DOI: 10.17122/ntj-oil-2020-4-29-38

УДК 622.24

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ЭКСПЕРИМЕНТАЛЬНАЯ ОЦЕНКА ЭФФЕКТИВНОСТИ БУРОВОГО ЗАБОЙНОГО КОМПЕНСАТОРА КОЛЕБАНИЙ ДАВЛЕНИЯ ПРОМЫВочНОЙ ЖИДКОСТИ

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EXPERIMENTAL EFFICIENCY ESTIMATION OF THE DRILLING DOWNHOLE COMPENSATOR FOR PRESSURE FLUCTUATIONS OF THE DRILLING FLUID

Введение

При бурении нефтяных и газовых скважин неизбежным обстоятельством является возникновение вибрационных процессов с различными амплитудно-частотными характеристиками в циркуляционной системе буровой установки, забойном устье и забойном оборудовании.

Из множества причин появления данных вибраций можно выделить работу буровых насосов, забойных двигателей, связанную с взаимодействием долота на забое и неизбежной реакцией последнего на долото, непостоянство осевой нагрузки ввиду ручной подачи инструмента на забой и др.

Следствиями колебательных процессов являются снижение долговечности оборудования, ухудшение технико-экономических показателей бурения.

Цели и задачи

В статье описывается разработанное и запатентованное на уровне изобретения устройство, монтируемое в компоновку низа

Background

When drilling oil and gas wells, an unavoidable circumstance is the occurrence of vibration processes with different amplitude and frequency characteristics in the circulation system of the drilling rig, downhole wellhead and downhole equipment.

Of the many reasons for the occurrence of these vibrations, you can highlight the work of the mud pump, downhole motors associated with the interaction of the bit on bottom and the inevitable reaction of the last bit, the variability of axial load in the form of a manual tool feed for slaughter etc.

The result of oscillating processes is a decrease in the durability of equipment, deterioration of technical and economic indicators of drilling.

Aims and Objectives

The article describes a device developed and patented at the level of the invention, which is mounted in the bottomhole assembly

бурильной колонны и позволяющее оказать существенное влияние на колебательные процессы, происходящие на забое.

Приводятся результаты исследований, проведенных на разработанном лабораторном стенде, оснащённом современными датчиками, а также выполнен их анализ. Дается оценка эффективности работы компенсатора.

Результаты

1. Колебания давления промывочной жидкости несмотря на наличие штатного пневмокомпенсатора бурового насоса имеют значительную амплитуду и приводят к непроизводительным затратам энергии, преждевременному износу бурового оборудования.

2. С целью уменьшения вредного влияния пульсаций давления и расхода промывочной жидкости в циркуляционной системе буровой установки на долговечность бурового оборудования и показатели бурения разработана и запатентована на уровне изобретения конструкция поршневого забойного гидромеханического компенсатора.

3. При проведении лабораторных испытаний использование забойного гидромеханического компенсатора сделало возможным снижение амплитуды пульсаций давления жидкости на выходе из компенсатора приблизительно в 2 раза, что является эффективным показателем работы забойного устройства.

and allows to have a significant impact on the oscillatory processes occurring at the bottom of the mine.

The results of research conducted on a developed laboratory stand equipped with modern sensors are presented, and their analysis is provided. The efficiency of the compensator is evaluated.

Results

1. Fluctuations in the pressure of the flushing liquid despite the presence of a standard pneumatic compensator of the drilling pump have a significant amplitude and lead to unproductive energy costs, premature wear of drilling equipment.

2. In order to reduce the harmful effect of pressure pulsations and flow of flushing liquid in the drilling rig circulation system on the durability of drilling equipment and drilling performance, the design of a piston downhole hydro-mechanical compensator developed and patented at the level of the invention is proposed.

3. During laboratory tests, the use of a downhole hydro-mechanical compensator made it possible to reduce the amplitude of liquid pressure pulsations at the outlet of the compensator by approximately 2 times, which is an effective indicator of the downhole device operation.

Ключевые слова: вибрация; буровой насос; буровой раствор; забойный гидромеханический компенсатор; стендовые исследования; амплитуда колебания давления, датчик давления

Key words: vibration; drilling pump; drilling mud; bottom-hole hydro-mechanical compensator; bench studies; pressure fluctuation amplitude; pressure sensor

Drilling of oil and gas wells is a complex process, accompanied by the inevitable occurrence of oscillatory processes of the drilling tool and the washing liquid, which, in turn, have a significant impact on the technical and economic indicators of drilling in General [1-7].

The construction technology of an average well requires maintaining the pressure in the circulation system in the range of 10-30 MPa.

