Production Performance Analysis of Su-6 Well Block in Sulige Gas Field, Ordos Basin, China

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Abstract. As a tight sandstone gas reservoir of Su-6 well block in Sulige gas field, part of the gas wells have a poorer production performance with a faster decline rate of formation pressure and production, which is inconsistent with static reservoir parameters of gas well. In order to improve the productivity of gas well, on the base of static and dynamic classification of 232 gas wells, the reasons of inconformity between production performance and static reservoir parameters are analyzed from the four aspects of sand body connectivity, reservoir heterogeneity, gas saturation and fluid accumulation in wellbore. The results show that the main reasons causing the inconformity are the strong heterogeneity and poor sand body connectivity, and the secondary reasons are fluid accumulation in wellbore and low gas saturation. The results of this paper is of great significance to improve the productivity of gas wells and guide the development of ultra-low permeability gas reservoir.

Keywords: Production performance; Gas well; Sand body connectivity; Reservoir heterogeneity; Sulige gas field.

1. Introduction

Sulige gas field is located at the west side of Jingbian gas field. The administrative region of sulige gas field belongs to the Wushenqi, Otogqi and Otogqianqi of inner mongolia autonomous region. Structurally, this gas field is located in the northwestern Yishan Slope, in the Ordos Basin. Sulige gas field is a large scale gas field with the proved reserves in excess of one trillion discovered on land in China. There are nine well blocks in Sulige gas field and the Su-6 well block is located in the midwest of Sulige gas field.

The major pay zones of Sulige gas field are the Shan-1 member of Shanxi formation (Lower Permian) and He-8 Member of Lower Shihezi Formation (Middle Permian), with the depth of 3200m-3500m and thickness of 80-100m. The distribution of gas reservoir in Sulige gas field is mainly controlled by the transverse distribution of sandstone and the change of reservoir physical property. The reservoir is a kind of sandstone with low porosity and permeability, intercalated by mudstone layers, with the effective permeability of less than $1.0\times10^{-3}\mu m^2$ and the porosity of less than $10%\textsuperscript{[1-2]}$.

Table 1 shows the statistics of the production distribution of every well at present. It can be seen from Table 1, the number of wells with the daily gas production below $0.5\times10^4 m^3$ has already exceeded 50%, and most of these wells have better static reservoir parameters including porosity, permeability and pay thickness. It is very important to effectively improve the productivity of these wells for increasing and stabilizing production of Su-6 well block.

Table 1: Statistics of the production distribution of every well at present.
Table 1. The statistics of the production distribution of gas wells.

| Daily gas production, $10^4$m$^3$/d | Number of wells | Proportion, % | Rate of casing pressure drop, Mpa/d | Daily gas production, $10^4$m$^3$/d | AOF, $10^4$m$^3$/d |
|-----------------------------------|-----------------|--------------|-----------------------------------|-----------------------------------|-----------------|
| Q=0                              | 40              | 17.2         | 0.0119                            | 0                                 | 6.0638          |
| 0<Q<0.5                          | 82              | 35.3         | 0.0162                            | 0.3658                            | 7.5024          |
| 0.5≤Q<1                          | 38              | 16.4         | 0.0183                            | 0.7536                            | 9.8657          |
| Q≥1                              | 72              | 31.1         | 0.0350                            | 2.4837                            | 23.1231         |

The purpose of this paper is to determine the reasons of these wells with inconformity between production performance and static reservoir parameters. In this work, firstly 232 gas wells are classified by static and dynamic method respectively to determine these wells with lower productivity and better static reservoir parameters. Then the reasons of inconformity between production performance and static reservoir parameters are analyzed from the four aspects of sand body connectivity, reservoir heterogeneity, gas saturation and liquid loading.

2. Classification of Gas Wells

2.1. Static Classification

The classification method of gas well can be divided into static and dynamic classification method. The static classification method is to use reservoir parameters, such as reservoir thickness, porosity and permeability[3-4]. The dynamic classification method is usually to use the dynamic production data of gas wells, such as gas production of unit pressure drop, pressure drop rate and absolute open flow (AOF)[5-6]. Because the reservoir parameters used in static classification method are usually obtained from logging data or core test, which can’t represent the reservoir condition outside the wellbore, so dynamic classification can better reflect well productivity than static classification. However, the dynamic data is limited before the large-scale development of the gas field, and the static classification result is usually adopted to make the development program of various gas wells. In order to determine the gas wells with the inconformity between production performance and static reservoir parameters, firstly, the 232 gas wells of Su-A well block are classified statically using reservoir parameters including porosity, permeability and reservoir thickness. The static classification standard is showed in Table 2. In this classification standard, the reservoir is firstly classified for class I, II and III according to the porosity and permeability, then the gas wells are classified by the reservoir distribution of class I and II.

