OPTIMIZATION THE PERIODICITY OF MANAGING OF PREVENTIVE MAINTENANCE OF TECHNICAL SYSTEMS

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INTRODUCTION

Timely managing of preventive maintenance operations and quality of their conduction represent effectiveness of preventive maintenance of technical systems. Frequency of failure occurrence in vehicles dictates times of preventive maintenance operations. Quality of failure identification depends on kind of discovering of defective elements, applied methods of defects prediction and periods predicted for preventive maintenance. Efficiency of preventive maintenance depends in essence on skill of electronic devicesusage.

Some of basic methods of failure prevention are:

- Quality control of devices functionality on the base of outgoing parameters. This method is based on the fact that change of intake parameters lead to interrupted functionality, which lead to changes of outgoing parameters. Here it is not straightforward possible to discover element which caused failure. For identification of defect is necessary to detect defective element and its maintenance.
- Use of statistical probability of part proper operation until first failure, obtained on the base of long term operation experience. In this case is possible, with certain probability, to predict moment of failure and to make steps to prevent it.
- Control of physically chemical changes of structure of considered parts if prediction devices are available.

Above methods are the most often applied for prevention of failures of electro mechanical devices and elements of technical systems, for which statistical rules of failure appearance are established.

ACUMULATION OF DEFECT TECHNICAL SYSTEMS

Planning of preventive maintenance on time mainly dictate its effectiveness in technical systems. Recognition of failure regularity of technical systems lead to schedule of execution of preventive maintenance. Too early maintenance causes unnecessary and irrational delays of technical systems, but too long periodT_{pr} leads to increase of failures caused with unfixed defects. Thus there is optimal periodicity of preventive operations$T_{pr\ opt}$, which leads to the best results, that is to maximal effectiveness of system.

Depending on method of defects prevention character of defect accumulation process in time may be described as follows

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1. If for some element predicting parameter is known, then probability of its operation without failure for time t may be estimated according following expression

$$P(t)=\int_{t}^{\infty}\Psi_{p1}(t)dt \quad , \qquad (1)$$

whereΨ_{p1}(t)- function obtained by calculation in time.

2. For parts of same type there are failures that can be prevent, as well as failures that cannot be prevent, and their statistical laws of distribution are known, leading to probability of work without failure given as follows

$$P(t)=\int_{t}^{\infty}f(t)dt \quad , \qquad (2)$$

where

$$f(t)=C_1 f_p(t)+C_2 f_n(t) \quad , \qquad (3)$$

f_p(t), f_n(t) - specific probability of distribution of appearance of unavoidable failures;C_1,C_2, - coefficients that determine contributions of f_p(t) and f_n(t), that compose f(t).

Lately there are more and more effective objective methods for evaluation of technical condition of mobile systems, based on implementation of automatic diagnostic systems. Coefficients C_1 and C_2 satisfy relation $C_1+C_2 = 1$.

In the first case, when prediction parameter is known, it is usual to determine certain boundaries of part qualities, which may be controlled in working process. Quality of element gradually decreases, when it approaches to moment after which failure occurs. Thereby it may be determined preliminary degree of controlled parameter after which one detects and replace defective parts. This level is called degree of prognosis. During analyzing of prognosis parameter changes in time following quantities are employed:

- $\overline{\alpha}_0$ - mathematical expectation of initial values dissipation,
- $\overline{\alpha}_{cr}$ - critical degree of operating ability (functionality) – mathematical expectation of limiting parameter values in which failure occurs,
- $\overline{\alpha}_{pr}$ prediction degree (preventive control),
- T_{pr} - prediction period – period between two preventive control,
- $\Delta\overline{\alpha}_{cr}$, $\Delta\overline{\alpha}_{pr}$ total and preventive reserve of parts reliability, which may be expressed in the following forms

$$\Delta\overline{\alpha}_{kr}=\overline{\alpha}_0-\overline{\alpha}_{kr} \, , \; \Delta\overline{\alpha}_{pr}=\overline{\alpha}_{pr}-\overline{\alpha}_{kr} \quad , \qquad (4)$$

With knowledge of statistical low of change of controlled parameter with time allows that on the basis of its measuring in the moment $\bar{t}_{cr}=\bar{t}_{pr}+T_{pr}$, represents precondition for prevention of failure of technical system.

