The Numerical Simulation of Gas Injection-Production in X Acid Gas Storage

Wang De-long[1,2](✉), Han Xing-gang[1,2], Li Jin-bu[1,2], Zhang Jian-guo[1,2], Yang Qiong-jing[3], and Xia Yong[1,2]

[1] Changqing Oilfield Exploration and Development Research Institute, Xi'an, China
738279887@qq.com
[2] National Engineering Laboratory of Low Permeability Oil and Gas Field Exploration and Development, Xi'an, China
[3] Changqing Oilfield Gas Field Development Department, Xi'an, China

Abstract. X Gas Storage is the first low permeability acid gas reservoir type gas storage at home and abroad. Compared with the early stage of gas reservoir development, the gas storage has a short period of high-speed injection-production, pressure and fluid composition of the gas well vary greatly. it is necessary to carry out numerical simulation study of gas storage. Based on the variation of natural gas composition, VFP pressure drop loss of wellbore in injection-production and refined processing grid, the mathematical model of acid gas storage is established in this article. Based on the analysis of reservoir Heterogeneity by cross-well interference, the flow law of acid gas "gas injection extrapolation, gas recovery return" is studied, which is used to guide numerical simulation and realize multi-parameter constraint fine fitting of acid gas storage. The gas production mode is optimized, the elutriation period of H_2S content in X gas storage is predicted, and the production law of acid gas is summarized. Through the above research knowledge, for the same type of gas storage numerical simulation study to provide technical reference.

Keywords: Gas storage of acid gas reservoir · Component model · Wellbore pressure drop · History fitting · H_2S content

1 Difficulties of Injection-Production Simulation of Acid Gas Storage

Compared with gas field development, the gas well spacing is small, the production, pressure and fluid composition vary greatly during the short-cycle operation of high-speed injection and production in x low permeability acid gas storage (Fig. 1). It is difficult to describe formation fluid flow and fluid composition change in gas storage by means of gas reservoir engineering. Numerical simulation is an effective way to describe the three-dimensional dynamic changes of underground injection and production in gas storage.

Compared with gas field development, the numerical simulation of this acid gas storage needs more precise fitting parameters, such as gas injection production, wellhead

J. Lin (Ed.): IFEDC 2021, SSGG, pp. 1269–1277, 2022.
https://doi.org/10.1007/978-981-19-2149-0_117

pressure, acid gas composition, etc. and it is very difficult to fit the model of gas storage with multi-parameters, and it is difficult to modify the model of gas storage to consider the constraints of multiple parameters such as gas injection and production rate, wellhead pressure, acid gas composition, etc.

Therefore, this paper develops the natural gas fluid component, establishes the component model of the gas storage, refines the processing grid, analyzes the friction of gas injection and gas production wellbore, the interferences between injection and production wells, and the flow law of acid gas injection and production.

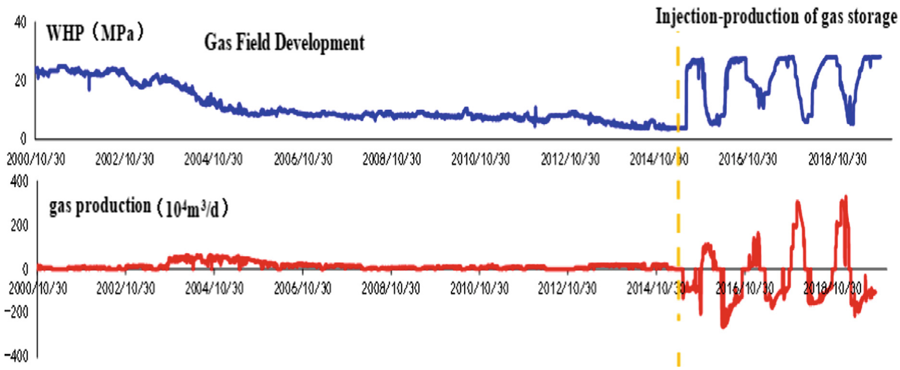

Fig. 1. Comparison of operation curves between gas field development and gas storage

2 Establishment of Numerical Simulation Model for Acid Gas Storage WHP (MPa)

Compared with gas field development, based on reservoir fine geological modeling, the numerical simulation of acid gas storage focuses on the fine processing grid, the establishment of acid fluid composition model and the wellbore pressure drop model of high-speed gas injection and production.

