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RELIABILITY ASSESSMENT OF THE SUCKER ROD PUMPING UNIT EQUIPMENT COMPONENTS AND THE DEVELOPMENT OF THEIR REPAIRS OPTIMAL PLANS-SCHEDULES

ОЦІНКА НАДІЙНОСТІ ОБЛАДНАННЯ СШНУ І РОЗРОБКА ОПТИМАЛЬНИХ ПЛАНІВ-ГРАФІКІВ РЕМОНТІВ

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Abstract *On the basis of the analysis of operational reliability of pumping unit, the most rational interval of its maintenance and repair has been determined. This problem is solved using the strategy of strict periodic recovery. This strategy involves the restoration of the system (pumping unit) after the failure, that is, the so-called emergency recovery. Determination of the optimal inter-repair period is based on minimization of specific expenses for the restoration of a work-able state of the pumping unit in case of its failure. The proposed method of finding the optimal time for the restoration of equipment allows more accurately determine the life of the oil and gas equipment and develop a rational strategy for their maintenance and repair.*

Key words: *sucker rod, pumping unit, failure, maintenance, reliability.*

Intoduction.

One of the ways to achieve a high level of reliability of sucker rod pumping unit (SRPU) is to use an efficient system of maintenance and repair of equipment. The development of the theoretical foundations of such a system requires solving some theoretical and practical problems in assessing the reliability of the renewable components of the deep installation and developing a strategy for the appointment of periods of maintenance and repair of equipment [1]. On the basis of the analysis of operational reliability of machine, we will determine the most rational interval of their maintenance and repair. We will solve this problem using the strategy of strict periodic recovery [2]. This strategy involves the restoration of the system (pumping unit) after the failure, that is, the so-called emergency recovery. If the system worked without failing the given time interval t, then preventive maintenance with replacement of the site is carried out. Determination of the optimal inter-repair period is based on minimization of specific expenses for the restoration of a workable state of the pumping unit in case of its failure.

Results of research.

Table 1 shows the results of calculating the reliability parameters of pumping unit, executed using the developed database on the basis of the collected statistical information.

The table 1 shows the average workout for the T_m failure, the Weibull distribution scale parameter η, form parameter β and the linear correlation coefficient R. This table includes a list of the main assemblies of the pumping unit, which are maximally responsible for the workability of the installation as a whole. Of course, this table can be expanded by increasing the number of pumping unit assemblies. Thus, in Figure 1, the dependence of the optimal working time of the pumping unit assemblies and parts of the pumping unit on the load on the balance head is presented more fully. The failures of the installation rejected at least one assembly referred to in Table 1.

Let C_a and C_n - average costs for emergency and preventive maintenance and at the same time $C_a > C_p$. If the playback interval is *t*, then the intensity of the operating costs

$$R(t) = \frac{C_a \cdot F(t) + C_n \cdot P(t)}{\int_0 P(t) \cdot dt}, \quad (1)$$

where $F(t)$ is the probability of failure: $F(t) = 1 - P(t)$.

Table 1

Parameters of reliability of the main assemblies and components of sucker rod pumping unit

№	Assembly or component of pumping unit	Parameters of reliability			
		T_m	β	η	R
1	Sucker rods (mln. cycles): σ_e=50-60 MPa	10,83	1,09	13,1	0,967
	σ_e =70-90 MPa	9,72	1,02	11,6	0,973
	σ_e =90-100 MPa	9,32	0,79	10,5	0,978
	σ_e =110-140 MPa	5,81	0,66	5,92	0,952
2	Plunger pumps (days): rod pumps НСВ1Б-32	118	3,37	137	0,930
	НСВ1-32	117	1,87	132	0,970
	НСВ1-38	110	1,67	129	0,940
	НСВ1-43	104	1,55	120	0,990
	НСВ1-56	62	1,35	70	0,960
	tubing pumps НСН2-56	102	2,63	121	0,960
	НСНА-68	84	2,38	94	0,980
	НСНА-93	70	1,30	84	0,940
3	Tubing (days): time to first failure	2646	1,89	2987	0,956
	Time between failures with water content 40%	1474	0,59	935	0,962
	70%	593	0,96	599	0,959
	90%	389	1,06	399	0,955
4	Wire line suspension (days)	1249	1,08	1291	0,993
5	Wire line (days)	1290	1,13	1354	0,994
6	Walking beam (days)	2020	1,04	2065	0,968
7	Crankshaft pin (days)	1611	1,10	1676	0,993
8	V-belt transmission (days)	1381	0,99	1386	0,984

