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Simulation Thermo-Hydraulic of an Onshore Gas Production Well

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Abstract

This study focuses on comprehending the thermo-hydraulic behavior of a Brazilian onshore gas production well under real operational conditions. The Multiflash software generated the PVT table based on the recombined fluid from a Gas-Condensate Ratio of 40000 sm³/sm³ and considering a water-cut of 51%. Further, the Peng-Robinson cubic equation of state with Peneloux volume translation, classical mixture rules, and Pedersen's viscosity model were applied to the PVT model. The gas well's three-phase flow and heat transfer were modeled through the 1D dynamic multiphase flow simulator, ALFAsim. A tubing of 2469 meters long and an internal diameter of 2.375 inches was considered to build the flow mesh. For the top boundary condition, a pressure of 71.58 kgf/cm² and a temperature of 311.32 K were adopted. The bottom boundary condition assumed a reservoir with a pressure of 144.11 kgf/cm², a temperature of 365.51 K, and a productivity index of 1730 sm³/d/kgf/cm². In the first two hours, the simulation reached steady, presenting the gas, oil, and water volumetric flow rates at the wellhead of 78686 sm³/d, 1.832 sm³/d, and 1.970 sm³/d, respectively. When compared to the field's data, the results showed an error of less than 2%.

Keywords

PVT Characterization; Multiphase Flow; Transient simulation.

Introduction

Operational efficiency is vital for production's technical and economic viability in mature fields. Production optimization, achieved through studies of Enhanced Oil Recovery (EOR), multiphase flow, and flow assurance, is crucial in reducing Operational Costs (OPEX) and maximizing oil and gas production[1]. Analyses depend on fluid characterization, well configuration, and operational conditions. The dynamic thermo-hydraulic profile under operational conditions is obtained through simulations, which is highly relevant for determining whether a natural wellbore flow occurs or if an artificial lift method would be necessary. However, in mature fields, fluid characterization and flow analysis are usually scarce, and the data provided is often old and no longer matches the current situation of the well[2]. Therefore, this study primarily focuses on comprehending the thermo-hydraulic behavior of an onshore gas well, particularly under real operational conditions, to contribute to the best production operational practices.

Methodology

The methodology was performed in two steps: the fluid's PVT characterization and the thermo-hydraulic transient simulation of the flow in the well.

Fluid Characterization

The recombined mixture used in this study is designated as "RJ". It represents the reservoir's fluid where the gas well is under surgency analysis. The Multiflash software was used to obtain the RJ fluid's recombination composition. The gas and condensate samples obtained at the test separator and used in recombination simulation present specific densities of 0.6595 and 0.7471, respectively, and a Gas-Condensate Ratio (GCR) of 40000 sm³/sm³ at the conditions of the test separator: 7.12 kgf/cm² and 311.12 K. Figure 1 shows the gas and condensate chromatography obtained under test separator conditions and the fluid recombination obtained through the simulation.

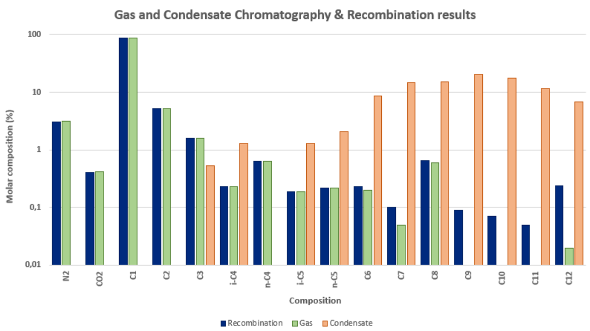

Figure 1 – Gas and Condensate chromatography & recombination results.

Based on the gas well's production period considered in this study, the water cut (WC) identified from the production tests was 51%. It fields a Gas-Liquid Ratio (GLR) of 19397.14 sm³/sm³.

PVT Model
The Peng-Robinson 78 cubic equation of state, considering Peneloux volume translation, classical mixing rules, Pedersen's viscosity model, and LBC thermal conductivity model, was defined at Multiflash to calculate the phase equilibrium and PVT properties[3]. The three-phase PVT table was simulated for the PT operating range from 273 K to 400 K for temperature and from 1 kgf/cm² to 300 kgf/cm² for pressure.

IPR Curve
The IPR curve in this study was built using the Fetkovich model, available in the simulator Petro-IPR[4], since it is appropriate for a gas-saturated reservoir. This model depends on the reservoir and bottom-hole pressure, as well as two adjustable parameters, C and n. Once these parameters are unknown, it is necessary to determine them using data from production tests.

Table 1 – Field production tests.

Tests	P_{wf} (kgf/cm²)	Q_{sc} (sm³/d)
1	99.00	62313
2	94.35	74890
3	87.74	83148
4	84.47	88055
5	82.02	86112

Then, using the tests 2 and 3 from Table 1, the value for adjustable parameters, C and n are 2.89 and 1.08, respectively. Besides, the PI value obtained was 1730 sm³/d/kgf/cm².

