Combination of Acid, Gas and Drilling Fluid Flow Multiphase Flow Behavior in Vertical Wellbore

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Abstract

For the hydraulic parameter design and wellbore pressure management in acid gas field drillings, the transition laws of multiphase flow in a wellbore during acid-gas mixture input are crucial. It can be complicated and difficult to appropriately predict the behavior of multiphase flow for an acid-gas combination and drilling fluid flow in a vertical wellbore. But there are some broad conclusions that may be drawn. A precise wellbore temperature and pressure are required for the acid-gas mixture to be in the supercritical phase, which results in drastic changes to the mixture's physical properties near to the critical point, claims the research. Additionally, the supercritical-liquid two phase flow, liquid-liquid two phase flow, liquid-liquid two phase flow, and gas-liquid two phase flow are all possible passageways for the multiphase flow in turn as the combined fluids rise from the bottom hole to the wellhead. Methods for calculating friction factors, drift flux models, and flow transition criteria have all been offered for this type of multiphase flow.

Keywords: Drift flux, Well bore

I. Introduction

Acid-gas mixtures are typically composed of Further gases include hydrogen sulphide and carbon dioxide. Injecting such gases into a wellbore, they can dissolve in the formation fluids, resulting in a change in the fluid composition and properties. This can affect the behavior of the wellbore's multiphase flow. Drilling fluids, on the other hand, are typically composed of a mixture of water, clay, and other additives, and are used to cool and lubricate the drill bit during drilling operations. When drilling fluids are circulated through the wellbore, they can encounter various formations with different properties, this may have an impact on how the multiphase flow behaves[1, 2]

One of the crucial elements that can affect the behavior of a wellbore's multiphase flow is the flow rate. At low flow rates, flow in distinct layers, with the acid-gas mixture at the top and the drilling fluid at the bottom. However, at higher flow rates, the fluids can become mixed, resulting in a more complex flow pattern. Another factor that can affect the performance of multiphase flow is the geometry of the wellbore. In a vertical wellbore, the fluids may experience gravity effects, which can result in stratification or slug flow. The presence of obstructions, such as casing or perforations, can also affect the flow pattern.[3] Overall, how drilling fluid flows in a vertical wellbore and how multiphase flow behaves for an acid-gas combination can be highly variable and dependent on many factors. Modeling and understanding the behavior of these fluids can be critical for optimizing well performance and minimizing the risk of equipment failure.

Underbalanced drilling technology has consistently advanced for enhancing drilling efficiency and minimizing engineering for drilling forming pollution. Wellbore multiphase flows with formation oil, gas, water, and drilling fluid, are inevitable as a result of the unbalanced drilling operations.[4] This has a crucial effect on the design of the drilling hydraulic parameters as well as the control of the wellbore pressure. More and more foreign experts are becoming interested in the transition rules for multiphase flow patterns. One of the early theories on the change in flow pattern attributes the change in flow pattern to the instability of the void fraction wave rather than the bubble coalescence[5]. Researchers split the flow patterns in an experimental study of the rules of two-phase gas-liquid flow in a vertical annular tube. There was a general consensus that their flow patterns resembled those of a vertical circular tube. But out of all of them, the four types of flow known as annular, bubbly, slug, and churn flow are the most often employed for drilling wells.

As more gas reservoirs with high CO_2 or H_2S content have been drilled for oil and gas exploration in recent years, a supercritical acid-gas combination may have invaded the bottom hole, that is distinct from air or CH_4. . Researchers were concerned about the supercritical CO_2 and H_2S in well drilling following the Chongqing "12.23" gas explosion in China in 2003. However, no earlier studies have examined how supercritical fluids affect the transition of the multiphase flow pattern in a vertical wellbore[6]. The traditional approach relies solely on gas-liquid two-phase flow for the wellbore multiphase flow simulation, which may result in significant data errors for the flow of drilling fluid and the acid-gas mixture. As a result, it is crucial to consider the multiphase flow behaviour of the acid-gas combination and drilling fluid flow in a vertical wellbore while designing the hydraulic parameters and maintaining the wellbore pressure in acid gas field drillings. This paper examined the behaviour of multiphase flows in wellbores and offered methods for calculating the transition threshold and friction factor. First, the phase transition of the acid-gas mixture was investigated to show how it changed under certain pressure and temperature circumstances in wellbores. The features of multiphase flow in a wellbore during the inflow of an acid-gas combination were then examined.[7]

