AN APPROACH FOR DETERMINING THE PERIODICITY OF REGULATION WORK OF RISK TECHNICAL SYSTEMS

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Abstract: The estimation of the regulation work periodicity of the risk technical systems is an extremely important moment for its technical service. Many scientific publications concern this problem but most of them deal with a service process for an infinite technical exploitation period. In the present paper a solution of the problem for a limited interval of technical exploitation is suggested. A reliability model of the observed process is developed as the intensity of the failure flux is chosen for a reliability criteria.

Keywords: - Regulation works periodicity, risk technical systems, technical service

1. INTRODUCTION

Flux failure intensity \( \omega(\Delta t) \) for a final technical exploitation interval \( \Delta t \) is estimated on the basis of BDS [1] according to:

\[
\omega(\Delta t) = \frac{\sum_{i=1}^{N} \tau_i(\Delta t)}{N_{RTS}(\Delta t) \sum_{i=1}^{N} \tau_i(\Delta t)},
\]

(1)

where \( N_{RTS}(\Delta t) \) is the number of risk technical systems (RTS) operating system of the same type for the observed interval \( \Delta t \); \( r_i(\Delta t) \) - number of failures \( i \) of RTS for the observed interval \( \Delta t \); \( \tau_i(\Delta t) \) - life on the \( i \)-th RTS for time \( \Delta t \).

Flux failure intensity approximation is done through the constant function of time \( t \) for observed interval \( \Delta t \) represented as a polynomial in formula (2) according to [2]

\[
\omega(\Delta t) = \omega_0 + a_1 \cdot t + a_2 \cdot t^2 + \ldots + a_m \cdot t^m,
\]

(2)

where \( a_1, a_2, \ldots, a_m \) are coefficients determined by concrete points in the flux failure intensity function for \( t_i \) \( (i = 0, 1, 2, 3, \ldots) \) according to \( t_0 \) [2].

The complete equipment statistics RTS and (2) make possible the approximate reliability model of flux failure intensity through a linear function (after an initial moment \( t_0 \) ) in the regulation work interval [3]:

\[
\omega(\Delta t) = \begin{cases} 
\omega_0 & \text{for } t = t_0; \\
\omega_0 + 2V\Delta t & \text{for } t > t_0.
\end{cases}
\]

(3)

where \( \omega_0 \) is the interval amount of flux failure intensity of moment \( t_0 \); \( V = d\omega(\Delta t)/dt \) is the velocity of flux failure intensity increase for the observed interval \( \Delta t \).

The model (3) makes possible the optimum regulation work periodicity \( \theta_{RW_{opt}} \), estimation which provides RTS reliability for the observed period with least regulation works expenses. For that purpose we consider RTS worked out regularly over a certain period of time with periodicity \( \theta_{RW} \).

During the regulation work the necessary expenses amount to \( C_{RW} \) and expenses for current repairs \( C_{CR} \).

For the time between the regulation works when the total reconstruction of the RTS is done the leading function of the failure flux \( H(\Delta t) \) can be expressed by the following formula according to [1]

\[
H(\Delta t) = \int_0^{\theta_{RW}} \omega(\Delta t) \, dt.
\]

(4)

We consider the expenses for the technical exploitation of the equipment for the period of the regulation work in the following two cases

- \( E_{CR1} \) - expenses only for current repairs.
- \( E_{CR2} \) - expenses for regulation works and current repairs.
Having in mind the above mentioned and \([4, 5, 6]\) we can calculate savings from the technical exploitations \(S_{TE}\) of the RTS

\[
S_{TE} = E_{CR1} - E_{CR2} = C_{CR} \left[ H(\Delta) - mH(\theta_{RW}) \right] - C_{RW} m
\]

(5)

where \(m\) is the number of regulation work for the observed period of time.

The number of regulation work for the whole period of technical exploitation is defined according to \([6]\) from

\[
m = \frac{t}{\theta_{RW}} - k_{RW},
\]

(6)

where \(k_{RW}\) is the number of regulation work periods for the time \(t\).

In formula (5) member \(k_{RW}\theta_{RW}\) is life in the final interval on the RTS for work under the condition \(0 < k_{RW}\theta_{RW} < T_{RTES}\), where \(T_{RTES}\) is the technical resource till the end of the technical exploitation.

