Use of hydraulic drive of sucker-rod pump 120-6-24 in oil and gas industry as an alternative to import substitution of small-sized pumps

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Abstract. The purpose of this article is the research aimed at the improvement of the quality of hydraulic equipment, namely, investigation of the use of hydraulic drive of sucker-rod pump 120-6-24 in oil and gas industry as an alternative to import substitution of small-sized pumps. Nowadays, at the fields of Western Siberia, it is necessary to replace outmoded and worn-out equipment with modern equipment of proven efficiency. To a greater extent, the imported equipment is used in oil industry. For Russian industry import substitution is one of the key tasks. This article considers the task of wells operation with sucker rod pumping units with a surface hydraulic drive with an analysis of its performance. As an alternative to import substitution for small-sized pumps, it is recommended to use innovative equipment - a highly efficient hydraulic drive of a sucker rod pumping unit, which provides a general increase in the efficiency of production processes during operation, increasing oil production during well operation in optimal mode. The use of this drive leads to a decrease in the costs of oil and gas production enterprises by reducing the level of oil deficit and prevents equipment failure in oil fields. The method of oil production with a hydraulic drive hydraulic drive of sucker-rod pump 120-6-24 considered in this article is widely applied in oil and gas industry and became a valid alternative to small-sized pumps.

1. Introduction
Oil production using sucker rod pumping units appeared a long time ago, namely a century ago, with the invention of machine tools in the form of pumping chairs. Until recently, the sucker rod pumping units were considered a symbol of oil industry. Nowadays sucker rod pumping units are used less and less. Respectively, global changes in the dynamically developing world require the use of more modern equipment with effective performance. Only the last 20 years a drive have been applied in these pumps, functioning on the basis of a hydraulic drive. However, during the operation of the hydraulic drive, there are ambiguities about the climatic resistance, cost recovery of equipment, repair of hydraulic drive of sucker-rod pump, etc. The hydraulic drive provides pumping of fluid from oil wells according to the usual movement in the plunger of a sucker rod pump (SRP) [1].

The purpose of this article is to consider the prospects of the improvement of the quality of hydraulic equipment by analyzing indicators using import substitution by putting into operation wells of sucker rod pumping units with a surface hydraulic drive.

In this work, we will try to answer the main questions of the alternative to small-size pumps and find out how effective their use is through the example of hydraulic drive of sucker-rod pump.

The issues of the use of hydraulic drive of sucker-rod pump 120-6-24 in oil and gas industry as an
alternative to import substitution for small-size pumps was considered by the chief mechanic R.S. Garifullin, Leading Engineers of PJSC TATNEFT L.M. Akhmetzyanov., I. N. Garipov [2].

2. Materials and methods

The Government of the Russian Federation set oil producing companies the task to increase oil production by 2025, for example, the management of PJSC TATNEFT has the task to increase the production of hydrocarbons to 30 million tons by this period. With the current sanctions on the part of foreign countries, it is reckless to hope for such production. Therefore, the import substitution program is paramount at this stage. In this work, we consider the problem of the use of domestic equipment, which is equal to imported equipment in terms of technological characteristics.

In 2011, innovative equipment was developed on the basis of research and development corporation UralNeftService enterprise, a leader in the development of equipment for the production and processing of oil and gas. It was a highly efficient hydraulic drive of a sucker rod pump (hydraulic drive of sucker-rod pump “GERON”), competing with conventional pumping units. The studied hydraulic drive is equal to foreign analogues in terms of reliability and operation. During the development of high-tech equipment, the best experience in the extraction of petroleum products on a global scale was used, progressive views and opinions of leading oil producers were studied. The company engaged in testing the hydraulic drive of the sucker rod pump (HDSRP “GERON”) was “Rosneft” oil company, providing its fields. PJSC “Orenburgneft” was chosen as an experimental site, which tested the first hydraulic drives at its wells.

The improvement of hydraulic drives continues to this day. The producer - research and development corporation (RDC) UralNeftService LLC, located in Yekaterinburg, is developing a new generation of hydraulic drives in accordance with the needs and expectations of the market.

