Influence of complicating factors on the operation of an electric centrifugal pump installation

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Abstract. The article analyzes the complicated stock of producing wells equipped with electric-centrifugal pump installations in an oil field. The study identified factors causing complications in oil production. In the course of the study, a complicated well stock was examined, and possible ways to prevent the formation of complications during the operation of oil producing wells were studied. The article presents well performance indicators that reflect the factors that complicate the operation of electric centrifugal pump installations. It developed recommendations to improve the condition of the complicated deposit fund.

Keywords: installation of an electric centrifugal pump, complicating factors, failure, operational efficiency, scaling, mechanical impurities, corrosion, gas content.

1. Introduction

The main method of operating oil wells in the Russian Federation is a mechanized pumping method. A feature of this method of oil production in recent years is the manifestation of many complicated situations during the operation of wells associated with the commissioning of hard-to-recover oil reserves, as well as the intensification of oil production in existing fields. The number of oil wells operating low-productivity and heterogeneous reservoirs by a mechanized pumping method has increased, as well as the use of low-productivity pumps with relatively low efficiency indicators. The number of production wells introduced after the hydraulic fracturing technology has increased significantly. Because of the intensification of oil production, the content of free gas and the volume of mechanical impurities at the reception of electric centrifugal pumps increased. The developed head of electric centrifugal pumps increased, as well as the descent depths, because of which the operating temperature of submersible pumping equipment units’ increased, favorable conditions for scaling appeared on working elements of electric centrifugal pumps. As a result of the above changes, the well stock, with complicated characteristics, increased and, consequently, the frequently repaired fund increased, the overhaul period and mean time between failures decreased [1, 2].

High quality and reliable operation of the mechanized pumping stock of wells determines the performance indicators of an oil-producing enterprise. High rates of oil recovery, capital and operating costs, costs of the enterprise for power supply depend on the efficiency and reliability of the mechanized pumping stock of wells [3, 4].
To increase the mean time between failures and the overhaul period of the mechanized pumping stock of wells, we created software products that facilitate the implementation of technological measures, that will ensure the technological effect during their implementation [5].

The analysis of field data on the occurrence of failures of submersible pumping equipment is carried out and probable problems and causes that reduce the reliability of wells equipped for the mechanized method are determined [6].

The main efforts when working with a mechanized well stock were focused on the following areas:
- improving the reliability of submersible equipment units;
- strengthening control over the implementation of all requirements of technological regulations and standards;
- constant work with staff to improve the technical level and involvement in the process of "work on the result" [7].

To create conditions for the long and uninterrupted operation of electric centrifugal pump installations in order to ensure a basic level of oil production at oil producing enterprises, we take measures to monitor the current technical condition in order to reduce the number of failures. The most common causes of failure of the centrifugal pump installations are: failure of the electric centrifugal pump supply, malfunction of the cable electric line and lack of insulation resistance, violation of the tightness of the tubing when lifting well products, jamming of rotating elements and the likelihood of deformation and subsequent breaking of the shaft of the electric centrifugal pump [8, 9].

In the structure of complications of the mechanized well stock, five dominant directions can be distinguished (in importance):
- removal from the reservoir of solid particles (rock and proppant after hydraulic fracturing) that clog and abrade the pump;
- salt deposition on the working parts of electric-centrifugal pumps;
- temperature effect;
- structural reliability of individual nodes and the entire ESP system;
- staff qualifications.

2. Methods and materials

In the field practice of the Vankorskoye field, technological and technical solutions are used to fight the listed complications, for example, the use of filters, inhibitor protection, the use of formation fastening measures that significantly reduce the impact of complications on the operation of the pump and the installation of the electric centrifugal pump as a whole. Complications themselves are not manifested in hierarchy, but in the simultaneous combination of different species among themselves, which requires the use of integrated protection technologies [10].

As a result, the company carries out a certain amount of routine maintenance, uses various technologies that require costs to eliminate the complications that arose. The company has certain problems associated with a complicated fund that need to be addressed, the most common of which are as follows:
- determination of the estimated period of routine maintenance;
- scheduling routine maintenance;
- maintaining documentation of work performed and document management;
- determination of the effectiveness of work performed on implemented technologies;
- determination of the effectiveness of the work of personnel conducting the work;
- accounting for complications arising from individual wells and the field as a whole;
- development of a plan of work performed, ordering technical equipment, materials for the future;
- determination of the cost of work performed and the technical and economic effect of the measures.
A number of measures are being taken by oil enterprises to create conditions for the quality work of electric centrifugal pump installations:
- periodic measurements of the operating parameters of the wells using modern methods of hydrodynamic research of wells;
- conducting continuous monitoring and evaluation of the obtained data on the operation of wells in order to maintain an optimal operating mode, the subsequent selection of geological and technical measures and ensuring performance indicators of wells;
- ensuring adjustment of the operating mode of wells equipped with electric centrifugal pump units.

