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Model of operation of technical objects taking into account the defect state of their individual elements

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Summary. The article describes a model for the synthesis of maintenance strategies for technical facilities to minimize the risks of failures. The model is constructed taking into account the nature of the distribution of the probability of failure of individual elements of the technical object. To improve the quality of the model, it includes diagnostics of the pre-defect state of elements prone to fatigue failure

Key words. Model, risks of failures, technical object, pre-defect state, fatigue failure

INTRODUCTION

The problem of determining the optimal inter-repair period for technical facilities is very relevant There are many strategies for the technical exploitation of objects. However, all have certain drawbacks.

The aim of the work is to develop a strategy for the technical exploitation of objects taking into account the predefect state of their elements.

MATERIALS AND METHODS

General scheme of technical management of technically object shown in fig. 1

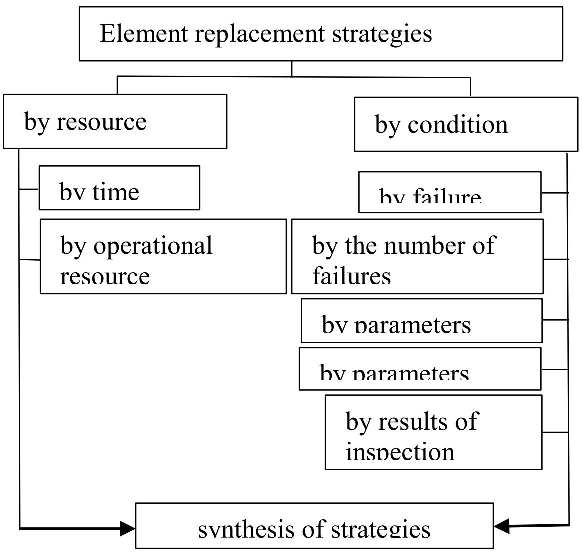

Fig. 1. The control circuit of technical object

The complexity of providing highly planned maintenance using the average reliability, is the fact that a different combination of all the factors affecting the reliability of parts and components of technical objects, the latter have different laws of the distribution of work to failure.

Consider the rationale for this provision. In the practical analysis of reliability, the dependence of the probability of failure of time is usually considered in the form of a generalized U-shaped aging curve $r(t)$ (fig. 2) [1- 4].

View of a single curve of aging $r(t)$ and its first derivative - the rate of aging $\dot{r(t)}$ - allows you to distinguish three areas: 1 - the area of initial aging, or grafting, characterized by increased velocity, which decreases over time; 2 - a section of normal working aging, having constant values of aging speed; 3 - a section of catastrophic aging. At this site, the process of rapid wear and loss of technical capacity of a technical object begins.

RESULTS

The graph of the failure function is shown in Fig. 2

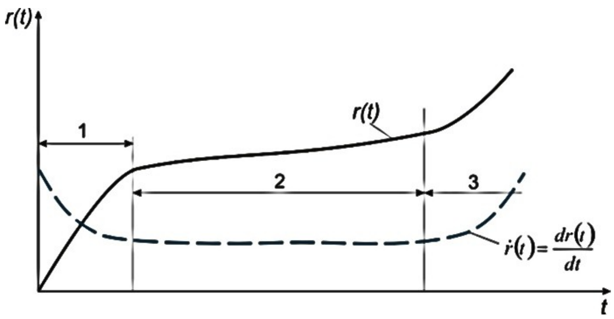

Fig. 2. View the graph of the function of the probability of failure $r(t)$

The situation when $r(t) = const$ (second section), means that the probability of failure-free operation is characterized by a constant value of the speed of wear $r(t)$ or aging of an element, and a function F(t) MTBF distribution is exponential, reflecting the values spine suddenly time between failures. That is, in this case F(t) can not serve as the basis for predicting the technical state of the element and determining the timing of its scheduled maintenance.

In these cases, planned replacements do not eliminate accidental failure, but can lead to a decrease in the reliability of the element due to the "attachment" mode, in which r(t) almost always increases, which leads to the risk of sudden failures.

In this case, you must have a system of indicators, signs on which equipment should be lacking.

However, using the known laws of distribution of random variables, it is impossible under any fixed set of parameters theoretically receive such a curve that would describe dependence, almost there. But one can build a function of the intensity of wear, based on its behavior.

The function of wear intensity has the form:

$$r = \frac{F'}{1-F}$$

Consider the function F(t) the following form: $F = 1 - e^{-\int_0^t r(t)dt}$, where $r = \frac{a}{t+t_1} + kt + b$.