2.1 Establishment of the Fluid Composition Model

According to the characteristics of high acid content in low permeability gas storage and large variation of natural gas components in gas production, it is necessary to establish component model. Based on the study of the optimization of state equation, the classification and merging of natural gas components, and the fitting of natural gas properties, a high pressure physical property model of typical gas samples is established, which provides reasonable PVT parameters for establishing the fluid composition model of gas storage in high-speed injection-production (Fig. 2).

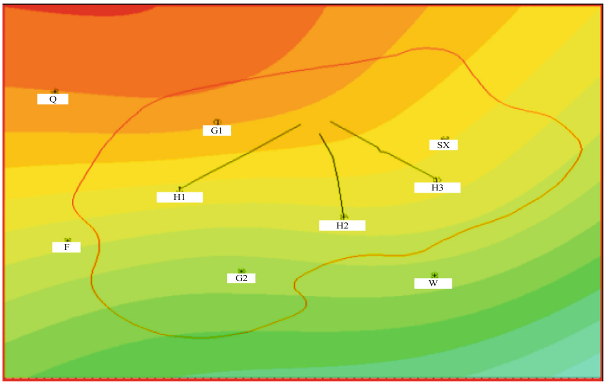

Fig. 2. X component model of original H_2S content in gas storage

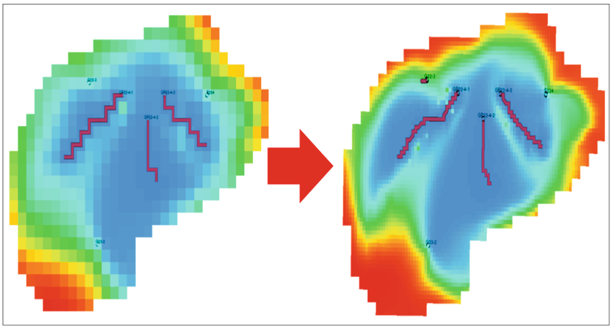

Fig.3. Comparison of CO_2 distribution at the end of gas injection before and after refinement of grid

2.2 The Fine Grid of Gas Storage

The storages are all rebuilt from the original gas reservoirs by deploying injection-production wells. Compared with the development well pattern of the gas reservoir, the well pattern density of the gas reservoir is larger and the distance between wells is smaller. Taking into account the Heterogeneity of the reservoirs, short-term high-speed injection and production will produce greater pressure drop near the wells and small control area.in order to more precisely simulate gas injection-production in storage, it is necessary to carry out fine processing for the reservoir grid. Through grid refinement and injection-production dynamic simulation, the injection-production boundary of H_2S, CO_2 component is finer and clearer, and the model is more accurate.

2.3 Establishment of VFP Model for Gas Injection and Production Wells

In the development stage of gas field, it is helpful to fit the BHP (bottom hole flow pressure) and WHP (wellhead pressure) accurately by establishing the proper VFP model for low-speed gas production. During the period of gas injection and production in gas storage, the wellbore friction increases gradually with the gas production rate rising, and the wellhead pressure drops rapidly. Compared with the actual wellhead pressure, the wellhead pressure calculated by the VFP model in gas field is higher and the is no VFP model in gas injection process of storage. Therefore, it is necessary to carry out dynamic pressure monitoring, re-establish the VFP model of high-speed gas injection and gas production, ensure the accurate fitting of wellhead pressure of gas well in gas storage.

3 Fine History Matching of Acid Gas Storage

Based on the analysis of interwell pressure and fluid composition interference, the heterogeneity reservoir of gas storage is studied, and the fluid change law of "gas injection extrapolation, gas production reflux" is analyzed. Fine fitting of injection-production history of gas well by adjusting reservoir parameters.

