing the reactor temperature more uneven and even dry up. Considering the safety of NTP, it is necessary to conduct a detailed analysis of flow instability and its mitigations. In this paper, computational fluid dynamics method is used to analyze the flow instability in the simplified two-dimensional porous media model of particle bed, whose applicability is verified by proving the existence of instability. The stability boundary is calculated and the characteristics of flow instability are summarized by comparing with classical two-phase instability in water reactor. Besides, a cold frit is added to the inlet of particle bed to analyze the influence of the interface back conduction on the mitigation at different cases.

Keywords

Particle Bed Reactor; Flow Instability; Mitigation; Back conduction

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