Methods of calculation of standard parameters in the system of maintenance and repair of the atmospheric column

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Abstract. The modern theory of repairability of machines and mechanisms has received significant development. Today there are already theoretical concepts and prerequisites for creating a scientifically sound system of maintenance and repair of technical products of various branches of technology. From these positions the review of various repair strategy in aspect of their applicability to an atmospheric column of K-2 of installation of primary oil refining of EDP-AVT-6 is interesting.

1. Introduction
By maintenance and repair system, is meant a set of interconnected tools, documentation and executors necessary to maintain and restore the quality of products included in this system [1]. The objectives of the repair system are:

1) prevention of equipment breakdowns and emergency stops;
2) maintenance of equipment operability during the entire service life;
3) ensuring reliable operation of the equipment;
4) ensuring the quality of products;
5) ensuring safety during equipment operation and environmental protection.

Organization of the enterprise maintenance system is carried out in the following matters:

a) selection of the type of repair organization;
b) development of a strategy and formation of conditions providing repair system.

The repair system strategy means the goals by coordinating and allocating the relevant resources of the enterprise, a generalizing model of actions necessary to achieve the set [2].

The presence of chlorides and water in the refined oil contributes to the hydrochloric corrosion of the equipment, leads to long downtime of process plants, reduces the service life of expensive catalysts used in secondary processes, and degrades the quality of commercial oil products.

Deep demineralization of oil ensures reduction of corrosion and reduction of deposits in equipment, increase of inter-repair runs of plants (especially AVT, visbreaking, thermal cracking and coking), improvement of quality of raw materials for catalytic processes, as well as commercial products - fuels, bitumen and electrode coke [3].

EDP-AVT - combined atmospheric-vacuum tube with oil desalination and dehydration unit. The purpose of the plant is the preparation and primary processing of oil. The plant includes EDP unit
(electric desalination and electrodeposition), AT (atmospheric distillation of oil to fuel oil), VT (vacuum distillation of fuel oil to tar to obtain oil distillates), gasoline stabilization and secondary distillation unit, flue gas heat recovery unit. The plant is designed to process unresolved West Siberian oils, their mixtures with coal-bearing oils, gas stable condensates (Yamburg, Urengoysky, Karachaganaksky, etc.), or other oils close in chemical composition and physical properties.

The choice of column K-2 justified by the fact that the column is the largest on the plant, the high temperature and nature of the processes makes it the main source of danger. Also, the column K-2 has a large destruction radius, the equipment on the plant is located at a short distance from each other, which, during depressurization and subsequent explosion of the column, will lead to subsequent resolution of the equipment [4-7].

2. Experimental procedures

The idea of the first strategy is that a piece of technological equipment is considered as a single object, the failure of any part of which leads to a "failure." A probability curve of failure distribution over time is constructed for this piece of equipment. Such a curve can be of the following types:

a) with a period of maximum number of failures clearly expressed in time;

b) with almost uniform distribution of failures;

c) with the distribution of the maximum number of failures in the initial period of time (start-up, adjustment and run-in period).

The corresponding calculations show that for equipment having a fault distribution pattern corresponding to a curve of type "a," there is a certain time of forced repair \( \tau_1 \), at which the equipment idle time will be minimal. For other fault allocation cases, no such time exists and forced scheduled repairs only result in increased downtime [8-10].

This strategy has the following drawbacks: not applicable to all types of equipment; does not take into account the possibility of changing the nature of the failure distribution curve over time, which leads to a change in the optimal repair period; does not take into account the uneven labor intensity of various repairs, which does not allow planning downtime; requires a very large amount of operational observations.

The second repair strategy is as follows. A piece of equipment is considered as an object consisting of many separate parts with different service lives. Repair is carried out after a period of time \( \tau_{ih} \), equal to the smallest service life of parts assigned to scheduled repair. Parts with service life less than \( \tau_1 \) are repaired as exits fail during overhaul. All other parts are divided into groups so that the first group includes parts whose service life is more than \( \tau_1 \) but less than \( 2\tau_1 \); in the second group - more than \( 2\tau_1 \), but less than \( 3\tau_1 \) in the third group - more than \( 3\tau_1 \), but less than \( 4\tau_1 \), etc. The following assumptions are accepted:

a) fluctuation of service life of parts does not exceed \( \tau_1 \);

b) labor intensity of repair of any group of parts is approximately the same.

Accepted assumptions are statistically valid for a number of equipment types studied. The number of part groups requiring scheduled repair is graphically displayed.

The idea of the third strategy is that the optimal periodicity of prevention (small repairs) only for assembly units of the product is established on the basis of the condition of achieving their maximum reliability in the interprophylactic period with a minimum of labor costs for preventive work. This condition depends on the minimum labor costs (hours) at a given level of reliability or the maximum reliability at a given level of labor costs.