3.1 Analysis of Reservoir Heterogeneity, Fitting Wellhead Pressure of Gas Injection-Production

According to the evaluation of gas field development stage, when G1, SX and G2 gas wells are produced together, the wellhead pressure drop curves are almost coincident, which indicates that the reservoir connectivity between the gas wells is good (Fig. 4). After the gas reservoir was transformed into gas storage, in order to test interwell interference, G1well is produced and SX and G2 well are shut in to measure pressure. The formation pressure of SX well keeps recovering, but the formation pressure of G2 well gradually restores in the early stage, and gradually drops in the later stage due to the gas production interference of G1well.This test shows that there is a tight reservoir between G2 and SX well. The tight reservoir takes part in formation flow in low production, but the tight reservoir does not take part in formation flow in high production, which plays a role of blocking flow (Fig. 5).

Take into consideration tight reservoir between G2 and GX wells, based on numerical simulation model during the gas field development, the control range of gas injection in H2 horizontal well is reduced and The gas injection pressure calculated by numerical simulation is closer to the actual pressure by modifying the physical parameters of reservoir. The fitting accuracy of the gas injection--production wellhead pressure in H2 well is further improved (Fig. 6, Fig. 7, Fig. 8, and Fig. 9).

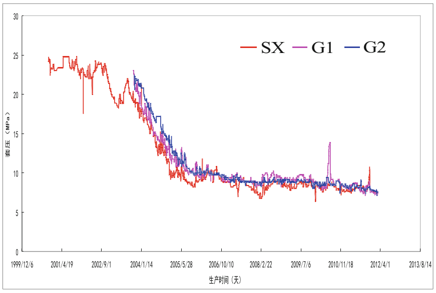

Fig. 4. Production pressure curves of 3 old wells

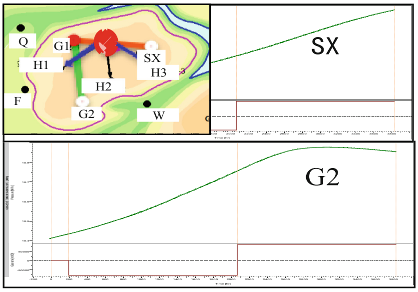

Fig. 5. Inter-well interference pressure curves

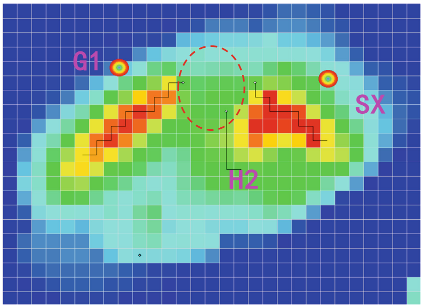

Fig. 6. Physical parameters model before adjustment

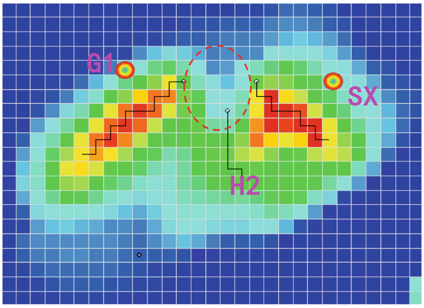

Fig. 7. Physical parameters model after adjustment

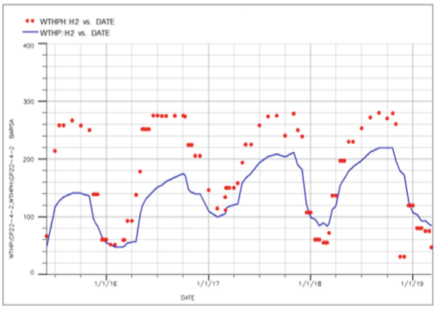

Fig. 8. Fitting pressure curve before adjustment

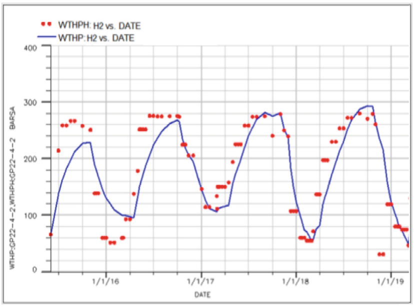

Fig. 9. Fitting pressure curve after adjustment

3.2 Study the Change Law of Injection-Production, Fitting the Content of H_2S in Gas Production