Based on this circumstance, we can conclude that the conditions for vibration of the BSC and the entire drill string with a significant amplitude of the pumping frequency [8-10]. In addition, the non-stationary flow of liquid inside the drill pipe column leads to periodic changes in the speed and power of the screw downhole engine and turbo-drill. As a result, vibrations of the engine and the entire drilling tool of different directions

are observed in space [2]. Due to changes in the speed of rotation of the hydraulic motor rotor over time, the area of stable operation of downhole motors in the zone of low rotation speeds is greatly narrowed, resulting in frequent stops of downhole motors, with increased load on the bit, and especially when drilling in elastic-plastic rocks.

To reduce the unevenness of the flow and pressure of the flushing liquid during drilling, a downhole hydro-mechanical compensator was developed, shown in Figure 1 [8].

The compensator is installed in the layout of the drill tool by means of adapters and locking threads 16 and 17. The oscillating liquid enters

the internal cavity of the compensator, thus affecting elements 5-7. As a result, the springs located under the pistons are compressed. The subsurface space is communicated to the annulus by means of the provided channels 8-10. This ensures a more uniform flow of liquid at the outlet of the compensator, stabilizes the operation of downhole equipment, and reduces the wear of PDC bits.

To conduct laboratory tests of the developed bottom-hole hydro-mechanical compensator, a laboratory stand was created at the Department of Oilfield Machinery and Equipment of the Oktyabrskiy Branch of Ufa State Petroleum Technological University (Figure 2).

- 1 - housing; 2, 3, 4 - partitions; 5, 6, 7 - pistons;
- 8, 9, 10 - communication channels with the annulus;
- 11, 12, 13 - bushings; 14 - springs; 15 - adapter;
- 16, 17 - connecting threads; 18, 19 - seals

Figure 1. Bottom-hole hydro-mechanical compensator

- 1 - capacity; 2 - drilling pump 9 Mgr;
 3 - hydro-mechanical compensator; 4 - pressure gauge;
 5, 9 - shut-off devices; 6 - pressure sensor;
 7 - data gateway GW-485.01 (RS-232/RS-485 Converter);
 8 - computer

Figure 2. Diagram of a stand for hydraulic testing of a hydro-mechanical compensator for fluid pressure fluctuations

The laboratory stand is a closed hydraulic system.

The stand includes a tank 1 with a liquid, a pumping unit 9 Mgr 2 with a standard pneumatic compensator that circulates the agent, a compensator 3, a strain gauge for measuring pressure with the required discreteness of measurements 6, valves 5 and 9, a gateway for transmitting information 7, a device for fixing and processing measurements 8.

Here are the main questions for research conducted in the laboratory when testing a device for vibration damping:

- measurement of the value of pressure pulsations generated in the hydraulic system of a laboratory installation as a result of liquid pumping by a reciprocating pumping unit;

- analysis of changes in the vibration amplitude of the pumped agent (liquid) after the inclusion of a three-piston device for damping vibrations in the hydraulic system.

The stand allows to study the operation of a hydro-mechanical compensator. The above pump unit 2 feeds the liquid agent from the tank to the hydraulic system of the laboratory stand. Passing through the internal cavity of the three-piston device, the liquid causes periodic compression of the sub-piston springs and has a smaller range of pressure fluctuations at the outlet, after which it is transported to the source tank. A strain gauge installed at the outlet of the compensator allows you to record changes in the pressure of the test liquid. The valves (shut-off devices) installed in the installation provide the

possibility of regulating the volume of liquid supply and the required pressure.

After removing the damping elements from the compensator body, the pressure fluctuations of the circulating liquid are measured in the same way.

When developing the measuring part of the stand, the following provisions were taken into account. During the operation of the drilling tool at the bottom of the well, pressure fluctuations in different frequency ranges are observed. In this regard, for the most accurate characteristics of vibration processes, certain requirements are imposed on devices for measuring changes in the pressure of the studied liquid. In particular, it is necessary to provide pressure measurements with appropriate discreteness, otherwise you can get a distorted picture of the studied characteristics.

It should be noted that in order to fix the time-varying pressure parameter in a laboratory installation, the condition of insignificant inertia of the measuring system of the device for measuring the required characteristics must be met [9]. Otherwise, the results of the research will be unreliable. Strain gauges that have a natural oscillation frequency in the range from 300 to 1000 Hz meet the stated need.

The principle of operation of these measuring devices is to change the resistance of materials conducting electric current, which are mounted on an elastic membrane. The change in the resistance of the conductors occurs due to periodic deformation of the elastic element when it is exposed to a non-stationary flow of liquid.