At this stage, the developers of alternative equipment for oil workers are engaged in the development, production and implementation of new samples of a number of different models of sucker rod pumping units that meet the needs of a new generation of customers. The priority feature of the hydraulic drive is quite simple assembly and disassembly, much lower power consumption, good automation and intellectualization of oil production process in comparison with a pumping unit. The use of a hydraulic drive allows quick assess to the parameters of well operation, remotel control of technological process in real time with minimal participation of maintenance personnel and equipment, and also increase of the average daily volume of oil production.

According to Alexey Molotkov, General Director of RDC UralNeftService the use of the new equipment turned out to be much easier and cheaper in operation compared to traditional pumping units, which was confirmed by the tests of hydraulic drive of the sucker rod pump. For the assembly of the lightweight and compact structure of “Geron” it is not necessary to use a special foundation, since the support is mounted on road plates or at the wellhead. This can significantly reduce the overall cost of construction and ensure convenience and safety of maintenance.

The hydraulic drive provides pumping of fluid from oil wells according to the usual movement in the plunger of a sucker rod pump (SRP) [3, 4]. Throughout the world, the practice of the use of a sucker rod pump is widespread due to optimal parameters for pumping out well fluid. This increases the filling factor of a pump, especially with high viscosity oil and high gas content in the recovered liquid. Due to the high efficiency of the hydraulic drive, the dynamics of energy consumption is reduced in comparison with electric centrifugal pumps with a flow rate of up to 50 m$^3$/day.

In addition, the introduction of hydraulic drives instead of conventional pumping units allows:
- reducing the time of assembly, disassembly of the drive;
- reducing the metal consumption of the mechanism in comparison with traditional drives of pumping units;
- reducing the cost of transporting the drive to oil production sites;
- simplifying the base for the assembly of hydraulic drives.

Nowadays, there are a large number of varieties of the design of hydraulic drives, both Russian and foreign.
The disadvantages of foreign analogues:
- high cost of drives;
- long term delivery of equipment and spare parts;
- high cost of components and parts;
- lack of a sufficient level of knowledge of service personnel.

The disadvantages of domestic hydraulic drives:
- lack of equipment with the required technical characteristics for effective oil production;
- insufficient reliability of equipment during operation in cold weather conditions due to the failure of hydraulic systems.

The analysis of the advantages and disadvantages of the characteristics of this pump, which have not proved themselves to be effective enough during operation, resulted in the necessity to use a sufficiently powerful hydraulic drive [3]. In order to increase the operation of wells, it was decided to use hydraulic drive of sucker-rod pump 120-6-24.

Figure 1. Design of hydraulic drive of sucker-rod pump 120-6-24: 1 - frame, 2 - hydraulic station, 3-4 - main run pipe, 5 - main run-back pipe, 6 - coupling, 7 - drain pipe, 8 - hydraulic power cylinder, 9-10 - nitrogen cylinder, 11 - motor drives, 12 - pumps, 13 - pump reservoir, 14-15 - secondary cylinder GK2-GK3, 16 - operating box.

Operation principle: during operation, power is supplied to the drive from the operating box using electromagnet to lift, the liquid flows through the run pipe into the lower cavity of the secondary hydraulic cylinder rod (2), acting on its lower piston, displaces liquid from the piston cavity (2). Under the influence of the total increase in the gas pressure of the accumulators in the upper piston (2), and created by the hydraulic pump, in the lower piston, the hydraulic power cylinder (HPC1) begins to move upward and, through the wellhead rod and the pump rod column, raises the sucker rod pump piston. The liquid displaced along the line from the cavity of the upper stem (2) returns to the pump.