Production System
The multiphase flow and heat transfer modeling and simulation in the gas well were performed using the 1D dynamic multiphase flow simulator, ALFAsim[5]. The production system considered in this study contains a vertical well with surface, intermediate, and production casings. Further, the tubing is 2469 meters long and has an internal diameter of 2.375 inches. The PVT model was configured with the generated PVT table previously in Multiflash. For the top boundary condition, the pressure condition was used with a pressure of 71.58 kgf/cm² and a temperature of 311.32 K. For the bottom boundary condition, considered a reservoir with a pressure of 144.11 kgf/cm², a temperature of 365.51 K, and productivity index of 1730 m³/d/kgf/cm². Figure 2 illustrates the geometric schematic of the RJ well.

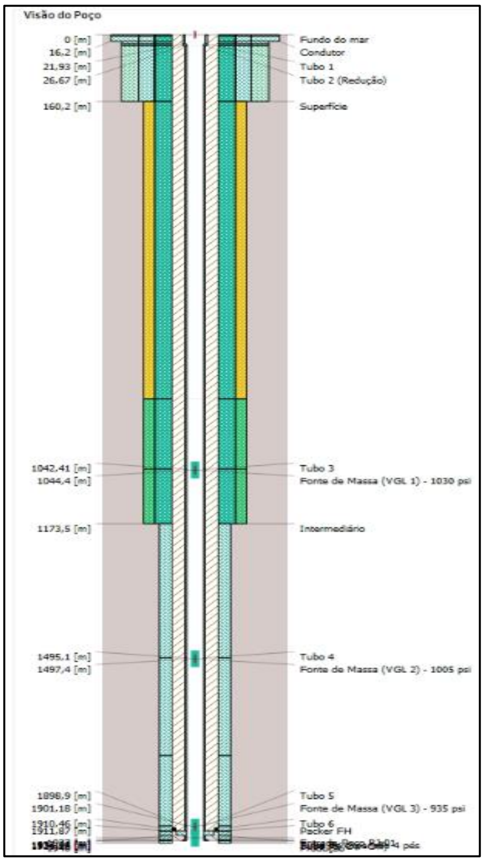

Figure 2 – Geometric schematic of the RJ well.

Results and Discussion
Figure 3 presents the phase envelope of the RJ fluid, which is composed only of the dew curve. In addition, the phase envelope also shows the pressure and temperature (PT) conditions of the reservoir (144.11 kgf/cm² and 365.11 K) and the wellhead (71 kgf/cm² and 311.32 K).

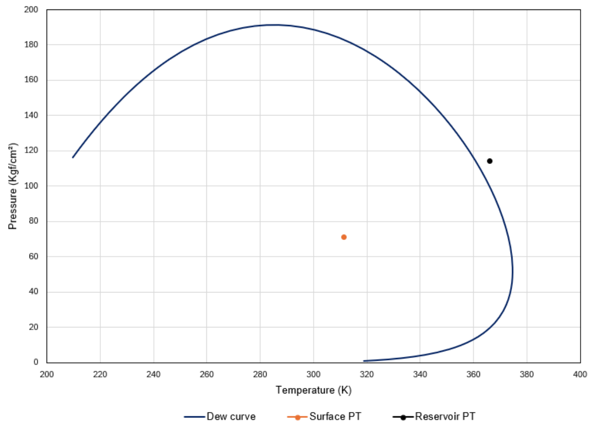

Figure 3 - Phase envelope and field conditions for the fluid RJ.

At the reservoir temperature (365.51 K), the RJ fluid has a dew point of 102.1 kgf/cm² and is in a single-phase condition near the saturation point. On the wellhead conditions, the RJ fluid is indicated by the orange dot inside of the two-phase region due to the condensate formation (1.5%). These conditions imply the occurrence of multiphase flow along the production column.

The simulation of the IPR curve and the study of the thermo-hydraulic behavior of the RJ well were based on verifying the natural upwelling and suggesting improvements in the operating conditions to obtain a better cost-benefit ratio. Figure 4 illustrates the IPR curve obtained for the RJ well.

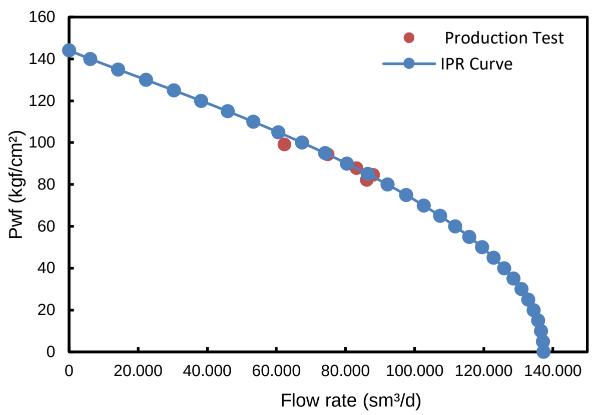

Figure 4 - IPR curve using the Fetkovich model.

The IPR curve's behavior shows a curved section derived from the characteristic of a saturated reservoir in which the production index is not constant. Notably, the production tests are very close to the IPR curve, and the AOF value is 137.297·10³ sm³/d.