The advantage of a digital signal from an analog signal is the ability to transport the signal over long distances without distorting the measured test results. Note that no less important aspects of digital signal application are: the quality and simplicity of signal interpretation, the ability to process large amounts of information on a computer, and the ability to store large amounts of information on various media. In this regard, it is recommended to convert the information to a digital signal as early as possible.

During the laboratory tests, PTM-01 measuring devices were used, which were manufactured by the company «Grant» (Figure 3), devices capable of measuring up to 16

MPa were selected for measurements during the tests. The connection was made via the gateway GW-485.01 (RS-232/RS-485 Converter). The received information was displayed in a special software «Manograph».

The main parameters of the measuring device are shown in Table 1.

Table 1. Main technical characteristics of PTM-01-02

Name of parameter	Parameter value
Upper limit of overpressure measurements	16 MPa
Error limits, % of the upper limit of measurement	± 0,25
Measurement Discreteness (set programmatically), s, not less than	0,02
Output signal	Digital via RS-485 interface
Power supply parameters: - power supply voltage, V - current type - current consumption, mA, no more - power consumption, W, not less more	
	5-17
	constant
	5
Communication line parameters: - cable type - number of cores - core cross-section, mm ² , no more - resistance, Ohms / km, no more - total capacity, UF, no more	
	supervisory
	4
	1,5
	25
Overall dimensions, mm	
	113x53
Weight, kg, no more	0,2
Operating conditions: - operating temperature range, °C - relative humidity at 35 °C to, % with condensation	
	from - 40 to + 85
	95

Data is transferred to the device for registration and data processing via the Modbus Protocol via the RS-485 interface. Important functions of the computer are: conversion, control, display, storage, and the ability to influence measurement processes.

Based on the results of laboratory studies, pressure curves were constructed depending on time. A graphic illustration of some of them is shown in Figures 4-7.

In Figure 4, you can see a graph of the pressure dependence of the working agent in the laboratory stand without including the piston compensator in the hydraulic system after setting the pressure at 3 MPa. Analyzing the figure, it becomes obvious that the range of the amplitude of pressure fluctuations can reach up to 1.5 MPa. This amplitude of pressure fluctuations corresponds to a coefficient of unevenness equal to 0.5, which indicates its excessive value.

Figure 5 illustrates the dynamics of changes in the value of pressure pulsation in the system when the developed three-piston compensator is included in the stand. By performing the analysis, it can be seen that at the same pressure of the agent, equal to 3 MPa, the amplitude

range of pressure fluctuations has decreased to 0.8 MPa.

Similar results of the research were also achieved in the case of increasing the pressure in the installation to 5 MPa (Figures 6, 7).

Tests performed in the laboratory indicate that compensator can be used to solve problems related to reducing the uneven movement of the washing liquid. In particular, it is established and recorded that in the case of laboratory tests at average pressures of 3 and 5 MPa, pressure fluctuations are excited in the system, the amplitudes of which take the values of 1.5 and 2.5 MPa, respectively. Using a three-piston compensator as part of the stand at constant pressure of the working agent, liquid pressure fluctuations with amplitudes reduced to 0.8 and 1.5 MPa, respectively, were registered in the system. The same results were observed for other values of average liquid pressure values.

Summing up the above, it should be noted that the use of a three-piston compensator during laboratory tests made it possible to reduce the unevenness of the liquid pressure by almost 2 times, which indicates the high efficiency of its operation.

Figure 3. Pressure transmitter measuring PTM

Figure 4. Time dependence of pressure at an average pressure of 3 MPa without a three-piston compensator

Figure 5. Time dependence of pressure at an average pressure of 3 MPa with a three-piston compensator

Figure 6. Time dependence of pressure at an average pressure of 5 MPa without a three-piston compensator

Figure 7. Time dependence of pressure at an average pressure of 5 MPa with a three-piston compensator

Conclusion

1. Fluctuations in the pressure of the flushing liquid despite the presence of a standard pneumatic compensator of the drilling pump have a significant amplitude and lead to unproductive energy costs, premature wear of drilling equipment.

2. In order to reduce the harmful effect of pressure pulsations and flow of flushing liquid in the drilling rig circulation system on the durability

of drilling equipment and drilling performance, the design of a piston downhole hydro-mechanical compensator developed and patented at the level of the invention is proposed.

3. During laboratory tests, the use of a downhole hydro-mechanical compensator made it possible to reduce the amplitude of liquid pressure pulsations at the outlet of the compensator by approximately 2 times, which is an effective indicator of the downhole device operation.

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