Based on the research of the function, it is possible to construct its schedule. He is pictured in fig. 3

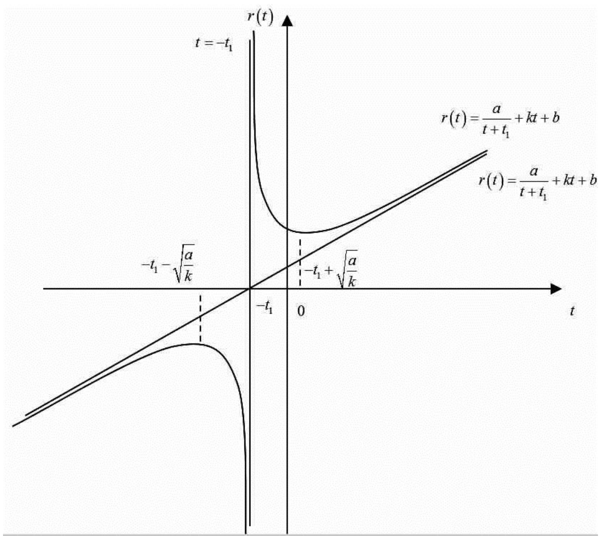

Fig. 3. The function graph r(t)

The resulting schedule consists of two parts. Requirements to U -shaped curve (positivity second derivative) satisfies that part of the curve, where $t > -t_1$. As can be seen from the study of the function, it has a minimum of one point $t = -t_1 + \sqrt{\frac{a}{k}}$ (Fig. 4).

However, as shown in Fig. 2, the function of the intensity of wear reaches a minimum not at one point, but on a certain segment $t \in \left[t^0_{\min}; t^1_{\min}\right]$. This discrepancy is not contradictory. This is displayed by the graphic shown in Fig. 5.

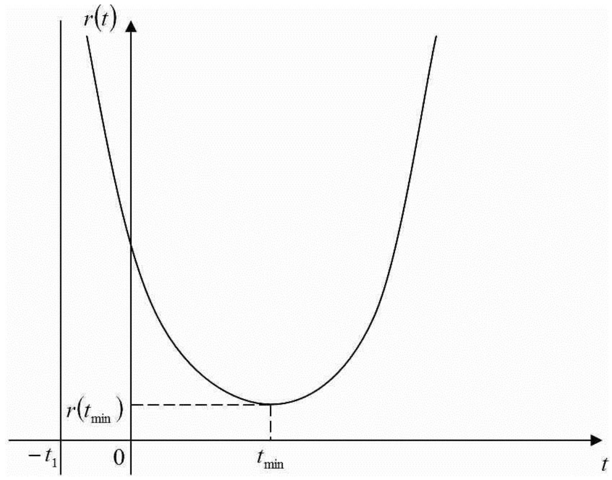

Fig. 4. The adjusted function graph r(t)

Determine the time "save" the value of the intensity of wear constant.

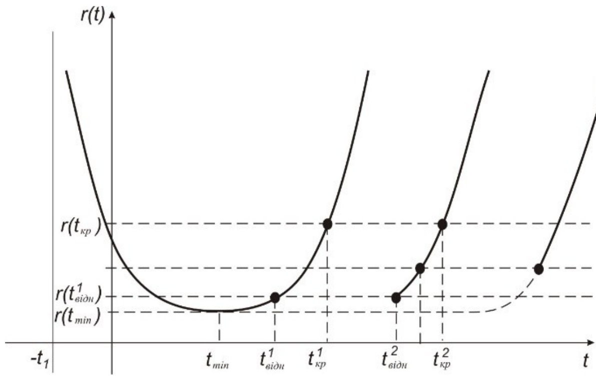

Fig. 5. Scheme of formation of U-shaped curve failure rate

To find the point estimates of the distribution parameters were applied the principle of maximum likelihood function. After the necessary transformations and simplifications, the following wear function has been obtained:

$$F(t) = 1 - \left(\frac{\theta}{t+\theta}\right)^a,$$

where: t>0 .

$$f(t) = \frac{\theta^a \cdot a}{(t+\theta)^{a+1}} = a \cdot \theta^a \cdot (t+\theta)^{-a-1}.$$

Thus, the function of the intensity of wear is found, as well as the parameters, knowing which, it can be constructed.

Thus the area running-in curve approximated exponential function on the site running-in renovated - Pareto function.

After analyzing experimental study developments failures components and assemblies for rail was installed similarity of the proposed models.