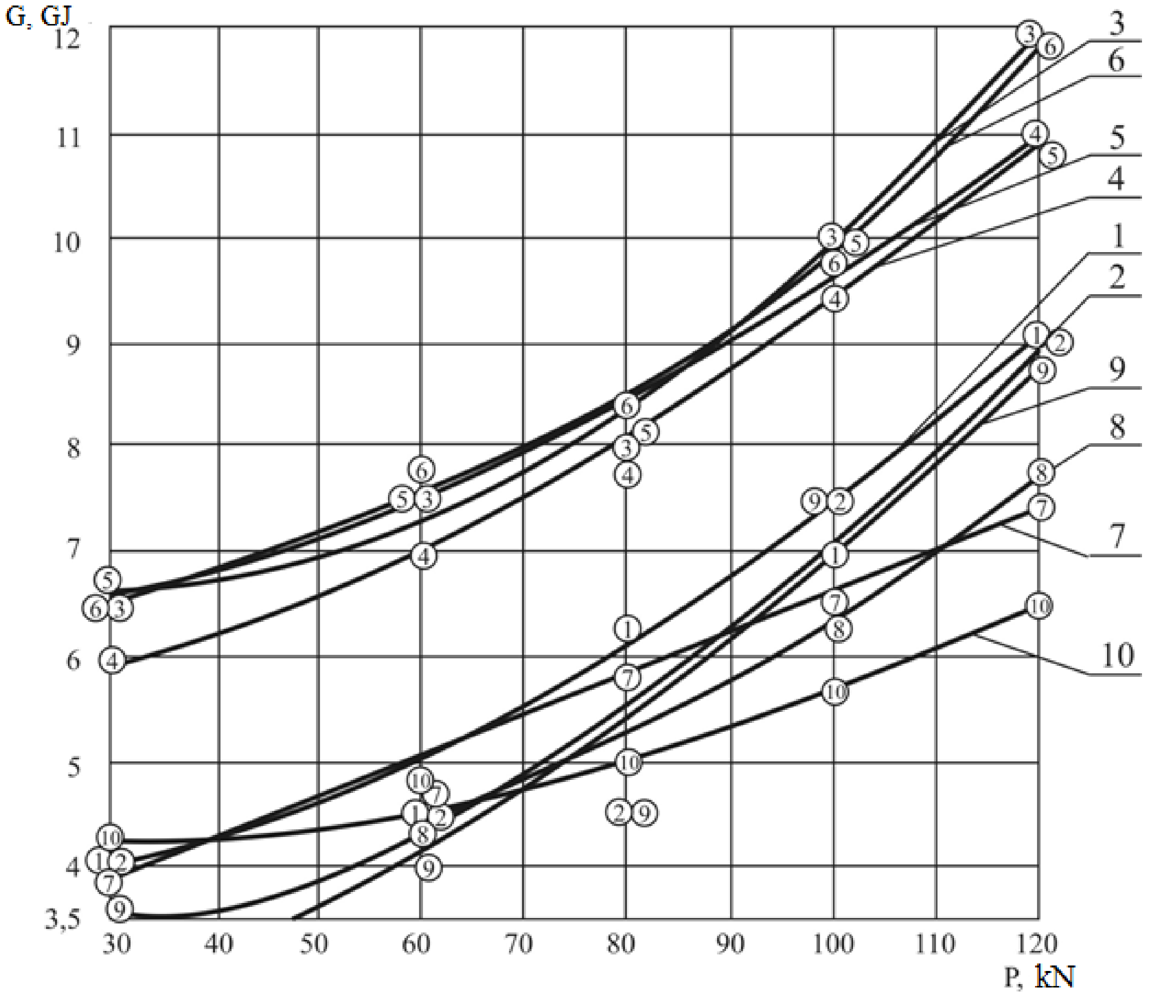

Fig.1. Dependences of optimal work *G* of an assembly or a component of a pumping unit from a load on a horsehead *P*:

1 – traverse bearing; 2 - a duct of a cable suspension; 3 – beam bearing; 4 – walking beam axle; 5 - the finger of the head; 6 - body of the horsehead; 7 - connecting rod; 8 - nut (left - right); 9 - polished rod plaque; 10 - a bushing

It is clear from this that, with an increased recovery interval *t*, the costs caused by emergency failures are increasing, and the cost of prevention is reduced. You need to choose a recovery interval that takes into account these two opposite to the overall cost trends. Thus, the desired recovery interval *t*, possessing this property, will be:

$$R(t')=\min R(t),\ when \quad 0<t<\infty \quad . \qquad (2)$$

In this case, t' is the result of the solution of the equation

$$\lambda(t)\int_0^t P(t)dt - F(t) = C\big/(1-C), \qquad (3)$$

where C = Cn / Ca.

We apply an exponential distribution law for which

$$F(t) = 1 - e^{-\lambda t},\ t > 0,\ \lambda > 0, \qquad (4)$$

where $\lambda = 1 / t_m$. Failure density $f(t) = \lambda e^{-\lambda t}$

Probability of failure-free operation P (t) = e- $^{\lambda t}$.

Substituting these conditions into (3), we find t'

$$\lambda(t)\int_{o}^{t} e^{-\lambda t}dt - e^{-\lambda t} = C \Big/ (1-C)\ , \tag{5}$$

$$-2\cdot e^{-\lambda t} + 1 = C \Big/ (1-C)\,. \tag{6}$$

Where

$$t' = -\frac{1}{\lambda}\cdot \ln \frac{1 - C \Big/ (1-C)}{2}\,. \tag{7}$$

