Application of Well Test Interpretation in Oilfield Based on PDA Method in Tight Gas Reservoir

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Abstract. The reservoir characteristics of tight sandstone gas reservoirs are characterized by low porosity and low permeability, which brings difficulties to the conventional pressure recovery well test in oil fields. The lower porosity and permeability greatly extend the test time. Radial flow was not detected when the oil well was shut down for more than one month. The well test curve showed strong multi-solution characteristics and could not obtain accurate formation parameters. In this paper, based on the characteristics of tight gas reservoirs, the well test interpretation method (PDA method) is applied to the application of production data. A set of explanations for using the production data to explain tight gas wells and carrying out capacity evaluation and prediction are proposed. The interpretation of the production data of 1 is compared with the interpretation results of the pressure recovery test of the well. The two methods have good consistency, and the multiple interpretation methods can better reduce the multi-solution of the well test interpretation, and verify the PDA. The feasibility of the method applied on tight gas wells, and finally the correctness of the method was verified by the capacity prediction method.

Keywords: Tight gas reservoir; Low porosity and low permeability; Pressure recovery well test interpretation; Production data well test interpretation; Flow integration pressure method; Capacity prediction.

1. Introduction
For the reservoir characteristics of low-porosity and low-permeability tight gas reservoirs, the test time of conventional unstable well testing and capacity test wells is greatly extended when interpreting gas well data [1]. Radial flow is not detected even when the well is shut down for more than one month. The curve shows strong multi-solution characteristics and cannot obtain effective formation parameters. The data of gas well production and pressure directly reflect the dynamic characteristics of gas wells, which is the basic data for optimizing production and adjusting the measures, but it has not been applied [2]. The use of production data for well testing analysis methods can make full use of a large amount of production data on site, reduce the impact of shut-in pressure measurement on production, improve production data utilization, and reduce testing costs [3-9]. Use production data for well test interpretation and capacity evaluation to determine the permeability, skin factor, formation pressure, productivity and other parameters of the gas well or the entire block, accurately understand the formation, and perform
fracturing, acidification, and new wells from the perspective of the entire field [10, 11]. The macro-adjustment of the old wells, transfer, transfer, replenishment, liquid extraction, water shutoff, etc., targeted measures and implementation, optimized design for gas well testing and stimulation measures [4].

2. Production data well test interpretation method--flow reforming pressure method

Production data well test interpretation method--flow reforming pressure method is based on typical curve fitting and history fitting as the main means to analyze production data, convert variable output/variable pressure drop data into equivalent constant pressure system, and introduce The definition of equivalent time and flow reforming pressure, and the analysis of production dynamics of production data and pressure data.

2.1. Material balance time

\[ t_e = \frac{Q}{q} = \frac{1}{q} \int_0^t q_i \, dt \]  

When the material balance time is used, the constant pressure solution is converted into the constant flow solution, and the quasi-steady-state flow period conforms to the law of harmonic reduction [1].

2.2. Flow reforming pressure method

The flow reforming pressure method uses flow reforming pressure to analyze variable flow or variable pressure production data. The definition of dimensionless pressure and time is the same as the well test interpretation [6].

Reforming pressure:

\[ \frac{\Delta p}{q} \]  

Reforming pressure points:

\[ \left( \frac{\Delta p}{q} \right) = \frac{1}{t_e} \int_0^{t_e} \frac{\Delta p}{q} \, dt \]

Reforming the pressure integral derivative:

\[ \left( \frac{\Delta p}{q} \right) = \frac{1}{t_e} \int_0^{t_e} \frac{\Delta p}{q} \, dt \]

Figure 1. Example of the combination of reforming pressure and reforming pressure derivative combination

The reforming pressure and the reforming pressure derivative are all obtained by fitting the typical plate of the decreasing curve through actual production data. K, s, re, Gi, etc., the well testing model can be directly used to analyze the flow reforming pressure method [7]. Using the well test interpretation
method to fit the data of the flow reforming pressure generated by the original data, the fitting model can be found according to the well test analysis theory. Then using the fitted model for further production predictions, we can get a trend of decreasing production and increasing cumulative production. Figure 1 shows an example of the fitting of the reforming pressure and the reforming pressure derivative. The reforming pressure derivative has the same characteristics as the pressure derivative curve explained by the unstable well testing [5].

