Extraction of High-Viscosity Coolant for the Use in High End Machinery

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ABSTRACT

Advancement of high-viscosity oil needed new technologies that may facilitate scale back the value of oil extraction. The primary task refers to the lifting of the extracted oil from the face to the wellhead. The second task is within the creation of a fluid recirculation loop within the productive reservoir. Extracted oil acts as fluid during this case. As incontestable by laboratory tests, the new technology is created supported a pump, a vortex pump, or a meter pump. Well conditions see because the most promising variants those with a meter pump or variants with a vortex pump, since these styles are additional economical once pumping extremely viscous liquids. The analysis work considers the queries on the ordered affiliation of process chambers during a multi-sectional volume pump. Considering the peculiarities of the applied kinematic theme, the rotor leveling within the pump is performed with the assistance of the angular displacement of the stator coil parts and therefore the rotor parts in separate sections. In bench tests of the warmth generator, current chambers created supported a pump, a vortex pump, a meter pump and a volumetric-dynamic kind were tested in laboratory conditions. The developed heat generator implements cycles with periodic offer of warmth energy to the productive reservoir. The developed technology also can be employed in combination with different technologies for extraction of high-viscosity oil.

Keywords: oil extraction, heat generator, coolant, recirculation, well, pump, reservoir.

1. INTRODUCTION

The current problems in the field of hydrocarbon extraction also highlight the problem of extracting high-viscosity oil. Most experts recognize that new technologies and equipment are needed to reduce the prime cost of extracting high-viscosity oil.

The modern technologies are usually associated with the supply of heat energy to the reservoir, to increase the temperature and reduce the oil viscosity. It can be noted that an additional set of special equipment is used to realize this heat transfer process. In this case, the pumping equipment and the special heat generating equipment, like the two subsystems, are more often functioning alternately, and one has to consider the fact that the total cost of equipment is increasing, and the time of direct operation of each subsystem in the total balance is reduced. As a rule, water vapor is used as a coolant. In addition to cyclic steam injection, technologies are also known where the pumping equipment and special heat generating equipment, like the two subsystems, function simultaneously [1-5]. However, as the well depth increases, heat energy losses increase from the wellhead to the reservoir. When assessing the oil extraction cost, it is necessary to consider the presence of a double column of production string and some increase in operating costs. In the general case, the problem of ensuring all the necessary conditions for the energetically efficient operation of a production well in highly viscous oil fields remains unresolved. At the same time, the search for new solutions to extract high-viscosity oil is regarded as a very urgent task.

2. CONCEPTHEADINGS

The research is based on the concept that a down-hole pump, in addition to the main function, can perform the functions of a heat generator. It is known that with the recycling of liquid hydraulic energy is converted into heat energy, while the pumping system is capable of performing the functions of a heat generator. In this case, the fluid that is pumped acts as a coolant. Liquid recirculating allowed for intensifying the process of heat transfer within the productive oil reservoir.

3. RESULT

Several options of the heat generator providing coolant recirculation are considered within the conducted researches. One of these options is schematically presented at Figure 1. The heat generator comprises a circulation chamber 1, a hydraulic chamber 2 and a heat exchange chamber 3. The developed equipment is being patented, registration numbers of applications for patents can be found below: No. 2017146028; No. 2018111988; No. 2018111989.

