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气侵过程井筒压力演变规律实验和模型

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Experimental simulation and numerical modeling of dynamic variations in wellbore pressure during gas-kicks

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摘要

储层钻进时,由于地层压力预测不准造成地层气体侵入井筒,形成不稳定气-液两相流并导致井筒内压力剧烈变化,产生巨大的井控风险.为了揭示气侵过程井筒压力的演变规律,利用大型实验架进行了可视化模拟实验,测量气侵过程井筒压力变化,观察管内流动物理特征.将该过程简化为液体循环条件下垂直同心环形管管底连续注气过程,并基于非稳态流动理论和漂移模型建立了井筒气-液两相流动瞬态预测模型.该模型具有跟踪气-液界面等流动参数的功能,可采用半隐式有限差分法数值求解.实验数据分析表明:随着管底开始注气,管内压力先增大再减小;管路下部比上部先达到压力峰值,压力波动程度随着管深的增加而减小.模型数值仿真结果与实验数据吻合程度较高,证明了模型可用于预测气侵过程井筒流体瞬态流动特征.研究成果深化了对气侵过程井筒压力演变规律的认识,丰富了复杂工况钻井的水力学模型.

关键词 : 垂直同心环形管, 气侵, 气-液两相流, 漂移模型, 瞬态流动模型

Abstract :

During the process of reservoir drilling, inaccurate pressure prediction can cause gas kicks, which will result in transient gas-liquid two-phase flow and lead to dramatic variations in wellbore pressure, significantly raising well control risks. This study aimed to reveal the evolution pattern of wellbore pressure during gas kicks. Visualization simulation was conducted using a large-scale experimental system to measure the variations in wellbore pressure and observe the physical characteristics of annular flow during gas kicks. This engineering process was then simplified into a continuous injection process at the bottom of a vertical concentric annular tube under liquid circulation. A transient two-phase flow prediction model was further developed based on transient flow theory and drift flux model to simulate the simplified process. The established model capable of tracking flow parameters (e.g., location of gas-liquid interface) was numerically solved using the semi-implicit finite difference algorithm. The experimental data show that when gas injection starts from the bottom, annular pressure first increases and then decreases. Peak pressure occurs in the lower part earlier than in the upper part of the annular tube, and the extent of pressure variation decreases with increasing depth. High coincidence between the simulation and experimental data indicates that the developed model can be used to predict the characteristics of transient flow in the wellbore during gas kicks. The results further the understanding about the evolution of wellbore pressure during gas kicks and diversify hydraulic models of drilling under complex conditions.

Key words : vertical concentric annular tube gas kick gas-liquid two-phase flow drift flux model transient flow model

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