PRODUCTION OPTIMISATION OF OIL WELLS EQUIPPED WITH SUCKER ROD PUMPS

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ABSTRACT. The article presents a procedure for production optimisation of brown oil wells produced periodically with sucker rod pumps. A characteristic feature of the methodology presented is that testing is done without interrupting the continuous work of the oil wells and without cut in oil and gas production. A principal procedure for conducting the testing is developed. The results from the test of the periodically produced oil wells are presented. Results are processed and analysed.

Key words: oil production, sucker rod pumps, oil.

ОПТИМИЗАЦИЯ НА ДОБИВА ОТ НЕФТЕНИ СОНДАЖИ, ОБОРУДВАНИ С ДЪЛБОЧИННИ ЩАНГОВИ ПОМПИ

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РЕЗЮМЕ. В статията е представена методика за изследване режима на работа на периодично експлоатирани с дълбочинни щангови помпи нефтени сондажи. Характерно за представената методика е това, че изследването се провежда по време на експлоатация на нефтения сондаж, без да се налага прекъсване на добива от нефт и газ. Разработена е принципна програма за провеждане на изследването. Представени са резултати от изследване на периодично експлоатирани с дълбочинни щангови помпи нефтени сондажи. Направена е обработка и анализ на резултатите .

Ключови думи: добив на нефтени сондажи, дълбочинни щангови помпи, нефт

Introduction

During the periodic production of oil wells equipped with sucker rod pumps, it is necessary to optimise the operation of the rod pump lowered into the well. Optimisation is related to the determination of the following technological and technical parameters: pump performance, pump operating mode, pump intake depth, and operating time (Gerov, 1987). For this purpose, it is necessary to develop a methodology for testing the mode of operation of periodically produced oil wells. The effective application of a certain methodology takes into account the specific geological and technical conditions of the respective oil field.

Methodology for a hydrodynamic test of the operating mode of periodically produced sucker rod oil wells.

The developed methodology for testing the mode of operation of periodically operated sucker rod oil wells consists in the following:

- according to a certain scheme, the liquid level is periodically measured during start-up, shutdown and operation of the rod pump installation. The time intervals during which the level measurement is performed take into account the specific geological and technical characteristics of the wells from the oil field;
- with dynamometric measurements, the operation of the pump installation and the sucker rod pump is periodically controlled;
- periodically measure the flow rate of the extracted liquid;
- the gas factor is measured;
- depending on the obtained results, a change in the measurement intervals is possible.

The main advantage of the developed methodology is that the test is carried out during operation of the sucker rod pump installed into the wellbore without having to interrupt the normal operating cycle. After analysing the results and when changing the rod pump installation and the rod pump, it is necessary to evaluate the technical and economic indicators (Mitev, 2006).

On the basis of the developed methodology, the results of a hydrodynamic test of the operating mode of oil well R-1 periodically produced with a sucker rod well pump are presented.

Oil well R-1 operating conditions

Oil well R-1 is produced in the following conditions:

- production casing: 5-1/2" with 7.72 mm wall thickness;
- tubing installed in the wellbore with a diameter of 2-7/8”, a wall thickness of 5.5 mm and a length of 2100 m;

- sucker rod pump with a diameter of 32 mm installed at a depth of 2100 m;
- stroke of the polished rod: 3 m;
- 6 double strokes per minute;
- Beam model – UP12T – 5000 - 10000;
- programmed operating mode;
- periodicity of work: 24 hours followed by 24 hours recovery time (pump off);
- high gas factor varying between 500-700 m^3/m^3;
- low productivity of the formation.

The theoretical productivity of the sucker rod pump, determined under these conditions is 20.8 m^3/d.

Sequence of the conducted hydrodynamic test in oil well R-1

The hydrodynamic test of the well was carried out in two periods, each lasting 24 h. During the first period, the well was producing (the sucker rod pump was working), and during the second period the sucker rod pump was not operating, i.e. the well was in reservoir pressure recovery mode. The total duration of both periods was 48 hours.

During each period, in accordance with the developed research methodology, the following parameters were measured:

- the change of the dynamic level in the annulus of the wellbore during operation of the sucker rod pump;
- the produced amount of liquid (oil emulsion and formation water) during certain time intervals and the total amount of produced liquid ~~is~~ was determined;
- the operation of the sucker rod pump and the installation by conducting dynamometric measurements (taking dynamometer cards);
- the change of the dynamic fluid level in the annulus of the wellbore after stopping the sucker rod pump (reservoir pressure recovery mode).

