UDK 62.519.2

LD Chumakov, AA. Chornaja

Estimation the effectiveness of the technical system operation as part of Inventory Management System in continuous monitoring of its serviceability using a mathematical model for periodic monitoring

Abstract. Estimates of the efficiency of operation of technical system during its development in the presence of a hierarchical system of inventory management are discussed.

Introduction

Most of complex technical systems (TS) do not provide a high level of efficiency in their use without special measures. For example, it is technical inspection of systems during their operation, architecture and operation of Inventory Management Systems (IMS), the choice of optimal strategies of using TS.

Choosing on the design phase of optimal structure and the number of IMS replacement TS at each level of the IMS is extremely important. Lack of spare parts store TS reduces TS efficiency, and excess can significantly increase the cost of their operation.

Analysis of publications on the topic of research

In [1] considered the problem of evaluating the effectiveness of group of TS, operating in conjunction with a two-level IMS. It was believed that the TS may be faulty both at their use and storage in the spare parts store of level 1. The condition of the TS is checked periodically in operation.

The formulas for evaluating the effectiveness of group of TS, as well as operating costs are given. Their dependence from characteristics TS and IMS is shown.

However, the technical condition of TS in the operation can be checked not only intermittently, but continuously.

In this case the evaluation of effectiveness of the technical system during its operation, taking into account features of the IMS can cause some difficulties.

The purpose of article

Purpose of the article is to show the possibility of assessing the operational efficiency of the group of TS with continuous monitoring of their technical condition using a mathematical model for periodic monitoring.

Main

The IMS structure is given in Fig. 1.

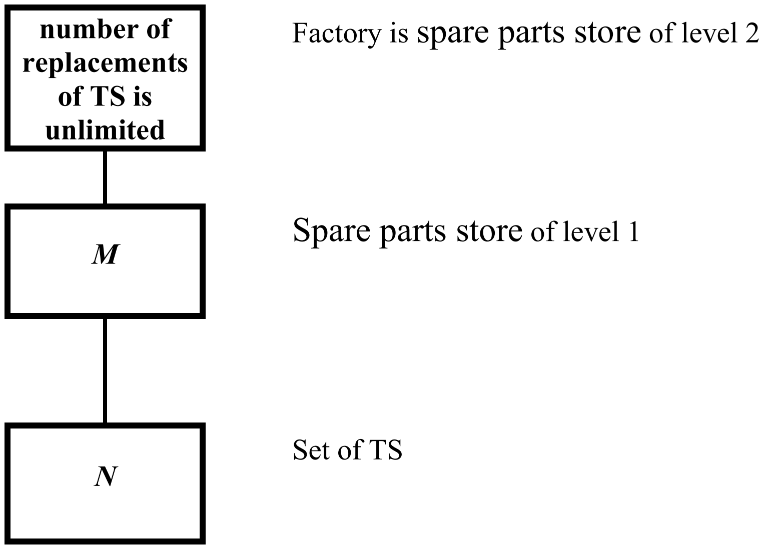

Fig. 1 Structure of Inventory Management System.

The process of operating $\boldsymbol{N}$ similar TS, which should perform a task when entering commands at a random time, uniformly distributed on the interval ($\boldsymbol{0}$, $\boldsymbol{T}$) is considered. Serviceability of all TS is checked at the same time over the intervals $\boldsymbol{\theta}$. Meanwhile, the number of identified faulty TS when checking is a random variable.

Replacement of defective TS to serviceable is performed by maintenance system, which includes IMS. IMS consists of two spare parts stores on two levels. Spare parts store of level 2 is the manufacturer.

The spare parts store of level 1 contain $\boldsymbol{M}$ spare TS in a good technical condition.

The spare parts store of level 2 have an unlimited number of TS in a good technical condition.

If a fault is detected, then faulty TS replaced from the spare parts store of level 1. To do this, the application is filed at the spare parts store of level 1, where you can select TS for replacement. The spare parts store of level 1 replenishes TS from the factory.

Time of onset of failure of TS is described by an exponential distribution, $F(t) = 1 - exp(-\lambda t)$, for which the parameter λ = const.

Duration of checking the technical state of the TS is equal to $\tau_э$.

Replacing faulty TS is continued z units of time.

Intervals between serviceability checks of all TS are given by:

$$\theta = T/(n+1), \qquad (1)$$

where T – the end of the TS operation period, n – number of inspections during the period of operation.

Coefficient of readiness of TS is estimated for the entire period of operation, which is defined by the formula:

$$k_Г = [\int_D k_Г(t)dt]/T, \quad (2)$$

where $k_Г(t)$ – current coefficient of readiness;

D – set of intervals between inspections.

$$k_Г(t) = \begin{cases} k_Г^*(t), \text{ if } t_i'' \le t \le t_{i+1}'; \\ 0, \text{ if } t_i' \le t \le t_i''. \end{cases} \quad (3)$$

Here t_i' – the beginning of the i-th periodic inspection TS; t_i'' – the end of the TS service after the i-th periodic inspection; $t_{i+1}'-t_i'= \theta$.

The quantity (4) is the lower bound for the coefficient of readiness

$$k_Г = \{1-exp(-\lambda\theta) + n[exp(-\lambda Z) - exp(-\lambda\theta)]\}/(\lambda T) \quad (4)$$

Here Z – duration of troubleshooting TS.

As a result of the u-th inspection x applications for receive serviceable TS from the spare parts store 1 is filed with probability P_x:

$$P_x = C_N^x\, exp(-\lambda(\theta+\tau_э)(N-x))[1-exp(-\lambda(\theta+\tau_э)]^x \quad (5)$$

where C_N^x – number of combinations of N on x.

