Biot-Gassmann Fluid Term Extraction Based on PP-PS Joint Inversion

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Abstract

Biot-Gassmann fluid term is an important elastic parameter that can be derived from prestack seismic inversion and subsequently used to geological characterization and reservoir prediction. Conventionally, the fluid term estimated indirectly from velocity and density data according to well-established petrophysical relationships or computed directly from the approximate equations. However, the former approach can introduce uncertainties in the calculation of fluid term because of accumulated biases and the difficulty of calculating density. The latter approach can also generate uncertainties, because the inversion method based on the approximate equations has poor performance with regards to utilizing far offset seismic amplitude information. And these methods are all based on PP-wave data. However, the method of inversion using only PP-wave data will reduce the accuracy of the inversion results to some extent. Therefore, the novel method based on exact Zoeppritz equations and PP-PS data is applied to obtain more stable and accurate value of fluid term, with no need for density information from seismic data. Firstly, poroelasticity theory is applied to express the Biot-Gassmann fluid term as a function of P and S-wave modulus. The introduction of modulus makes the derivation physically meaningful and natural. Then, a set of new forms of exact equations in terms of P and S-wave modulus are derived. Furthermore, Bayesian theory and double constraints are introduced to construct the objective function. The double constraints include the Trivariate Cauchy distribution constraint and the modified low-frequency constraint. The Trivariate Cauchy constraint can improve vertical resolution of inversion results. The modified low-frequency constraint can obtain more reliable low-frequency information without reducing the resolution of inversion results. The objective function is complicated. The ideas of generalized linear inversion and the iterative reweighed least-squares algorithm are applied to solve this function. Tests with synthetic data show that the inverted fluid term of the proposed method is still reasonable in moderate noise condition. Tests with field data show that the inverted results agree well with well-logging data.

Key words: Biot-Gassmann fluid term, PP-PS joint inversion, Bayesian theory, P and S-wave modulus, reservoir characterization

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