In the process of gas injection in storage, there is a big difference between the natural gas with H_2S in the original formation and the injected dry gas, there are only data of gas injection pressure, gas injection quantity and old well pressure without gas injection, and no data of H_2S content of natural gas in formation, so it is impossible to analyze the change of formation H_2S.Consider the original formation of H_2S-containing natural gas was injected into the gas outward drive, it is necessary to analyze the influence of reservoir heterogeneity, gas injection rate and formation diffusivity on the distribution of H_2S content.

After shut-in of gas injection, the front of gas injection will change due to the re-balance of formation pressure between gas wells, it is necessary to analyze the degree of fusion between injected gas and original formation gas. When gas wells and old wells are producing gas together, it is necessary to analyze the injection gas recovery margin, to analyze the non-uniformity of H_2S content distribution, to fit the H2S content in the initial stage of each well. By analyzing the rising rule and interwell interference of H_2S content, physical parameters of reservoir are adjusted many times to fit the H2S content history data in gas production stage.

H3 well is a horizontal well for gas injection and production in Shaan X gas storage, The H_2S content of produced gas calculated is generally lower than the actual value in every period of this well. The analysis shows that the injected gas mainly diverges to two sides When gas is injected into well H3, and that the H_2S output of the well is closely related to SX when the H3 is produced. Based on the analysis of gas injection rate, injection gas production edge and reservoir heterogeneity in well H3, and considering the fitting effect of gas produced by SX, the model parameters were adjusted properly to fit the injection production pressure, injection gas production rate and H_2S content in well H3, finally, the H_2S content curve of well H3 is fitted well, and the fine description of gas injection and production in gas storage is realized (Fig. 10, Fig. 11, and Fig. 12, Fig. 13).

