Artículo de investigación

Study of the effect the choice criterion reliability of the results of modeling the optimal backup system elements downhole equipment of oil wells

Исследование влияния выбора критерия надежности на результаты моделирования оптимальной системы резервирования элементов насосного оборудования нефтяных скважин

Estudio del efecto del criterio de elección fiabilidad de los resultados del modelado de los elementos óptimos del sistema de respaldo del equipo de fondo de pozos petroleros

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Abstract

The paper considers the influence of the choice of the probability indicator of failure-free operation as the main parameter on the backup system of its individual elements to optimize the maintenance and repair system. The research material was data on the laws of the distribution of failures, the actual time between failures and the main causes of failures of downhole pumping equipment of production wells of the Tarasovskoye field of Rosneft-Purneftegaz company. The study showed that oil wells equipped with sucker rod pump units have greater operational reliability.

The main results of the study are the quantitative values obtained of the necessary reserve elements of pumping units at given optimal values of the probability of failure-free operation. When using the model proposed in the study for practical application in production, it is possible to carry out calculations while establishing other requirements for the optimal value of the probability of failure-free operation.

Key Words: Downhole pumps, modeling of reserve elements, optimization of maintenance of electric submersible pumps pumping systems reliability, the distribution law of failures, maintenance system.

Аннотация

В статье рассматривается влияние выбора показателя вероятности безотказной работы в качестве основного параметра системы резервирования отдельных элементов скважинного оборудования для оптимизации системы технического обслуживания и ремонта. Материалом исследования послужили данные о закономерностях распределения отказов, фактическом времени между отказами и основных причинах отказов скважинного насосного оборудования эксплуатационных скважин Тарасовского месторождения компании Роснефть-Пурнефтегаз. Исследование показало, что нефтяные скважины, оснащенные штанговыми насосными установками, обладают большей эксплуатационной надежностью.

Основными результатами исследования являются полученные количественные значения необходимых резервных элементов насосных агрегатов при заданных оптимальных значениях вероятности безотказной работы. При использовании модели, предложенной в исследовании, для практического применения в производстве, можно проводить расчеты, устанавливая другие требования к оптимальному значению вероятности безотказной работы.

Ключевые слова: скважинные насосы, моделирование резервных элементов, оптимизация обеспечения надежности насосных систем, закон распределения отказов, система технического обслуживания.

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Resumen

El documento considera la influencia de la elección del indicador de probabilidad de operación libre de fallas como el parámetro principal en el sistema de respaldo de sus elementos individuales para optimizar el sistema de mantenimiento y reparación. El material de investigación fue datos sobre las leyes de distribución de fallas, el tiempo real entre fallas y las principales causas de fallas de los equipos de bombeo de fondo de pozo de los pozos de producción del campo Tarasovskoye de la empresa Rosneft-Purneftegaz. El estudio mostró que los pozos de petróleo equipados con unidades de bomba de varilla de bombeo tienen mayor confiabilidad operativa.
Los principales resultados del estudio son los valores cuantitativos obtenidos de los elementos de reserva necesarios de las unidades de bombeo a valores óptimos dados de la probabilidad de una operación libre de fallas. Cuando se utiliza el modelo propuesto en el estudio para su aplicación práctica en la producción, es posible realizar cálculos mientras se establecen otros requisitos para el valor óptimo de la probabilidad de una operación libre de fallas.

Palabras clave: Bombas de pozo, modelado de elementos redundantes, optimización de la confiabilidad de los sistemas de bombeo, ley de distribución de fallas, sistema de mantenimiento.

Introduction

At the present stage of development of the oil industry, most large fields have entered the late stage of development, which is characterized by a decrease in oil production, an increase in water cut in produced products, an aging well stock, etc. Due to the fact that at the present time the commissioning of new fields does not provide a significant increase in production volumes, and the applied physicochemical methods of intensification can only stabilize oil production, the main way to solve the problem of increasing production is to put wells into operation from the idle pool (Lysenko, Grajfer, 2005).

