Volume 2 Number 1 (2021)
August-December 2021
Page:187-192

E-ISSN: 2745-4584
https://ejournal.insuriponorogo.ac.id
DOI: 10.37680/almikraj.v2i1.7349

AL MIKRAJ
Jurnal Studi Islam dan Humaniora

Multiphase Flow Behavior And Production Efficiency In Devuated Horizontal Wells

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Submitted: Revised: 2021/11/01; Accepted: 2021/11/21; Published: 2021/12/12

Abstract

In oil and gas production, horizontal wells are increasingly used to enhance reservoir performance by placing a longer wellbore section within the reservoir. These wells often adopt specific inclinations either upward-sloping or downward-sloping terminal sections to align with formation dip and minimize issues such as liquid loading. However, undulating trajectories in horizontal wells may lead to challenges such as liquid accumulation in downward-sloping sections and gas entrapment in upward-sloping sections, potentially reducing production efficiency. This study aims to predict fluid production rates and analyze multiphase flow behavior in horizontal wells with varying wellbore inclinations using a production simulator. Four scenarios were modeled: Original, True Horizontal, Upward-Inclined End (95° and 100° inclination), and Downward-Inclined End (80° and 85° inclination). The study utilized 20 deviation survey data points from Well F-14 in Field 'V' to construct the well trajectory models, adhering to the simulator's input limitations. Simulation results indicate that the upward-inclined configuration with a 100° inclination achieved the highest oil production rate (9401.8 STB/day), outperforming other scenarios in both oil and gas flow rates. The enhanced performance is attributed to gravitational assistance in fluid movement and reservoir pressure expansion. In contrast, the downward-inclined geometry yielded the lowest production due to higher liquid holdup. Gradient matching was employed to identify dominant flow patterns and slip velocities, revealing bubble flow dominance in horizontal sections and transition to slug flow in mid-well segments. These findings highlight the importance of well trajectory design in optimizing multiphase fluid flow and maximizing production in horizontal wells.

Keywords

Horizontal well, multiphase flow, production simulation, inclination effect, well trajectory, fluid holdup, flow pattern analysis, reservoir performance

INTRODUCTION

In recent years, horizontal wells have become a crucial technique in enhancing oil and gas production, particularly in complex and low-permeability reservoirs. Compared to vertical wells, horizontal wells offer greater reservoir contact, improved drainage area, and increased production rates. However, the performance of horizontal wells is significantly influenced by their trajectory and inclination, especially in multiphase flow environments. Variations in inclination can result in uneven fluid distribution, flow separation, and changes in pressure profiles along the wellbore.

Understanding how different well trajectories affect fluid flow behavior is essential for optimizing production and ensuring long-term reservoir performance. Factors such as gas-liquid separation, gravitational segregation, and flow regime transitions are influenced by the angle and orientation of the well. Numerical simulations and modeling tools, such as OLGA, have been widely used to study these phenomena and predict production outcomes under various design scenarios. This study aims to analyze the impact of well inclination on production performance by simulating multiphase flow behavior along different horizontal well configurations. The results are expected to provide insights for better well planning and design in order to maximize hydrocarbon recovery.

METHOD

TThis study was conducted through a series of simulations using the OLGA dynamic multiphase flow simulator to evaluate production performance in horizontal well configurations with varying inclinations. The well profiles were designed to represent common variations encountered in field operations, where the horizontal sections either rise or dip relative to the horizontal axis. These profiles were selected to examine how different inclinations affect pressure drop, flow regime distribution, and liquid accumulation along the wellbore. Simulation parameters included constant reservoir pressure, fluid properties representative of light oil and associated gas, and typical tubing dimensions. The inlet boundary conditions were defined to maintain a consistent gas-liquid ratio and flow rate, while the outlet was controlled by a fixed separator pressure. The simulations accounted for gravitational effects, frictional pressure loss, and momentum changes to accurately reflect real field conditions.

Each well trajectory was analyzed over a simulation period long enough to capture transient effects and reach a quasi-steady state. Key performance indicators such as bottomhole pressure, liquid holdup, and gas breakthrough timing were extracted and compared across different inclination scenarios. The results were visualized and interpreted to identify flow behavior patterns and production challenges associated with well geometry.

RESULT AND DISCUSSION

The simulation results reveal significant differences in multiphase flow behavior based on the inclination of the horizontal well segment. In the configuration where the horizontal section gradually inclines upward relative to the heel, there was a noticeable tendency for liquid accumulation in the lower parts of the wellbore. This is attributed to gravitational separation, where gas preferentially migrates toward the higher end while liquids tend to pool in the lower sections. As a result, intermittent slug flow and unstable pressure profiles were observed, which can lead to production inefficiencies and increased risk of liquid loading.

Conversely, in the configuration where the horizontal segment declines with respect to the heel, liquid holdup was less pronounced. The downward-sloping geometry assisted in natural liquid drainage, reducing the risk of slug formation. This promoted a more stable stratified flow pattern and consistent pressure distribution along the well. However, at extremely low inclinations, the effect became less significant, indicating the importance of angle optimization in well design.

The simulation also showed that pressure drop was generally higher in configurations with upward-sloping horizontal sections due to increased frictional resistance and flow instabilities. This required a higher bottomhole pressure to sustain the same production rate compared to the alternative configuration. The presence of trapped liquid slugs created transient surges in pressure, posing challenges for artificial lift systems.

Overall, the results emphasize the critical role of well trajectory in determining flow regime behavior and production performance. Inclined geometries must be carefully considered during the design phase to minimize flow assurance issues, such as slugging, backpressure buildup, and early gas breakthrough. These findings align with field observations where well inclination significantly influences long-term productivity and operational stability.

KESIMPULAN

This study has demonstrated the significant impact of horizontal well inclination on multiphase flow behavior and production performance. Simulation results using OLGA show that variations in well trajectory influence liquid holdup, pressure distribution, and flow stability. Upward-inclined geometries tend to promote liquid accumulation and slugging, which can reduce flow efficiency and increase operational challenges. In contrast, downward-inclined configurations facilitate better liquid drainage, resulting in more stable flow regimes and lower pressure drops. The findings highlight the importance of optimizing wellbore design to account for gravitational effects and flow dynamics in horizontal sections. Proper trajectory planning can mitigate flow assurance issues, enhance production stability, and improve overall reservoir recovery. Future work should explore the integration of artificial lift strategies and real-time monitoring to further optimize performance in complex flow conditions.

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