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基于离散余弦变换的集合Kalman滤波方法对河流相油藏渗透率场的反演

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Inverse of the fluvial channel reservoir permeability field using ensemble Kalman filter based on discrete cosine transform

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摘要

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摘要 针对河流相油藏参数场的非高斯性及油藏生产数据与地质模型之间的非线性关系,提出了耦合离散余弦变换的半迭代集合Kalman滤波方法对河流相油藏进行生产历史拟合及反演.将河流相油藏非高斯渗透率场利用离散余弦变换变为类似高斯分布的DCT(Discrete cosine transform)系数,利用能量压缩特性对DCT系数进行截断,使得反演渗透率场的分布变得光滑,较好地解决了河流相油藏的非高斯分布问题.半迭代集合Kalman滤波法很好地解决了油藏生产数据与地质模型之间的非线性问题.理论证明了半迭代集合Kalman滤波与EnRML方法的等效性.比较了标准EnKF、耦合DCT的EnKF及耦合DCT的半迭代EnKF法对河流相油藏渗透率场的反演.讨论了DCT系数保留模式及系数保留数量对耦合DCT的半迭代集合Kalman滤波方法反演结果的影响,结果表明三角形系数保留模式可以用更少的系数保留参数场的地质特征,当保留2.5%的DCT系数时,反演结果已经充分反映了河流相油藏的地质特征.

关键词: 离散余弦变换 集合Kalman滤波 河流相 历史拟合 反演

Abstract: Focusing on the non-Gaussian distribution of the field and the nonlinearity between the production data and the reservoir model of the fluvial channel reservoir, the HIEnKF method coupling discrete cosine transform was used to invert for the fluvial channel reservoir model by automatic history matching method. The non-Gaussian permeability field is transformed to nearly Gaussian distributed DCT coefficient by discrete cosine transform. DCT exhibits excellent energy compaction for highly correlated images. The estimated permeability field is smoother if the low frequency DCT coefficients are retained. The non-Gaussian problem of the fluvial channel reservoir can be solved by the discrete cosine transform. The HIEnKF method can solve the nonlinearity of the production data and the reservoir model. The equivalence of the HIEnKF to EnRML is proved theoretically. The results of standard EnKF, standard EnKF coupling with DCT and HIEnKF coupling with DCT were compared. The effects of retained mode and the retained number of the DCT coefficients were discussed. The results show that less DCT coefficients need to be retained to capture the geological structure when the triangular area mode was used to truncate the coefficients. The estimated results can get the main geological structure of the fluvial channel reservoir when only 2.5% DCT coefficients were retained.

Keywords: Discrete cosine transform Ensemble Kalman filter Fluvial channel History matching Inverse

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