Analysis of technical failures objects found belonging random variables MTBF three classes of probability distributions (Fig. 6).

Normal distribution law ($P(t) \sim e^{-\frac{(t-m)^2}{2\sigma^2}}$ - Curve 1) random variables subject to time between failures of elements and components that lose their efficiency as a result of gradual deterioration. Exponential (curve 2) - random values of the time of work, but such parts and nodes, which are characterized by sudden failures. Curve 2 shows the distribution law, where Density distribution the random value of the development is determined by the dependence:

$$P(t) = \exp\left[-\left(\frac{t}{a}\right)^b\right]$$

where: a and b - positive constants. The constant a is a run that corresponds to the probability of safe operation $P(a) = \exp(-1) = 0{,}368$ (regardless of size b) In figs. 6,7, the curve 2 corresponds to the case when b<1 and Weibull law close to exponential, and reflects the character of F(t) and P(t) for details and units with concealed slowly leaking its damage accumulation process.

Stepwise statistics subject to random variables developments equipment that is in the red zone risk and belongs to a class equipment, limiting turnaround runs.

From the charts P(t) for these laws it can be seen that if the planned precautionary substitution of elements 1, 2, 3 is carried out due to the average time of elaboration T_{cp} Then the time of replacement refusal held 50% of items 1 (normal law), 65% of item 2 (exponential law) and 80% of items 3 (Pareto distribution).

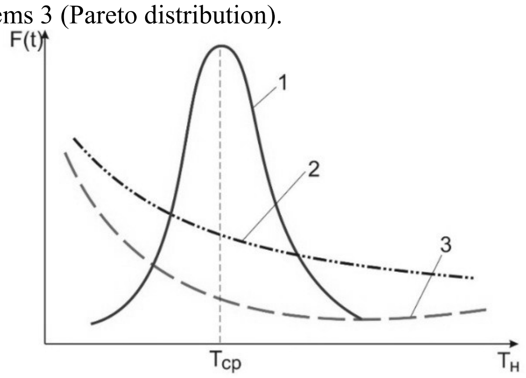

Fig. 6. The probability of safe operation of the equipment under normal (1), exponential (2) and the step (3) of law distribution

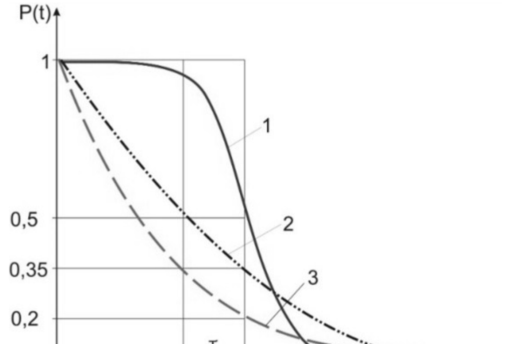

Fig. 7. Charts density distribution of random variables MTBF under normal (1), exponential (2) and the step (3) of law distribution

However, if you are to replace parts in an hour $T_з = T_{cp} - \tau$, will go down only 2% 1 elements, ie elements 1 can provide the service mode in which practically be excluded refusal. For elements 2 and 3 even with $T_з = T_{cp} - \tau$ to carry out the preventive replacement ineffective.

Such a simple control algorithm can not be sufficiently reliable.

The difference between a normal and a stepped distribution laws is not formal and fundamental nature [3]. If the system's statistics are described by the normal distribution law, then over 99.7 % Events deviates from the average value of *m* is not more than 3 σ, and, say, 5 σ is knocked out and at all less than one event per million. In this case, there is an opportunity "legally" to neglect very large events, considering them almost unbelievable, that is, you can "cut off" tail distribution. If distributions with heavy tails selective medium and small and unstable nformat and BH and in disrepair law of large numbers.

In terms of safety assessment and risk tail distribution corresponds to the so-called hypothetical accidents [5], the possibility of which, as already follows from the title, the practice is not considered [6-9].

As the number of registered events increases n their selective mean $\frac{x_1 + x_2 + \ldots + x_n}{n}$ seeks expectation [10, 11] and when it $\alpha < 1$ infinite Nonlinear and magnifying rise time of the total loss is explained by the decisive influence on its loss on the value of the largest events [12, 8]. At $\alpha < 1$:

$$\lim_{n\to\infty} \mathrm{E}\, \frac{x_1 + x_2 + \ldots + x_n}{\max\{x_1, x_2, \ldots x_n\}} = \frac{1}{1-\alpha} ,$$

that is, in the sum of random variables, the distribution of which has a tail of the form previously shown with $\alpha < 1$, with the precision of the coefficient, the contribution is made only by the maximal term (while for the values with the final average contribution of any particular term the sum amounts to zero).

