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Hydromechanical device to clean the inside of pipes from paraffin deposits

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ABSTRACT

The formation of solid deposits of paraffin contained in oil on the inner surface of tubing (tubing) is one of the adverse factors that significantly complicate the operation of oil wells. The available material on this subject has been studied; existing methods of cleaning of pipes from paraffin deposits are considered; the scheme and design of the hydro-mechanical device used for cleaning of internal pipes from paraffin deposits have been developed; conducted laboratory and practical tests of the developed device. According to the results, we can say that hydro-mechanical methods of purification from paraffin deposits are the most effective.

Key words: asphaltic resinous paraffine sediments, ARPS, oil pipes, drive, hydro-mechanical device.

1. INTRODUCTION

The current state of development of oil fields in Russia is characterized by an increase in well depths, high water cut of produced well products, and the use of various physicochemical methods to increase oil recovery. The implementation of methods for increasing oil recovery requires the use of pumping equipment with increased productivity with increased suspension depth. The latter causes an increase in the stress-strain state of the downhole pumping equipment and a decrease in the efficiency of its operation.

One of the unfavorable factors that significantly complicates the operation of oil wells is the formation of solid deposits of paraffin contained in oil on the inner surface of tubing. Their presence significantly increases hydraulic losses during the production of borehole products due to a decrease in the internal passage section of the tubing. The deposition of paraffin on the inner surface of the tubing occurs due to a decrease in the temperature of the produced well products during its rise to the surface, as well as a decrease in the pressure of the well products to saturation pressure and below. As a result, a decrease in the flow rate of wells and MTBF, an increase in hydraulic pressure in the oil gathering system, an increase in the number of underground well repairs that negatively affect the cost of produced oil.

Mechanical methods are most common for removing paraffin deposits from the inner surface of downhole equipment and pipe systems. Polyurethane pistons and balls are used to remove paraffin deposits in field pipelines of oil recovery systems. The creation of a method for the removal of paraffin deposits by mechanical means, using the hydraulic energy of the fluid flow to implement it, will significantly increase the efficiency of solving the problem.

Thermal, mechanical, magnetic, electric heating and chemical methods, the effectiveness of which depends on the method of oil production, the composition and properties of the oil produced, are used to prevent and prophylactic removal of asphaltic resinous paraffine sediments (ARPS) [1]. Each of these methods has its advantages and disadvantages, as well as the field of effective application [2].

Currently, solvents are widely used to eliminate paraffin deposits. The thermal exposure method using commercially available 1ADN-4-150 mobile units for dewaxing downhole equipment and oilfield pipes with hot oil is widespread for removing paraffin deposits of oilfield pipes in field conditions [3]. To increase the efficiency of removal of paraffin deposits by this method, it is proposed to use a combined cleaning method - thermal and vibrational. Studies by many authors have established that the imposition of vibration exposure leads to the destruction of the structural network of paraffin hydrocarbons, while the oil sludge acquires the ability to flow.

Several types of acoustic vibration sources have been tested to implement this method for cleaning paraffin deposits:
- Magnetostrictive emitters, exciting ultrasonic vibrations with a frequency of 22 kHz;
- Hydrodynamic, converting the energy of the fluid flow into acoustic vibrations, etc. [3].

The results of the action of acoustic emitters on the process of formation of paraffin deposits were unsuccessful due to the local nature of the propagation of acoustic vibrations and the low reliability of the emitters. Flushing using a hydromechanical vibrating device equipped with a rotary mechanism, with cutting and calibrating cutters, is recommended at the mouth and bushes [4] for cleaning tubing from solid ARPS [5].

2. DESIGN AND PRINCIPLE OF OPERATION OF A HYDRO - MECHANICAL DEVICE FOR CLEANING TUBING

A schematic diagram of the above hydromechanical device is shown in Figure 1.

The device (see Figure 1) consists of a stator 1, which has an axial passage channel 2, a rotor 3, which is mounted on a support 4 and equipped with cutting 5 and calibrating 6 knives. Flow channels 7 and 8, directed oppositely to each other, are made in the stator and rotor. A nut 9 is provided for adjusting the gaps between the stator and the rotor. The gap between the stator and the inner surface of the tubing is sealed by means of a seal 10 installed in the groove 11. The stator 1 is equipped with a fitting 12 for attaching a flexible hose to allow the use of a device for removing paraffin deposits in Tubing of various lengths or in its local areas.

