

The Pore Scale Simulation of Gas and Water Two-Phase Flow in Rough-Walled Fractures

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Abstract

The pore-scale behaviour of gas and water in rough-walled hydrophilic fractures is critical to understanding the gas production features of naturally fractured formations. In this study, the volume of fluid (VOF) approach is utilised to perform a systematic examination of gas and water flow characteristics in both single-fracture and Y-shaped junction fracture models. According to numerical simulations, the gas/water rate ratio altered the shape, phase distribution, and saturation of gas bubbles and slugs. The gas/water ratio has a bigger influence than fracture roughness and tortuosity, whereas total fluid rate has no effect. Because the channel aperture ratio alone controls the phase distribution and referential paths in Y-shaped junction models, the impact of the intersecting angle and fluid flow rate can be ignored.

Keywords: Hydrophilic fractures • Fluid flow • Multi phase flows

Introduction

Laboratory microfluidics and numerical simulation have been proposed as two types of investigation tools for studying the pore-scale interactions between water and gas. Multi-phase flows can be directly observed at micron-scale geometries thanks to microfluidics. The gas and water flow patterns in a single fracture or complex fracture network have been the subject of numerous experiments. The interactions between water and gas at the pore scale were directly observed in previous experimental work. However, because the majority of these earlier works utilized microchip models with particular wall roughness, they did not provide insights into how the flow pattern is affected by the fracture roughness. Due to the limited resolution of images, the microfluidic method also has difficulty with interpretation accuracy. The picture goal of current business magnifying lens is for the most part on the size of micrometres. However, the recorded images are unable to accurately depict the fluid distribution on the rough surface if the wall roughness is less than a few nanometers. In addition, microfluidic experiments typically come at a high cost and necessitate the use of specialized microfluidic chips, microscopes, and high-speed digital cameras.

Literature Review

Natural fractured gas deposits such as coal, shale, and carbonate are examples of naturally fractured gas formations that contribute considerably to world energy sources. Gas and water two-phase flows are prevalent in discrete fractures because they contain either naturally existing water or injected water-based fracturing fluids. The interactions of gas and water at the pore scale are well known to have a substantial impact on the production properties as well as the spatial distribution and flow capacity of the fluids.

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The CFD method is regarded as being more accurate than the PNM because it is able to directly simulate fluid flows on genuine physical models with intricate geometries. Besides, the CFD strategy is fit for displaying a more mind boggling multiphase stream that includes blend wettability, heat move, and strong molecule stream. Among the different CFD techniques, the LBM and VOF are the most usually utilized for demonstrating two-deliberately ease streams in permeable media at the mesoscale. The LBM strategy is better than the VOF technique as far as union steadiness and preservation precision for recreating incompressible liquid stream. However, when simulating multiphase flow with a high density and viscosity ratio (such as gas/water or gas/oil two-phase flow), conventional LBM is associated with the problem of numerical instability. Additionally, when compressible fluids are taken into account, the LBM method encounters inherent difficulties when dealing with compressibility issues. Mass conservation is an inherent benefit of the VOF method, and it doesn't need a complicated phase interface tracking algorithm to calculate two-phase flow in complex geometric shapes. As a result, when it comes to simulating multiphase flow in pathways with intricate geometries using compressible fluids and a high density/viscosity ratio, the VOF method is more mature and reliable than the LBM. Combining the volume fraction model with the Navier–Stokes equations and then employing numerical computation methods to solve the discretized equations is the fundamental tenet of VOF.

Numerical simulations, in comparison to the microfluidic experiment, are typically less expensive, more adaptable, and offer quick predictions for a wide range of flow conditions. Particle network modelling (PNM) and computational fluid dynamics (CFD) are two of the most widely used approaches to simulating multiphase flow at the mesoscale (or pore scale). Instead of using the actual flow path geometry, the PNM runs simulations on conceptual models with simplified pores and throats geometries. As a result, the reconstructed discrete physical pore–throat model's accuracy plays a significant role in determining the PNM's accuracy. For geometric models with high irregularity, it is acknowledged that the PNM is unable to make accurate predictions of fluid–solid interactions and flow characteristics. Besides, the PNM requires a predefinition of specific components, for example, the snap-off and pore-filling for displaying multiphase streams, which definitely gets extra mistakes.