Due to these reasons the decision not to be more objective on the threshold, and the statistical characteristic characterizing the scale of possible events $Sc\, x = \mu_2 / \mu_1$ which is the average taken from the weight *x,* that determines the characteristic size of large events or inclination to risk systems [13, 14].

That is, it can be seen that the proposed algorithm for deciding on the withdrawal of an object from operation due to the risk of failure can not be considered sufficiently reliable.

However, if used diagnostic methods to identify pre-defect state element, the algorithm will be significantly changed. In this case, a combination of analytical and experimental methods for determining the performance of a technical object is proposed. Land 2 in Fig. 1, the end stage " pre-defect " invited to consider periodical stage (or regular) examinations of important elements that prone to sudden destruction to determine the onset they pre-destruction state [9, 15-18]. Note that many elements pre-defect condition is not accompanied by outward signs, such as corrosion or mechanical wear, deformation, etc. These are mainly elements that are destroyed by the fatigue mechanism. Pre-defect condition for them comes when starting phase of stable growth fatigue cracks and steel elements can be defined magnetometer methods [7, 11, 19, 20].

The element of time between the onset pre-destruction state with satisfactory accuracy can not be determined, and for security reasons adopted zero. It is believed that the element is in a state of destruction. Next to consider, that the rejection element is instantaneous and the fact of failure is immediately known. An item can be replaced by a work order in the order of prevention or in an emergency mode (in case of refusal). Indicate the appropriate costs through C_1 and C_2.

Obviously that $C_1 \geq C_2$, since after the replacement of the rejected element often plans additional checks.

Define the given resource, as the workout, after which the element should be replaced. An indicator by which the specified value of the element's resource is selected is the readiness coefficient $p(x,t)$. This indicator makes sense the probability of finding an item in its proper state at any given time X and work smoothly after the moment over time [12, 16]. Suppose that the times of scheduled replacement of elements are realizations of some random variable Y , which has a distribution function G(t) . The intervals between the substitution elements form a sequence of independent, equally distributed random variables in time.

The event is that the element works smoothly in the space $(t, t+x)$, is the sum of the following events: in the interval $(0,t)$ there is no planned replacement of a valid item, and in the range $(0, t+x)$ element is not rejected (for the time offset operating technical object X its replacement is not planned); at the moment $\xi(0 \leq \xi \leq t)$ the replacement of the item (working or after failure) has ended and is further in the range (ξ, t) no replacement of a valid item is planned, but within a period of time $(\xi, t+x)$ there was no element failure.

After making the necessary changes get function extremum condition $p(x,\tau)$:

$$\frac{C_2}{C_1-C_2}=\left[\frac{F(\tau+x)-1}{1-F(\tau)}F(\tau)+\lambda(\tau)\int_0^T[1-F(t)]dt\right]\frac{1-F(\tau)}{1-F(\tau+x)}+$$
$$+\frac{1}{C_1-C_2}\left[\frac{1-F(\tau)}{1-F(\tau+x)}\int_0^\tau[1-F(t+x)]dt-\int_0^\tau[1-F(t)]dt\right]$$

decision which determines the current value of the resource element after element of this resource must undergo preventive regulation (or replaced) [11].