The device operates as follows. Since the flow channels 7 and 8 are located at an angle to each other, the liquid jets flowing from them create a reactive moment due to the action of the Segner wheel effect, which causes the rotor to rotate. During the rotation of the rotor, the flow channels in the stator periodically overlap, causing a cessation of fluid flow, accompanied by a hydraulic shock. As a result of hydraulic shock, a force arises that allows both automatic movement (axial feed) of the device inside the tubing and dynamic (shock) interaction with deposits of paraffin from cutting 5 and calibrating knives 5 and 6. The latter makes it easier and faster to cut the layer of paraffin deposits. Thus, the device allows to automatically move inside the tubing and in a pulsed mode to cut paraffin deposits from the inner surface of the tubing and their subsequent removal by a wash fluid stream.

The frequency of hydraulic shocks is regulated by changing the number of flow channels 7 and 8 by the number of revolutions of the rotor.

In order to ensure the operability of the treatment device in the field for its intended purpose, a theoretical study was conducted of the interaction of the fluid flow with flow channels 7 and 8 (see Figure 1). The calculated values of the acting forces and pressures arising from this interaction were determined, as well as the value of the torque required to rotate the rotor of the treatment device.

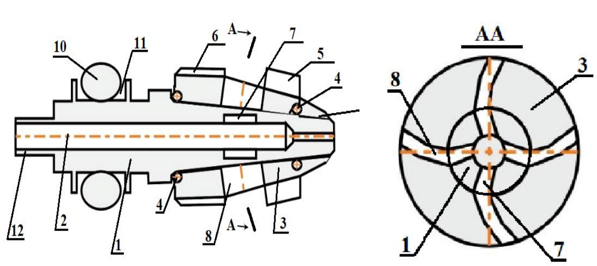

Figure 1: Structural diagram of a device for cleaning the inner surface of pipelines

The value of the torque on the rotor of the treatment device is determined by the formula

$$M = Q\rho(c_1 \cos \alpha_1 - c_2 \cos \alpha_2)\tau_{\text{cp}}, \qquad (1)$$

where Q is the volumetric flow rate of the liquid;
ρ is the fluid density;
$c_1 \cos \alpha_1$, $c_2 \cos \alpha_2$ are projections of absolute velocities at the inlet and outlet of the rotor of the treatment device;
α_1 is the angle between the absolute and peripheral velocity of the fluid flow at the entrance to the rotor;
α_2 is the angle between the absolute and peripheral fluid flow rate at the outlet of the rotor of the treatment device;
τ_{av}. is shoulder exposure to fluid on the wall of the rotor.

The maximum value of the force that ensures the destruction of deposits of a layer of paraffin with a thickness of 30 mm in a tubing with a diameter of 73 mm is determined from the expression

$$P_{\text{СД}} = \sigma \cdot S \qquad (2)$$

where S is the area of the paraffin layer 30 mm thick, cut off by the cutting knives of the treatment device;
σ is the ultimate shear stress of paraffin.

According to the results of the calculations, the cleaning device will ensure the cutting of paraffin deposits in the tubing, since the value of the force acting on the cutting knives of the cleaning device exceeds the maximum value of the force providing the cutting of a layer of paraffin with a thickness of 30 mm.

To ensure translational movement in the tubing, the treatment device is equipped with a drive, the structural diagram of which is shown in Figure 2.

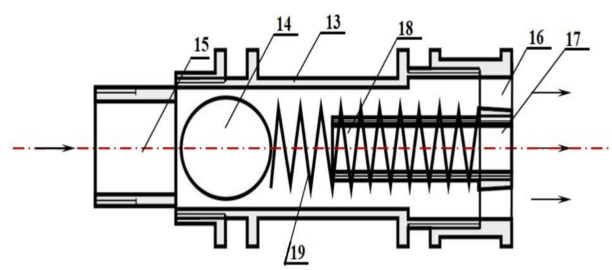

Figure 2: Structural diagram of the treatment device drive

The drive of the cleaning device consists of a hollow body 13, inside of which a ball is placed 14. The body is equipped with an input channel 15 and four output channels, three axisymmetric holes 16 and a central hole 17. The ball 14 is pressed by a spring 19. The hollow stop 18 is secured to the body 13 by means of a threaded connection.

The drive of the cleaning device operates as follows. When pumping fluid through a hollow body, the ball performs longitudinal vibrations. Due to the periodic blocking of the input and output channels by the ball, water hammering occurs. Under the influence of axial forces arising from water hammer, the forward movement of the treatment device drive is carried out.

