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求解3D弹性波方程的并行WNAD方法及其TI介质中的波场模拟

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Parallel WNAD algorithm for solving 3D elastic equation and its wavefield simulations in TI media

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摘要 准确模拟TTI介质中弹性波的传播是研究地震各向异性、AVO反演的基础. 在二维加权近似解析离散化(WNAD)算法的基础上, 本文发展的并行WNAD算法是一种研究三维横向各向同性(TI)介质中弹性波传播的、快速高效的数值模拟方法. 我们首先介绍三维WNAD方法的构造过程, 然后与经典的差分格式——交错网格(SG)算法进行了比较. 理论分析和数值算例表明, WNAD算法比交错网格算法更适合在高性能计算机上进行大规模弹性波场模拟. 同时, 本文利用并行的WNAD方法研究了弹性波在TTI介质中的传播规律, 观测了TI介质中弹性波传播的重要特征:横波分离、体波耦合和速度各向异性等. 在TTI介质分界面处, 弹性波产生更加复杂的折射、反射和波型转化, 使得波场非常复杂, 研究和辨别不同类型的波能够加深我们对由裂隙诱导的各向异性介质的认识.

关键词 波场模拟, 加权的近似解析离散化方法, TTI介质, 数值频散, 并行计算

Abstract: The accurate modeling of elastic wave propagation in TTI media is significantly important for the study of the anisotropy, amplitude versus offset (AVO) analysis, and other inverse problems. A new numerical algorithm named parallel weighted nearly-analytical discrete (WNAD) method is presented in this paper. As an extension of 2D WNAD, the parallel WNAD method is a fast and efficient algorithm for simulating the elastic wave propagation in TTI media. We first show how to formulate the 3D WNAD method, and then compare the wavefield generated by this method with the wavefield computed by a conventional staggered-grid method. The numerical results show that the WNAD algorithm is more suitable for the simulations of the large-scale seismic wavefield by using the high-performance computers. Using the parallel WNAD algorithm, we study the elastic wave propagation in the TTI media and observe the important feature of TI media: shear-wave splitting, the quasi body wave coupling and velocity anisotropy. The reflected, refracted, and converted waves are generated at the interfaces. This makes the wavefield complex. To better understand the anisotropic media induced by fracture, it's useful to study and identify those waves.

Keywords Wave-field simulation, Weighted nearly-analytic discrete method, TTI media, Numerical dispersion, Parallel computing

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