Dynamic Sanding Prediction Model of Horizontal Well and Its Application

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Abstract

After production for more than ten years, many wells have the widespread phenomenon of sanding production in the S1 gas field, west of South China Sea. Due to the critical sanding pressure drawdown of the formation and the sanding production characters is not clear, it always uses regulating the production system to reduce the sanding production. Based on the Reservoir rock data of the S1 gas field and the production situation of gas wells, which were used to analyze of the gas wells underground situation, a comprehensive system was established to analyze and diagnose the dynamic sanding prediction in the late stage, find out the rules of the sanding production and clear the main reason for the sanding production. With the production continued, the formation pressure decreased significantly, and the average decline rate is about 0.47MPa/a; The critical pressure of the reservoir is also decreased obviously, and the most is less than 2MPa, and the average drop is about 0.2MPa-0.5MPa. According to the conclusion of the dynamic sanding prediction, adjusting the working system of the gas field can slow down the further deterioration of the sanding effectively, and ensure the normal production of the gas field.

Keywords

Sanding prediction; critical pressure drawdown; horizontal well; gas field.

1. Introduction

Sanding production and sanding control of formation has been the major problems in the development of unconsolidated sandstone gas reservoirs. The study of the sanding production characters is helpful for the scientific and rational optimization design of sanding control technique and the comprehensive evaluation of the sanding control effect, which is the key to improve the exploitation level of the unconsolidated sandstone gas reservoir. At present, we can control the sanding well production only by adjusting the nozzle, but there is no clear reasonable production pressure drawdown as the evidence of control, which seriously restricts the development of the gas field. Therefore, it is significant to make clear the critical sanding pressure drawdown and the sanding production rules for the sanding control in gas field. The basic content of the prediction system of sanding include the experience qualitative sanding prediction, the critical sanding pressure drawdown and critical production output prediction, and the dynamic sanding prediction, which are based on the reservoir rock mechanics parameter testing and the original prime stress prediction of reservoir. A horizontal static sanding critical pressure drawdown prediction model can be established, in which several main factors need to be considered, including the change of rock strength, the influence of water saturation and the reservoir effective stress changes.

2. Establishment of static sanding production prediction model

2.1 Calculation of rock mechanical parameters in a single well

By using logging data, the reservoir mechanical parameters distribution of many wells was simulated, for example, S1-X2h wells.

