

Hydromechanical vibrator-pulsator for restoring the injectivity of injection wells

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Abstract. The article presents a bench model of a vibrator pulsator with a hydromechanical principle of operation designed for processing the bottom-hole zone of the reservoir of injection and production wells, columns of tubing, field pipelines. The design uses a spring-loaded rotary valve. The design of the test bench is described. According to the results of bench tests, the parameters of the pulsator's stable operation were revealed: at a liquid flow rate of 0.012 m³/s, the oscillation amplitude of the pulsator body was 300 microns, the amplitude of liquid pressure fluctuations was 1.8 MPa at a frequency of 8 Hz. The results of field tests for cleaning columns of pumping and compressor pipes, field pipelines of oil collection are presented.

1 Introduction

In the process of aging of oil fields during the operation of injection and production wells, the bottom-hole zone of the formation is flooded with mechanical impurities, inorganic salts, asphalt-resin-paraffin compounds [1-2]. This leads to a decrease in the intake capacity of the well formation, changes the hydrodynamic conditions of injection in the reservoir pressure maintenance system and reduces the production rate of hydrocarbon raw materials, increases the pressure in the oil collection system [3-4]. Periodically, such wells and pipelines are treated with injection of oil, acid, aqueous solutions of surfactants, gas-liquid mixtures, energy-releasing binary mixtures [5-8].

The most effective vibro-pulsating treatment combines the injection of media with their simultaneous pulsation [8-9, 16-17]. Structurally, the most widely used are hydromechanical and electrohydraulic pulsators. The article is devoted to the development of a pulsator vibrator and is a continuation of the authors' publications on the problem of restoring the pick-up of injection wells, cleaning the bottom-hole zone and pumping and compressor pipes of producing wells [10-15].

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2 Methods and Materials

A new design of a hydromechanical pulsator vibrator is proposed, which creates vibration of the body and pressure pulsation in the passing liquid. For testing the pulsator vibrator model, a stand has been developed that provides vibration measurement and analysis. Vibration measurements were carried out with a Corsair vibrometer, which is connected to vibration sensors through a vibration transducer.

A loop oscilloscope is installed in the circuit. The limit of the basic permissible error at a frequency up to 100 HZ when measuring the overall vibration level is 5%. Field tests were carried out during hot oil treatment with an increase in the current load of rod depth pumping units by 15% and a decrease in flow rate by 20-25%. Field pipelines were treated with an increase in the pumping operating pressure by 25-30%.

3 Results and Discussion

The bench model of the pulsator vibrator includes a housing that contains openings for the entry and exit of liquid, a centralizer mounted on a spring, which, in turn, rests on a stop. The rotary valve is mounted on the body by means of an axis. The crank is connected to the valve by means of a finger, to the centralizer by means of a pin. The pulsator operates as follows. When liquid is supplied due to hydraulic forces, the valve and its associated components begin to perform oscillatory movements. In this case, the passage channel of the pulsator opens and closes, as a result, hydrodynamic waves are excited.

The design diagram of this pulsator vibrator is shown in the Figure.1. The pulsator vibrator consists of a housing 1, inside which there is a cone 2, which is attached to the housing by a translator 3. The stop 4 is equipped with a rack 5, which has a thread in the lower part, a square section in the upper part. A worm wheel 6 is mounted on the axis of the stop 4. The rack 5 is equipped with a nut 8, which enters the groove of the stop 7 with protrusions. A spring 9 rests on the nut 8. The sleeve 10 mounted on the spring has a protrusion 11. The lever 12 in the lower part rests on the protrusion 11, in the upper part it connects to the valve 13. The valve 13, in turn, is connected to the housing 1 by an axis 15. A worm 16 is used to drive the worm wheel, which is mounted on supports 17 and 18.

When pumping liquid under the action of hydraulic forces, the "valve-crank-spring" system occupies the position shown in Figure2 sequentially, thereby oscillations in the liquid flow are excited. The amplitude and frequency of liquid pressure fluctuations are regulated by compression of the spring 9 by the worm mechanism of the pulsator vibrator. The main geometric parameters of the stand version of the pulsator vibrator are determined.

- The outer diameter of the case is 114 mm.
- The length in the mounting version is 580mm.
- The length of the rotary valve is 130 mm.
- The length of the valve console is 60mm.
- The length of the crank element is 140mm.
- Spring parameters:
 - Outer diameter 87mm.
 - Spring height 230 mm.
 - The diameter of the spring wire is 8-9mm.
 - The number of complete turns is 9.
 - Stiffness is 4-5 kN/m.
 - Corrosion-resistant design.
- Connecting threads of the internal Z-76.

The study of the operation of the pulsator vibrator was carried out on a laboratory stand, which allows solving the following problems related to the design and experimental refinement of operating parameters:

- Justification of the parameters of the working elements (geometric dimensions, shape and weight).
- Selection of conjugations of individual elements.
- Justification of the parameters of sustainable operation.
- Building a performance characteristic.
- Selection of materials for the main parts.
- Definitions of input and output parameters.
- Preliminary tests on various modes.

The closed design of the laboratory stand will include the following elements tied with a pipeline: valves; a centrifugal pumping unit with an electric motor; a working tank; a measuring tank; a flow meter; a pressure gauge; a sensor; a switchboard; an amplifier; an analog-to-digital converter; a vibration displacement sensor; a flow regulator, a vibrometer, a laptop. A pulsator vibrator is installed in the circulation system. The pump circulates the liquid in the stand system and creates a pressure in the system up to 6 MPa with a flow rate of 1.2 l/s. With the help of valves, the direction of circulation of the liquid flow is ensured.

