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求解声波方程的辛可分Runge-Kutta方法

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Symplectic partitioned Runge-Kutta method for solving the acoustic wave equation

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摘要 本文基于声波方程的哈密尔顿系统,构造了一种新的保辛数值格式,简称NSPRK方法.该方法在时间上采用二阶辛可分R
Kutta方法,空间上采用近似解析离散算子进行离散逼近.针对本文发展的新方法,我们给出了NSPRK方法在一维和二维情况
条件、一维数值频散关系以及二维数值误差,并在计算效率方面与传统辛格式和四阶LWC方法进行了比较.最后,我们将本文
声波在三层各向同性介质和异常体模型中的波传播数值模拟.数值结果表明,本文发展的NSPRK方法能有效压制粗网格或具有
况下数值方法所存在的数值频散,从而极大地提高了计算效率,节省了计算机内存.

关键词: 哈密尔顿系统 辛算法 近似解析离散 波场模拟 数值频散

Abstract: In this paper, we develop a new symplectic numerical scheme based on Hamiltonian system
acoustic wave equation, which is called the NSPRK method in brief. The NSPRK method uses the nearly-a
discrete operators to approximate the high-order differential operators, and employs the second-order sy
partitioned Runge-Kutta method to numerically solve the Hamiltonian system. For the proposed NSPRK m
this paper, we obtain the stability conditions for 1D and 2D cases, the numerical dispersion relation for th
case and 2D numerical errors. Meanwhile, we compare the NSPRK against the conventional symplectic m
the fourth-order LWC method in computational efficiency. Finally, we apply the NSPRK method to model
wave propagating in a three-layer isotropic medium and an abnormal body model. The promising numerica
illustrate that the NSPRK method can effectively suppress the numerical dispersion caused by discretizin
acoustic-wave equation when coarse grids are used or models have large velocity contrasts between ad
layers. Therefore, the NSPRK method can greatly increase the computational efficiency and save comput
memory.

Keywords: Hamiltonian system Symplectic method Nearly-analytic discretization Wave-field simula
Numerical dispersion

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