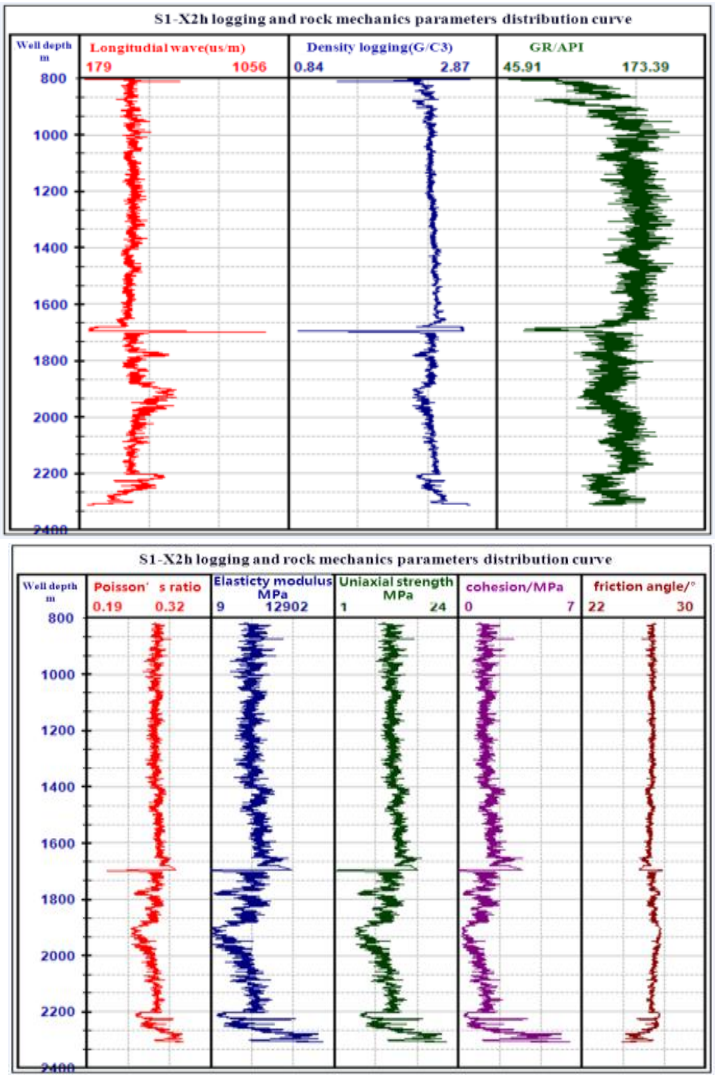

Fig.1 The reservoir mechanical parameters distribution in X2h wells

The reservoir mechanics parameters of the three reservoirs are statistically analyzed, according to the production layer of the sanding well.

Tab.1 Statistics of the reservoir mechanics parameters of each reservoir in the S1 gas field

layer	P-wave Transit Time /(us/m)	S-wave Transit Time /(us/m)	Rock Density /(kg/m^3)	Rock Poisson's Ratio	Elastic Modulus /MPa	Compressive Strength /MPa	Tensile Strength /MPa	Cohesive Strength /MPa	Internal Friction Angle /°
I	361	732.61	2173.25	0.272	5642.9	13.7	2.29	2.16	26.51
III_1	406.37	813.3567	2225.177	0.2644	4903.233	12.2733	2.0467	2.3133	26.4467
II_2	440.9414	874.8957	2181.845	0.2595	4050.8	10.9843	1.8343	1.7571	26.6729

As shown in Table 1, Reservoir II_2, III_1 and I, in S1 Gas Field, Rock Poisson ratio was between 0.26 and 0.27, Elastic Modulus 4000-6000MPa, Compressive Strength 10MPa -14MPa, Cohesive Strength 1.7MPa -2.4MPa, Internal Friction Angle 26 °-27 °. According to the above statistics, the rock strength of Reservoir II_2, III_1 and I, in S1 Gas Field, is basically quite, but Reservoir I is slightly better. It belongs to the weak cementation sanding reservoir generally.

2.2 Calculation of Original Prime Stress

Using the logging data and the rock mechanics parameters distribution data, the original prime stress of formation can be calculated in X2h wells by Two Unequal Stresses Model and Software, and compared the statistics, to provide the basis for the prediction of the sanding critical pressure drawdown. The prime stress profile is calculated.