The fluid level in the wellbore annular space was measured by an Echometer survey (fluid shot). A dynamometer was used to diagnose the condition of the system downhole pump – rod string – tubing string.

The measurement of the fluid flow rate (oil emulsion and formation water) was done by an individual measuring tank.

Results of the conducted hydrodynamic test in oil well R-1 in the first and second period

During the operation of the sucker rod pump, the fluid level in the annulus space of the wellbore was measured every three hours. The amounts of liquid produced (oil emulsion and formation water) were measured every hour. The dynamogram card recording was done three times: when the well was put into operation, when it was stopped, and one intermediate measurement. Prior to the survey, the well was scheduled to run for 24 hours and recover for 24 hours. The data from the conducted hydrodynamic test in oil well R-1 are shown in Table 1.

Table 1. Data from the hydrodynamic study in oil well R-1.

Time	Duration, h	Dynamic level, m	Fluid production m^3	Sum produced fluid, m^3
10:00	0	554	0	0
11:00	1		0,4	0,4
12:00	2		0,3	0,7
13:00	3	1342	0,25	0,95
14:00	4		0,35	1,3
15:00	5		0,4	1,7
16:00	6	1479	0.4	2.1
17:00	7		0.5	2.6
18:00	8		1.1	3.7
19:00	9	1702	0.1	3.8
20:00	10		0.1	3.9
21:00	11		0.1	4
22:00	12	1640	0.3	4.3
01:00	15	1516	0.8	5.1
04:00	18	1954	0.8	5.9
07:00	21	1096	0.4	6.3
10:00	24	2090	0.5	6.8
13:00	27	2000		
16:00	30	1741		
19:00	33	1530		
22:00	36	1520		
01:00	39	1233		
04:00	42	1124		
07:00	45	1330		
10:00	48	1141		

During the test, the well produced in complex conditions. The flow rate of the well during the first study period was fluctuating. The likely reason for this is the presence of free gas in the formation fluid. As the gas rises in the tubing string, it expands, thereby contributing to the liquid being ejected in portions. Due to the fact that the gas occupies a large volume of the space inside the tubing string, no liquid enters until the pump restores the volume of liquid expelled. In the initial period of operation, it was found that fluid began to flow from the well 35 minutes after the installation was put into operation.

The summarised data from the first period of the conducted test are presented in fig. 1.

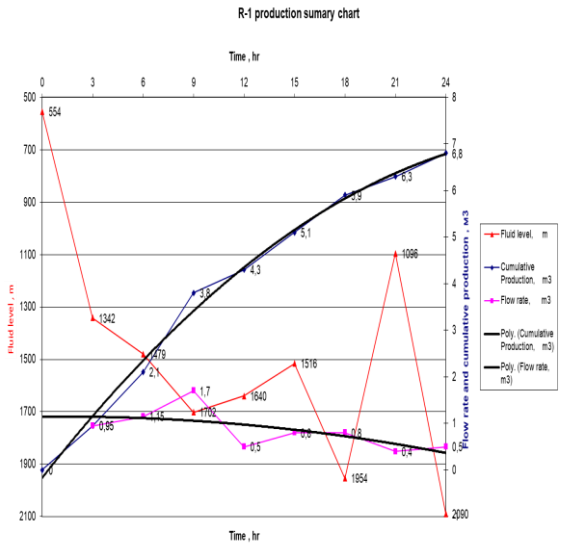

Figure 1. Change in the measured parameters for the first period of the hydrodynamic test.

The summarised data from the first and second period of the conducted test are presented in Fig. 2.

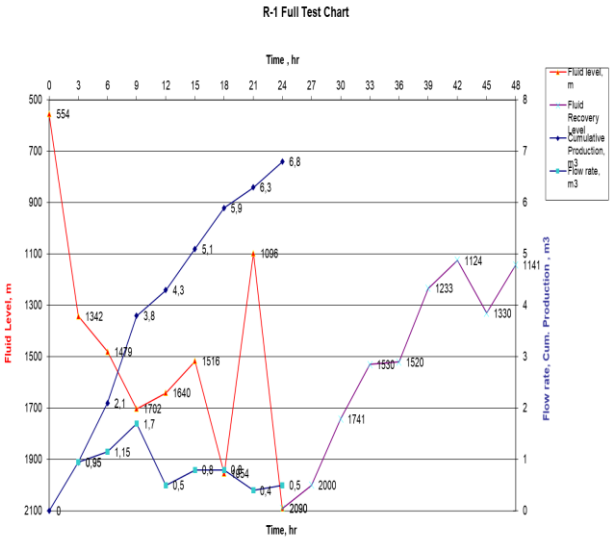

Figure. 2. Change of the measured parameters for both periods of the hydrodynamic test.