Equations (4) and (6) are used for (5) investigation if only the current time parameter will be in time limit. We get the following differential equation

\[
S_{ER} = C_{CR}\left[ \alpha_{0} \Delta t + V(\Delta t) \right] - \frac{\Delta t}{\theta_{RW}} - k_{RW} \left[ C_{CR} \alpha_{0} \theta_{RW} + C_{CR} V_{1R} \theta_{RW} \theta_{RW} \right] + C_{CR} V_{2R} (\theta_{RW} - t_{0}) \]

(7)

After investigating equation (7) we get the following differential equation

\[
\left( C_{RW} + C_{CR} V_{1R} \right) \left( k_{RW} + C_{CR} V_{2R} \theta_{RW} \theta_{RW} + 2 C_{CR} V_{2R} \theta_{RW} \theta_{RW} \right) k_{RW} - 2 C_{CR} V_{2R} k_{RW} k_{RW} -
\]

\[
\left( C_{CR} V_{2R} \Delta t \right) + \frac{C_{CR} V_{2R} \theta_{RW}}{\theta_{RW} \theta_{RW}} \Delta t - \frac{C_{CR} V_{2R} \Delta t}{\theta_{RW} \theta_{RW}} = 0.
\]

(8)

There is no solution to (8) so we do:

\[
u = C_{CR} V_{2R} k_{RW}^{2} + \left( C_{RW} + C_{CR} V_{2R} \theta_{RW}^{2} + 2 C_{CR} V_{2R} \theta_{RW} \theta_{RW} \right) k_{RW}.
\]

(9)

Filling (8) with (9) we get the following equation:

\[
u' + \frac{C_{RW} \Delta t}{\theta_{CR}} + \frac{C_{CR} V_{2R} \Delta t \theta_{RW}^{2}}{\theta_{RW} \theta_{RW}} - C_{CR} V_{2R} \Delta t = 0.
\]

(10)

Its solution is as follows:

\[
u = C_{CR} V_{2R} \Delta t \theta_{RW} + \frac{C_{CR} V_{2R} \Delta t \theta_{RW}^{2}}{\theta_{RW} \theta_{RW}} + C_{RW} \Delta t + C_{i}.
\]

(11)

We equalize (9) and (11) and get the algebraic equation

\[
C_{CR} V_{2R} \theta_{RW}^{3} = \left( C_{RW} \theta_{RW} + C_{CR} V_{2R} \theta_{RW} + C_{CR} V_{1R} \theta_{RW} \right).
\]

(12)

In order to define the integration constant \(C_{i}\) we use \(\theta_{RW} = 0.5 \Delta t\), from which follows \(m = 1\), \(k_{RW} = 1\). We use these equation (12) and we get

\[
C_{i} = -C_{RW} - C_{CR} V_{1R} \Delta t_{0} - \frac{C_{CR} V_{2R} \Delta t_{0}^{2}}{2}.
\]

(13)

Filling equation (12) with \(C_{i}\) from (13) we receive the final

\[
C_{CR} V_{2R} \theta_{RW}^{3} - \left( C_{RW} \theta_{RW} + C_{CR} V_{2R} \theta_{RW} + C_{CR} V_{1R} \theta_{RW} \right),
\]

\[
k_{RW} + C_{CR} V_{2R} \Delta t_{0} + C_{CR} V_{1R} \Delta t_{0} + C_{RW} \Delta t -
\]

\[
- \left( C_{RW} + C_{CR} V_{1R} \Delta t_{0} + \frac{C_{CR} V_{2R} \Delta t_{0}^{2}}{2} \right) \theta_{RW} = 0.
\]

Equation (14) proves the dependence of \(k_{RW}\) and \(\theta_{RW}\). Filling in it \(k_{RW} = (\Delta t - m \theta_{RW}) \theta_{RW}^{3}\) we get the algebraic equation which is the link between \(\theta_{RW}\) and \(m\). It is the following

\[
\left( C_{CR} V_{2R} \theta_{RW}^{2} - 2 C_{CR} V_{2R} \Delta t_{0} \theta_{RW} + 0.5 C_{CR} V_{2R} \right)
\]

\[
- \frac{C_{CR} V_{2R} \Delta t_{0}^{2} \theta_{RW}^{2}}{2} - C_{CR} V_{1R} \Delta t_{0}^{2} - C_{RW} = 0.
\]

Solving (15) for \(\theta_{RW}\) we get

\[
\theta_{RW} = \frac{\Delta t}{m + 1} + \sqrt{\frac{\left( \Delta t \right)^{2} \left( m + 1 \right) - \frac{C_{RW} \left( m + 1 \right)}{2 C_{CR} V_{2R} \left( m + 1 \right)}}{m + 1}}.
\]

(16)

In order to get the real quantities on \(\theta_{RW}\) equation (16) is solved under the following terms

\[
1 \leq m \leq \frac{C_{CR} V_{1R} \left( m + 1 \right)}{2 C_{RW} \Delta t_{0}^{2} + 2 C_{CR} V_{2R} \Delta t_{0}^{2}}.
\]

(17)

Filling (15) with (16) we get

\[
k_{RW} = k_{RW} \left( m \right) = \frac{\Delta t - m \sqrt{A}}{\Delta t - (m + 1) \sqrt{A}},
\]

(18)

where
\[ A = \frac{(\Delta t)^2}{2m(m+1)^2} - \frac{C_{RW}(m-1)}{C_{CR}V_{m}(m+1)} + \frac{i^2(m-1)}{m(m+1)} \]

2. CONCLUSIONS

From equation (16) and (18) we can estimate the regulation works periodicity of the risk technical systems. These equations make possible the estimation of the period numbers with definite regulation works for a certain technical exploitation period.

3. REFERENCES