Diagnostics of the condition of pumping equipment includes:
1) comparison of the planned indicator of the technical condition with its actual current state;
2) determining the coherence in the work of the underground and ground parts of electric centrifugal pump installations with an oil reservoir;
3) detection of negative factors that disrupt the operation of the underground and ground parts of the electric centrifugal pump units and the bottomhole zone of the well.

According to the data obtained during diagnostics, the necessary recommendations are developed for the required geological and technical measures, both in the current mode and subsequently in time. They recalculate well productivity, oil and fluid production rates for specific facilities and the field as a whole for any period of well operation. Timely diagnostics of the state of electric centrifugal pump installations allows us to effectively change the current situation and introduce optimal solutions that increase the efficiency of well operation [11].

Various kinds of complications during the operation of the mechanized pumping stock of wells affect the final result due to the failure volumes of electric centrifugal pump installations. The performance of the entire pumping system is simultaneously affected by many factors, while determining the dominant root cause of failure is the most important issue for the further selection of equipment protection methods. Wrong decisions in the diagnostic process when identifying the real cause of failure lead to their re-manifestation and additional overhead costs to eliminate the consequences.

In managing complications, the determining role is played by the identification of criteria for the application of various technological measures and the choice of the most effective one from a number of alternative solutions.

There are a number of unsolved problems that reduce the efficiency of the production cycle:
- The most acute problem is the removal of proppant from the formation after hydraulic fracturing. In such wells, the concentration of solid abrasive particles is tens of times higher than the permissible values for the normal operation of the ESP pump (150–450 mg/l), which reduces their production time by 2.5–4 times.
- Inflows with low rates (up to 30 m³/day) that do not provide stable operation of electric centrifugal pumps in a constant mode. For such a well stock, it is necessary to purchase more low cost low-cost equipment (ESP 20–40) with a lower efficiency factor, the operating time of which is 45–50 % lower than the average operating time in these wells, equipped with electric centrifugal pump installations in periodic mode (ESP 45–90 ). The transfer to operation of a sucker rod pump will not allow preserving the existing level of production caused by restrictions on the depth of descent of pumping equipment.
- Constant work with personnel servicing the objects in question is required. Changing the design of pumping equipment, new, relevant modern requirements for technological processes, other various factors require constant attention to training personnel, any incorrect decisions of which negatively affect the result of work.

The process of oil and gas production is associated with a large number of complicating factors. For this reason, one of the main tasks facing the oil company is to reduce the degree of influence of these factors, which in turn will reduce costs and increase production efficiency.
3. Results

Dynamics of changes in the complicated well stock from 2011–2015 presented in figures 1 and 2.

The main complications by type:
- the harmful effects of gas;
- corrosion downhole pumping equipment;
- mechanical impurities;
- scaling.

As you can see the problem of ESP failure at the Vankor field due to complicating factors such as clogging, high gas factor, corrosion, and fur. impurities, the deposition of salts rises quite sharply (Figure 3).

The main reasons for the growth of complications:
- decrease in bottomhole pressure;
- increased water cut;
- decrease in reservoir pressure.

The increase in water cut in wells is affected by:
1) corrosion;
2) salts;
3) mechanical impurities.

The decrease in reservoir pressure is affected by:
1) gas;
2) mechanical impurities.

The decrease in bottomhole pressure is affected by:
1) gas;
2) mechanical impurities.

![Figure 1. Distribution of ESP failures for reasons of occurrence: number of failures, years, gas, mechanical impurities, salts, corrosion](image1)

![Figure 2. The dynamics of the ESP fund by years: number of wells, years](image2)

In the conditions of the Vankorskoye field, the saturation pressure is equal to the initial reservoir pressure.
In this case, the saturation pressure is a multiple of the current bottomhole pressure, which leads to complications in the operation of the ESP associated with a large amount of free gas in the ESP.

In 2015, the decrease in MTBF was due to an increase in the number of failures. Given the decrease in the number of new wells, the increase in the share of the complicated stock, as well as the late effect of the ongoing measures to combat complications, in 2015 the overhaul period and failure rate remained at the level of 2011-2014 (Figures 4 and 5).

One of the main reasons for the growth of failures is a significant increase in the share of the complicated fund, and as a result, an increase in the negative impact of complicating factors on the operation of electric centrifugal pump installations, as well as an increase in the failure rate of electric
centrifugal pump plants with high operating time, which is caused by an increase in the number and proportion of wells with high operating time (figure 6).

