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基于Boltzmann模型方程不同流区复杂三维绕流HPF并行计算

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HPF Parallel Computation Based on Boltzmann Model Equation for Flows Past Complex Body from Various Flow Regimes

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摘要

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摘要 随着现代航空航天快速发展, 是否能建立一套可有效模拟稀薄流到连续流各流域绕流问题统一算法, 已成为工程应用部门和学术研究领域关心的问题。通过开展基于Boltzmann简化速度分布函数方程数值求解, 发展起从稀薄流到连续流统一算法。借助区域分解并行化方法研究建立气体运动论统一算法并行方案, 通过对统一算法进行HPF并行化程序设计及算法考验, 拟定不同流域三维球体绕流及类“神舟”返回舱外形绕流算例, 进行HPF并行计算, 并将计算结果与有关实验数据、DSMC模拟值进行定量比较、分析。研究表明, 所发展的统一算法具有很好的并行独立性, 基本达到了线性加速的并行效果, 算法负载均衡和并行可扩展性较好, 可望建立起新型的能可靠模拟不同流域三维绕流问题的HPF并行算法研究方向。

关键词: 流体力学 Boltzmann模型方程 离散速度坐标法 速度分布函数 有限差分法 HPF并行计算

Abstract: With the development of modern aerospace technique, the algorithm for flows past three-dimensional body from various flow regimes has been being considered in the field of engineering application and academic study, as will be the end-goal of the research of this paper. The unified algorithm for the gas flows from rarefied transition to continuum regime can be developed by numerically solving the Boltzmann simplified velocity distribution function equation. The parallel strategy for the gas-kinetic unified algorithm for 3-D flows is studied and presented by using the domain decomposition techniques. The gas flows from various flow regimes around three-dimensional sphere and spacecraft are computed and verified by the HPF parallel computation in high performance computer with massive scale parallel, where the computed results are found in high resolution of the flow fields and good agreement with the theoretical, DSMC and experimental results. The preferable parallel efficiency and speed-up ratio are found. It is practical and hopeful that the new HPF parallel computation in solving three-dimensional complex problems from various flow regimes will be processed.

Keywords: fluid mechanics Boltzmann model equation discrete velocity ordinate method velocity distribution function finite difference method HPF parallel computing

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