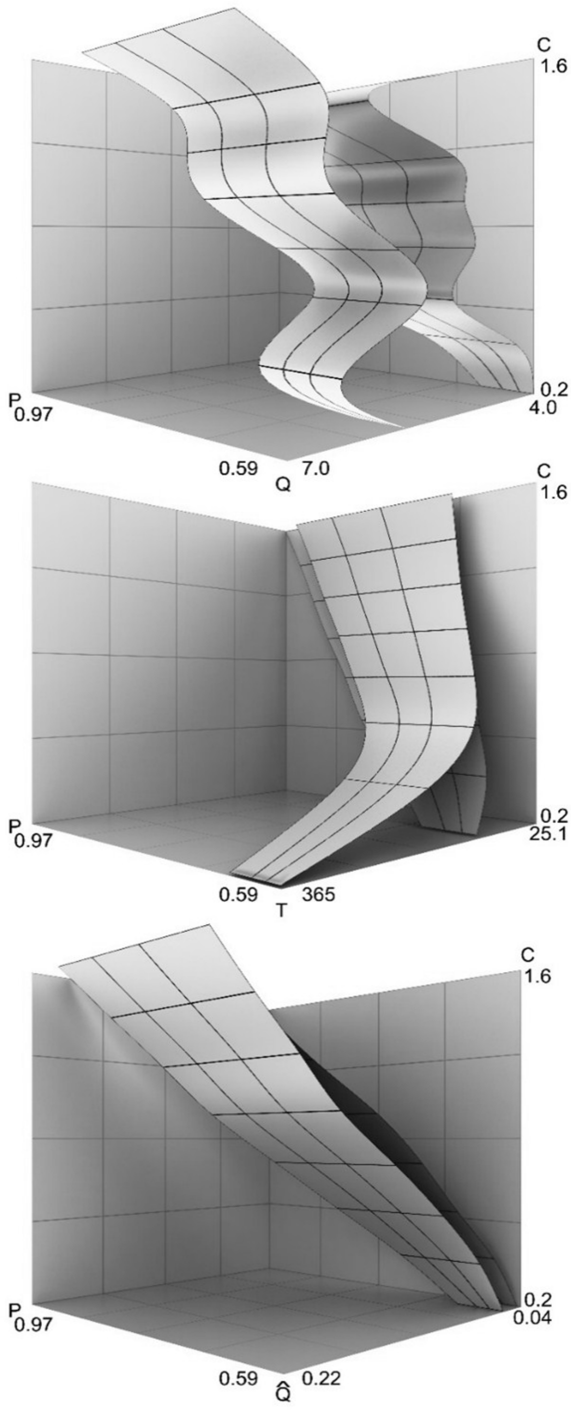

Fig. 8. Comparative analysis of the warning strategy control and without such

After accounting estimates made for the operation of technical objects with a high probability of state pereddefektnoho one of their elements required period monotonically increasing function failures λ(t) , will be written as [17]:

$$\frac{C_2}{C_1}=1-\frac{1}{e^{-\int_0^{\tau_0}\lambda(t)dt}+\lambda(\tau_0)\int_0^{\tau_0}e^{-\int_0^{t}\lambda(t)dt}dt}\ .$$

Entering different values C_2 , and, consequently, relations C_2/C_1 at a fixed value C_1-C_2=A , determine the term of the work τ_0 , expressed in terms of time n . In fig.

8 are given depending mean time to first failure T , average specific costs Q on system development, average costs $\hat{Q}$ for one refusal and coefficient of readiness p of the cost C maintenance of technical objects.

Analyzing these graphs one can draw the following conclusions. That is, elements belonging to the group substantial risk management for minimal risk gives significant gains in reliability (the availability, mean time to first failure) and cost per unit time compared to running on middle characteristics of the process. But such a strategy leads to a significant reduction in repair intervals, and is very costly.

Can significantly reduce costs by combining this strategy with diagnosing the onset predefect state for items that are prone to fatigue. This strategy could potentially save millions of hryvnia in the economy of Ukraine.

CONCLUSIONS

1. It was established that in the management of the operation of the technical objects of risk-orientation, taking into account both gradual and sudden breakdowns, it is possible to construct a repair cycle with an increase in the average time to the first failure in comparison with the repair cycle based on the average characteristics of the distribution functions of random variables of production equipment of technical objects.

2. Depending on the ratio of the costs of conducting precautionary measures (preventive maintenance) and the cost of adjusting the parameters in emergency mode, risk management yields a gain in reliability (readiness factor) and average costs per unit of equipment.

3. The use of a periodic survey of elements that are prone to fatigue fracture to determine their defect state allows us to obtain the most effective strategy of service of technical objects.

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determination of the operability of metal structures. // TEKA. Commission of motorization and energetic in agriculture, vol. (15), No 4, 41 – 46

МОДЕЛЬ ЭКСПЛУАТАЦИИ ТЕХНИЧЕСКИХ ОБЪЕКТОВ С УЧЕТОМ ПЕРЕДДЕФЕКТНОГО СОСТОЯНИЯ ИХ ОТДЕЛЬНЫХ ЭЛЕМЕНТОВ

Дмитрий Марченко Андрей Жидков

Аннотация. В статье описана модель синтеза стратегий обслуживания технических объектов с целью минимизации рисков отказов. Модель построена с учетом характера распределения вероятности выхода из строя отдельных элементов технического объекта. Для повышения качества модели в нее включена диагностика преддефектного состояния элементов, подверженных усталостному разрушению

Ключевые слова. Модель, риск отказа, технический объект, переддефектное состояние, усталостное разрушение.