



Research on the Timing of Dewatering Gas Production Measures on Gas Wells in Low Permeability Gas Fields

Bo Zhang^{1,2(✉)}, Yuan Xue^{1,2}, Pengcheng Liu^{1,2}, Jianning Luo^{1,2},
Peng Li^{1,2}, and Zhanhai Yu^{1,2}

¹ Exploration and Development Research Institute,
PetroChina Changqing Oilfield Company, Xi'an, China
zhangbol_cq@petrochina.com.cn

² National Engineering Laboratory for Exploration and Development of Low
Permeability Oil and Gas Fields, Xi'an, China

Abstract. With the increasing number of gas wells and the continuation of production time, gas wells are affected by liquid production more and more seriously in Suliige gas field.

At present, more than 80,000 wells needs to be injected foaming agent each year, and the dewatering gas production workload increases year by year with the deepening development of the gas field. How to effectively solve the timing of dewatering gas production measures on gas wells has become more and more urgent and important. In this paper, the timing of dewatering gas production measures on water-producing gas wells has been studied in detail from the aspects of critical liquid-carrying flow rate, liquid holdup, and kinetic energy factor.

The effectiveness of the measures is embodied in two aspects: ensuring continuous production and stimulation of gas wells. Based on the premise of ensuring continuous production, when the production capacity of gas wells is reduced to a certain extent, dewatering gas production measures should be taken in advance to ensure the continuous production of gas wells.

Keywords: Gas field · Dewatering gas production · Liquid-carrying flow rate · Liquid holdup · Kinetic energy factor

Copyright 2019, IFEDC Organizing Committee.

This paper was prepared for presentation at the 2019 International Field Exploration and Development Conference in Xi'an, China, 16–18 October, 2019.

This paper was selected for presentation by the IFEDC Committee following review of information contained in an abstract submitted by the author(s). Contents of the paper, as presented, have not been reviewed by the IFEDC Technical Team and are subject to correction by the author(s). The material does not necessarily reflect any position of the IFEDC Technical Committee its members. Papers presented at the Conference are subject to publication review by Professional Team of IFEDC Technical Committee. Electronic reproduction, distribution, or storage of any part of this paper for commercial purposes without the written consent of IFEDC Organizing Committee is prohibited. Permission to reproduce in print is restricted to an abstract of not more than 300 words; illustrations may not be copied. The abstract must contain conspicuous acknowledgment of IFEDC. Contact email: paper@ifedc.org.

© Springer Nature Singapore Pte Ltd. 2020

J. Lin (Ed.): *Proceedings of the International Field Exploration and Development Conference 2019*, SSGG, pp. 36–42, 2020.

https://doi.org/10.1007/978-981-15-2485-1_4

1 Foreword

Sulige gas field belongs to the low permeability gas field and low water content of the gas wells is universal. More than thousands of gas wells cannot have normal production due to liquid loading from kinds of reasons, which has a serious influence on the normal production of the gas wells. According to the actual production status of the gas wells, it is particularly important to carry out the dewatering gas production measures to make normal and continuous production of the low production and low effectiveness gas wells.

In order to effectively ensure the continuous production and stimulation of gas wells, under the premise of the continuous production, the dewatering gas production measures should be taken in advance to ensure that gas wells can be continuously produced when the production capacity of gas wells reduce to a certain extent. Therefore, the dewatering gas production measures in advance are crucial to ensure the continuous production of gas wells. This paper carries out a detailed research and discussion on the timing of dewatering gas production for water-producing gas wells from the aspects of critical liquid-carrying flow rate, liquid holdup and kinetic energy factor.

2 Critical Liquid-Carrying Flow Rate of Gas Wells

For the gas wells tubing of given specification, the gas wells will have the liquid holdup when the actual gas production capacity is more than or equal to the critical liquid carrying flow rate [1]. Li Min's analysis show that there is certain differential pressure before and after the droplets when they are moving in high-speed gas flow. Under the influence of differential pressure, the droplets will change from sphere to ellipsoid and the incident flow area of ellipsoid is greater than that of the sphere. So the ellipsoid is more easily taken to the ground by the gas flow and the required liquid drainage speed is also lower. Therefore, Li Min considers that it is necessary to research on the influence of droplets deformation to the liquid holdup of gas wells when we research on the liquid holdup of gas wells. A new droplet model of liquid holdup of gas wells is provided according to the actual production of Sulige gas field.

