Deliverability Evaluation on Horizontal Well with DHC in Tight Sandstone Gas Reservoir

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Abstract. Sulige gas field is a typical tight sandstone gas reservoir. In order to reduce the pressure in gathering line, cut engineering investment, and enhance recovery, down-hole choke (DHC) is widely applied in the area. However, this device could lead to unstable production, plus the lack of data of pressure and deliverability test in the area, traditional deliverability methods like empirical method, index curve, and IPR relationship could not be applied. Since the year of 2011, horizontal wells are widely developed in Sulige gas field. Take block S1 for instance, based on production data, decline analysis and flowing material balance equation; three deliverability forecasting methods are developed, which include using conventional production data, initial production rate, and absolute open flow. Applying this combined deliverability forecasting method in block S1, field application shows that rational rate of horizontal wells in the first three years of the area is about 4.3×10^4 m^3/d, which caters to the practical situation. This method has provided a research strategy for the similar gas field and could be used as a reference for well deployment, gas gathering line construction, and reservoir development potential prediction.

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1 Introduction

Sulige gas field is located on the northwest side of Yishan slope of Ordos basin. As a typical tight sandstone reservoir, the pay zone of the field is He 8 and Shan 1 layers. And both layers yield severe heterogeneity, low pressure, low abundance, and low permeability. Since 2006, large-scale development becomes reality for enhancing technology, encouraging creativity, and controlling cost. Since 2011, horizontal wells were largely developed in Sulige field, especially S1 block.

S1 block is located in the middle part of Yishan slope of Ordos Basin, the Upper Paleozoic is dominated by delta plain, and the following formations are developed in the field: Ben Xi, Shan Xi, lower Shihezi, upper Shihezi, and Shiqianfeng. The pay zones are Shanxi and lower Shihezi, which developed a reservoir with 6–9 m thickness, 6–12% porosity, and 0.1–1 mD permeability.

There are a few pressure, and deliverability test data in the block S1 for DHC is widely applied in the area. More than 50% wells in the area are horizontal wells, and accurate production prediction is vital in making developing decisions.

2 Rational Rate Elevation

In order to maintain plateau, reduce pressure decline influence, and improve production rate, the allocation should take single well-controlled reserve into consideration, so that a gas well could maintain a 2–3 years of plateau. Conventional deliverability evaluating method includes empirical method, inflow performance relationship, and nodal analysis [1]. Absolute open flow is the prerequisite for empirical method, and coefficient A and B in deliverability equation are requirements for inflow performance relationship and nodal analysis. However, these factors could only be acquired from deliverability tests.

Due to the DHC, deliverability tests' data are rare in Sulige gas field; as a result, conventional deliverability predicting method can hardly applied in the area. Based on production data, decline analysis, and flowing material balance equation, three deliverability forecasting methods are developed, which include using conventional production data, initial production rate, and absolute open flow.

2.1 Allocation Evaluation Method Based on Conventional Production Data

Block D1 in Jingbian oilfield is a neighboring reservoir of S1 block. They share similar geological condition and the same pay zone. But, block D1 has a pretty long production history and owns abundant pressure testing material for not applying DHC. As a result, material balance equation could be used for GIIP (gas initially in place) evaluation. Based on GIIP evaluation result of more than 100 wells in D1 block and cumulative production rates when casing pressure decline to 16 MPa/14 MPa/12 MPa/ 10 MPa/ 8 MPa/ 6 MPa, a deliverability predicting equation (Eq. 2) has been established.

$$\frac{Gp}{GIIP} = f = 6.0846 \times p_c^{-1.4954} \tag{1}$$

$$Q = GIIP \times f/t \tag{2}$$

In which

Gp = cumulative production rate (10^4 m^3)
GIIP = gas initially in place (10^4 m^3)
Pc = casing pressure (MPa)
Q = gas production rate (10^4 m^3/d)
t = elapsed time (d)

In order to predict deliverability using conventional production data, a relationship of production rate, casing pressure, and GIIP is developed based on Eq. (2). As shown in Fig. 1, the rational allocation of block S1 should be 4.3 × 10^4 m^3/d, with a GIIP of 0.81 × 10^8 m^3 and a casing pressure of 5.7 MPa.

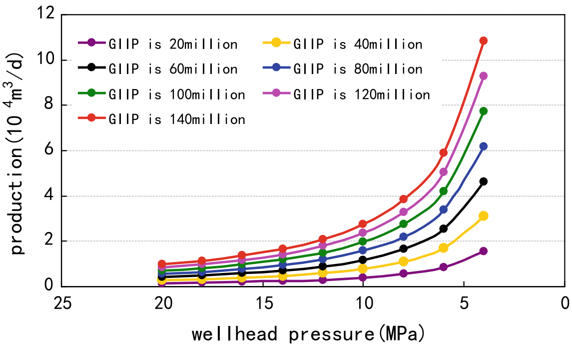

Fig. 1. Plate of deliverability prediction using conventional production data

2.2 Allocation Evaluation Method Based on Initial Production Rate

Due to the DHC, gas rate in Sulige gas field yields a decline character from the beginning of production. And the analysis shows that the decrease follows the rule of depletion decline (n = 0.5), as shown in Eq. (3), which could be transformed as Eq. (4). According to Eq. (4), a correlation chart between initial gas rate, rational allocation, and producing time has been established (Figs. 2 and 3).