To stabilize the production of hydrocarbons, a large amount of geological and technical measures is required. These measures are carried out during the operation of production wells in conditions complicated by the processes of salt deposition, paraffin, tussing of directional wells, increasing depression on the formation, etc. During operation, corrosion processes intensify due to the appearance of hydrogen sulfide in the production of wells and an increase in water cut of produced products, which necessitates urgent measures to increase the corrosion resistance and strength of underground equipment. Significant material and labor resources are required to maintain the production fund of wells in working condition. All this creates a problem of evaluating the effectiveness of the applied maintenance and repair systems (MRS), which should be solved by the technical re-equipment of the oil and gas industry based on the introduction of more advanced equipment and technology for oil and gas production. And this is due to the urgent need to ensure their operational reliability, which is a function of factors of industrial, technical and operational nature (Kuchumov, Pyalchenkov etc, 2005; Pyalchenkov, 2013). The composition of each of the groups of factors, their impact on the value of maintainability characteristics is determined by the purpose and design features of the oil and gas field equipment, the conditions of its operation, maintenance and repair.

Methods

One of the main tasks solved during the operation of systems is the task of ensuring their reliable operation. The severity of this problem is due to the complexity of technical devices and high values of operational loads. Therefore, reliability should be understood as the property of technical devices to perform specified functions, while maintaining their operational performance within specified limits for the required period of time or the required operating time in certain operating conditions (Lysenko, Grajfer, 2005; Pyalchenkov, 2013).

In practice, among other reliability indicators it is customary to operate with the average value of the overhaul period (MCI) regardless of the type of underground repair. Such an approach to assessing the activities of fisheries is completely untrue. The concept of MCI in the normative and technical documentation governing the conduct of repair work is usually absent. Its counterpart for wells is the average time between the current repairs, which characterizes the time between the wells and, on average, one current repair in the considered interval of the total operating time (Pyalchenkov etc., 2016; Dolgushin, Pyalchenkov, Kulyabin, 2016).

A feature of these tasks is that the system reliability indicator is expressed as the product of the corresponding reliability indicators of individual sections of the system:

$$R(x_1,...x_m)=\prod_{i=1}^{m} R_i(x_i) \qquad (1)$$

where $R(x_1,\ldots,x_m)$ – system reliability indicator, provided that at the 1st site there are x_1 reserve elements, …, an m site – x_m reserve elements, $R_i(x_i)$ – reliability indicator of the i-th part of the system, provided that it contains x_i backup elements (i=1, 2, …, m).

Usually, in optimal reservation problems, it is assumed that the "weight" of the system as a whole W $(x_1, \ldots, x_m)$ is determined:

$$W(x_1,...,x_m)=\sum_{i=1}^{m} W_i(x_i) \qquad (2)$$

where $W_i(x_i)$ - “weight” of the i-th element of the system, provided that it has x_i spare elements [8].
The "weight" of the i-th component of the system is determined by:

$$W_i(x_i)=w_i x_i\,, \qquad (3)$$

where w_i is the "weight" of one backup element used on the i-th part of the system.

In the presence of one limiting factor, two optimal reservation problems can be formulated.

The first task is to ensure that the reliability indicator is not less than the specified R0 with a minimum “weight” of the system as a whole, by redundantly reserving the system consisting of m sections.
This task can be written as:

$$\text{search } \min W(x_1,...,x_m) \text{ provided that } R(x_1,...,x_m)\geq R_0$$

The second task is to ensure, by separately reserving the system, consisting of m sections, that, at the maximum possible indicator of the system R, the “weight” of this system does not exceed the specified value W_0.

Results

This problem was solved by the method using the modified dynamic programming method (Belyaev, 1977; Pyalchenkov, Pimnev, 2017).

The initial data for the calculations were distribution laws for installations of sucker rod pumps (SRP) and electric centrifugal pumps (ECP) of the Tarasovskoye field of Rosneft-Purneftegaz company (Kuchumov etc., 2005; Pyalchenkov, 2015; Grechin etc., 2017; Dolgushin etc., 2016).

Based on the calculation results, the graphical dependencies shown in figures 1-8 for ECP installations.

Based on the calculation results, the graphical dependencies shown in figures 1-8 for ESP installations.