Forecasting period depends on rates of changes of parameters with time. On that basis any prediction parameter$\alpha_{(t)}$ may be evaluated according coefficient of its change in time:

$$K_\alpha = \frac{\overline{\alpha}_0 - \overline{\alpha}(t)}{t}, \tag{5}$$

That coefficient characterizes process of failure multiplication in time.

Distribution of time of occurrence of unavoidable failure, with acceptable accuracy, may be approximated according exponential lows [1]:

$$f_N(t) = \lambda \exp(-\lambda t), \tag{6}$$

Whereλ - intensity of unavoidable failure.

For failures that may be avoided it is possible to assume distribution described with truncated (partial) normal law [1]. In that case superposition of described laws, according expression (3), having in minds equations (6) and (2), will lead to expression

$$f(t) = C_1 \frac{c}{\sigma\sqrt{2\pi}} \exp\left[-\frac{(t-T_{sr})^2}{2\sigma^2}\right] + C_2 \lambda \exp(-\lambda t), \tag{7}$$

In expressions (3) and (7) coefficient C_1, which determines number of failures which may be prevent, represents coefficient of failure character $A(T_e)$.
Having in minds relation

$C_1+C_2 = 1$, it may be obtained that is $C_2 = 1 - A(T_e)$, (8)

It may be shown that substitution of (7) in (2), using (8), expression (2) may be transformed as follows

$$P(t) = A(T_e) \frac{\Phi\left(\frac{t-T_{sr}}{\sigma}\right)}{\Phi\left(\frac{T_{sr}}{\sigma}\right)} + \left[1 - A(T_e)\right] e^{-\lambda t}, \tag{9}$$

were

$\Phi\left(\frac{t-T_{sr}}{\sigma}\right), \Phi\left(\frac{T_{sr}}{\sigma}\right) -$ are tabulated function of probability integral [2].

Expression (9) characterizes statistic distribution during process of multiplication of failures without existence of prediction parameter. If, in expression (7), coefficients C_1 and C_2 are expressed with coefficient of failure character $A(T_e)$, it may be obtained expression for determination of frequency of failure appearance$\lambda_c(t)$ in case of superposition of exponential and truncated normal law:

$$\lambda_c(t)=\frac{A(T_e)\frac{c}{\sigma\sqrt{2\pi}}\exp\left[-\frac{(t-T_{sr})^2}{2\sigma^2}\right]+\left[1-A(T_e)\right]\lambda\exp(-\lambda t)}{A(T_e)\frac{c}{\sigma\sqrt{2\pi}}\int_0^t\exp\left[-\frac{(t-T_{sr})^2}{2\sigma^2}\right]dt+\left[1-A(T_e)\right]\exp(-\lambda t)}, \quad (10)$$

Pre-request for timely undertake of procedure for preventive maintenance technology of technical systems is knowledge of laws of appearance of failure in time (rate of change of prediction parameterK_α in the first case, and statistical distribution of probability of work without failure in second case).

POSSIBILITIES OF FAILURE DETECTIONS

Efficiency of preventive maintenance works on technical system depends not only on well-timed recognition and quality of maintenance, which in turn depends on general timing, but on preventive maintenance according to in advance set schedule. This quality depends on all staff competency, equipment quality and time devoted to it. In practice is important to determine timing of preventive maintenance, when skill level of staff and prognostic equipment's are known. Time necessary for preventive maintenance of any technical system consists of time for detection t_B, time for repair t_y, and time for subsidiary works, such as tool and accessories preparation, assemblies etc. Time necessary for detection of defect parts depends on kind of work. These works are connected to time random processes of defect parts discovery and, therefore, they have random character. Maintenance time may be calculated as

$$T_{pc}=\sum_{i=1}^{d}t_{pi}, \quad (11)$$

where t_{pi} – time for performance of i-th work, and *d* – number of different kinds of work.