When approaching the upper position of the rod of the power hydraulic cylinder (PHC1), the flag
attached to it sends a signal to the proximity switch. This causes the reverse fluid flow by changing the inclination of the pump washer in the opposite direction. The movement of the liquid in this case is as follows: the pump run pipe is the cavity of the upper rod (2). The rod (2) under the influence of the force on the upper piston begins to move upward, as a result of which the pump piston from the downhole rod moves downward under the action of its own weight and the weight of the pump rod string. The rod of the hydraulic cylinder (2) moves upward, exceeding the resistance of the compressed gas under the action of the total force of the pump in the upper piston and the liquid ejected from the cavity of the rod of the hydraulic cylinder (HC 1). The flag attached to it sends a signal to the lower proximity switch, which leads to a change in the direction of fluid flow through the hydraulic pump. The operation cycle repeats. In order to protect the hydraulic system from overloads, safety valves are provided in the hydraulic system [5].

If the control pressure of the valves in the hydraulic system is exceeded, the oil is drained from the run line into the run-back hole. The alignment of a possible leakage of fluid from the cavity of the hydraulic cylinder rod (HC1) and the lower piston cavity of the auxiliary secondary cylinder (2) occurs through the reverse compensation valve. The stabilization process takes place automatically at the end of the stroke in the upper position through the compensation valve.

Economic feasibility of a sucker rod pump in comparison with an electric-centrifugal pump is reasoned by:
- increased reliability in the presence of mechanical impurities in well fluid
- less sensitivity to salt and asphaltene sediments
- significantly lower energy consumption at flow rates up to 50 m³/day.

The advantages over chain drive, pumping units and hydraulic drive with pneumatic balancing are as follows:
- Simple and reliable drive design
- Compact dimensions and ease of transportation.
- Assembly does not require the installation of a special foundation, ordinary road plates or screw piles are enough.
- Less metal construction.
- Reduced time for assembly and disassembly by 4-6 times compared to swinging machines and chain drives.
- Reduced maintenance and maintenance costs, because electronic control system (ECS) continuously monitors the operation.
- Power consumption is reduced:
  - up to 50% compared to rocking machines and chain drives;
  - up to 30% compared to a hydraulic drive with pneumatic balancing;
- Simplicity and ease of maintenance, due to the placement of the pumping station and ECS in a block box with a removable cover.
- Lack of massive moving and open rotating parts, there is no need for fences. It is safe for others.
- Remote control of the drive operation using telemetry.
- Lack of ropes reduces maintenance and increases safety.
- The unloading of the hydraulic drive is due to the frequency converter, therefore no power reserve is required. It allows significantly energy reduction during operation.
- Easy regulation by the number of swings and the stroke length using ECS allows complete selecting the well flow rate and adjusting the selection depending on the change in flow rate, according to the constant analysis of the dynamometer chart.
- Easy provision of small numbers of swings in low-rate wells. It is possible to install sucker-rod pumping units with a large rod diameter, reducing the number of oscillations, thereby increasing the service life of underground equipment.
- Lack of bending and tensile alternating loads on the power parts of the structure.

The process cyclicity of the pumping by a sucker rod pump contributes to the increase in the permeability of the well bottom zone.
3. Results and Discussion
According to the official reviews of Orenburgneft Company, pilot tests of hydraulic drive sucker-rod pumping unit Geron with an energy recovery unit were carried out at well No. 163 of Pron'kinskoye field, the pilot test results were positive. The main economic effect was obtained by reducing electricity by 27% compared to a similar drive without a recuperation unit. The equipment is recommended for implementation at the facilities of Orenburgneft [6].

In addition, according to the reviews of “Enterprise Kara Altyn”, as a result of the experimental operation of the hydraulic drive of sucker-rod pump “Geron” of type HDSRP-80-3.0A with energy recovery, produced by Ural RDC UralNeftService at the Agan oil field in 2015, it was possible to more than double the productivity of the well, due to the competent selection of the speed regime when lifting and lowering the rod of the deep-well pump, as well as the correct setting of the stroke length and the number of double strokes according to the analysis of the deep dynamometer chart [7]. At the same time, electricity consumption, compared to the pumping unit previously operated at this well, significantly decreased (up to 40%). The well was transferred from the periodic mode to the permanent one. Taking into account the positive results of pilot testing, Geron hydraulic drive is recommended for further operation at the fields of company.

