Contribution ID: 79 Type: 海报展示

HTR-PM600 新燃料贮存容器内球床力学行为模拟研究

摘要

本文采用基于赫兹接触的 FEM 耦合 DEM 方法，对 HTR-PM600 新燃料贮存容器内规则排列球床在 15m 跌落工况下的冲击破坏行为展开研究，通过试验对数值计算准确性进行验证。结果表明对法向赫兹接触曲线进行线性化处理可以在提高计算效率的同时，使计算精度处于可接受范围。以往的研究中，一般认为跌落工况下球床受力从容器底部到顶部依次减小，碎球主要集中在容器底部。然而，本研究的试验和模拟均发现了球床受力的离散性、分层性和链式传递特性，表明受力分布具有显著的非均匀性。本研究不仅深化了对规则排列球床破坏机制的理解，还为工程设计和安全评估提供了新的理论依据，为后续优化燃料容器性能奠定了重要基础。

关键词

赫兹接触；离散单元法；链式传递；离散性；规则排列球床

Abstract

This article uses a combination of the Discrete Element Method (DEM) and the Finite Element Method (FEM) based on Hertz contact theory to study the impact failure behavior of the regularly arranged pebble-bed in the HTR-PM600 fresh fuel storage canister under 15m drop conditions. The accuracy of numerical calculations is verified through experiments. Linearizing the normal Hertz contact curve can improve computational efficiency while maintaining acceptable accuracy. In previous studies, it was generally believed that the force within a canister decreases sequentially from the bottom to the top under drop conditions, and the broken pebbles were mainly concentrated at the bottom of the container. However, both the experiments and simulations in this study discover the discreteness, layering, and chain transmission characteristics of the force on the pebble-bed, indicating significant non-uniformity in the force distribution. This study not only deepens the understanding of the failure mechanism of regularly arranged pebble-bed, but also provides new theoretical basis for engineering design and safety assessment as well as important foundation for optimizing the performance of fuel canisters in the future.

Keywords

Hertz contact; discrete element method; chain transfer, discreteness; regularly arranged pebble-bed

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Session Classification: 海报展示

Track Classification: 02 海报展示: 海报展示