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基于渗透率连续变化的低渗透多孔介质非线性渗流模型

Model of nonlinear seepage flow in low-permeability porous media based on the permeability gradual recovery

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英文关键词:Douglas-Jones predictor-corrector finite different method low-permeability porous media nonlinear flow threshold pressure gradient numerical solution

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中文摘要:

基于低渗透多孔介质渗透率的渐变理论,确定了能精确描述低渗透多孔介质渗流特征的非线性运动方程,并通过实验数据拟合,验证了非线性运动方程的有效性。非线性渗流速度关于压力梯度具有连续一阶导数,方便于工程计算;由此建立了低渗透多孔介质的单相非线性径向渗流数学模型,并巧妙采用高效的Douglas-Jones预估-校正有限差分方法求得了其数值解。数值结果分析表明:非线性渗流模型为介于拟线性渗流模型和达西渗流模型之间的一种中间模型或理想模型,非线性渗流模型和拟线性渗流模型均存在动边界;拟线性渗流高估了启动压力梯度的影响,使得动边界的移动速度比实际情况慢得多;非线性越强,地层压力下降的范围越小,地层压力梯度越陡峭,影响地层压力的敏感性减弱,而影响地层压力梯度的敏感性增强。

英文摘要:

According to the theory of gradual recovery of the permeability in low-permeability porous media,the nonlinear kinematic equation was formulated.It can accurately depict the seepage flow behavior in low-permeability porous media.Through experimental data fitting,the validity of the nonlinear kinematic equation was verified.Its nonlinear seepage velocity with respect to the pressure gradient has continuous first-order derivative,which is very convenient for the engineering computation.Then the mathematical model of the single-phase nonlinear radial flow in low-permeability porous media was established.The efficient Douglas-Jones Predictor-Corrector finite difference method was adopted masterly to obtain its numerical solution.Analysis on numerical results shows that the nonlinear flow model can be considered as the intermediate model or the optimal model between Darcy flow and pseudo-linear flow models; there exists moving boundaries in the models of nonlinear flow and pseudo-linear flow; pseudo-linear flow model overestimates the effect of the threshold pressure gradient,which makes the moving boundary moves more slowly than the actual situation; the stronger the nonlinearity,the smaller the area of the formation pressure drop,the sharper the formation pressure gradient,the weaker the sensitivity of the effect on the formation pressure,and the stronger the sensitivity of the effect on the formation pressure gradient.

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