Critical flow velocity of droplets is derived according to the new model and the force balance of droplets in the critical state.

$$v = \sqrt[4]{\frac{8g(\rho_l - \rho_g)\sigma}{3\rho_g^2 C_D}} = \sqrt[4]{\frac{8g}{3C_D}} * \left(\frac{(\rho_l - \rho_g)\sigma}{\rho_g^2} \right)^{0.25} \quad (1)$$

The formula for the critical liquid-carrying flow rate for the new model is:

$$q_{sc} = 2.5 \times 10^8 * \frac{\pi d^2 p}{4zT} * \sqrt[4]{\frac{8g}{3C_D}} * \left(\frac{(\rho_l - \rho_g)\sigma}{\rho_g^2} \right)^{0.25} \quad (2)$$

Where, v means the critical flow velocity of droplets (m/s);
 g means the gravitational acceleration (m/s^2);
 d means inside diameter of tubing (m);
 p means the tubing pressure at wellhead (MPa).
 z means the compressibility factor (dimensionless);
 T means temperature (K);
 ρ_l means the density of the droplets (Kg/m^3);
 ρ_g means the gas density (Kg/m^3);
 σ means the surface tension of natural gas and droplets (N/m);
 CD means the drag coefficient (dimensionless);

Table 1. Theoretical calculation sheet of critical liquid-carrying flow rate

Liquid-carrying flow rate (m^3/d) Tubing pressure at wellhead (MPa)	Tubing diameter (mm)			
	76	62	50.7	31.8
1	8955	5210	3479	1919
2	12641	7365	4911	2709
4	17812	10381	6920	3817
6	21750	12668	8445	4652
8	25021	14571	9716	5351
10	27880	16524	10882	5968

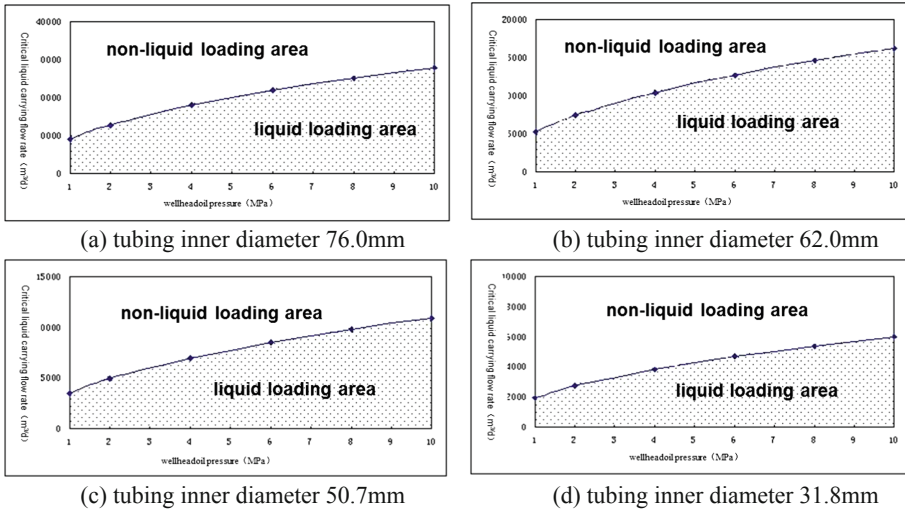


Fig. 1. Relation curve between critical liquid-carrying flow rate and wellhead tubing pressure of different tubing inside diameter

According to the principle of critical liquid-carrying flow rate of gas wells and the actual production of Sulige gas field, 1/2–2/3 (adjustable) of the theoretical critical

liquid-carrying flow rate is selected to be as the boundary reference value to decide whether the water-producing wells have liquid holding [2]. Therefore, the dewatering gas production measures can be taken in advance to avoid the liquid loading of gas wells, to ensure the continuous liquid holdup of gas wells and to ensure continuous production when the gas wells have reached to the critical liquid-carrying flow rate (Table 1 and Fig. 1).