For an example, we define the optimal interval for the restoration of the pumping unit SK8-3,5-4000. Substituting in (7) $\lambda\cdot = 1,25\ \ 10^{-4}$ houre^{-1} with relation C = Cn / Ca = 1/3, we obtain the optimal period (interval) for the restoration of the pumping unit - 1200 h. Thus P (t) reaches 0,2-0,22, that is, up to 80% of components of the pumping unit exhausts its resource.

The inter-repair period of the pumping unit can also be determined by the graphical method: the span of the abscissa is postponed by the time span (the work of the pumping unit), and on the ordinate - the costs of the enterprise for the current and emergency repairs and the probability of failure of the pumping installation (Fig.2).

The following curves are constructed (the curves are constructed according to the data of NGDU "DolynaNaftogaz"):

1 - cost curve of the enterprise for the maintenance of the current repair of one installation; if the repair is carried out every day, the management costs will consist of:

$$W = \frac{Tp}{n}\cdot\ , \qquad , (8)$$

where *Tp*- the chosen settlement period of 365 days (one year); *n* - periodicity of repair (in a day, in two days, in three, etc.); *Tp / n* - the number of repairs in the calculation period; *C* - average costs for carrying out one current repair.

2 - is the distribution curve for the pumping unit probability of failure as a whole. For its construction it is necessary to know the probability of failure of the pumping unit at a given performed work.

3 - cost curve for the elimination of accidents related to the pumping unit failures; this curve can be constructed by two methods: graphical or computational.