The production flow rates in the wellhead condition were simulated using the ALFAsim based on the production system described in the previous section. Thus, it is possible to evaluate the behavior of these variables when compared with the real field data found in the well tests and the values presented in the IPR curve. Figure 5 illustrates the volumetric flow rate curves of the gas, oil, and water phases simulated at the wellhead condition during the four-day (96h) simulation period.

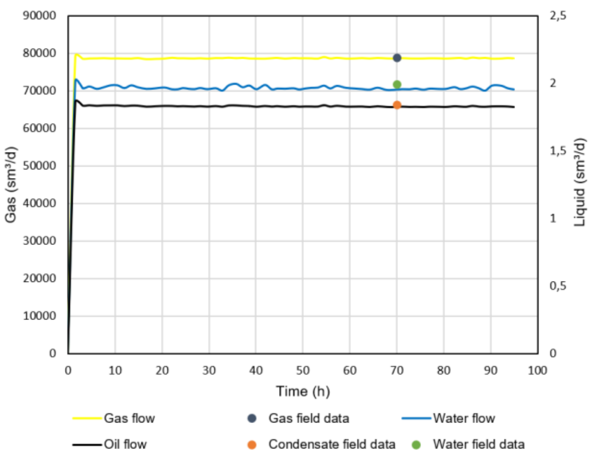

Figure 5 - Volumetric flow rate of gas, oil, and water phases.

Analyzing the flow rate curves, the three-phase fluid reaches the surface in less than 2 hours of simulation, confirming the well's natural elevation. In addition, the simulation reached a steady state. Therefore, the RJ well remains with fluid upwelling to the surface during the simulation. Table 2 compares the simulated volumetric flows, the values obtained from the field, and the mean relative absolute error.

Table 2 - Comparison of the simulated flow rate concerning field values and the errors.

Fluid	Q – Field Data (sm³/d)	Q – Study Case (sm³/d)	Error (%)
Gas	78903	78686	0.275
Oil	1.845	1.832	0.747
Water	1.994	1.970	1.203

Therefore, the simulation of the multiphase flow of the RJ well is validated with the volumetric flows, in which the error obtained between the field data and the simulations is below 2%. That is, the simulation results are representative of the real scenario. The Figure 6 illustrates the Thermo-hydraulic profile from RJ well.

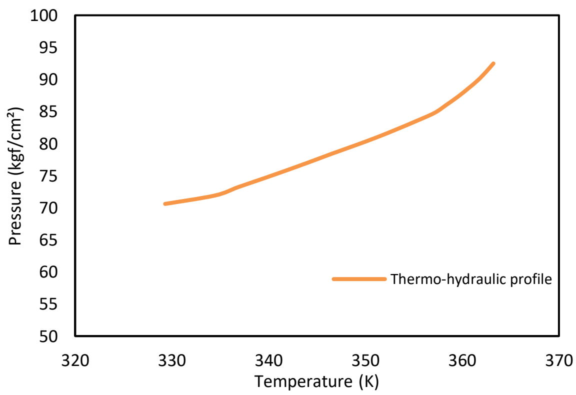

Figure 6 – Thermo-Hydraulic profile simulated for the RJ well.

In Figure 6, for the wellhead, the pressure achieved was 70.6 kgf/cm² and a temperature of 329.30 K. For the bottomhole, the results obtained for pressure and temperature were 92.49 kgf/cm² and 362.22 K, respectively. These values are in agreement with the operational conditions observed in the field.

Conclusions

The present study successfully investigated the thermo-hydraulic behavior of the RJ well under real operational conditions since the fluid's PVT characterization and the well's operational condition simulations.

This study plays a fundamental role in the gas industry as it identifies ways to increase efficiency in gas well production. By understanding the fluid in reservoir conditions and the behavior of gas, oil, and water production, the operation time can optimize production conditions, minimize flow assurance risks, and reduce operational costs.

The simulation was generated to analyze the well surgency based on real field data. In the next steps, this study will investigate the influence of the choke valve opening and the rate of liquid accumulation in the production column.

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Responsibility Notice

The authors R. R. Araújo Júnior, B. Parizotto, and A. M. Barbosa Neto are the only ones responsible for the printed material included in this paper.

References

[1] DANTAS, S; PESSOA, A. *Estudo sobre os métodos de recuperação de campos maduros onshore*. [s. l.], n. c, p. 8–11, 2020.

[2] GUO, BOYUN; LYONS, WILLIAM; GHALAMBOR, Ali. Petroleum Production Engineering, A computer Assisted Approach. [S. l.]: Elsevier Science & Technologu Bookds, 2007.

[3] PEDERSEN, K.; CHRISTENSEN, P.; SHAIKH, J. Phase Behavior of Petroleum Reservoir Fluids. Second ed. New York: CRC Press, 2015.

[4] Araújo Júnior, R. R.; Heyde, H. H., Barbosa Neto, A. M. (2022) Development of a simulator for Inflow Performance Relationship analysis. Rio Oil and Gas Expo and Conference, article 283, doi: 10.48072/2525-7579.rog.2022.283.

[5] ESSS. Technical Manual - ALFAsim artificial lift and flow assurance simulator. [s. l.], p. 45, 2019.