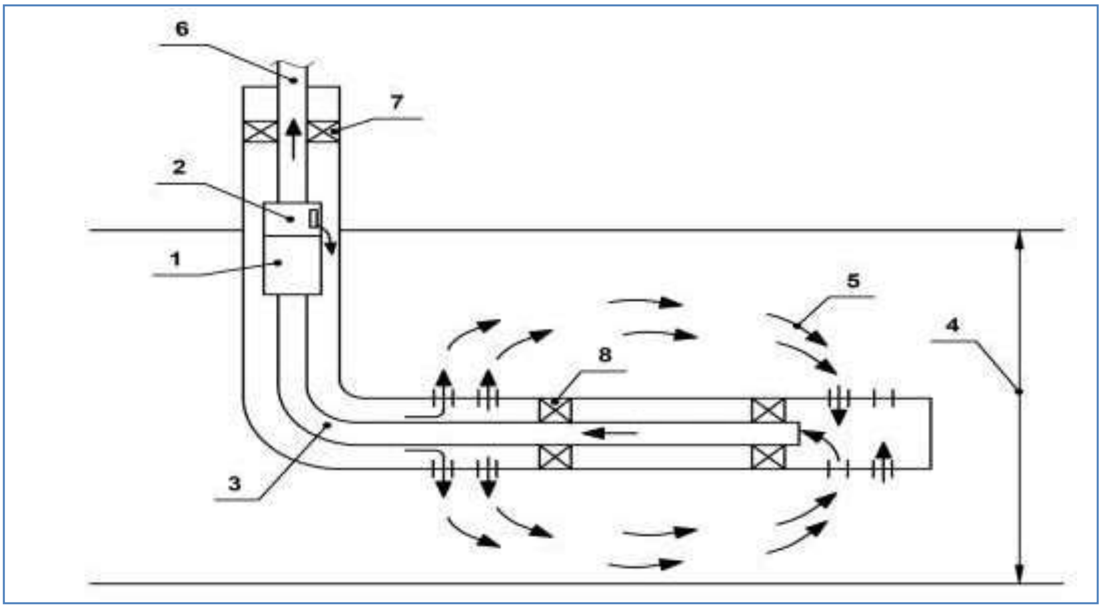

Figure1: Shows heat generator, which ensures coolant recirculation in the reservoir conditions.

The hydraulic chamber 2 can be equipped with a remotely controlled valve through which some of the liquid is returned to the well. This example considers the option a heat generator placed in the horizontal section of the producing oil well, in production reservoir 4. If the valve in the hydraulic chamber 2 is in the closed position, it is possible to hydraulically link the circulation chamber 1 to the production string 6. If, however, the valve in the hydraulic chamber 2 is open, it is possible to connect hydraulically the circulation chamber 1 to the heat exchange chamber 3 in let through the annulus in the well, to form a closed circulation loop 5, directly in the productive reservoir 4. In order to organize the flow direction in the recirculation loop, it is possible to use sealing devices 7, 8 or other technical solutions. Heat exchange chamber can be equipped with an additional system with a heating cable, which will expand the possibilities for controlling the flow of heat energy in the pore throats of the productive reservoir.

As demonstrated by laboratory tests, the circulation chamber 1 can be made based on a centrifugal pump, a vortex pump, or a volumetric pump. Well conditions see as the most promising variants those with a volumetric pump or variants with a vortex pump, since these designs are more efficient when pumping highly viscous liquids. With the support of the existing scientific reserve, the authors of the manuscript also considered the options of the circulation chamber, the construction of which was carried out similarly to volume-dynamic pump s[7-18], which were designed specifically for the extraction and transfer of high-viscosityliquids.Sofar,therearedevelopedandpatentedpumpdesigns,withsolvedproblems of the rotors vibrational activity and with newly developed geometric shapes of processing chambers, which are characterized by high process ability in production [10-13,19].

One of the circulation chamber options, made on the basis of a volumetric pump, is schematically shown in Fig. 2. The analogue pump was chosen under the RF Patent No.2103553 [6].

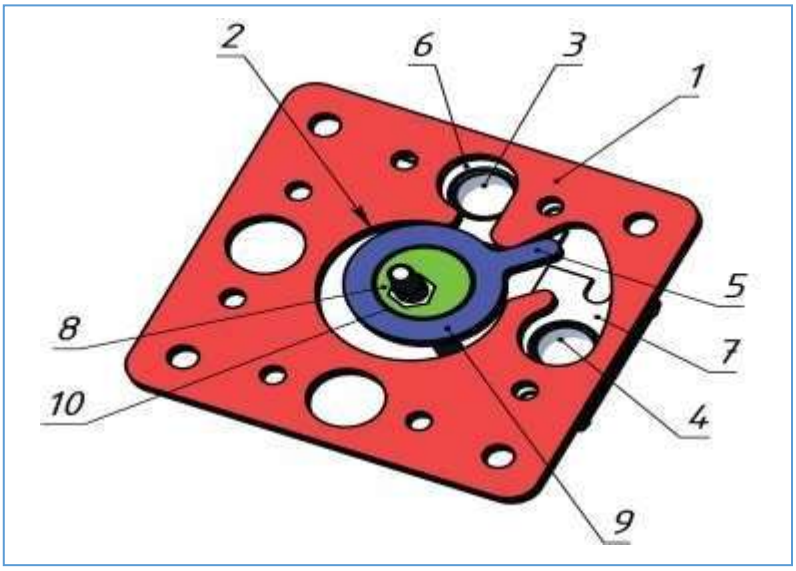

Figure2: Shows circulation chamber based on a volumetric pump.