The pressure is controlled by a pressure gauge. The flow rate is regulated and adjusted by the flow regulator. The liquid pressure is recorded by pressure sensors and the signal is transmitted through a switchboard, an amplifier to a laptop. Vibration is measured using a vibration analyzer and the information is transmitted to a laptop with the construction of an amplitude-frequency response. The permissible relative error of measuring the vibration level of 5% has been determined.

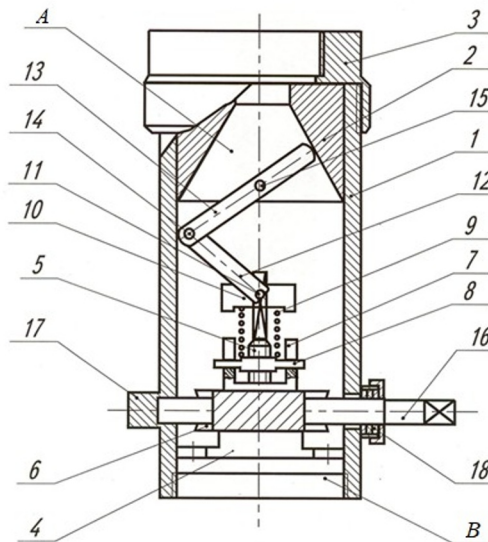


Fig. 1. Structural design of a bench model of a vibrator-pulsator.

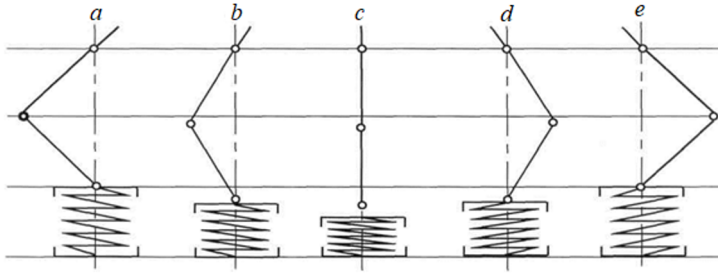


Fig. 2. Scheme of operation of a vibrator-pulsator.

After conducting a complex of laboratory studies and identifying optimal operating parameters, a complex of field tests was carried out at oil production facilities and field pipeline transport.

The following set of technical means was used to process wells. Three tanker trucks were tied through a comb for parallel oil supply using soft corrugated hoses and oil supply to the ADPM well dewaxing unit, the unit pumped oil into the well through steel quick-release pipelines. On the injection line from the ADPM unit to the mouth, a pulsator vibrator was installed. The oil supply was carried out continuously, controlling the pressure and flow rate. The amount of injected oil was defined as twice the internal volume in the column of the deflated tubing and twice the volume of the annular space in the production column in the well. When processing field pipelines, the volume of pumped oil must be more than twice the volume of the treated section of the pipeline. It is possible to carry out ring and central flushing of wells equipped with ESP and installation of a rod depth pump.

During the annular flushing of the downhole equipment of the ESP, the liquid is fed by the ADPM pumping unit into the discharge line, through a check valve into the pulsator vibrator, then into the wellhead fittings, the annular space, the downhole pump and further into the column of tubing. Wells equipped with installation of a rod depth pump are treated in a similar way. This is a backwash.

During the central flushing of wells equipped with ESPs, it is necessary to install a controlled circulation valve in the column of tubing above the pumping unit.

For flushing wells equipped with installation of a rod depth pump, it is necessary to ensure that the suction valve of the non-removable pump is disrupted or the plug-in pump is torn from the lock support.

The following set of technical equipment was used to clean field pipelines: an ADPM dewaxing unit, a pulsator vibrator, a flow meter and a pressure gauge, tankers with hot oil, strapping pipelines. Oil was supplied from the tanker to the ADPM unit and then through the pulsator vibrator into the field pipeline being cleaned. Thus, during the processing of the field pipeline, 20 m³ of oil was pumped at a temperature of 120⁰C according to the technology described above. Before processing, the working pressure in the pipeline was 2.4 MPa. During the initial treatment period, the pressure increased to 2.6 MPa, and then gradually decreased within 2 hours. Operation of the pipeline was resumed at an operating pressure of 1.7 MPa. This confirms the effective cleaning of asphalt-tar-parfin deposits using hot oil and a vibratory pulsator.

Experimental studies have determined the optimal parameters of the pulsator vibrator, with a liquid flow rate of 0.012 m³/s, the pulsator operates steadily with a rotary valve length of 135 mm, a cantilever length of 60 mm, a valve width of 58 mm, a crank length of 140 mm, and a spring stiffness of 4.4 kN/m. At a liquid flow rate of 0.012 m³/s, the oscillation amplitude of the pulsator body is 277 microns, the liquid is 1.8 MPa, the frequency is 8 Hz.

4 Conclusion

- A design model of a pulsator vibrator designed for processing the bottomhole zone of the formation based on a rubberized rotary valve has been developed. The hydromechanical effect on the bottom-hole zone of the formation in the low frequency range, implemented using the developed pulsator vibrator, will ensure the restoration of the pick-up of injection wells operated for a long time
- The design of a laboratory stand with a closed circulation has been developed, which allows comprehensive tests of a full-size pulsator vibrator, substantiate the parameters of the design, determine the optimal input and output parameters. Bench tests allow you to evaluate the performance and establish the operating parameters of the body vibrations and liquid pulsation.
- Bench tests of the model version of the pulsator vibrator were carried out. The design of the pulsator vibrator is justified. The simplicity of the design, high reliability, and the ability to adjust parameters will ensure the wide application of vibration wave technology to the bottom-hole zone of injection and production wells, field pipelines.
- Field pilot industrial uses of a pulsator vibrator for cleaning columns of pumping and compressor pipes and field pipelines from asphalt-resin-paraffin deposits have been successfully carried out.

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