Table 2. The static classification standard of gas wells.

| Standard of reservoir classification | Class I reservoir | Class II reservoir | Class III reservoir |
|-------------------------------------|------------------|-------------------|---------------------|
| Porosity, %                         | ≥12              | 8-12              | 5~8                 |
| Permeability, $10^{-3}$ m$^2$        | ≥1               | 0.5~1             | 0.1~0.5             |
| Standard of well classification     | Class I well     | Class II well     | Class III well      |
| Single layer thickness, m           | Class I reservoir≥5 | Class I reservoir=3~5 | Class I reservoir≤3 |
| Total thickness, m                  | Class I reservoir≥8 | Class I+II reservoir≥8 | Class I+II reservoir≤8 |

2.2. Dynamic Classification

The dynamic classification method of gas well is usually based on the absolute open flow (OAF) obtained by gas testing. But in Sulige gas field, the AOF is tested before gas wells putting into production, and AOF only reflects the flow characteristics of induced fracture near wellbore formation. With the gas
well production, the energy of matrix reservoir in further bore zones is gradually applied, so gas well classification simply by AOF can’t correctly reflect the gas well productivity. For this reason, in combination with the production characteristics of fractured gas wells in low-permeability reservoirs, the gas wells are classified dynamically using the three parameters including gas production of unit casing pressure drop, pressure drop rate and AOF. The dynamic classification standard of gas wells is showed in Table.3.

Table 3. The dynamic classification standard of gas wells.

| Standard of well classification | Class I well | Class II well | Class III well |
|--------------------------------|-------------|---------------|----------------|
| Gas production of unit casing pressure drop, $10^4 m^3/Mpa$ | ≥80 | 40–80 | ≤40 |
| Pressure drop rate, MPa/d | ≤0.01 | 0.01–0.02 | ≥0.02 |
| AOF, $10^4 m^3/d$ | ≥10 | 4–10 | ≤4 |

Figure 1 shows the result of static and dynamic classification of 232 gas wells of Su-A well block in Sulige gas field. From Figure 1 we can see that there is a significant difference between static and dynamic classification. For static classification, there are 181 gas wells of class I accounting for 78% of the total wells, while for dynamic classification there are only 124 gas wells accounting for 53.4% of the total wells. Some wells which is classified into class I when static classification may be categorized into class II or class III when dynamic classification, therefore class II and class III wells of dynamic classification are more than that of static classification. Through the Statistics for classification results, it can be found that there is a total of 75 wells with the inconformity between static classification and dynamic classification, with 36 wells of class I in static classification but class II in dynamic classification, 21 wells of class I in static classification but class III in dynamic classification and 18 wells of class II in static classification but class III in dynamic classification.

3. Reason Analysis of Inconformity between Production Performance and Reservoir Parameters

It can be seen from the gas well classification results that the wells with better reservoir parameters may have poor production dynamics. Since the low permeability reservoir has strong heterogeneity, the static reservoir parameters obtained by logging can not fully reflect the production performance of gas wells, so it is normal that there is a difference between static classification and dynamic classification. There are many factors affecting gas well productivity, including formation water, reservoir heterogeneity,
reservoir physical property, well pattern, well spacing, gas saturation, etc [5-7]. Based on the reservoir characteristics and development status of Sulige gas field, the effects of sand body connectivity, reservoir heterogeneity, reservoir physical property, fluid accumulation in wellbore and gas saturation on gas well productivity are mainly analyzed.

3.1. The Sand Body Connectivity
The sand body connectivity depends on many factors including the sedimentary characteristics of sand body, reservoir fractures and structural faults, et. al [8-9]. Through drawing the fence diagram of sand body and analyzing the sand body connectivity, it can be found that most of the wells with inconformity between production performance and static reservoir parameters have a poor connectivity with the adjacent wells on sand body. For example, the well Su20-A-5, which is a class II well for dynamic classification but a class I well for static classification. The fence diagram of sand bodies of well Su20-A-5 and its adjacent wells is shown in Figure 2. From Figure 3 it can be seen that there is no connected sand body in the west and north of H8x1 horizon, while for S13 horizon, there is no connected sand body in the west, east and south. The poor connectivity of sand body causes the small gas supply radius, thus making the wells with better static reservoir parameter have a poor production performance.

3.2. The Reservoir Heterogeneity
Although there is a continuous sand body at a certain direction, but the physical properties of the sand body gradually deteriorate or the sand body gradually thins. For example, the well Su20-B-14, which is a class III well for dynamic classification but a class I well for static classification. Figure 3 shows the fence diagram of sand bodies of well Su20-B-14 and its adjacent wells. From Figure 3, we see that for the H8x1 reservoir, there is no continuous sand body in the south, north and west. In the east, the sand body is connected with poor gas zone of well S20-B-15, so the reservoir physical property become worse gradually. For the Shan1 reservoir, the sand body is connected with poor gas zone in the north and east, and the reservoir physical property become worse gradually, and the reservoir thickness become thin gradually.