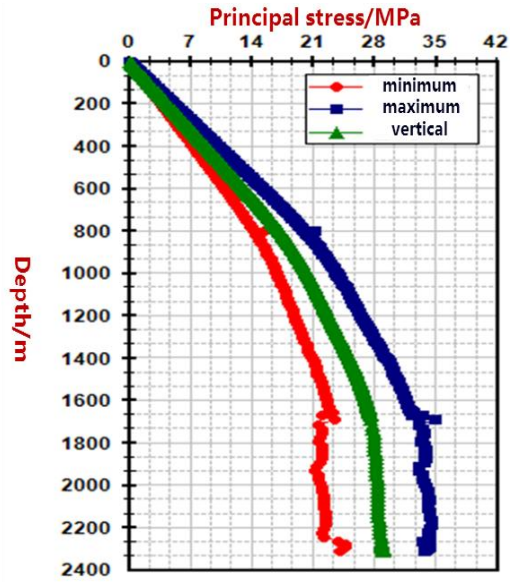

Fig. 2 The original prime stress profile of X2h well

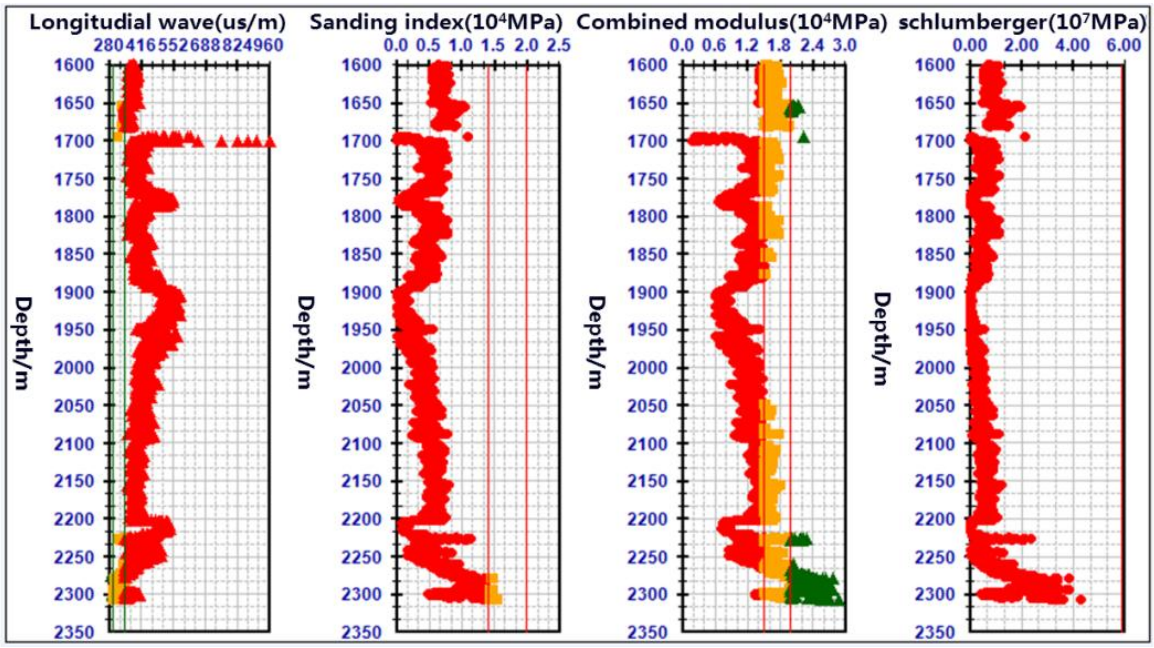

Fig. 3 The experience qualitative sanding prediction of X2h well

3. Dynamic Sanding Prediction

The dynamic sanding prediction of reservoir is constantly changing with the critical production pressure drawdown and the output, and the main influencing factors include:①The strength of the rock is changed with the production time of the sanding, and the more serious the sanding is, the more obvious the strength reduce of the rock is;②With continuing to produce, water saturation or water content is increasing which means that near the water saturation of wellbore rock increases. And for the low initial water saturation of rock, with the increase of water content and the physical and

chemical work of water on rock, the rock strength decreases and the sanding production get more serious;③With the formation pressure dropping, the effective stress on the reservoir is increased, and the rock structure of the reservoir is destroyed, which cause the sanding production more serious.

3.1 The experience qualitative sanding prediction

Four experience qualitative methods, such as Sonic Transit Time, Combination Modulus, Sanding Index, Schlumberger Ratio, was used to predict the sanding production of the S1-X2h well.

In the above figure, the red means a large risk of sanding in general production, while the green means the smaller or less risk. As the figure shown, the X2h well has a obvious symbol, which means a great possibility of sanding.

3.2 The sanding critical pressure drawdown prediction

Using the rock mechanics and the original prime stress data, the change rules of the sanding critical production pressure in the production well section of S1-X2h well is predicted by using the software, as shown in fig.4.

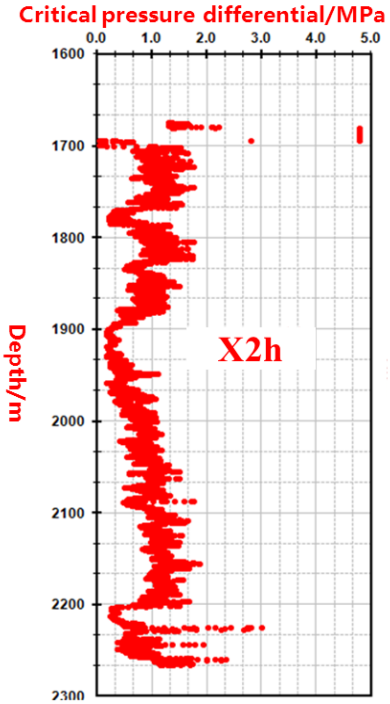

Fig. 4 the results of sanding critical pressure drawdown prediction of X2h well

According to the results of sanding critical pressure drawdown prediction in 7 wells of S1 gas field, the critical production pressure of sanding in each well is obtained as shown in Tab.2.

As shown in Tab.2, the sanding critical pressure drawdown (SCPD) is about 0.5MPa -3.7MPa in the S1 gas field, which is small generally and easy to sanding in bad production conditions; the SCPD of various well make a great difference in the same bed.