The design of “Geron” hydraulic drive proved itself in the most extreme climatic conditions of both Turkmenistan and Colombia, where the temperature rises to +56\(^0\)C. The flow rate of formation fluid with a conventional pumping unit was 4 m\(^3\)/day, and when using the hydraulic drive of sucker-rod pump it was 9 m\(^3\)/day. Under the conditions of the Far North, the studied hydraulic drive proved itself at a temperature of -55\(^0\)C. In Nyagan, Khanty-Mansi Autonomous Okrug-Yugra, the flow rate of formation fluid with a conventional pumping chair was 9 m\(^3\)/day, and when using hydraulic drive of sucker-rod pump on this well it was 11 m\(^3\)/day. Good indicators for oil production rates were obtained at Kogalymneftegaz enterprise.

Successful experience of restoring marginal wells, at the Sovetskoye field for well 707 of well platform No. 104 and well 11 of well platform No. 4 of Nizhnevartovskoye field, was obtained using Geron hydraulic drive, as a result of which the flow rate increased several times (the ability to swing the well, thereby select the optimal operating mode).

The positive effect of using hydraulic drives of sucker-rod pump 120-6-24 is expressed in:
- increase in oil production.
- reduction of the level of structural failures.
- reduction of equipment downtime and repair costs.
- optimization of the operating costs of hydraulic systems in comparison with traditional ground drives (pump jack, chain drive).
- annual economic effect is one unit - 97.8 thousand rubles per year roughly estimated.

**Table 1.** Technical characteristics of hydraulic drives in relation to well parameters (depth, well rate)

| Parameter                                      | Value               |
|------------------------------------------------|---------------------|
| Maximum load at the suspension point of the rods, kN | 200                 |
| Maximum stroke length of the wellhead rod, m     | 1÷ 6                |
| Maximum number of double strokes per minute with 6 m length | 4                  |
| Maximum number of double strokes per minute with 4 m length | 6                  |
| Maximum pressure of the working fluid in the hydraulic system, MPa | 18                 |
| Electric motor type: three-phase, asynchronous 220/380 V, rotation speed 1500 rpm. Maximum power consumption including recuperation, kW / h | 2-18               |
| Working fluid tank volume, l                     | 300-800             |
| Working fluid brand                              | Multigrade low-temperature hydraulic oil of technical regulations 38,101479-00 |
| TBF, not less than, hour                         | 8000                |
| First overhaul period, hour                      | 87500               |
| Full average service life, years                 | 20                  |
In terms of productivity and quality, Geron surpasses the equipment of the leading producers of the USA, Canada and Germany. Table 1 shows the technical characteristics of hydraulic drives.

Hydraulic drive of sucker-rod pump is used not only in Russian oil industry, where the key customers are Rosneft, Lukoil, Tatneft, Orenburgneft, Varyeganneftegaz and Kara Altyn Enterprise.

The companies from Argentina and Iran expressed interest in cooperation with the Urals, a contract was signed with the state concern Turkmennebit (Turkmenneft), cooperation with partners from Azerbaijan, Kazakhstan and other countries continues.

4. Conclusion

Thus, the measures for the introduction of Hydraulic drive of sucker-rod pump, related to the equipment of a new generation, which have been successfully tested both at national and international oil fields provides an overall increase in the efficiency of production processes during operation, increases oil production during well operation in the optimal mode up to 60%, reduces the costs of oil and gas production company by reducing the level of oil deficit to 50% or more, saves up to 30% of electricity due to the frequency converter and prevents equipment failure in oil fields.

All these aspects determine the efficiency and prospects of further use of the hydraulic drive, prove the economic feasibility of the use of this type of equipment, leading to the decrease in the cost of producing a barrel of oil [8].

This article discusses a method of oil production using a hydraulic drive of sucker-rod pump 120-6-24, which is widely applied in oil and gas industry and became an alternative to import substitution for small-size pumps.

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