II. Acid-Gas Combination Phase Transition in Wellbore

In a wellbore, an acid-gas combination can undergo phase transition due to changes in temperature and pressure as the mixture flows through the wellbore. The acid-gas mixture typically consists of carbon dioxide gas hydrogen sulfide and other gases, which can have different vapor pressures and boiling points. When the acid-gas mixture encounters a lower pressure zone in the wellbore, such as near the surface, the lower pressure can cause some of the gases in the mixture to vaporize or "flash." As a result, the mixture's structure may alter, and gas bubbles may emerge in the liquid phase. Conversely, when the acid-gas mixture encounters a higher pressure zone in the wellbore, such as in deeper sections of the well, the higher pressure can cause some of the gases in the mixture to dissolve into the liquid phase.[8] This can result in a change in the composition of the mixture and the formation of liquid droplets within the gas phase. The temperature of the wellbore can also play a role in phase change. When the temperature of the acid-gas mixture drops below its dew point temperature, the gas phase can condense into a liquid phase. Conversely, when the temperature of the mixture rises above its boiling point temperature, the liquid phase can vaporize into a gas phase. Phase change can have significant implications for the behavior of the acid-gas mixture in the wellbore, including the formation of gas bubbles or liquid droplets, changes in the fluid properties, and alterations to the flow pattern[9]. Understanding and modeling the phase behavior of an acid-gas mixture in a wellbore is essential for optimizing well performance and ensuring safe and efficient operations.[10]

III. Acid and gas combination using a multiphase flow type

The multiphase flow type for drilling fluid flow and an acid-gas combination in a wellbore can depend on the flow rates, properties of the fluids, and the geometry of the wellbore[11]. In general, the two main types of multiphase flow are stratified flow and slug flow. When the fluids move there is stratified flow in distinct layers or streams, with each phase occupying a separate portion of the wellbore. At low flow rates drilling fluid, the acid-gas combination, may flow in distinct layers, with the combination of gas and acid at the top and the drilling oil underneath. However, at higher flow rates, the fluids can become mixed, resulting in a more complex flow pattern. Slug flow occurs when large gas bubbles or slugs of liquid alternate with smaller bubbles or liquid streams. This type of flow is more difficult to model, as the behavior of the fluids can be highly dynamic and unpredictable. Slug flow can occur in the wellbore when the gas or liquid phase is dominant, and the other phase is present in the form of intermittent slugs.[12]

The actions of a drilling fluid and an acid-gas combination in a wellbore can also depend on the geometry of the wellbore[13]. In a vertical wellbore, the fluids may experience gravity effects, which can result in stratification or slug flow. The presence of obstructions, such as casing or perforations, can also affect the flow pattern. Overall, the Multiphase flow type for movement of drilling fluid inside a wellbore and an acid-gas combination can be highly variable and dependent on many factors. Understanding the behavior of these fluids can be critical for optimizing well performance and minimizing the risk of equipment failure.[14]