3. Well No.1 Interpretation Results Comparison

Well No.1 is located in the Ordos Basin and was drilled in August 2002. It was then tested by DST and tested for fracturing. During the production period, a total of 6 shut-in pressure recovery tests were conducted, and complete pressure recovery test data was obtained. The well was taken from the production data for nearly 9 years since the production was put into operation for well test interpretation, and the two well test interpretation methods were compared and analyzed.

3.1. DST test interpretation curve analysis

According to the DST test curve, the double logarithmic curve of the secondary shut-in recovery shows a distinct radial flow straight line segment. The Horner permeability of the formation is 0.086 md, which can be considered as the true permeability of the formation. The detection radius is 24.53m. There is no boundary reflection within the range, and the skin coefficient is 5.01, indicating that there is slight pollution in the formation. The curve fitting diagram is shown in Table 1 and the results are shown in Table 1.
3.2. **Analysis of previous pressure recovery test curves**

The well was tested for shut-in pressure recovery in 2005, 2006, 2007, 2008, 2009, and 2010. Figure 5-10 shows the double logarithmic fit of previous pressure recovery tests. The obvious fracturing well morphology can be seen from the figure. Although the curve of the front well section is irregular, the shape behind the curve is relatively consistent, with good inheritance, and there is no big change in the properties of the reaction stratum. The results of previous tests are more accurate. The results of previous pressure recovery interpretation are shown in Table 1.

![Figure 5. Double logarithmic fit of pressure recovery in 2005](image)

![Figure 6. Double logarithmic fit of pressure recovery in 2006](image)

![Figure 7. Double logarithmic fit of pressure recovery in 2007](image)

![Figure 8. Double logarithmic fit of pressure recovery in 2008](image)

![Figure 9. Double-logarithmic fitting of pressure recovery in 2009](image)

![Figure 10. Double logarithmic fitting of pressure recovery in 2010](image)
3.3. Production data test curve analysis

Well No.1 has been self-injected since its official production. In order to reduce clogging in the production process, methanol is injected. The production data of nearly 9 years was used for well test interpretation, and the interpretation curves are shown in Figures 11 and 12. As shown in the figure, the fitting effect is good, and the yield, cumulative yield, pressure, and reforming pressure derivative curve can be well fitted.

3.4. Comparative analysis of test results

The DST, pressure recovery test and production data test results are compared, as shown in Table 1.

Table 1. Comparison of production data interpretation and pressure recovery test interpretation results

| Method | test time | Interpretation model                  | Epidermis S | Crack half length Xf(m) | Diversion capacity | Initial pressure Pi (Mpa) | PermeabilityK(md) | Boundary distance L(m) |
|--------|-----------|--------------------------------------|-------------|-------------------------|--------------------|--------------------------|-------------------|-----------------------|
| PDA    | 2003.9    | finite diversion crack + circular boundary | 0           | 301                     | 5.5                | 21.8                     | 0.086             | 402                   |
|        | DST test  | Infinitely large                      | 5.016       |                         |                    | 26.64                    | 0.086             |                       |
|        | 2005year  | Limited diversion crack               | 0           | 226                     | 49                 | 23.4                     | 0.086             |                       |
|        | 2006year  |                                      | 0           | 259                     | 43                 | 22.3                     | 0.086             |                       |
|        | 2007year  |                                      | 0           | 257                     | 40                 | 21.1                     | 0.086             |                       |
|        | 2008year  |                                      | 0           | 270                     | 21                 | 19.8                     | 0.086             |                       |
|        | 2009year  |                                      | 0           | 238                     | 21                 | 19.6                     | 0.086             |                       |
|        | 2010year  |                                      | 0           | 322                     | 9.7                | 18.7                     | 0.086             |                       |