The pump comprises a body1with an internal cylindrical bore 2, an inlet 3 and an outlet 4 channels, a separation plate 5, end caps 6, 7 a shaft 8 eccentrically located on the shaft 8 of the rotor 9. Bearings 10 are installed between the eccentric shaft 8 and the rotor 9. When the pump is operated by a rotating eccentric shaft 8, the rotor 9 is driven into the oscillating motion. This parathion plate 5 prevents rotation of the rotor 9. In this case, the contact line,

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the rotor 9 cylindrical surface together with the cylindrical bore 2 in the body 1 move along the shaft 8 rotation direction and separate the two cavities formed in the pump processing chamber. One of these cavities, delimited by the said contact line and the separation plate 5, hydraulically communicates with the inlet 3; another cavity is hydraulically connected to the outlet 4. By changing the volume of the cavities, the pumped medium flow is formed in the processing chamber in the direction from channel 3 to channel 4. This pump can be designed as a reversible one, with the possibility of changing the liquid flow direction through its processing chamber.

4. DISCUSSION

The research work considers the questions on the sequential connection of processing chambers in a multi-sectional volume pump. Considering the peculiarities of the applied kinematic scheme, the rotor balancing in the pump is performed with the help of the angular displacement of the stator elements and the rotor elements in separate sections similarly to the patent [19]. Due to the angular displacement of the sections in the pump, it is possible to eliminate the vibrational activity of the rotor at a high rotational speed. The manuscript also considers the special questions on the successive connection of processing chambers at different values of the working volume of individual chambers in the pump, which is especially important for estimating the conditions for pumping gas-liquid mixtures.

Figure 3 shows a photograph of the circulation chamber prototype. During the tests, the rotor rotation speed reached 3,000 rpm. Individual parts of the rotor and circulation chamber housing, according to the developed three-dimensional models, were made with laser cutting technology. Individual parts for the circulation chamber were made using additive technologies, on a 3D printer.

Figure 3: Shows developed circulation chamber prototype, made based on an experimental volumetric pump.

In bench tests, circulating chambers constructed based on a centrifugal pump, a vortex pump and a volumetric pump were tested in laboratory conditions.

Figure 4showsa typical graph that reflects the nature of the change in the coolant temperature during bench tests of the produced heat generator. In the course of the first laboratory tests, the maximum temperature reached 80degrees Celsius, and was limited to

100 degrees Celsius. However, with the use of appropriate structural materials, the temperature can be much higher.

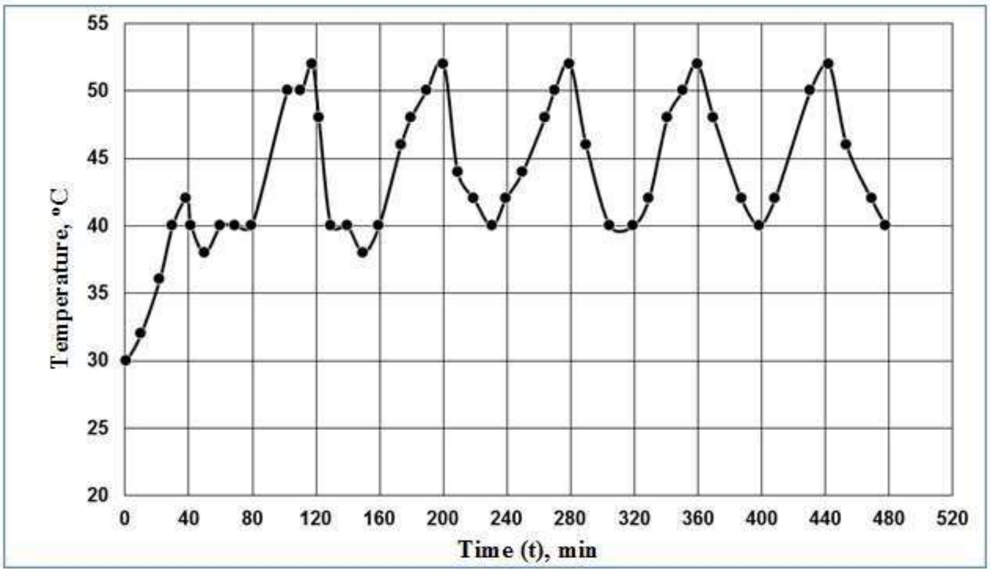

Figure4: Shows temperature change in the coolant recirculation loop, when the heat generator is cycled.