Intervals for necessary works cannot be set in advance. Intervals necessary for discovering of defect parts usually is much greater than those for amendment, that is $t_B >> t_y$. Remain preventive works such as replacement of defect parts, re-assemblages, examinations, cleanings, lubrications, etc, have routine character. Time necessary for their fulfillment may be calculated as

$$T_{py}=\sum_{j=1}^{r}t_{pj}, \quad (12)$$

where r - number of different kinds of work.

Preventive, which include both random and determined works and all working processes may be set on the basis of amendment intervals. Same as efficiency of any process, which may be estimated on the basis of number of products in time and time necessary for production, preventive efficiency may be estimated on the basis of number of detected and amended failures., Number of detected, checked and amended elements during preventive works, in general, are not linearly dependent because of random character of failure detection. Productivity of preventive maintenance is determined with number of checked elements in time unit. Intensity of detection of failed elements means number of detected defect elements, which is prevented failures, in tome unit in comparison with their number in moment t.

Now we are going to establish connection between probability and frequency of detection of defect parts, and time interval necessary for preventive work T_p. In random detection of defects frequency n(t), in analogy with failure intensity, may be determined with rate of number of detected defect parts in unit time, in relation to undetected defects. Therefore one obtains:

$$\nu(t) = \frac{dn_{pv}}{\left[n_p\left(T_{pr}\right) - n_{pv}(t)\right]dt}, \qquad (13)$$

Where n_P (T_{pr}) – number of preventively fixed defects, accumulated up to beginning of preventive operation, n_P (T_{pr}) – npr (t) – number of defects undetected up to moment t.

After some simple algebra it may be obtained

$$\nu(t) = \frac{P_{pv}^{/}}{1 - P_{pv}}, \qquad (14)$$

Integration of expression (14) and easy transformations lead to

$$P_{pv} = 1 - \exp\left[-\int_0^{T_p} \nu(t)\,dt\right]. \qquad (15)$$

There fore in preventive maintenance random process of detection of defected elements may be approximated with expression (15). In the case of scheduled process of failure detection probability of failure prevention, mainly, depends on prediction accuracy and on time used for it. It may be assumed that probability of defect part overlooking, because of inaccuracy of measuring equipments, mistakes made by technicians and shortage of time Q(L), independent. In that case probability of failure detection may be expressed as

$$P_{pv} = [1 - \delta]\left[1 - Q(L)\right], \qquad (16)$$

where

$$Q(L) = \begin{cases} 1 - LT_p,\ pri 0 \le T_p \le T_{p_0}; \\ 0,\ pri T_p > T_{p_0}. \end{cases}$$

T_{p_0} − *time necessary for preventive maintenance,*

$L = \frac{1}{T_{p_0}}$ − time norm for preventive operations, D - relative error of real system.

Knowing laws of failure detection process (eqns. 15 and 16), leads to reliable determination of time for preventive work.

CONCLUSIONS

Effective preventive maintenance means timely determination of necessary preventive operations, and quality of their performances. Time of preventive operations is governed with speed of defect appearance. Quality of defect detection depends on applied prediction methods, on way of defect detection and time planned for preventive operations.

It is obvious that in both cases efficiency of preventive maintenance depends on skilled exploitation of equipment. In analysis of preventive measures are often imposed questions connected with quantitative estimations and comparisons of different methods of preventive maintenance. Mathematical model, shown here, allows quantitative estimation of preventive arrangements influence on reliability of technical systems. In analysis of preventive arrangements often it is not reliable benefit only criterion, but it should be considered cost of achieving it.

Mathematical model, shown here, may be employed for estimation of quality of preventive works, as well as for quantitative cost analysis. Usage of obtained characteristics may lead to estimation of preventive maintenance influence, depending on cost of its application, on reliability of technical systems.

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