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Biot流动和喷射流动耦合作用下波传播的FCT紧致差分模拟

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FCT compact difference simulation of wave propagation based on the Biot and the squirt-flow coupling interaction

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摘要 本文从含流体多孔隙介质中同时包含Biot流动和喷射流动两种力学机制的BISQ (Biot-Squirt)方程出发, 利用FCT (Flux-Corrected Transport)紧致差分方法数值模拟了在Biot流和喷射流共同作用下的波在含流体多孔隙各向同性介质中的传播. 通过与仅受Biot流动作用下的波场结果对比, 我们研究了耗散系数*b*和慢P波速度以及能量衰减之间的关系. 同时, 本文也研究了波在双层双相孔隙介质中的传播规律. 数值结果表明, 由于喷射流动的影响, Biot流动和喷射流动共同作用下的快P波传播速度比仅受Biot流动影响下的快P波传播速度慢、慢P波衰减得更快, 表明具有局部特征的喷射流动对压缩波的衰减和频散具有重要影响;而对于剪切波, 两种模型得到的剪切波速几乎一致, 说明在各向同性情况下喷射流对剪切波的影响不明显. 这一结果与波衰减和频散的理论分析结果一致, 同时本文结果也表明FCT紧致差分方法能有效压制粗网格条件下模拟弹性波场所引起的数值频散以及源噪声, 适合于双相孔隙介质中的弹性波场模拟.

关键词: BISQ方程 Biot方程 波场模拟 FCT紧致差分方法

Abstract: In this paper, the wave-fields simulation based on the general BISQ equation which combines the Biot and squirt-flow mechanism in the isotropic medium is performed by using the FCT (Flux-corrected transport) compact difference method. We study the relationship between the dissipation coefficient *b*, the velocity and the energy attenuation of the slow quasi P-wave by comparing to the wave field snapshots generated by BISQ model and Biot equations, respectively. We also investigate the characteristics of wave propagation in the two-layer two-phase porous medium. Numerical results show that, relative to the Biot model, the fast quasi P-wave propagates slower and the energy attenuates faster in the BISQ model. The numerical results also imply that the squirt-flow which has local character affects the compression wave dispersion and attenuation significantly. For the shear wave, these two models have almost same results which show that the squirt flow has little efftect on shear wave. All of these are consistent with the theoretical analysis. It also indicates clearly that the FCT compact difference method can suppress the numerical dispersion and the source noise effectively. It is suitable for the elastic wave field simulation in the two-phase porous media.

Keywords: BISQ equation Biot's equation wave-fields simulation FCT compact difference scheme

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