3 Analysis on Liquid Holdup of Gas Wells

Hagedorn-Brown [1–5] experimental studies suggest that the theoretical liquid holdup is related to 4 dimensionless parameters and 3 related curves respectively as follows:

$$\text{Liquid velocity number: } N_{lv} = v_{sl} \times \left(\frac{\rho_l}{g \times \sigma} \right)^{0.25} \quad (3)$$

$$\text{Gas velocity number: } N_{gv} = v_{sg} \times \left(\frac{\rho_l}{g \times \sigma} \right)^{0.25} \quad (4)$$

$$\text{Liquid viscosity number: } N_l = \mu_l \times \left(\frac{g}{\rho_l \times \sigma^3} \right)^{0.25} \quad (5)$$

$$\text{Tubing diameter: } N_d = d \times \left(\frac{\rho_l \times g}{\sigma} \right)^{0.5} \quad (6)$$

The calculation formula of the actual liquid holdup is derived according to the definition of liquid holdup, described in Formulas (7) and (8).

$$H_{actual} = \frac{V_w}{V_w + GLR \times V_w \times \left(\frac{p_{sc} \times Z \times T}{T_{sc} \times p \times Z_{sc}} \right)} \quad (7)$$

Simplified as:

$$H_{actual} = \frac{1}{1 + GLR \times \left(\frac{p_{sc} \times Z \times T}{T_{sc} \times p \times Z_{sc}} \right)} \quad (8)$$

Where:

- H_{actual} —actual liquid holdup
- H_l —theoretical liquid holdup
- GLR—gas water ratio, m^3/m^3
- v_{sl} —liquid apparent velocity m/s
- v_{sg} —gas apparent velocity m/s
- ρ_l —density of water, kg/m^3
- g —the gravitational acceleration (m/s^2)

- μ_l —liquid viscosity, mPa.s
- σ —liquid surface tension, mN/m
- d —inside diameter of tubing, m
- p —pressure, MPa
- T —temperature, K
- P_{sc} —Standard case pressure, MPa
- T_{sc} —Standard case temperature, MPa
- Z —deviation factor of natural gas
- Z_{sc} —deviation factor of natural gas of standard case

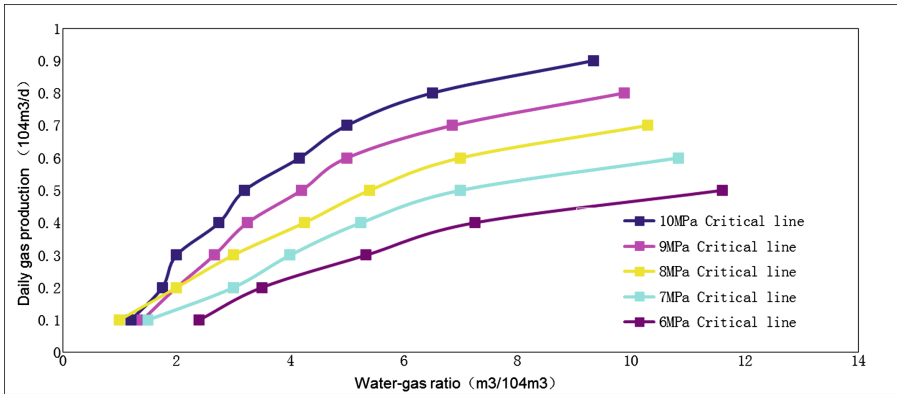


Fig. 2. Discrimination board for the liquid loading timing of gas wells

It is clear that there is a certain relation between the theoretical liquid holdup and the actual liquid holdup of gas wells and wellbore: there is no liquid loading in the gas wells if the actual liquid holdup is less than the theoretical liquid holdup; there is liquid loading in the gas wells if the actual liquid holdup is higher than the theoretical liquid holdup. We can decide whether there is liquid loading and the timing of liquid loading in the gas wells, the timing of the dewatering gas production measures can be decided to ensure the continuous production of gas wells (Fig. 2).