Maintenance time of one of TS is defined as the average value:

$$Z = (\sum_{x=1}^{M} Z_1 P_x + \sum_{x=M+1}^{N} Z_2 P_x)/N, \quad (6)$$

where Z_1 – duration of maintenance with replacement of faulty TS from the spare parts store 1 and Z_2 – maintenance time with the replacement of the defective TS from the spare parts store 2.

Operation cost is determined by the formula:

$$C=c_1+(c_n+c_M+c_{з1}+c_{з2}+c_П(1-k_Г)/N. \quad (7)$$

where c_1 – value of one TS;

c_n – cost of inspections of N TS;

c_M – cost of maintenance IMS;

$c_{з1}$ – cost of replacements from the spare parts store 1;

$c_{з2}$ –cost of replacements from the spare parts store 2;

$c_П$ – cost of losses due to inability to complete the task TS.

Example. Operates the 10 onboard computers (OBC). The structure consists of 17 LSI with failure rate 9E-07 1/hr., 72 LSI with failure rate 1E-08 1/hr., 905 ICI with failure rate 2.5 E-09 1/hr., 84 IC with failure rate 9E-09 1/hr., 1106 transformers with failure rate 3E-09 1/hr., 606 diodes with failure rate 2E-09 1/hr. Failure rate OBC is 2.36 E-05 1/hr. OBC supposed to be used for 87600 hours. We will use the following values of the characteristics of maintenance: $\tau_э$ = 20 hours, Z_1 = 5 hours, Z_2 = 20 hours.

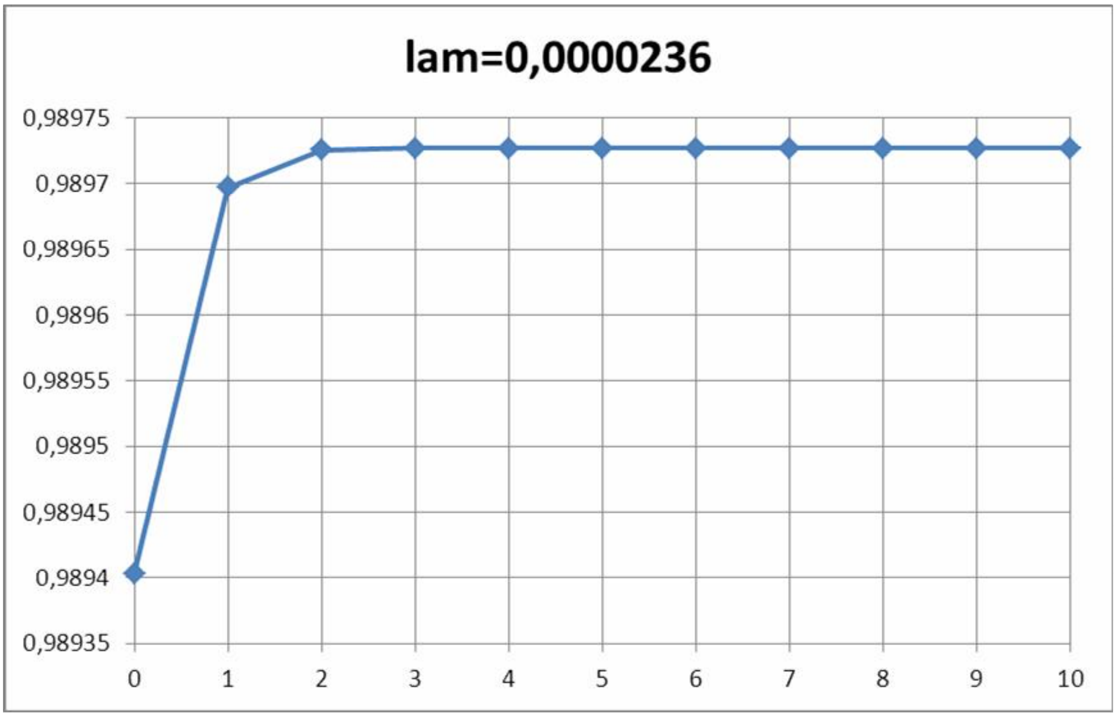

Fig. 2. Dependence $k_Г = f(M)$.

To simulate of the continuous monitoring of TS in the model for periodic monitoring we significantly increased the number of inspections, so that the value of the interval between checks is substantially diminished.

From Fig. 2 follow that, depending on the requirements to the value of the coefficient of readiness, you can change the structure of the IMS. So, if $k_Г \leq 0.989$, you cannot use the special IMS and implement replacement from factory.

If the $k_Г$ should be at least ***0.99***, there needs to be the spare parts store of level 1 with the number of replacement TS $M = 1$.

Conclusions and prospects for future research

Thus, the possibility to use mathematical models operating of systems with periodic technical inspections to assess the efficiency of systems with continuous monitoring of their technical condition is shown. This approach allows us to analyze the functioning of hierarchical Inventory Management Systems and to find optimal values of their characteristics in the design.

In future it is planned to carry out further research work on hierarchical Inventory Management Systems.

REFERENCES

1. Chumakov LD A determination of the readiness coefficient and the cost of a periodic maintenance of a technical arrangement in the presence of a two-level supply system and a limited number of repair units [Text] / LD Chumakov. Probabilistic and statistical methods for studying complex systems sciences. Naukova Dumka, K.: 1977, p. 95-100.