3.3 The changing rules prediction of sanding critical production pressure

Based on the prediction method of formation dynamic sanding production, the SCPD of the present formation is predicted by using software in the S1 gas field. For the S1 gas field, it has been mined for ten years, but the water is less and more stable, so we can ignore the influence of formation water saturation and temperature change. The decrease of reservoir pressure is the main factor of the dynamic change of SCPD in the S1 gas field. According to the pressure data of S1 gas field, the formation pressure drop rules of the 7 wells is analyzed. The average formation pressure drop rate is about 0.47MPa/a in the S1 gas field, while it is about 0.9MPa/a in X2h well.

Table. 2 The results of sanding critical pressure drawdown prediction in 7 wells of S1 gas field

Well Number	Horizon	Sanding Critical Pressure Drawdown Prediction /MPa
S1-X2h	Ⅱ2	0.963
S1-X3h	Ⅰ	1.923
	Ⅱ2	3.73
	Ⅲ1	1.298
S1-X5h	Ⅱ2	1.871
	Ⅲ1	2.135
S1-X6h	Ⅱ2	1.317
	Ⅲ1	1.596
S1-X7h	Ⅱ2	0.706
S1-X8h	Ⅱ2	0.502
S1-Y1h	Ⅱ2	0.858

Set X2h well has produced for 10 years, the formation pressure has been down from the initial 14MPa to the current 5MPa. Using the dynamic sanding prediction method, the changing rules of the SCPD is predicted in X2h well, as shown in Fig.5, in which the SCPD decreases with the decrease of formation pressure and the production continuity.

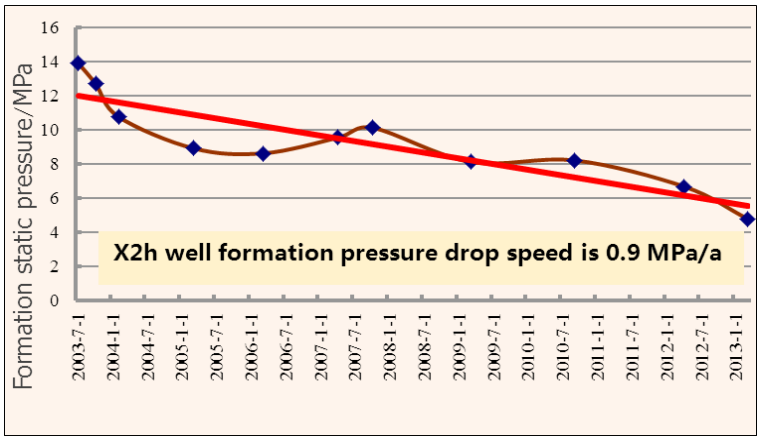

Fig. 5 The rules of formation pressure changing with production time in X2h well

As shown in Fig.6 and Fig.7, X2h well formation pressure drops from 14MPa to 5MPa, the SCPD from 1.45MPa to the current 1.1MPa; with the production continue, the SCPD will drop to about 1.05MPa after 15 years of production.

According to the pressure and production dynamic data of the S1 gas field, the rules of the flow pressure and pressure difference of the 7 wells are analyzed, and the variation rules of the X2h well is shown in Fig.8.