Discussion

The VOF method was used to run numerical simulations of gas and water flows in Y-shaped junction models with rough walls and single fractures, taking into account a variety of factors. The following summarizes the main conclusions drawn from the simulation results:

The gas/water ratio is the primary factor that determines gas bubble

geometries, phase distribution, and saturation in single-fracture models. The impacts of unpleasantness and convolution on the state of gas air pockets and leftover water immersion are observable however fundamentally not exactly the impact of the gas/water proportion. In single-fracture models, the gas and water flow pattern is not significantly affected by total fluid rate.

When the apertures of the adjacent downstream channels are not the same, gas preferentially flows through larger paths in the Y-shaped junction model. In Y-shaped junctions, the characteristics of the phase distribution are largely unaffected by the intersecting angle and fluid flow rate. Although it has been demonstrated that the VOF method is capable of simulating compressible fluid flows in channels in meso- and macroscale sand packs or pipelines, very little research has reported the use of the VOF method to investigate the interactions between gas and water in pore-scale fracture networks. However, this is something that is still a work in progress. The only paper that, to the best of the authors' knowledge, reported gas and water flow simulations in micro scale fractures and demonstrated the precision of CFD simulations of gas and water flow patterns in Y-junction models. However, all of the simulations used smooth fractures, which are not the same as rough fractures in reality. Additionally, the effects of gas compressibility are ignored by the utilized model. Two-phase gas and water flows were simulated in rough-walled single-fracture and Y-shaped junction models using the compressible VOF technique in this study. New insights will be shared as a result of the investigation of the interactions that take place between the two-phase fluids in various fracture geometries [1-5].

Conclusion

Because the fracture wettability was considered to be hydrophilic in this study, the findings may not apply to mix-wetting or hydrophobic fractures. As a result, the effect of wettability on the two-phase flow characteristics of rough-walled fractures may merit further investigation. It should also be noted that the conceptual single- and Y-junction fracture models are the focus of this paper. The spatial distribution and connectivity of the fracture network may be more

intricate in naturally fractured reservoirs. As a result, simulations of gas and water flow across actual fracture networks are expected to demonstrate the two-phase interaction features under the impact of various elements such as flow rates and fracture network patterns.

References

1. Lu, Yuejian, Dameng Liu, Yidong Cai, Changjing Gao, Qifeng Jia, and Yingfang Zhou. "AFM measurement of roughness, adhesive force and wettability in various rank coal samples from Qinshui and Junggar basin, China." *Fuel* 317 (2022): 123556.
2. Maghsoudy, Sina, Omid Bakhtiari, and Soroush Maghsoudy. "Tortuosity prediction and investigation of fluid flow behavior using pore flow approach in heap leaching." *Hydrometallurgy* 211 (2022): 105868.
3. Wang, Min, Yi-Feng Chen, Guo-Wei Ma, Jia-Qing Zhou, and Chuang-Bing Zhou. "Influence of surface roughness on nonlinear flow behaviors in 3D self-affine rough fractures: Lattice Boltzmann simulations." *Adv Water Resour* 96 (2016): 373-388.
4. Liu, Yang, Steffen Berg, Yang Ju, Wei Wei, Jisheng Kou, and Jianchao Cai. "Systematic investigation of corner flow impact in forced imbibition." *Water Resour Res* 58 (2022): e2022WR032402.
5. Hou, Jinjian, Shuanglong Lin, Ming Zhang, and Wei Li. "Salinity, temperature and pressure effect on hydrogen wettability of carbonate rocks." *Int J Hydrogen Energy* (2022).

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