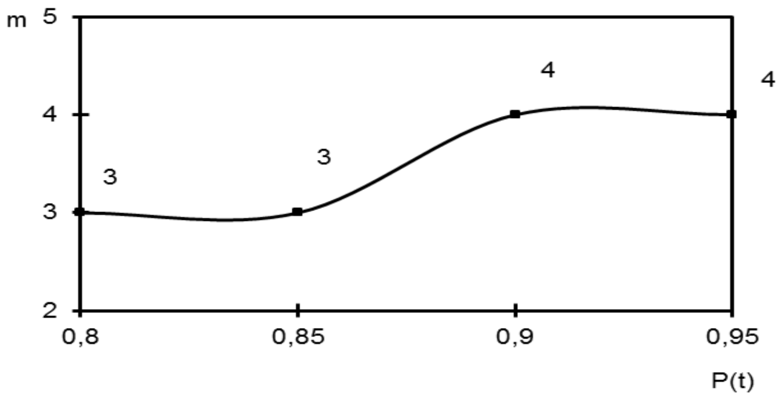

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Fig. 1. The dependence of the number of spare sets compensator from a given FBG (ESP)

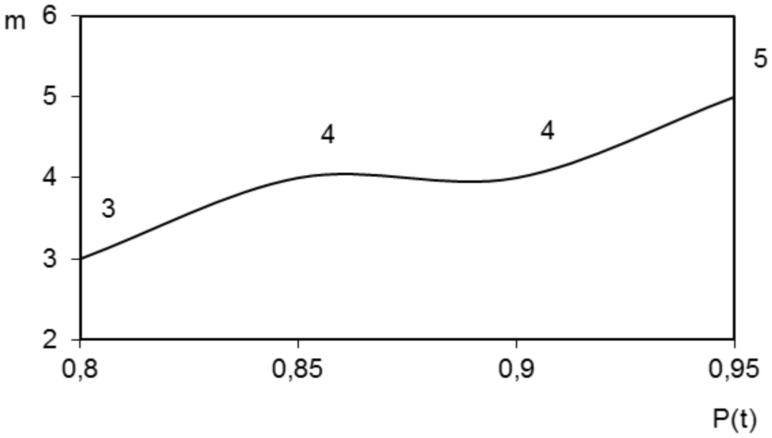

Fig. 2. The dependence of the number of spare sets of connectors on a given FBG (ESP)

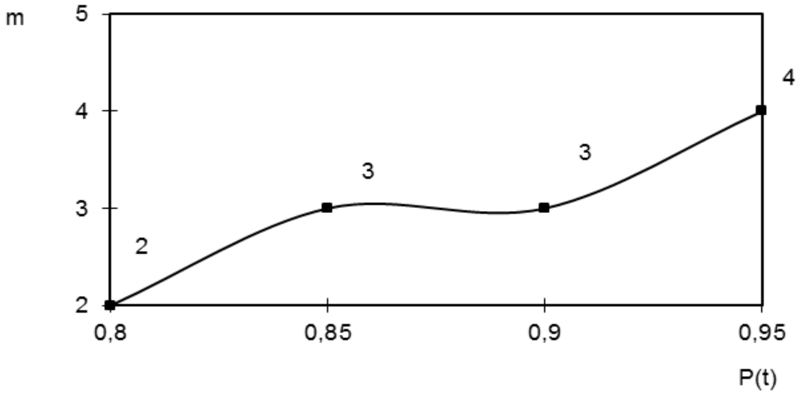

fig. 3. The dependence of the number of spare sets of hydraulic protection on a given fbg (esp)

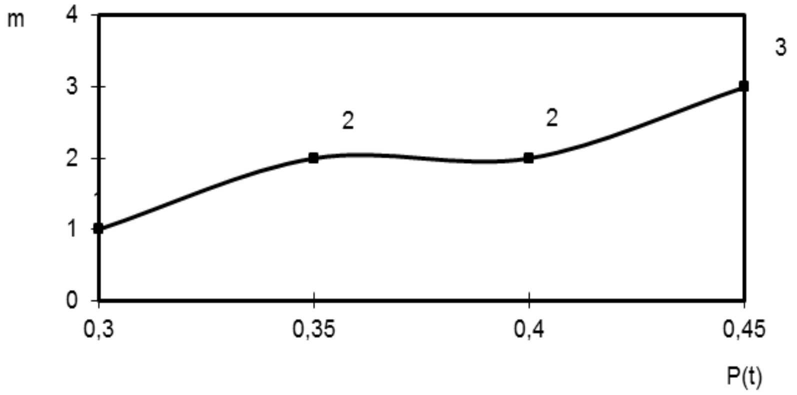

Fig. 4. Dependence of the number of spare sets of impellers on a given FBG (ESP)

