

基于栅格法的随机堆积球床几何全六面体网格生成算法

摘要

随机堆积球床具有复杂的孔隙结构，其颗粒间接触和狭窄流道给热工水力分析中的计算网格生成带来了较大困难，尤其容易在接触点附近产生低质量网格。针对这一问题，本文提出了一种面向随机堆积球床几何的基于栅格法的全六面体网格生成算法。该方法以笛卡尔网格作为初始背景网格，通过边界识别、网格投影和几何贴合，使网格逐步贴合到球体及容器壁面边界；同时在网格生成过程中引入自动化接触处理策略，以改善颗粒-颗粒及颗粒-壁面接触区域的网格质量。在此基础上，进一步结合缓冲层插入和网格质量优化方法，提高边界附近及局部复杂区域的网格正交性和鲁棒性。两个代表性球床几何算例表明，该方法能够稳定生成高质量全六面体网格，并在网格质量和生成效率方面优于商业软件 Fluent Meshing。结果表明，本文提出的算法能够较好地适应随机堆积球床复杂多孔几何，为复杂多孔介质中的高精度 CFD 模拟提供可靠的网格生成方法。

关键词

六面体网格；网格生成算法；随机堆积球床；接触点处理

Abstract

The complex porous geometry of randomly packed pebble beds poses significant challenges for thermal-hydraulic analysis in industrial applications. In particular, the presence of inter-particle contact points often hinders the generation of high-quality computational grids for computational fluid dynamics (CFD) simulations. To address this issue, this paper presents a grid-based, all-hexahedral meshing algorithm designed specifically for randomly packed pebble beds. The method begins with a Cartesian base mesh, which is subsequently projected and conformed to the geometric boundaries. Automated contact treatments are integrated into the meshing process and refinements to the algorithm include insertion of a buffer layer and mesh optimization. Two representative cases for the pebble bed geometry demonstrates the advantage of the hexahedral mesh and the robustness of the algorithm. Furthermore, the algorithm shows a better computational efficiency compared to commercial software Fluent Meshing. Results show that the proposed hexahedral meshing algorithm is capable to handle the complex, porous geometries of randomly packed pebble beds, which establishes a foundation for high-fidelity CFD simulations in complex porous media.

Keywords

Hexahedral mesh; Mesh generation; Packed pebble bed; Contact points

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