During the tests, the operating mode of the circulation chamber changed cyclically, and it is possible to point out the two modes. In the first mode, the coolant was pumped in a closed loop; oil recirculation loop was simulated in the bench conditions within the productive reservoir. In the process of recirculation, the temperature of the coolant increases, which is reflected in the graph. In the second mode, the heated coolant was pumped out of the recirculation loop, the process of raising the heated oil from the face to the wellhead was simulated in the bench conditions, during this time the cooler and more viscous oil enters the recirculation loop. At the same time, the temperature in the recirculation loop decreases to the initial reservoir temperature. This is the way, in which the cycles with periodic supply of heat energy to the productive reservoir are implemented. At the same time, the system presented allows for using the technology when two working processes are simultaneously performed in addition to cyclic coolant recirculation: recirculation of the coolant through the productive reservoir and pumping oil to the wellhead.

The sectional design of sealing devices in new pumps allowed for getting rid of complex screw surfaces, replacing them with flat and cylindrical surfaces. In addition, such a technical solution allows, if necessary, for eliminating the use of elastomers for manufacturing pump parts, thereby increasing the pump operating temperature (when evaluating other possible applications for new equipment, it is possible that such pumps can be used and for pumping molten metal’s in metallurgy when all pump parts are made of ceramic materials).

Figure5 shows one of the studied pumping systems, which is designed for oil extraction in complicated conditions. The peculiarity of this pumping system is the use of a reversible pump for oil extraction. The possibilities of reverse pumps in oil extraction have been poorly studied so far.

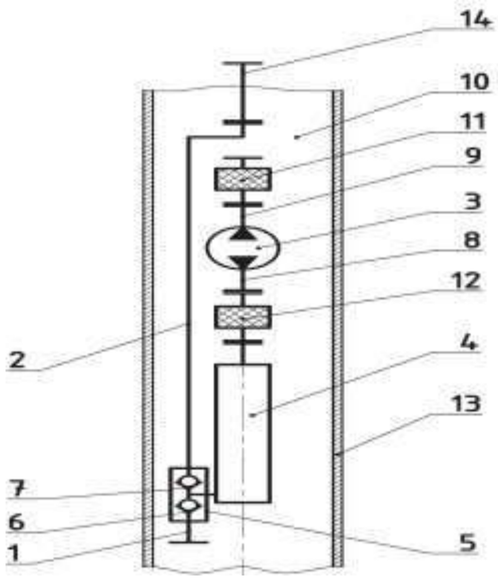

Figure5showspumpingsystemdiagram

The pumping system comprises an inlet 1 and an outlet 2, a pump processing chamber 3communicating via a connecting pipe 4 with a valve assembly 5 equipped with a suction valve 6 and a discharge valve 7. The pump processing chamber 3 communicates with the inlet 1through the suction valve 6 and communicates with the outlet 2 through the discharge valve7.

The pumping system is equipped with a pump processing chamber 3 of the reversible type, which is flow-through and has at least two connection channels 8 and 9. One of these channels 8 communicates with the connecting pipe 4 and the other connection channel 9communicates with the hydraulic chamber 10 which in the lower part communicates with the inlet 1. In order to protect the pump processing chamber 3 from getting into it mechanical impurities, known techniques can be used, for example, filters 11 and 12 installed in each of the channels 9 and 8. The condition that the pump processing chamber 3 is of irreversible type can be provided by using a reversible pump. Such a pump can be connected to an electric motor. The figure does not show an electric motor driving a reversible pump having a flow-through processing chamber 3. When using the pumping system for oil extraction, the internal cavity of the production string 13 is the hydraulic cavity 10. The discharge duct 2 is connected with the flow string14.

The connecting pipe 4 is arranged vertically and its upper part is connected to the pumpprocessingchamber3, and its lower pipe4is connected to the valve unit 5.

