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考虑颗粒碰撞的多重Monte Carlo算法

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摘要 从减少计算代价和改进碰撞算法出发，提出了考虑颗粒碰撞的多重Monte Carlo算法，它采用直接模拟Monte Carlo算法来考虑颗粒碰撞，并与求解颗粒拉氏Langevin方程的Monte Carlo算法耦合起来，跟踪比实际颗粒数目小得多的虚拟颗粒．提出了时间步长选定标准、虚拟碰撞伙伴所在控制容积的判断准则、颗粒碰撞发生的判断准则、虚拟碰撞伙伴的选择、基于随机碰撞角度的碰撞动力学，构成了考虑颗粒碰撞的完整多重Monte Carlo算法．对理想工况的细微颗粒流和粗重颗粒流进行了数值模拟，颗粒碰撞率的模拟结果与理论分析解和DNS结果均符合很好，颗粒场演变的细节信息，如时间平均和特定时刻的颗粒数密度，速度和颗粒湍动能等，均与DNS结果符合很好．数值模拟结果证明该算法不仅具有较低的计算代价，而且能够达到足够的计算精度．

关键词 颗粒,碰撞,多重Monte Carlo算法,计算代价,计算精度

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Multi-Monte Carlo Methods for Inter-particle Collision

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Abstract

In the interest of improving collision arithmetic and decreasing computation cost, a new Multi-Monte Carlo (MMC) method for inter-particle collision is prompted. The particle motion is described by the Langevin equations, which is solved by Monte Carlo (MC) method. On the same time, Inter-particle collision is modeled by Direct Simulation Monte Carlo (DSMC) method. DSMC is coupled with forenamed MC method, as it is called Multi-Monte Carlo method. The simulation particle of MMC method is fictitious particle which number is far less than real particle. In order to form an integrated MMC method for inter-particle collision, a series of methods are developed, which include the restriction of the setting of time step, the guide line to judge in which control volume fictitious collision partner lies, the guide line to judge whether or not inter-particle collision event occurs, the choice rule of fictitious collision partner, and particle collision dynamics based on stochastic collision angle. Fine particles and heavy coarse particles flows are chosen as standard cases to validate MMC method. The simulation results of MMC methods are in good agreement with both theoretical solution and Direct Numerical Simulation (DNS), not only on macroscopical facets such as particle collision frequency but also on microcosmic facets such as the evolvement of particle fields. Numerical simulation proves MMC method for inter-particle collision not only has enough low computation cost but also gets to enough high computation precision.

Key words

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