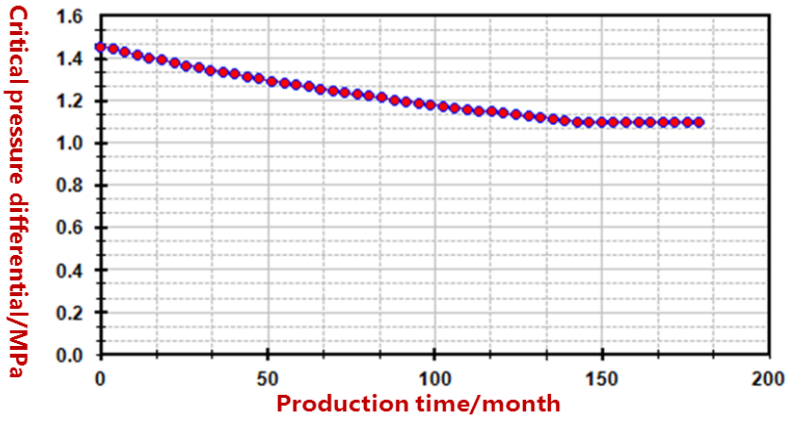

Fig. 6 The rules of SCPD changing with production time in X2h well

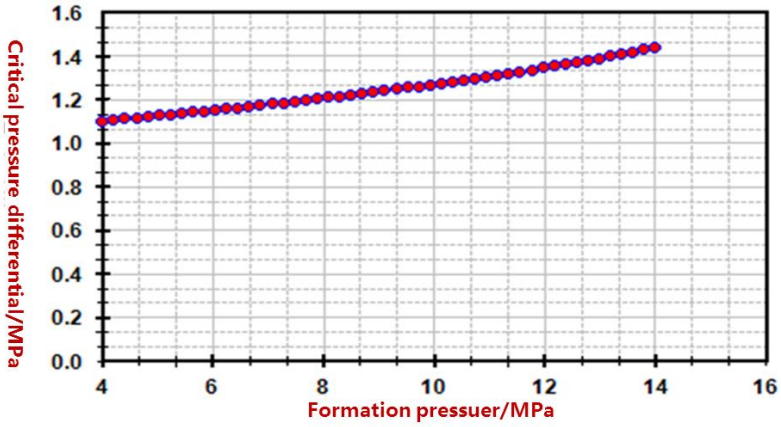

Fig. 7 The changing rules of SCPD and formation pressure in X2h well

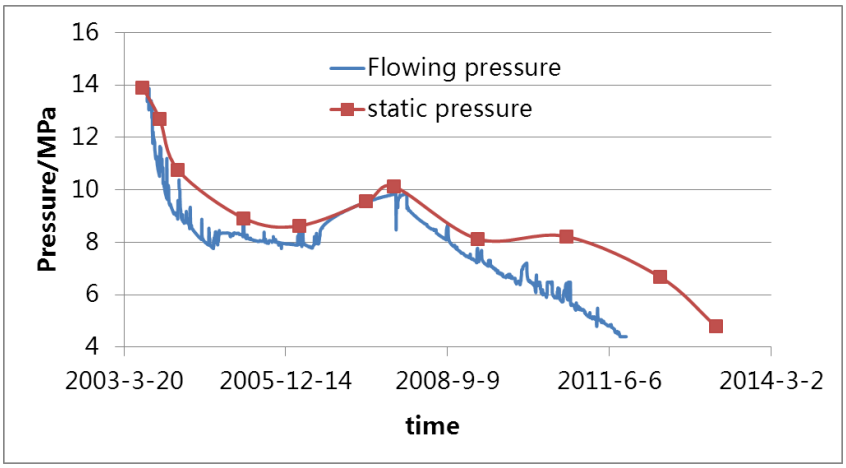

Fig. 8 The variation of pressure difference in X2h well

According to the prediction results, the SCPD is 0.5MPa-3.7MPa in the reservoir of the S1 gas field, in which the SCPD of most well is less than 2MPa, and the SCPD will be decreased by about 0.2MPa -0.5MPa after the production of 10 years. According to the results of Fig.8, the production pressure difference of part gas well is over SCPD in the S1 gas field. The production pressure difference of 10 wells is greater than 2MPa, and 4 wells is higher than 3.5MPa in the 4 platform of S1 gas field. The production pressure difference exceeds the SCPD, which causes the sanding of formation. Even if the sanding control measures are taken, the sanding control and completion pipe is in existence. But the formation still can be out of sanding and gradually fills the annular space, if the formation of the strata is objectively up to the sanding condition.

4. Conclusions and Recommendations

(1) As production continues, formation pressure decline faster in unconsolidated sandstone gas reservoirs, and average formation pressure decline rate is about 0.47MPa/a. In addition, the effective stress on the reservoir is increased, which destroys the rock structure of the reservoir and causes the sanding.

(2) The critical pressure of the reservoir is also decreased obviously, and the most is less than 2MPa, and the average drop is about 0.2MPa-0.5MPa. Most part of the wells production pressure difference is higher than the SCPD in S1 gas field, and the sanding is more serious with the fluctuation of the production system.

(3) According to the conclusion of the dynamic sanding prediction, adjusting the working system of the gas field can slow down the further deterioration of the sanding effectively, and ensure the normal production of the gas field.

(4) A sudden switch well or a change of operating system makes a high alternating additional pressure in the bottom within a short period of time in the gas wells production process, which causes the sanding. Therefore, it is essential to standardized and rational exploitation of the work.

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