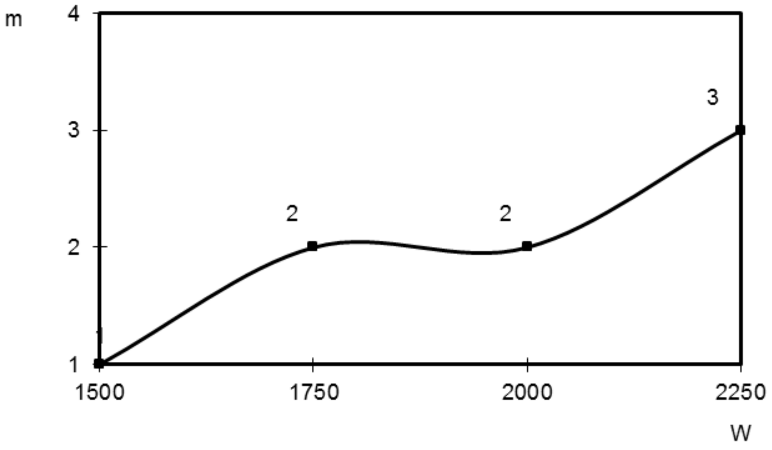

Fig. 5. The dependence of the number of spare sets of compensator on the "weight" of the system (ESP)

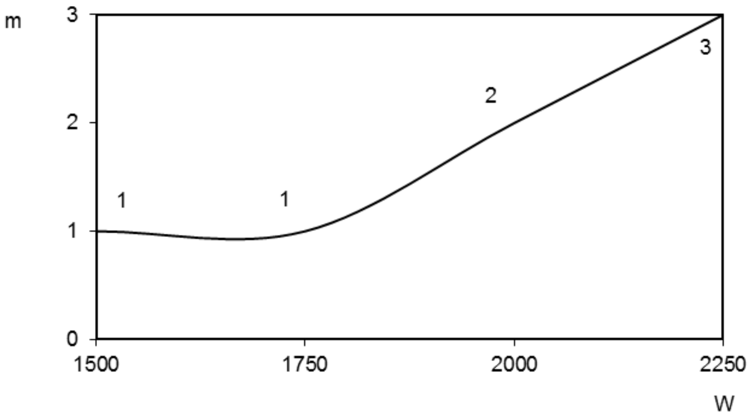

Fig. 6. Dependence of the number of spare sets of plug connectors on the "weight" of the system (ESP)

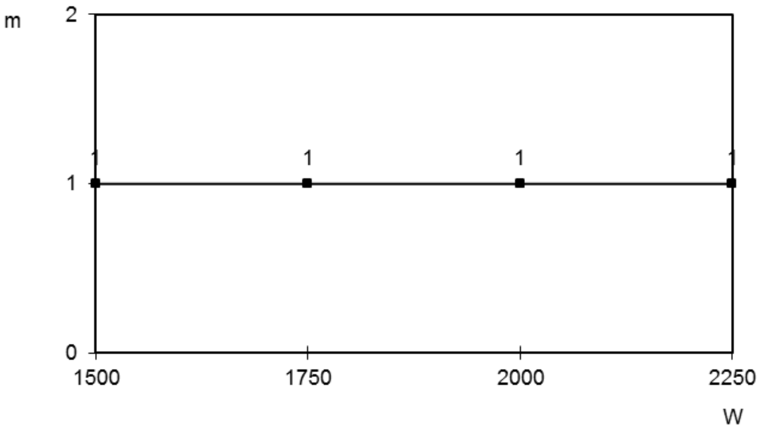

Fig. 7. Dependence of the number of spare waterproofing kits on the "weight" of the system (ESP)