Figure 6. Dynamics of ESP operating time by years: profit per 24 hours, years

Measures to protect electric centrifugal pump installations from the negative impact of complicating factors used at the Vankor field are as follows:

1) by the complicating factor "Clogging with mechanical impurities":
   - the use of separators of mechanical impurities and sand filters;
   - operation of electric centrifugal pump installations with increased pressure at a reduced frequency;
   - normalization of the face during the current and capital repair of wells;

2) by the complicating factor "Corrosion":
   - introduction of suspensions of tubing with production material - steel with a chromium content of 13%;
   - the use of tubing corrosion-resistant performance with a protective silicate-enamel coating;
   - the introduction of protectors to protect the submersible motor from the negative effects of corrosion;
   - transfer of oil wells to constant dosing with a chemical reagent through a BDR reagent dosing unit, refusal from periodic treatments;
   - applying a corrosion-resistant coating "Monel" and "Stainless steel" by the method of electric arc spraying on the casing of the installation of electric centrifugal pumps;

3) according to the complicating factor "Salt deposits":
   - transfer of wells to constant dosing with a chemical reagent through a BDR reagent dosing unit, refusal of periodic treatments;
   - the deposition inhibitor in the reservoir under pressure;

4) by the complicating factor "Effect of gas":
   - the use of installations of electric centrifugal pumps of a smaller size - 400 series instead of 538;
   - the use of cone assemblies of electric centrifugal pump installations with a retaining section of greater productivity at the pump intake;
   - the use of electric centrifugal pump units with enlarged sections of the MVP multiphase pump;
   - descent of gas separators;
• testing of devices for monitoring the performance of pumps during operation on the boundary of the supply stall due to the influence of gas.

4. Conclusion
In the period 2011–2015 the average failure rate remains at approximately the same level, with the exception of 2014 (a decrease of 24 %). At the same time, there is a dynamic of a smooth decrease in the overhaul period (also with the exception of 2014), which is typical for the initial stage of field operation. In 2014, there was a significant increase in the overhaul period, due to a significant increase in the fund and a decrease in the number of failures compared to the plan.

In general, the average failure rate in 2015 remains at the level of 2011–2013.

References
[1] Ji Hong, Sun Lei, Xu Dandan et al 2009 The efficiency analysis of an electric, motor-pump with port-plate centrifugal pump 7th Int. Conf. on Fluid Power Transmiss. and Control (ICFP 2009) pp 183–8
[2] Sengpanich K, Bohez Erik L J, Thongkrue P and Sakulphan K 2019 New mode to operate centrifugal pump as impulse turbine Renewable Energy 140 983–93
[3] Zainagalina L Z, Suleimanov R I, Gabdrakhimov M S and Khabibullin M Ya 2018 Determining oscillating system dynamic parameters of a near-bit junk pulper Advan. in Engineer. Res. (AER) Int. Conf. Actual issues of mechan. Engineer. (AIME 2018) vol 157 pp 642–5
[4] Kuleshova L S, Kadyrov R R, Mukhametshin V V and Safiullina A R 2019 Design changes of injection and supply wellhead fittings operating in winter conditions IOP Conf. Ser. Mater. Sci. and Engineer. 560(1(012072)) 1–5. DOI: 10.1088/1757-899X/560/1/012072
[5] Cortes B, Araujo L R and Penido D R R 2018 Passive Filters Design Applied to an Electrical Submersible Pump System IEEE Latin Amer. Transact. 16( 7) 1992–9
[6] Stan M, Pana I, Minescu M, Ichim A and Teodoriu C 2018 Centrifugal Pump Monitoring and Determination of Pump Characteristic Curves Using Experimental and Analytical Solutions Processes 6/2
[7] Davydov A Yu 2018 Utilization of expert systems for screw pump sets with surface drive management Advan. in Engineer. Res. (AER) Int. Conf. Actual issues of mechan. Engineer. (AIME 2018) vol 157 pp 129–33
[8] Zainagalina L Z, Petrova L V and Petrov V A 2019 Analysis of the efficiency of telemetric systems for drilling wells IOP Conf. Ser. Mater. Sci. and Engineer. 560(1(012096)). DOI: 10.1088/1757-899X/560/1/012096
[9] Akhmetov R T, Kuleshova L S and Mukhametshin V V 2019 Application of the Brooks-Corey model in the conditions of lower cretaceous deposits in terrigenous reservoirs of Western Siberia IOP Conf. Ser. Mater. Sci. and Engineer. 560(1(012004)) 1–4. DOI: 10.1088/1757-899X/560/1/012004
[10] Sun H, Yuan Sh, Luo Y et al 2017 Unsteady characteristics analysis of centrifugal pump operation based on motor stator current Proc. of the Instit. of Mech. Engineers Part A – J. of Power and Energy 231(8) 689–705
[11] Khabibullin M Ya and Suleimanov R I 2019 Automatic packer reliability prediction under pulsed transient flooding of hydrocarbon reservoirs IOP Conf. Ser. Mater. Sci. and Engineer. 560(1) Art. no 012024. DOI: 10.1088/1757-899X/560/1/012024