The PDA in Table 1 represents the interpretation of the production data, and the PTA represents the results of the stress recovery test interpretation. The DST test was carried out before fracturing, so the homogeneous model was used, and the epidermis was larger, indicating that there was contamination near the well near the well; the results of 6 times of the recovery test were observed because the permeability explained by the DST Horner method is the true penetration of the formation. Rate, so the permeability explained by DST is used in the interpretation of pressure recovery, so the permeability is consistent. After the fracturing, the skin is 0 due to the selection of the fracturing model; the well storage coefficient is very different, which is abnormal with the curve in the well storage stage. Relevant; from the results of 6 times of pressure recovery test, the crack half length has an increasing trend, the conductivity is reduced, but the numerical difference is not large, the fracturing well is obvious, the formation coefficient changes little, several times. The recovery interpretation has a good consistency, indicating that the model selection is reasonable. The production data interpretation also uses the DST test to explain the permeability. The fractures obtained by the production data are half-length 301 meters and the dimensionless conductivity is 5.5, which are similar to the pressure recovery test results in 2010.
The overall explanation shows that the pressure recovery and production data reflect the stratum has the same nature and the selection of the stratigraphic model is reasonable.

After removing the anomalous curve of the previous well storage stage from the six recovery curves from 2005 to 2010, it is plotted on a graph, as shown in Fig. 13. It can be seen that the double logarithmic curve and the derivative curve opening, and the fracturing curve The trend is basically the same, reflecting that the properties of the stratum remain basically unchanged during the test, and there is no major adjustment to change the stratum; however, the six curves do not completely coincide, indicating that the nature of the six test wells and the nature of the cracks are not completely consistent. It can be seen from the interpretation results that the formation permeability and the skin factor remain unchanged, but as the production time increases, the crack half length gradually increases, and the fracture conductivity gradually decreases.

Take multiple compression curves for deconvolution transformation, and the pressure drop response of all the tests can be obtained by pressure recovery, and then compared with the interpretation results of production data, comprehensive analysis and interpretation.

Figure 14 shows the deconvolution calculation results. From the curve shape, the deconvolution transformation is similar to the production data curve shape (Fig. 15). After the two curves are superimposed, the curves are completely coincident. This is the pressure recovery data and production data. Co-explanation results show that the models selected by the two interpretation methods are reasonable, and the stratigraphic information of the reaction is the same, so that the two methods mutually verify and explain, minimize the multi-solution, and greatly improve the accuracy of the well test interpretation.
3.5. Capacity Forecast

In order to verify that the production data interpretation model is correct, we can make a production forecast. The production data was first intercepted in January 2009, and then the existing model was used to predict the output in April 2012, and then compared with the actual production to verify whether the model is in line with the actual formation. Figure 12 is a predicted fit map. The yellow solid line indicates the measured data curve, and the red indicates the prediction curve. The measured end point pressure is used for prediction. The prediction results are shown in Table 12. From the forecast results, after two and a half years, the predicted output is 5,268,790 square meters, the actual output is 5,250,700 square meters, the error is 0.35%, and the prediction results are more accurate, indicating that the interpretation model used is in line with the actual stratigraphic characteristics, and the interpretation results are credible.

![Figure 12. Predicted fit map.](image)

**Figure 12.** PDA method for well testing interpretation of oilfields in tight gas reservoirs

4. Conclusion

1) Contrast shows that the production data well test interpretation results and the pressure recovery interpretation results reflect the same stratum properties, indicating that the production data can be used for well test interpretation in tight gas wells, which can greatly reduce the test time and reduce the yield reduction caused by the test influences.

2) The simultaneous interpretation of multiple methods can verify and mutually constrain each other, which greatly reduces the multi-solution of the well test interpretation.
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