The pumping system works as follows. The reservoir fluid, a mixture of oil and water, together with associated gas bubbles and with mechanical impurities, enters the production string 13 and goes further to the inlet 1. Electric energy in the electric motor is converted into mechanical energy. Mechanical energy in the pump processing chamber 3 is converted into hydraulic energy, since chamber 3 applies force to the liquid. A flow of the pumped medium is generated in the direction from the connecting duct 8 further through the chamber 3 upwards along the duct 9 into the cavity 10. The reservoir fluid, a mixture of oil and water, together with bubbles of associated gas and with mechanical impurities, goes through the inlet1, through the suction valve 6 and enters the connecting pipe 4. At the moment when pipe 4 is filled, the rotation direction of the electric motor shaft is changed. At that, the pump processing chamber 3 of the reversible type provides a change in the liquid flow to the

M opposite direction: the liquid flow is directed from the hydraulic chamber 10 through the connection duct 9 and the pump processing chamber 3 through the connection duct 8 into the connecting pipe 4 cavity. The formation fluid, a mixture of oil and water, together with bubbles of associated gas and with mechanical impurities, goes from the connecting pipe 4through the discharge valve 7 and the outlet 2, and then enters the production string 14 and further goes upwards to the well head. The liquid from the cavity10, passing through the filters 11 and 12, is cleaned of mechanical impurities and fills the connecting pipe 4 cavity, moving from top to bottom. The contaminated reservoir fluid, a mixture of oil and water, is completely expelled through the discharge valve 7 and the outlet 2 into the production string 14. The connecting pipe 4 is arranged vertically and its upper part is connected to the pump processing chamber 3, and its lower pipe 4 is connected to the valve unit 5. With the vertical arrangement of the connecting pipe 4, the operation of the gravitational forces prevents the entry of mechanical impurities into the pump processing chamber 3, which contributes to an increase in the efficiency of the pumping system in complicated conditions in the presence of gas and mechanical impurities in the pumped medium flow. Also, it is possible to exclude gas accumulation in chamber 3, since chamber 3 is flow-through, and there is a possibility for reverse and for changing the flow direction, while gas is easily removed into cavity 10, and this helps to increase the pumping system efficiency. This increases the reliability of pumping systems designed to extract liquid from wells complicated by the presence of gas and mechanical impurities. Also this eliminates the harmful effect of gas and mechanical impurities on the operation of pumping equipment, including when extracting high-viscosity oil.

After filling, the connection pipe 4 with the purified liquid, the processing cycle repeats. The electric motor rotation direction is changed. A flow of the pumped medium is generated in the direction from the connecting duct 8 further through the chamber 3 upwards along the duct 9 into the cavity 10. The reservoir fluid, a mixture of oil and water, together with bubbles of associated gas and with mechanical impurities, goes through the inlet 1, through the suction valve 6 and enters the connecting pipe 4. The cycle repeats. The duration of this processing cycle in the considered pumping system can be controlled by controlling the electric motor operation using known technical means and technologies. The presented pumping system can be used as a part of a heat generator, in extracting high-viscosity oil.

5. CONCLUSIONS

The task for extracting high-viscosity oil is significantly complicated with increasing depth of production wells. The problem of creating energy-efficient technologies for increasing the temperature in the zone of the productive reservoir and for reducing the viscosity of the oil produced remains very topical. The research is based on the concept that a down-hole pump, in addition to the main function, can perform the functions of a heat generator, since when the liquid is re-circulated, the hydraulic energy is converted into heat. In this case, the produced coolant or multiphase medium, for example, a mixture of oil, reservoir water and oil gas, can act as a coolant. Several options of the heat generator providing coolant recirculation are considered within the conducted researches. As demonstrated by laboratory tests, dynamic pumps with a vane or vortex working process, as well as volume pumps can be used to provide coolant recirculation. For well conditions, the most promising options are with a volumetric pump or options with a dynamic pump and a vortex working process, since these set-ups are more efficient when pumping highly viscous liquids. The research work considers the questions on the sequential connection of processing chambers in a multi-sectional volume pump. Due to the angular displacement of the sections in the pump, it is possible to eliminate the vibrational activity of the rotor at a high rotational speed. The developed heat

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generator implements cycles with periodic supply of heat energy to the productive reservoir. At the same time, the system presented allows for using the technology when two working processes are simultaneously performed in addition to cyclic coolant recirculation: coolantrecirculationthroughtheproductivereservoirandliftingofoiltothewellhead.Thedeveloped technology can also be used in combination with other technologies for extraction of high-viscosity oil. Thus, the developed heat generator can be equipped with an additional system with a heating cable, which will expand the possibilities for controlling the heat energy flow in the porethroats of the productive reservoir.

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