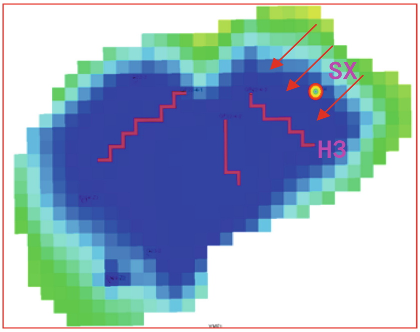

Fig. 10. H_2S content distribution after gas injection

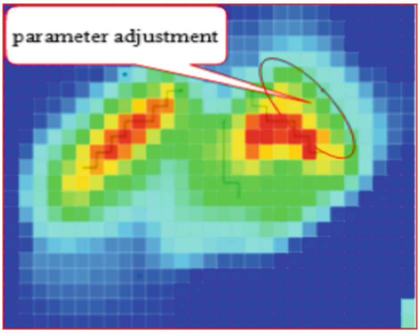

Fig. 11. Property parameter adjustment area diagram

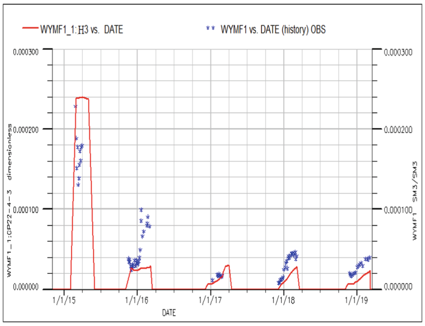

Fig. 12. Fitting curve of H_2S content before adjustment

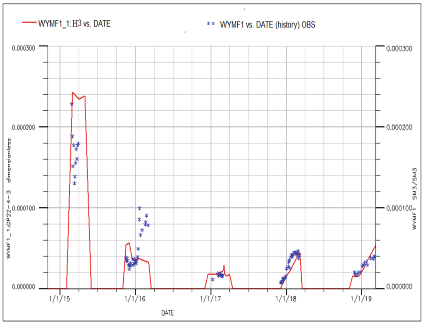

Fig. 13. Fitting curve of H_2S content after adjustment

4 Forecast the Change of H_2S Content in Gas Storage by Numerical Simulation

Based on the detailed numerical simulation of gas storage, the variation law of H_2S content in gas produced from x gas storage is analyzed. According to different design schemes, the H_2S Safety Standard (H_2S & Lt; 20 mg/m^3) period is predicted by numerical simulation. The gas production plan was optimized by comparing and analyzing the washing rate of H_2S in two sets of gas production plan reservoirs. Design Proposal 1: During gas production, all 10 wells are open for production, and it is predicted that H2s can reach the safety standard after 8 cycles. design proposal 2: During the low peak demand of early gas production, five wells of high H_2S content are open for gas production. During the peak demand of gas production occurs, all 10 wells are open for production,,the safety standard can be reached after 7 cycles. By optimizing the gas production mode, the H_2S washing cycle can be shortened, the cost of gas desulfurization can be reduced, and the benefit of the gas storage can be improved by one cycle (Fig. 14).

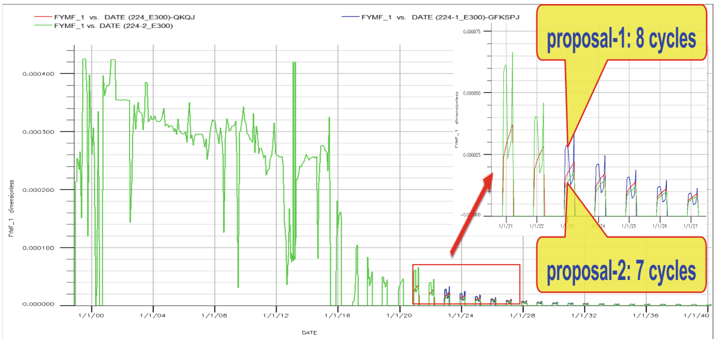

Fig. 14. Comparison of H_2S content change curves of injection-production in gas storage with two schemes

According to the law of acid gas composition change at the end of gas injection and production cycle in Shaan x gas storage, it is realized that the H_2S content of gas produced from gas storage decreases logarithmically with the increase of injection and production cycle (Fig. 15), and the H_2S content of gas produced from gas storage decreases with the increase of gas production rate, the results show that the elutriation cycle can be shortened obviously by increasing gas injection production (Fig. 16).

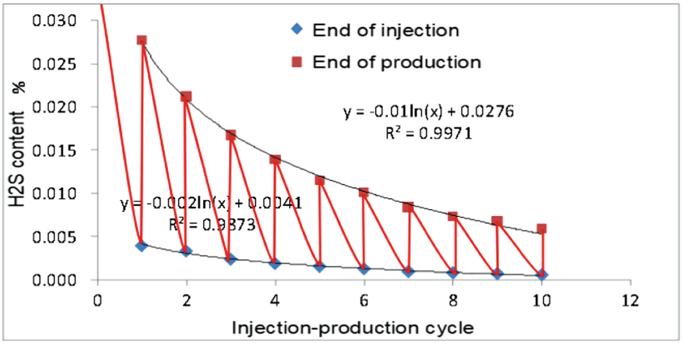

Fig. 15. Changes of H_2S content in gas storage at the end of injection-production Cycle