The expression for optimal periods of interprophylactic service (days, hours) is as follows:

\[
\tau_{opt} = \frac{1}{\lambda_1} \sqrt{\frac{\tau_2 \tau_3 \lambda_1}{\tau_3}}
\] (1)
where \( \lambda_i \) - is the failure rate of the assembly unit of the product for the interprophylactic period; 
\( \lambda \) - product failure rate in general for the same period; 
\( \tau \) - the effective periodicity of prevention prior to optimization; 
\( r_{2} \) - labour input of preventive maintenance of assembly unit; 
\( \tau_{3} \) - labour intensity of elimination of sudden failures of the assembly unit.

This strategy allows you to assign separate periods of prevention (minor repairs) for three periods of the product's life: running in, normal operation and increased wear and tear.

The number of all prophylaxis is

\[
{n = \frac{\tau_{\text{max}}}{\tau_{\text{opt}}}}
\]  

(2)

where \( \tau_{\text{max}} \) - all service life of a product.

The fourth strategy is as follows. Separately, for each period of the product operation, for each assembly unit, by statistical processing, the value \( \lambda_i \) and the number of failures \( n_i \) are then determined also for each period, and for each assembly unit a ranked number of numbers from the number of failures is made \( n_i = 0 : n_i = 1, \ldots , n_i = m \).

By resorting to probabilistic Poisson distribution, you can get the probability of failure detection per operating time of the article \( T_c \) at the number of failures \( n_i \)

\[
P_1 = (\lambda_{1j} \tau_{1j})^{n_{1j}} e^{-\lambda_{1j} \tau_{1j}}
\]  

(3)

where \( j \) - is the number of the assembly unit of the product.

For each assembly unit and a specific period of operation, you can plot the dependencies:

\[
P_{ij} = \varphi(\tau_{ij})
\]  

(4)

Size \( \tau_{\text{opt}} \) is on crossing of a curve with number of refusals of \( n_i = 2 \) with abscissa axis

\[
\tau_{\text{opt}} = \frac{\lambda_i \tau_i}{2}
\]  

(5)

since this case corresponds to the probability of no more than one failure in the assembly unit equal to 0.01.

If the curve does not match the number of failures \( n_i = 2 \) with the abscissa axis, it can be extrapolated to this axis. As with the previous strategy

\[
{n = \frac{\tau_{\text{max}}}{\tau_{\text{opt}}}}
\]  

(6)

When such a strategy is applied, the number of necessary input data decreases and is reduced only to the definition of \( \lambda_i \). Events corresponding to the scope of prevention of each assembly unit are assigned specifically.

The third and fourth strategies are not applicable to the equipment of the primary oil processing plant EDP-AVT-6, since they evaluate the repair system of only the assembly units of the product.

In the case of the fifth strategy, all work related to preventive maintenance of equipment is divided into two separate subsets: \( M_1 \) and \( M_2 \).

In the first subset, all preventive work of \( i \) and direct costs for their carrying out \( y_{i} \) (rubles) are placed. Thus, the direct costs of \( y_{li} \) and the maximum permissible periodicity of prevention of \( x_{li} \) correspond to each \( i \) preventive work. In the second subset, all preventive work of \( \frac{1}{4} 2 \) and their
corresponding unit costs $y_{i_2}$, (RUR/h of work) are placed. And in this case, the maximum permissible frequency of prevention of $x_{i_2}$ is also known.

It is assumed that the following data are known: $\omega_0$ - the average annual operating time of the product, $y_n$ - losses from one hour of the product downtime, $B_i$ - the average value of the downtime when performing each $i$-th preventive work.

The fifth strategy can be applied to the construction of the maintenance system of the equipment of the crude oil processing unit EDP-AVT-6, since all the necessary data are available [11-15].

The sixth strategy is based on the normal density distribution of failure probabilities of assembly units. At the same time, the overhaul life of these assembly units may be

$$\tau = \tau_{av} - 3\sigma$$

where $\tau_n$ - average development on refusal of the considered assembly unit; 

$3\sigma$ - third - sigma deviation from $\tau_n$.

According to this strategy, intervals can be assigned between the current repairs of all assembly units of this type of equipment, which requires the collection and systematization of statistical material and is very laborious.

The total number of average repairs is:

$$n = \frac{\tau_{max}}{\tau}$$

The latter strategy is based on an analysis of the costs associated with the increasing wear and tear of the equipment. The fact is that as wear increases, equipment parameters deteriorate. Hence, it is necessary to assign economically feasible repair dates to restore deteriorating parameters. The comparison of depreciation costs with the costs caused by the wear and tear itself is the basis for the timing between the necessary repairs (average or capital).

The overhaul period cannot be longer than the established duration of operation of the main assembly units of equipment. It can be less if economically feasible.

3. Conclusions

The analysis of repair strategies makes it possible to justify and develop a calculated scheme of maintenance periodicity, number of overhaul periods and intervals between current and overhaul for atmospheric column K-2 and other equipment of the crude oil refinery EDP-AVT-6.

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