Figure 2. The sand body fence diagram of Su20-A-5.
3.3. Fluid Accumulation in Wellbore

Fluid accumulation in wellbore is an important factor affecting gas well production. If the gas does not carry the liquid effectively and the liquid is accumulated in the wellbore, it will cause the production to decline, the production time will be shortened, and even the production will be stopped. When there is a fluid accumulation in wellbore during production, the differential of casing pressure and tubing pressure will gradually increase, and the corresponding production will gradually decrease. Therefore we can be from pressure and production curves to determine a fluid accumulation in wellbore. The well of Su20-C-2, for example, is a continuous production well without choke, and the production curves are showed in Figure 4. From Figure 4 we can see that there is an obvious fluid accumulation in wellbore at the interval between two dotted lines, and the gas well production has been reduced to 0 because of serious fluid accumulation in wellbore. The analysis of the profile of the gas reservoir shows that the north, north west and west of the He8 reservoir are connected with the gas and water mixed layer of the neighboring well, so the water is produced.

3.4. Gas Saturation

| Horizon | Perforated interval, m | Thickness, m | Porosity, % | Permeability, $10^{-3} \mu m^2$ | Gas saturation, % | Log interpretation  |
|---------|------------------------|--------------|-------------|-------------------------------|------------------|-------------------|
| He8     | 3475.0-3479.1          | 4.1          | 5.76        | 0.38                          | 32.38            | gas-bearing reservoir |
|         | 3485.7-3489.6          | 3.9          | 6.48        | 0.48                          | 45.92            | gas reservoir      |
|         | 3500.6-3504.0          | 3.4          | 4.81        | 0.37                          | 39.62            | gas-bearing reservoir |
The gas saturation can affect the effective permeability of gas in reservoir, thus affecting the gas well productivity. The gas well with low gas saturation has a poor production performance. For example, the well of Su20-D-5 with an average gas saturation from logging interpretation of only 39.31%, is a class I well for static classification but a class III well for dynamic classification. The producing zone data of well Su20-D-5 is shown in Table 4.

4. Conclusion
(1) There is a serious inconformity between static classification and dynamic classification. The number of class I wells in dynamic classification is lower than that in static classification, while the number of class II and class III wells in dynamic classification is higher than that in static classification.
(2) The main reasons causing the inconformity between production performance and static reservoir parameters are the strong heterogeneity and poor sand body connectivity, and the secondary reasons are fluid accumulation in wellbore and low gas saturation.

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References
[1] Tiantai Li, Xing Huang. Classification of horizontal wells based on dynamic data and its application in ultra-low permeability gas reservoirs. Chemistry and Technology of Fuels and Oils, 53, No.1, 123-134(2017)
[2] Liu Guangdi, Sun Mingliang, Zhao Zhongying, et.al, Characteristics and accumulation mechanism of tight sandstone gas reservoirs in the Upper Paleozoic, northern Ordos Basin, China. Pet.Sci, No.10:442-449(2013)
[3] Zhao Tao, Sun Xinya, Li Wenpeng, et.al. Research on the classification method of gas well in Sulige gas field. Journal of Yangtze University (Nat Sci Edit). No.8:66-69(2011)
[4] Li Yuegang, Xu Wen, Xiao Feng, et.al. Optimization of a development well pattern based on production performance: A case study of the strongly heterogeneous Sulige tight sandstone gas field, Ordos Basin. Natural Gas Industry B, No.2, 95-100(2015)
[5] Fan Zhaoting, Zhang Shengtao, Liu Jia, et.al. Effect of the chemical composition of formation water on gas well productivity. Chemistry and Technology of Fuels and Oils, 50, No.3, 252-256(2014)
[6] Li Qi, Ye Liyou, Gai Zhaohe, et.al. Influence of bound and mobile water on gas well production in a low-permeability sandstone gas reservoir. Chemistry and Technology of Fuels and Oils, 53, No.2, 263-273(2017)
[7] Luo Rulian, Han Yongxin, Yu Shuming, et.al. Production Performance Analysis of Hydraulically Fractured Horizontal Wells in Sulige Gas Field. International petroleum technology conference(IPTC), 16528(2013)
[8] Xiao Wei, Wu Xiaodong, Liu Xiaojuan. Simplified graphical correlation for determining flow rate in tight gas wells in the Sulige gas field. Pet.Sci. No.5:258-262(2008)
[9] Wenge Hu, Xiangfang Li, Keliu Wu. The model for deliverability of gas well with complex shape sand bodies and small-scale reserve of Sulige Gas Field in China. J Petrol Explor Prod Technol. No.5:277–284(2015)