The graphic method consists in conducting horizontal lines at a probability of 0.1, 0.2, 0.3, etc. to intersect them with curve 2. Further, perpendiculars are lowered through the intersection points. Accordingly, on each perpendicular, we postpone the cost of emergency repairs. The calculation method is performed by the points according to the formula:

$$Wa' = Q\,(t), \qquad (8)$$

where *Wa'*- average cost of one well-failure elimination .Curves 1 and 3 intersect. The intersection point indicates that the costs of the NGDU at the given work will be minimal.

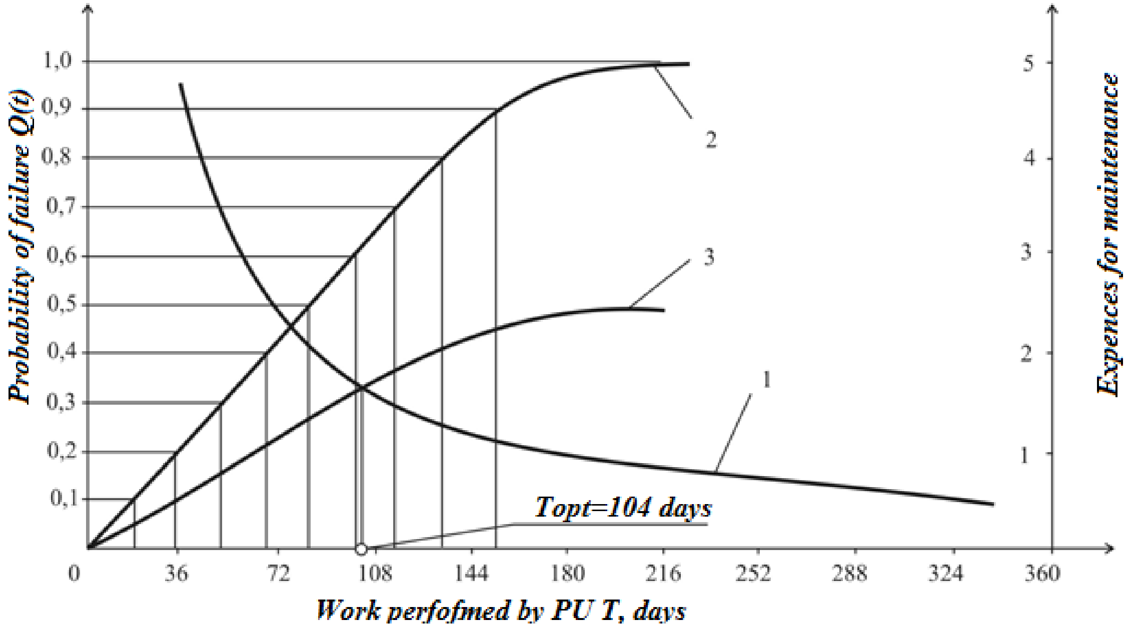

Fig. 2. Finding of the optimal maintenance period of the pumping unit

Conclusion.

Consequently, in this case, a technical review of the pumping unit is proposed to be carried out every 104 days of exploitation of the well, or every 2496 hours of machine hours. The above-stated methods of finding the optimal time for the restoration of equipment allow more accurately determine the life of the oil and gas equipment and develop a rational strategy for their maintenance and repair.

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Анотація. *На основі аналізу експлуатаційної надійності верстатів-качалок проведено визначення найбільш раціонального інтервалу їх технічного обслуговування і ремонту. Вирішено це завдання використовуючи стратегію строгого періодичного відновлення. Ця стратегія передбачає відновлення системи (верстата-качалки) після відмови, тобто так зване аварійне відновлення. Якщо ж система відпрацювала без відмов заданий інтервал часу t, то проводиться профілактичне обслуговування із заміною вузла. Визначення оптимального міжремонтного періоду основане на мінімізації питомих витрат на відновлення працездатного стану СШНУ у випадку її відмови.*

Ключові слова: *насосна штанга, верстат-гойдалка, відмова, технічне обслуговування, надійність.*

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