UDK 621.391.175

L. Chumakov

OPTIMIZATION OF STRATEGY OF THE CONTROL OF SERVICEABILITY OF SYSTEM WITH DUPLICATION ON FUNCTIONING

Abstract. Questions of a finding of the optimal length of intervals between inspections serviceable condition of the technical system with redundancy are discussed.

Keywords: technical system, functional testing, the optimal testing strategy.

Introduction

At operation of technical system it is possible occurrence of failures over a set of parameters defining its working capacity. Checks of serviceability of technical system are spent for their elimination. Various groups of parameters can be supervised continuously, periodically or they are not supervised during all term of operation.

In the course of system engineering it is necessary to choose such strategy of the control of its serviceability which provides the efficiency of its use to destination.

Various kinds of redundancy of subsystems, units, elements are used for the purpose of increase of level of non-failure operation of technical systems. One of the most widespread is redundancy under the scheme "1 of 2" or duplication.

By working out of technical system there is a problem of definition of optimum characteristics of its service, in particular, a type of reliability check, number of the periodic control checks and the moments of their carrying out.

Let's conditionally consider that the technical system consists of two elements and the scheme of the loaded reserve is used.

The analysis of publications on a research theme

Problems of an estimation of efficiency of operation of technical system at a modular method of repair are considered in works [1-3].

In work [5] influence of characteristics of non-failure operation of an element of the duplicated system, duration of the control of serviceability of each element on efficiency of use of technical system is investigated.

The formula for the approached estimation of optimum duration of an interval between checks in case of check of serviceability of the basic and reserve element was obtained.

Purpose of article

Purpose of article is to show the decision of a problem of a choice optimum durations of intervals between checks for system with duplication at check on functioning when it is not known, redundancy remains or not.

The basic part

The technical system which is in a condition of readiness to carry out any problem on interval $[0, T]$, where T is the term of operation, is considered.

At the casual moment of time in regular intervals distributed on interval $[0, T]$, the command on application of technical system can arrive. Then existence of the latent refusals of elements of system is possible. Checks of serviceability of technical system are spent for their elimination.

In this case the periodic control of serviceability is considered. We will consider, that control strategy is defined by a vector of intervals between checks $\vec{\theta}$.

At check on functioning refusal of one element will not be noticed, and the system will be considered as the serviceable. However its efficiency will lowered.

Let efficiency of operation of technical system is defined by readiness factor

$$K_\Gamma(\vec{\theta}^*) = \sup_{\vec{\theta} \in R} K_\Gamma(\vec{\theta}),$$

where R – the range of set of admissible strategies of the control.

Let's look, as duplication of elements influences strategy of the control.

Duplication is a special case of the scheme of redundancy "m of N", when m = 1, and N = 2.

Let's consider the ideal control when errors of diagnosing of a technical condition of system are absent.

In this case the system can be in following conditions: E_1 – both elements are serviceable, E_2 – one element has given up, E_3 – both elements have given up.

Probability of non-failure operation of system $P(t) = 2p(t) - p^2(t)$, where $p(t)$ – probability of non-failure operation of an element.

Let time of non-failure operation of an element is distributed on exponential law with parameter λ.

In this case process of change of conditions of system can be described by Markov casual process.

Let's suppose that checks of serviceability of system are beginning in the moments $t'_{\varphi-1}$, and they are finished in the moments $t_\varphi = t'_\varphi + \tau$, where τ – the resource expense at one check.

Probabilities of conditions of system during any moment of time t, $t_\varphi \le t \le t'_\varphi$ are determined as follows:

$$R(t) = R_0(t)\Pi_{j=1}^{\varphi-1}A(\theta_j)BA(t - t_{j-1}) \qquad (1)$$

where ***R*** *(t)*, ***R₀*** *(t)* – matrixes of probabilities of conditions of system during the moments t and t_0, ***A*** and ***B*** – matrixes of probabilities of transitions during of the interval between checks and at check [1].

The uniform arrangement of checks is optimal strategy of the control of serviceability for system without a reserve [4].

Elements of matrix ***A*** are calculated under formulas: $a_{11} = e^{-2\lambda\theta_j}$, $a_{12} = 2e^{-\lambda\theta_j}(1 - e^{-\lambda\theta_j})$, $a_{13} = (1 - e^{-\lambda\theta_j})^2$, $a_{21} = 0$, $a_{22} = e^{-\lambda\theta_j}$, $a_{23} = 1 - e^{-\lambda\theta_j}$, $a_{31} = 0$, $a_{32} = 0$, $a_{33} = 1$.