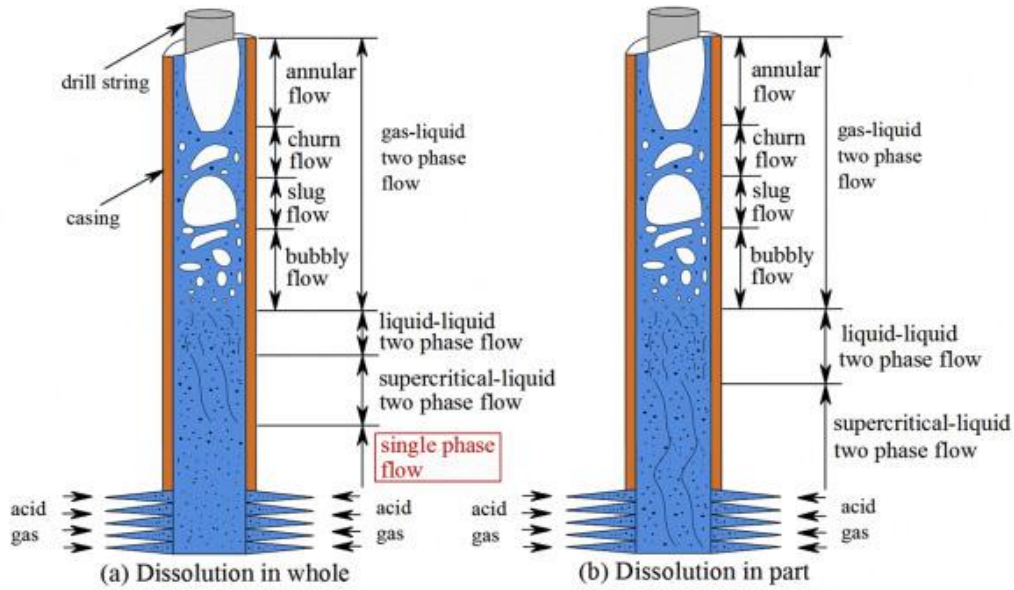

Figure. 1 Multiphase flow types in Vertical Wellbore

IV. Criteria for Multiphase Flow Transition

Multiphase flow transition criteria are the conditions at which the flow regime of two or more fluids changes from one type to another. These conditions depend on a number of factors, such as the fluid properties, flow rates, and the geometry of the pipe or wellbore.[15]

Single phase flow

Single phase flow refers to the flow of a single fluid, typically either a liquid or a gas, through a pipeline or wellbore. In single-phase flow, the properties of the fluid, such as density, viscosity, and velocity, remain constant throughout the flow[16]. The behavior of single-phase flow can be described by the equations of fluid mechanics, which relate the pressure, velocity, and other properties of the fluid to the geometry of the pipe or wellbore and the boundary conditions at the inlet and outlet[17]. In general, single-phase flow is smooth and continuous, with a laminar or turbulent flow pattern depending on the Reynolds number.[18]

The ratio of inertial forces to viscous forces in a fluid is described by the Reynolds number, a dimensionless quantity. When the Reynolds number is low, the fluid travels in smooth layers with little mixing in between when the flow is laminar. When the Reynolds number is high, the fluid is moving in turbulent, chaotic, and erratic patterns with significant mixing. Many industrial applications, such as water distribution systems, chemical processing facilities, and oil and gas pipelines, use single-phase flow. Understanding the behavior of single-phase flow is essential for designing and operating these systems efficiently and safely.

V. CONCLUSION

The behavior of the the mix of acid and gas in the drilling fluid flow in a vertical wellbore is complex and can be influenced by several factors. In the case of an acid-gas mixture, the acid gas can dissolve in the drilling fluid undergoes changes in fluid characteristics as a result, such as viscosity and density, and leading to changes in the flow regime. The acid gas can also react with the rock formation, causing corrosion and potentially damaging the wellbore. The phase transition of acid and gas combination in a wellbore can occur due to changes in temperature, pressure, and the concentration of acid and gas in the drilling fluid. The phase transition can cause changes in the fluid properties, such as density and viscosity, and can lead to changes in the flow regime. Understanding the behavior of combination of acid and gas in drilling fluid flow is crucial for optimizing wellbore operations, reducing costs, and minimizing damage to the wellbore and formation. To address these challenges, numerical simulations, experimental studies, and field measurements can be used to understand the behavior of acid-gas mixture. Proper modeling and analysis can help optimize wellbore design, reduce risk, and improve the efficiency and safety of drilling operations.

References

[1] Y. Liu, T. A. Tong, E. Ozbayoglu, M. Yu, and E. Upchurch, "An improved drift-flux correlation for gas-liquid two-phase flow in horizontal and vertical upward inclined wells," *Journal of Petroleum Science and Engineering,* vol. 195, p. 107881, 2020.