$$G_p = \frac{Q_i}{0.5D_i}\left(1 - \frac{1}{1 + 0.5D_i t}\right) \tag{3}$$

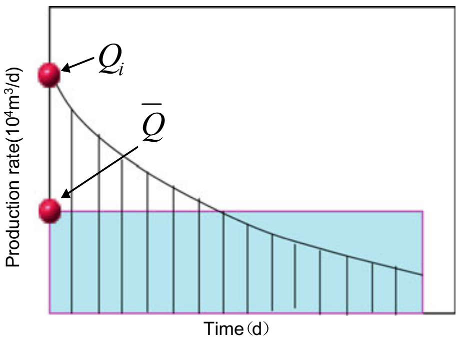

Fig. 2. Correlation chart between rational allocation and initial gas rate

$$Q_i = \frac{(1 + 0.5D_it)G_p}{t} = \frac{(1 + 0.5D_it)\bar{Q}}{t}t = (1 + 0.5D_it)\bar{Q} \tag{4}$$

In which

Qi = initially gas rate (10^4 m^3/d)
Di = initial decline rate (dimensionless)
t = elapsed time (d)

Figure 3 is the production history of three different types of well. Equation (4) and Fig. 3 indicated that rational allocation in the first three years of the first class of horizontal wells in block S1 is about 7.1 × 10^4 m^3/d, the second class of horizontal wells 4.1 × 10^4 m^3/d, and the third class of horizontal wells 2.3 × 10^4 m^3/d. Weighed by well number, the average allocation in the first three years in block S1 is about 4.2 × 10^4 m^3/d.

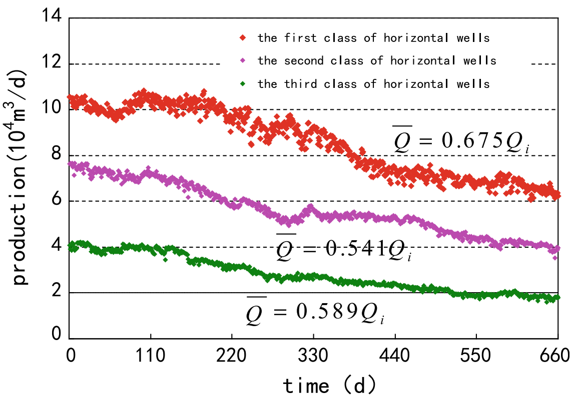

Fig. 3. Production history of block S1

2.3 Allocation Evaluation Method Based on AOF

AOF shows the fracture permeable feature of initial producing history near the wellbore. The empirical method, which is taken 1/4–1/6 of AOF as the rational allocation, may trigger problem [2]. A higher allocation may cause a quick rate decline and reservoir damage due to pressure sensitivity effect. And a lower allocation may initiate liquid loading [3, 4].

Large-scale fracture changed the relationship between allocation coefficient and AOF [5]. Statistical data show that these two variables follow the rules of power function, as shown in Fig. 4, which indicate a larger AOF corresponding to a smaller allocation coefficient.

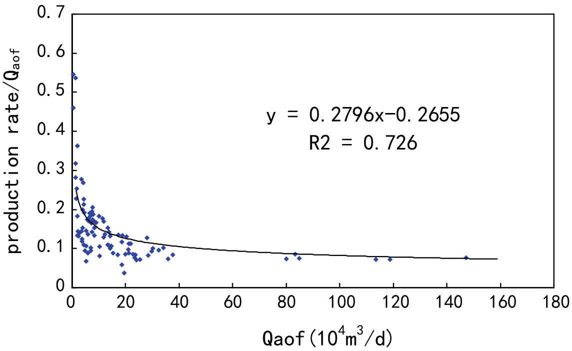

Fig. 4. Relationship between AOF and allocation coefficient

The average AOF of horizontal wells in the study area is about 41.4×10^4 m^3/d. And according to the relationship, the rational allocation in the first three years is about 4.3×10^4 m^3/d.

3 Comprehensive Evaluation

Based on production data of more than 200 horizontal wells in block S1, three evaluation methods show that the average rational allocation of the study area is about 4.3×10^4 m^3/d, as shown in Table 1.

Table 1. Allocation evaluation result of horizontal wells in the first three years

No.	Allocation evaluation method	Rational allocation (10^4 m^3/d)
1	Conventional production data	4.3
2	Initial production rate	4.2
3	AOF	4.3
Comprehensive evaluation		4.3

4 Inclusion and Cognition

(1) Wells in tight sandstone reservoir with DHC yield short producing history, unstable production rate, and rare pressure testing material. Based on production data, three allocation evaluation methods are developed, which include using conventional production data, initial production rate, and absolute open flow.

(2) Allocation evaluation method based on conventional production data shows that the rational allocation in the first three years is about 4.3×10^4 m^3/d, initial production rate method indicates a rational allocation of 4.2×10^4 m^3/d, and AOF method implies an allocation of 4.3×10^4 m^3/d.

(3) The above allocation evaluation method is independent of deliverability test and long producing history. And so, it provides an effective method to evaluate rational allocation of horizontal wells with DHC.

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