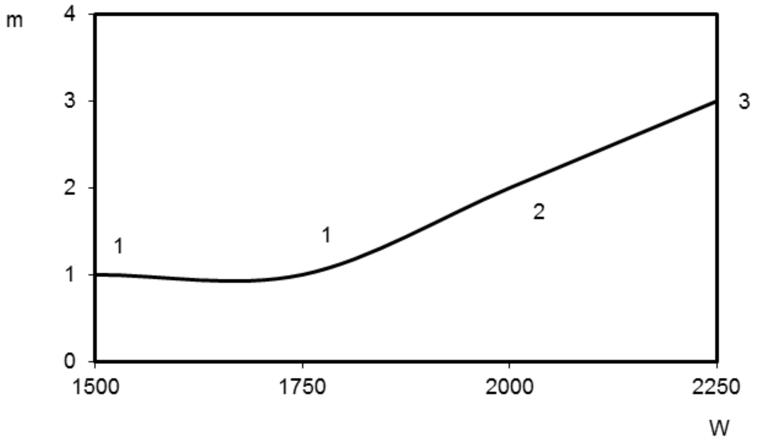

Fig. 8. The dependence of the number of spare sets of impellers on the "weight" of the system (ESP)

In figure 1-4 shows the graphical dependencies for calculating the optimal backup task to achieve a certain reliability indicator of oil equipment, for which the probability of failure-free operation was taken. As initial limitations, the FBG was taken from 0.8 to 0.95 and the maximum "weight" of the system was 2500. As can be seen from the graphs, the most reliable element in the installation are the impellers, which require from 1 to 3 sets to achieve FBG from 0.8 to 0.95. The most unreliable element, according to the calculations, will be a plug, spare sets of which are required from 3 to 5. Behind it are a compensator, which requires from 3 to 4 sets, and hydraulic protection, which requires from 2 to 4 sets. Based on these data, we can draw some conclusions that the company should adhere to the strategy of achieving FBG in the range from 0.8 to 0.9, since when changing it from 0.8 to 0.95, the number of spare sets of some nodes may change by 2. For example, at P (t) = 0.8 and 0.95, the number of spare sets of plug connectors will be 3 and 5, and the sets of waterproofing 2 and 4. Creating large stocks can negatively affect costs and absorb all the profit from a longer operation (Kuchumov etc., 2005; Pyalchenkov, 2013; Dolgushin etc., 2016).

The second group of figures (5-8) shows the results obtained when solving the problem according to the second method - the method of limiting the "weight" of the system. Under the "weight" of the system, the cost of the entire installation as a whole was adopted, and under the "weight" of the element, its cost. The minimum value of FBG is 0.7. As can be seen from the obtained dependences, the most reliable element in the system according to this technique is hydroprotection; for any admissible "weight" of the system, 1 spare set is required. A plug connector goes behind it and the impellers need from 1 to 3 sets when changing the "weight" from 1500 to 2250. The most unreliable element in the system, according to this method, is a compensator - it also requires 1 to 3 sets, but unlike from the previous elements with W = 1750, the indicator will be 2 units.

Discussion

As can be seen from the graphs, the most reliable element of the installation according to the first method is a plunger pair - it requires 1 to 2 sets to ensure the required level of FBG, and the most unreliable valve seat, which requires 2 to 4 spare sets. The most optimal level of FBG can be considered its value of 0.85, since with it the number of spare sets of valve seat, ball and shut-off valve will be 2, and the plunger pair - 1. At a value of P (t) = 0.9, the number of required replacement kits for all items except the ball.

Considering the results of calculations according to the second model, we can say that the most reliable will also be a plunger pair, and the valve seat is the most unreliable part of the installation. The differences with the results of the first method are only in quantitative indicators, the level of which is lower in the second method, and the general trends will remain the same.

Conclusions

Comparing the results of calculations for both models, we can conclude that the SRP units have more durability than the ECP units. Firstly, the level of optimal FBG for SRP will be 0.85, and for ECP - 0.8. Secondly, in the SRP installations, not a single component was identified, the backup sets of which are required more than 4, while in the installation of ECP plug connectors, 5 are required.

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