[2] H. Shi *et al.*, "Drift-flux modeling of multiphase flow in wellbores," in *SPE Annual Technical Conference and Exhibition*, 2003: OnePetro.

[3] Y. Bangtang, L. Xiangfang, S. Baojiang, and H. ZHANG, "Hydraulic model of steady state multiphase flow in wellbore annuli," *Petroleum Exploration and Development,* vol. 41, no. 3, pp. 399-407, 2014.

[4] J. Brill and S. Arirachakaran, "State of the art in multiphase flow," *Journal of Petroleum Technology,* vol. 44, no. 05, pp. 538-541, 1992.

[5] Y. Liu, E. R. Upchurch, and E. M. Ozbayoglu, "Experimental study of single taylor bubble rising in stagnant and downward flowing non-newtonian fluids in inclined pipes," *Energies,* vol. 14, no. 3, p. 578, 2021.
[6] L. Wenqiang *et al.*, "Wellbore drift flow relation suitable for full flow pattern domain and full dip range," *Petroleum Exploration and Development,* vol. 49, no. 3, pp. 694-706, 2022.
[7] P. Pourafshary, A. Varavei, K. Sepehrnoori, and A. Podio, "A compositional wellbore/reservoir simulator to model multiphase flow and temperature distribution," in *International Petroleum Technology Conference*, 2008: OnePetro.
[8] B. Sun *et al.*, "Multiphase flow behavior for acid-gas mixture and drilling fluid flow in vertical wellbore," *Journal of Petroleum Science and Engineering,* vol. 165, pp. 388-396, 2018.
[9] Y. Liu, E. R. Upchurch, and E. M. Ozbayoglu, "Experimental and Theoretical Studies on Taylor Bubbles Rising in Stagnant Non-Newtonian Fluids in Inclined Non-Concentric Annuli," *International Journal of Multiphase Flow,* vol. 147, p. 103912, 2022.
[10] X. Chen, T. Butler, M. Volk, and J. Brill, "Techniques for measuring wax thickness during single and multiphase flow," in *SPE Annual Technical Conference and Exhibition*, 1997: OnePetro.
[11] T. A. Tong, Y. Liu, E. Ozbayoglu, M. Yu, R. Ettehadi, and R. May, "Threshold velocity of non-Newtonian fluids to initiate solids bed erosion in horizontal conduits," *Journal of Petroleum Science and Engineering,* vol. 199, p. 108256, 2021.
[12] A. K. Sleiti, G. Takalkar, M. H. El-Naas, A. R. Hasan, and M. A. Rahman, "Early gas kick detection in vertical wells via transient multiphase flow modelling: A review," *Journal of Natural Gas Science and Engineering,* vol. 80, p. 103391, 2020.
[13] Y. Liu, E. M. Ozbayoglu, E. R. Upchurch, and S. Baldino, "Computational Fluid Dynamics Simulations of Taylor Bubbles Rising in Vertical and Inclined Concentric Annuli," *Available at SSRN 4135059*.
[14] A. Matzain, M. S. Apte, H.-Q. Zhang, M. Volk, J. P. Brill, and J. Creek, "Investigation of paraffin deposition during multiphase flow in pipelines and wellbores—part 1: experiments," *J. Energy Resour. Technol.,* vol. 124, no. 3, pp. 180-186, 2002.
[15] J. P. Brill, "Multiphase flow in wells," *Journal of petroleum technology,* vol. 39, no. 01, pp. 15-21, 1987.
[16] W. Lou, Z. Wang, B. Guo, S. Pan, Y. Liu, and B. Sun, "Numerical analysis of velocity field and energy transformation, and prediction model for Taylor bubbles in annular slug flow of static power law fluid," *Chemical Engineering Science,* vol. 250, p. 117396, 2022.
[17] W.-Q. Lou *et al.*, "High-precision nonisothermal transient wellbore drift flow model suitable for the full flow pattern domain and full dip range," *Petroleum Science,* 2022.
[18] P. Pourafshary, *A coupled wellbore/reservoir simulator to model multiphase flow and temperature distribution*. The University of Texas at Austin, 2007.