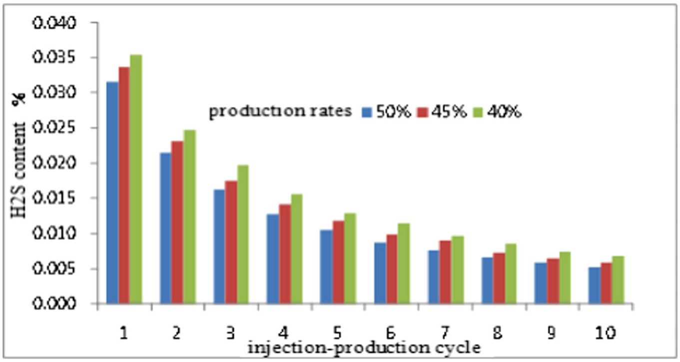

Fig. 16. Changes of H_2S content at the end of gas production under different production rates

5 Conclusion

In order to solve the problems of short-period high-speed injection-production, complex formation seepage flow and fast change of fluid composition in acid gas reservoir-type gas storage, the numerical simulation of injection-production in gas storage was carried out, there are some understandings as follows:

(1) In the process of injection and production of acid gas storage, because of the change of fluid composition, the small control range of single well in short period and the

large pressure loss of high-speed injection and production wellbore,on the basis of fine geological modeling of reservoir, it is necessary to set up acid fluid composition model, wellbore VFP model of high-speed injection and production, model and fine grid processing of reservoir.

(2) There are tight reservoirs that can not be identified in low-speed gas production in gas field development, but when the gas reservoir is injected and produced at high-speed, but such tight reservoirs have obvious flow resistance during high-speed gas injection and production in gas storage, so it is necessary to use various methods to analyze reservoir heterogeneity, improving numerical simulation fitting effect and realizing injection-production fine description of gas storage.

(3) In the process of injection and production of acid gas storage, the injected dry gas extrapolates the original acid cushion gas gradually.During the numerical simulation of gas storage, it is necessary to analyze the influence of H_2S content distribution, such as gas injection speed, gas injection front, recovery edge, reservoir hetreogeneity, etc. Considering multi-parameters and multi-wells, the model parameters should be adjusted properly to improve the fitting effect of gas wells.

(4) optimizing gas production mode can further shorten the scouring cycle of H_2S and reduce the cost of gas desulfurization in gas storage. With the increase of injection-production cycle, the H_2S content of produced gas decreases logarithmically. With the increase of gas production rate, Acid gas elutriation will be accelerated in the gas storage.

References

1. Yufei, T.: Technology and Numerical Simulation of Underground Natural Gas Storage. Petroleum Industry Press, Beijing (2007)
2. Jian, P., Shuhe, Y., Shumei, H., et al.: Numerical simulation of dazhangtuo underground gas storage. Nat. Gas Ind. **20**(1), 9–11 (2002)
3. Yong, W., Yifei, L., Xingli, C., et al.: Study on fine history matching technique of numerical simulation for low permeability carbonate gas reservoir. Drilling Prod. Technol. **36**(2), 52–54 (2013)
4. Yifei, L., Dongxu, W., Yong, W., et al.: Study on integrated technology of geological modeling and numerical simulation for Jingbian gas field. Spl. Iss. Nat. Gas Dev. Technol. **32**, 230–233
5. Yong, L., Baozhu, L., Yongle, H., et al.: Study on numerical simulation method of component coarsening in carbonate condensate gas reservoir. J. Southw. Pet. Univ. **32**(1), 97–99 (2010)
6. Haiyan, W.: Optimization of injection-production capacity of gas well in gas storage reservoir considering multi-factors. Pet. Geol. Dev. Daqing **38**(3), 54–57 (2019)
7. Yong, L., Lau, E., Yongge, L.: Effect of wellbore pressure drop on injection-production system of horizontal well. Sci. Technol. Eng. **31**(13), 9197–9200 (2013)
8. Yunjun, Z., Yu, F., Qinglin, A., et al. :Study on acid gas change law of gas storage in low sulfur gas reservoir. Petrochem. Appl. **35**(3), 89–91 (2016)
9. Jian, L., Zhi, L., Jiang Long, F., et al.: Study on the variation law of recovery gas component in acid gas reservoir-taking Shaan x gas storage in Ordos Basin as an example. Nat. Gas Ind. **37**(8), 96–100 (2017)