The value of the amplitude of the pressure pulsation is determined from the expression

$$\Delta p = \rho Q^2\left(\left(\frac{1}{3S_1}\right)^2 - \left(\frac{1}{3S_1+\varepsilon_4 S_4}\right)^2\right)/2. \qquad (3)$$

where ρ is the density of the wash fluid;
Q is the fluid flow rate;
S_1 is the cross-sectional area of axisymmetric holes;
S_4 is the cross-sectional area of the Central hole;
ε_4 is the compression ratio of the liquid jet when it expires through the Central hole.

The parameters of the liquid pressure drop during operation of the treatment device drive are determined by solving the Bernoulli equation.

3. LABORATORY STUDIES OF THE OPERATION OF THE DRIVE OF A HYDRO - MECHANICAL DEVICE

The laboratory bench was designed in order to study the operation of the drive of the treatment device. Schematic diagram of the stand is shown in Figure 3.

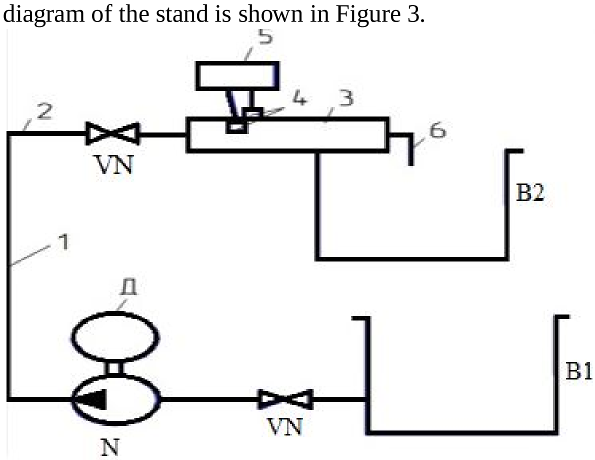

Figure 3: Stand for the study of the drive device

The stand includes a receiving tank B1, VN valves, pipeline 1, a centrifugal pump N driven by an electric motor M, a pipe 2 for supplying water to the device under test, a treatment device 3, vibration sensors 4, and a Diana-2M vibration analyzer 5 for registration and processing of vibration parameters, measuring tank B2, drain pipe 6.

Stand for research on the operation of the drive of the treatment device operates as follows. The fluid from the receiving tank B1 is pumped by pump N through the pipe 1 and pipe 2 to the test chamber 3, which houses the drive assembly with a cleaning device, which is the source of vibrations transmitted to the body of the test chamber. The vibration parameters that occur during operation of the treatment device drive are transmitted by sensors 4 to the Diana-2M model vibration analyzer, which performs their registration and processing. The laboratory bench allows full-scale simulation of the operation of the treatment device and its drive with registration of vibration parameters generated by the working drive of the device.

The two-channel vibration analyzer "Diana-2M" is designed to measure the vibration of rotating equipment. The following values of vibration parameters are displayed on the liquid crystal display of the vibration analyzer: V is vibration velocity in mm / s, A is vibration acceleration in mm / s^2 and S is vibration displacement in microns.

The Diana-2M vibration analyzer is equipped with piezoelectric type vibration accelerometers with built-in preamplifiers that provide noise immunity and a linear characteristic of the recorded parameter values in the entire measurement frequency range, as well as high sensitivity of the measured parameters. A vibration analyzer can record and analyze high-resolution vibration processes using frequency spectra.

The “Atlant” and “Aurora-2000” vibration diagnostics software were used to process the measurement results. The Atlant program allows storage of vibration signals and spectra in a computer. Information is transmitted from the vibration analyzer to the computer using a USB port.

When conducting research at the laboratory bench, the systematic error of the measurement results was due to the metrological characteristic of the measuring instrument — a vibration analyzer: its value did not exceed 5%. Liquid flow during laboratory tests was determined by the volumetric method. The design of the experiment included the study of the effect of fluid flow (factor x1), spring stiffness (factor x_2) on the standard deviation of the vibration velocity of the treatment device drive (output parameter Y) by setting up a full-factor experiment with three-fold duplication of the experiments.

Experimental laboratory studies of the treatment device drive have proved its operability at a flow rate of 0.15 to 0.63 l / s. With the specified range of fluid flow rate, the drive of the treatment device provides stable vibration displacement of the treatment device. It has been experimentally established that the maximum speed of vibration displacement of the treatment device is achieved at a flow rate of from 0.55 to 0.63 l / s.