Elements of matrix ***B*** are defined as follows: $b_{11} = e^{-2\lambda\tau}$, $b_{12} = 2e^{-\lambda\tau}(1 - e^{-\lambda\tau})$, $b_{13} = (1 - e^{-\lambda\tau})^2$, $b_{21} = 0$, $b_{22} = e^{-\lambda\tau}$, $b_{23} = 1 - e^{-\lambda\tau}$, $b_{31} = e^{-2\lambda\tau}$, $b_{32} = 1 - e^{-\lambda\tau}$, $b_{33} = (1 - e^{-\lambda\tau})^2$.

Distribution of time of non-failure operation of system is not exponential for system with a redundancy, and, strictly speaking, the uniform arrangement of checks is not optimal.

Let's consider how lengths of intervals between checks are variated in our case. For simplicity we will assume, that one check is spent on interval $[0, T]$. Then from expression (1) it follows:

$$K_r(t) = \left\{\frac{2}{\lambda}\left(1 - e^{-\lambda\theta_1}\right) - \frac{1}{2\lambda}\left(1 - e^{-2\lambda\theta_1}\right) + \left[1 - 2e^{-\lambda(\theta_1+\tau)} + 2e^{-2\lambda(\theta_1+\tau)}\right]\left[\frac{2}{\lambda}\left(1 - e^{-\lambda\theta_2}\right) - \frac{1}{2\lambda}\left(1 - e^{-2\lambda\theta_2}\right)\right] + \left[2e^{-\lambda(\theta_1+\tau)} - 2e^{-2\lambda(\theta_1+\tau)}\right]\left[\frac{1}{\lambda}\left(1 - e^{-\lambda\theta_2}\right)\right]\right\}/T, \qquad (2)$$

where θ_j – duration of j-th interval between checks.

Example. Let the onboard computer consists of two channels included under the scheme of the loaded reserve, failure rate of one channel λ = 0.21 1/year, τ = 0.002

years, T=1 year. Then optimal duration of intervals $\theta_1 = 0.653$ years, $\theta_2 = 0.347$ years and $K_g = 0.9933$. If failure rate at check on two order above, than in an expectation mode, $\theta_1 = 0.666$ years, $\theta_2 = 0.334$ years and $K_g = 0.9927$.

If to accept strategy of checks at which intervals between checks are equal, $K_g = 0.9926$, and in the second case of $K_g = 0.9911$.

Thus, in practice it is possible to use strategy of checks with equal intervals between checks.

Conclusions and prospects of the further researches

Studies of ways of definition of optimal strategy of checks of serviceability of the technical system which elements are duplicated were conducted, and at check process of functioning is supervised only.

Optimization of lengths of intervals between checks was carried out. It is shown, that at check of system with duplication on functioning, optimal strategy is such, at which lengths of the subsequent intervals are reduced. However application of strategy of checks with identical length of intervals between checks slightly reduces efficiency of technical system operation.

In the long term it is supposed to extend the received results to other, widely used kinds of redundancy.

References

1. Переверзев Е.С. Параметрические модели отказов и методы оценки надежности технических систем [Текст] / Е.С. Переверзев, Л.Д. Чумаков ; [отв. ред. В.С. Будник] ; АН УССР. Институт технической механики. – К. : Наук. думка, 1989. – 184 с. : ил. – Библиогр.: с. 179-182. – ISBN 5-12-000536-5.
2. Курасов В.Г. Надежность системы при комбинированном контроле и экспоненциальном распределении времени до отказа и времени восстановления [Текст] / В.Г. Курасов, Л.Д. Чумаков / Сб. "Надежность и прочность технических систем". – К. : Наукова думка, 1976 – С. 73-83.
3. Чумаков Л.Д. Надежность, стоимость эксплуатации технического устройства при комбинированном контроле исправности и возможности ошибок контролирующей аппаратуры [Текст] / Л.Д. Чумаков / Сб. "Прочность и долговечность конструкций". – К. : Наукова думка, 1980 – С. 174-183.

4. Чумаков Л.Д. Оптимизация стратегии контроля исправности хранящейся системы [Текст] / Л.Д. Чумаков / Сб. " Надежность сложных технических систем". – К. : Наукова думка, 1974 – С. 36-43.
5. Чумаков Л.Д. Оптимизация стратегии контроля исправности системы с резервными элементами [Текст] / Л.Д. Чумаков // Системные технологии. Регион. межвуз. сб. научн. работ. – Днепропетровск, 2011.– Вып. 2 (73). – С. 50–55.