4 Analysis of Kinetic Energy Factor of Gas Wells

Kinetic energy factor reflects the flow features of gas and liquid in the tubing, represents the energy of gas wells [8, 9], and shows the liquid holdup capability of the producing gas wells. The critical liquid holdup models, represented by Turner [6, 7] model, are calculated based on the idealized fog flow model. Laboratory simulation experiment of gas and water phase has found that the liquid holdup capability has been existing in the loop fog flow and the slug flow, and the following relations exist between the kinetic energy (kinetic energy factor) of the unit fluid, the gas production, the relative density of natural gas and the flowing pressure.

$$F = v_s \sqrt{\delta_s} = 2.9 \frac{Q}{d} \sqrt{\frac{rT_s Z_s}{P_s}} \tag{9}$$

Liquid loading in the gas wells can be diagnosed through calculating the kinetic energy factor, and then the best timing to carry out the dewatering gas production measures will be decided (Fig. 3 and Table 2).

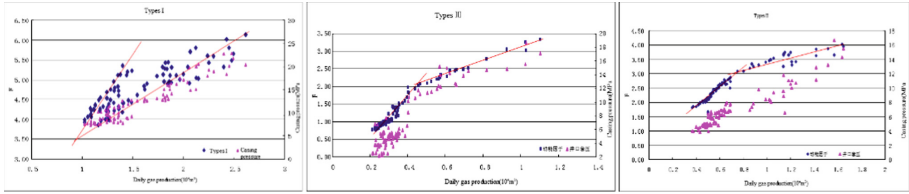


Fig. 3. Change cure of daily production of kinetic energy factors of different type wells

Table 2. Calculation results of kinetic energy factors of different type wells

Types	Kinetic energy factors	Daily gas production (10 ⁴ m ³ /d)
I	3.5	0.9
II	3	0.7
III	2	0.45

By calculating the kinetic energy factors, it is found that kinetic energy factor shows a decreasing trend of two ends as a whole. The gas wells may be disturbed by the liquid loading if there is a turning point shows in the change of the kinetic energy factor, and the dewatering gas production measures should be taken in time to this type of gas wells in this stage.

5 Conclusion

According to the actual and theoretical calculations, it's suggested that adopting the dewatering gas production in advance can help to ensure the continuous production of gas wells and it should be as one of the main means of the refined management of gas wells. The dewatering gas production measures should be taken in time when the following situations appear:

- (1) When the liquid holdup of gas wells is close to the critical liquid holdup;
- (2) When the actual liquid holdup is higher than the theoretical liquid holdup (according to the discrimination board for the liquid loading timing of gas wells);

- (3) When a turning point shows in the change of the kinetic energy factor, the turning point for Type I gas wells is about 3.5 with the daily gas production of $0.9 \times 10^4 \text{ m}^3/\text{d}$; the turning point for Type II gas wells is about 2.5 with the daily gas production of $0.7 \times 10^4 \text{ m}^3/\text{d}$; the turning point for Type III gas wells is about 1.5–2 with the daily gas production of $0.5 \times 10^4 \text{ m}^3/\text{d}$.

References

1. Li, M., et al.: New Viewpoints of liquid holdup for gas wells. *Pet. Explor. Dev.* **5**, 105–106 (2001)
2. Li, S., et al.: *Natural Gas Engineering*. Petroleum Industry Press, Beijing (2005)
3. Yang, J.: *Technological Basis for Gas Production*. Petroleum Industry Press, Beijing (1992)
4. Li, A., et al.: Progress review of research of vertical gas-liquid phase pipe flow. *Pet. Drill. Technol.* **22**(4), 45–47 (2000)
5. Li, X., et al.: Analysis method of well testing for gas wells with wellbore liquid loading. *Pet. Explor. Dev.* **21**(1), 80–83 (1994)
6. Huang, B., et al.: *Gas Reservoir Engineering and Dynamic Analysis Method*. Petroleum Industry Press, Beijing (2004)
7. Wang, N., et al.: *Practical Dynamic Analysis Method for Gas Reservoir*. Petroleum Industry Press (2011)
8. Liu, H., et al.: Application of kinetic energy factor in diagnosing the liquid holdup timing for sulige gas wells. *Petrochem. Appl.* **7**, 45–48 (2014)
9. Liu, G., He, S., Gu, D.: Calculation methods for critical production of continuous liquid holdup of gas wells. *Nat. Gas. Ind.* **26**(10), 114 (2006)