After the laboratory tests were successfully passed, the hydromechanical device was subjected to practical testing. They were carried out to check the operability of the hydromechanical treatment device, to determine the effectiveness of cleaning the inner surface of tubing by a device for cleaning the inner surface of tubing.

The study of the operation of the hydromechanical treatment device was carried out in the workshop for the repair and cleaning of the Oil and Gas Production Department Fedorovskneft of the Open Joint Stock Company Surgutneftegas. The tests were carried out at the bench for cleaning, diagnosing and repairing tubing, were performed according to the technological scheme (Figure 4).

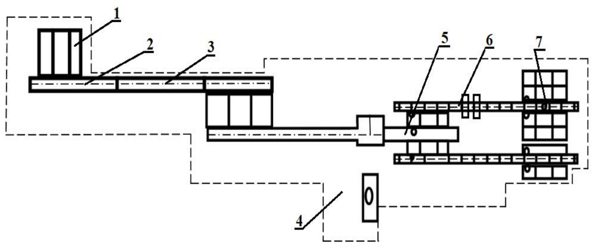

Figure 4: Scheme of the experimental stand for testing the device

Field tests of the experimental design of the hydromechanical treatment plant were carried out in accordance with the standard technological regulations approved by the Fedorovskneft Oil and Gas Production Unit.

According to this regulation, the tubing is cleaned of paraffin deposits by flushing their internal cavity using a flushing head mounted on the rod. The tubing cleaning process is carried out by the reciprocating movement of the washing head from one end of the tubing to the other. When cleaning the tubing from paraffin deposits, water is supplied to the washing head at a pressure of 0.4 ÷ 0.5 MPa at a temperature of t = 90÷95 °C. The average duration of cleaning one tubing from soft and loose paraffin deposits having a minimum thickness of one to two millimeters is 2 minutes on average, and the average duration of cleaning one tubing of soft and loose paraffin deposits having a maximum thickness of 10 mm is 7 minutes.

When conducting field tests of the experimental design of the hydromechanical device, the cleaning process took place automatically, observing the same temperature and pressure parameters for pumping heated water into the treatment device that were installed for the standard technology for cleaning tubing in the specified oil and gas production department.

Under these test conditions, the use of the experimental design of the hydromechanical device allowed to reduce the cleaning time of one tubing from paraffin deposits. For example, the duration of cleaning the tubing from soft and loose paraffin deposits having a minimum thickness of one to two millimeters was on average one minute 47 seconds, and the duration of cleaning the tubing of soft and loose paraffin deposits having a maximum thickness of 10 mm was 5 minutes 12 seconds on average.

In the process of conducting field tests using the experimental design of the hydromechanical device, 50 dismantled tubing were cleaned of paraffin deposits. Thus, when using the experimental design of the hydromechanical device developed with the participation of the author of this work, the duration of cleaning one tubing from soft and loose paraffin deposits was reduced by 21%. When conducting field tests of a hydromechanical device for cleaning 50 tubing, the first degree of quality of cleaning the surface of the tubing, established by GOST 9.402-80, was provided.

During field tests of the hydromechanical device, the flow rate of the working fluid was 0.21 l / s, that is, it was in the range of 0.15 ÷ 0.63 l / s. This flow rate is necessary to ensure the functioning of the drive of the hydromechanical device, which is installed according to the results of theoretical and laboratory studies.

Field tests of the hydromechanical device have confirmed the results of theoretical and laboratory experimental studies.

4. CONCLUSION

Based on the analysis of methods and methods for cleaning the surfaces of products from deposits used in various industries, the high technical and economic efficiency of applying mechanical methods to remove ARPS from the inner surface of the tubing has been revealed. The design of the device for hydromechanical removal of paraffin deposits from the inner surface of the tubing was developed, supplemented by the functionality of its automatic movement along the length of the tubing when it is cleaned from paraffin. Mathematical studies of the dynamics of the device for the hydromechanical removal of paraffin deposits in tubing have been carried out, the results of which determine the force upon application of which the deposition of a paraffin layer with a thickness of 30 mm will be destroyed.

Conducted laboratory and experimental experiments of the developed device prove its high efficiency. The developed design of a hydromechanical device for cleaning tubing from paraffin deposits is recommended for widespread use in field practice.

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