After analysing the change of the dynamic level during the operation of the pump, a significant uneven change of the level in the wellbore is visible. Therefore, significant amounts of free gas are being produced from the formation, which is also confirmed by the irregular operation of the sucker rod pump. The uneven change in the dynamic levels makes it impossible to compare the produced quantities with the volume of the tubing – casing annulus, which makes it difficult to determine the flow of fluid from the formation. Analysis of the dynamograms revealed significant amounts of free gas at the pump inlet. The amount of gas produced during the test can be utilised by mobile hybrid gas systems (Karadzhov, 2022).

From the analysis of Fig. 1, it can be seen that during production of the well, the flow rate decreases progressively as the working time increases. The fluid level in the wellbore of 554 m on start-up reaches close to the pump inlet at 2090 m. The volume of the annulus space in this interval (554 -2090 m) is 12.1 m^3, and only 6.8 m^3 have been produced. From the data, it can be concluded that there is a presence of free gas in the liquid column in the annulus. This also means that during the time the well was recovering prior to starting the test, the liquid and the gas were mixed in the annulus and gas bubbles where forming into the wellbore while the gas is given time to rise and expand in the annulus.

Figure 1 clearly shows that the measurements of the liquid level in the wellbore have a "pulsating" character. If we exclude the points from the chart which are significantly increased - at startup, at the twelfth hour, at the fifteenth hour, and at the twenty-first hour - a different chart is built as shown on Fig. 3. From it, it was determined that the production has started from the "real" level, corresponding to 1150 m.

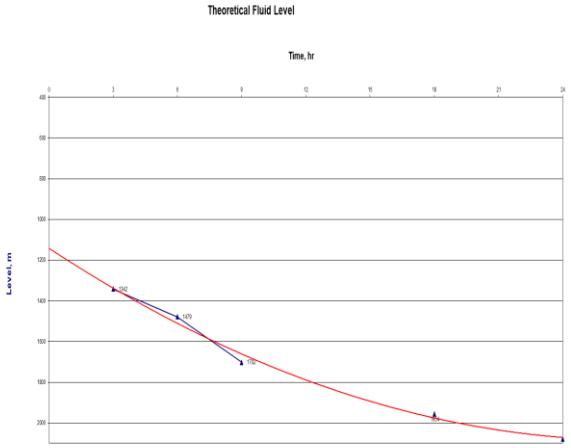

Figure. 3. Theoretical fluid level in the wellbore during production cycle.

Figure. 4 shows the level recovery curve in well R-1. From data on this chart, it is visible that after 24 hours of recovery a level similar to the theoretical level shown in Fig.3 is registered.

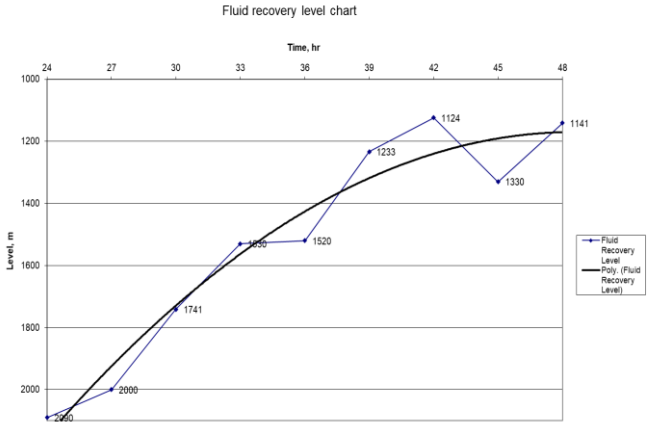

Figure. 4. Curve of fluid level recovery in well R-1.

Conclusion

As a result of the hydrodynamic studies carried out according to the developed methodology in oil well R-1 and the subsequent data processing, the following conclusions can be made regarding the periodic operation of the well:

- The periodic production of well R-1 is carried out under extremely complex downhole conditions: pump intake is at maximum setting depth of 2100 m, a high gas factor, varying in the range of 500-700 m^3/m^3, and low productivity of the formation;

- The technological mode of production of well R-1 used during the test is technologically justified and can be continued;
- It is advisable that an additional test be carried out, shortening the production mode by 6 hours. Probably with 18 hours of work mode and 30 hours of recovery mode, it is possible to improve the working conditions of the downhole pump;
- It is necessary to replace the downhole equipment currently in use for the production of the well. A downhole separator must be installed under the downhole rod pump to prevent the entry of free gas into the pump intake and thus improve the pump output.

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