UDC 681.3(07)

Ph.D. **Banzak G.V.** (OSATRQ)
Ph.D. **Tsytsarev V.M.** (VIKNU)
Ph.D. **Leschenko O.I.** (OSATRQ)
Bondarenko T.V. (VITI)

TECHNIQUE OF OPTIMIZATION PARAMETERS OF STRATEGY REGULATED MAINTENANCE SERVICE

In clause the analysis of the maintenance of process of maintenance service (MS) of object of radio-electronic technics is made and necessity of a choice best strategy MS corresponding reliability -cost characteristics of object is proved. It is shown, that for complex objects of radio-electronic technics potentially the most effective is strategy MS «on a condition». MS and its private representations the general mathematical model of process is developed for following strategy MS: MS on a condition with constant periodicity of the control (MSC); MS with adaptive change of periodicity of the control (AMS); MS on a resource (MSR). Indicative limitedness of the constructed analytical model of process MS, impossibility to consider in it real constructive and reliability structure of complex object of radio-electronic technics. The analytical model which is used as the initial formal description of process MS by development of imitating statistical model (ISM) process of maintenance service and repair is developed.

Keywords: non-failure operation of object, maintenance service, optimum parameters, periodicity of the control, technical condition.

Statement of a problem. Prominent feature of complex technical objects of special purpose is presence in their structure of a plenty (tens, hundred thousand) polytypic completing elements which have a various level of reliability, various laws of processes their deterioration and ageing. This feature demands more thin approach to the organization and planning MS during their operation.

The problem consists that by development of such objects all the questions connected with maintainability and maintenance service should be solved already at early design stages of object. If to not provide in advance necessary equipment rooms and software of the built in control technical conditions (TC) of object, to not develop and "not build in" object technology of carrying out, to realize in the future a possible prize in non-failure operation of object due to carrying out THAT it will not be possible. As all these questions should be solved at a stage of creation objects (when the object still is not present), mathematical models of process by means of what it would be possible to count a possible prize in a level of non-failure operation of object due to carrying out MS are necessary, to estimate cost expenses demanded for it. Then on the basis of such calculations to make a decision on necessity of carrying out MS for the given type of objects and if such decision is accepted, to develop structure of system MS to choose the most comprehensible strategy MS, to define its optimum parameters [1,3,4].

Unfortunately, mathematical models known now and design procedures of optimum parameters of processes MS are poorly suitable for application to real technical objects. The basic lack of these models consists that in them or the complex structure of object is not considered at all, or there is an opportunity to consider only some elementary structures [2,5,6]. In [7,8] the comparative analysis of the problems arising at the decision of problems MS “on a resource” and “ on a condition ” is made. The review of the last for that period of works is resulted in the field of MS and repair of complex systems. In [9,10,11,12] theoretical generalization of known mathematical models of processes MS is made. However these models do not allow to build on their basis suitable techniques for practical use.

The basic part. In view of statement of problems (1) and (2) with reference to optimization of parameters of strategy TOC with constant periodicity of the control it is concretized as follows:

Optimization by criterion $\min\ c_{уп}$:

$$T_0(E^*_{\text{то}},U^*_{\text{то}},T^*_{\text{к}}) \geq T_0^{\text{тр}};$$
$$c_{э}(E^*_{\text{то}},U^*_{\text{то}},T^*_{\text{к}}) \to \min\ , \qquad (1)$$

optimization by criterion $\max K_{\text{ти}}$:

$$T_0(E^*_{\text{то}},U^*_{\text{то}},T^*_{\text{к}}) \geq T_0^{\text{тр}};$$
$$K_{\text{ти}}(E^*_{\text{то}},U^*_{\text{то}},T^*_{\text{к}}) \to \max\ , \qquad (2)$$

where $T_0^{\text{тр}}$ - the set requirement to a level of non-failure operation of object;

$E^*_{\text{то}}$, $U^*_{\text{то}}$ and $T^*_{\text{к}}$ - required optimum values of parameters MSC with constant periodicity of the control.

It is obvious, that parameters $E^*_{\text{то}}$, $U^*_{\text{то}}$ and $T^*_{\text{к}}$, received as a result of the decision of problems (1) and (2), will be various.

The space in which search of optimum values $E^*_{\text{то}}$ should be carried out, $U^*_{\text{то}}$ and $T^*_{\text{к}}$, in both problems equally and represents the cartesian product of a following kind:

$$\{E_{\text{то}}\} \times [0,1]^{|E_{\text{то}}|} \times [0,\infty), \qquad (3)$$

where $\{E_{\text{то}}\}$ - set of all sets consisting of elements, entering into set $E_{\text{то}}$;

$[0,1]^{|E_{\text{то}}|}$ - hypercube, each point in which represents a vector dimension $|E_{\text{то}}|$, elements of a vector are the numbers belonging a piece $[0,1]$;

$[0,\infty)$ - numerical axis containing all positive numbers.

Clearly, that a generating element of space (3) is the set of served elements $E_{\text{то}}$. The set $E_{\text{то}}$ is defined by the developer, it joins the least reliable elements for which defining parameters are known and there are means of their measurement. At a development cycle of object RET for some potentially served elements defining parameters can be still unknown. However, and such elements can be included in set $E_{\text{то}}$ with the purpose of check expediency in the future of additional researches on revealing defining parameters for these elements. By results of modeling the developer has an opportunity to define an expected prize in reliability of object due to carrying out

MS of these elements. If there will be, that a prize essential, the developer can make a decision on additional charges on changes of a design object with the purpose of maintenance measurement defining parameters.

So, the set $E_{\text{то}}$ is set in view of already accepted decisions on necessity MS for a part elements, and also from reasons of check of expediency of inclusion in number of served other elements.

The problem (1) (the same as also (2)) is supposed to be solved a problem as sequence of private problems in which the set of served elements is fixed. On each step the auxiliary set $E^+_{\text{то}}$ by addition in it on one element taken from $E_{\text{то}}$ is formed. Before it all elements of set $E_{\text{то}}$ are ordered on increase of an average operating time to refusal of elements.

On each step for the fixed set $E^+_{\text{то}}$ the private problem of definition optimum parameters $U^+_{\text{то}}$ and $T^+_{\text{к}}$, satisfying to a condition is solved

$$c_{\text{э}}(E^+_{\text{то}}, U^+_{\text{то}}, T^+_{\text{к}}) \to \min_{U_{\text{то}}, T_{\text{к}}} . \qquad (4)$$

The decision $\text{P}^+_{\text{то}} = \left\langle E^+_{\text{то}}, U^+_{\text{то}}, T^+_{\text{к}} \right\rangle$, satisfying to a condition (4), we shall name conditionally optimum decision received provided that set of served elements has structure $E^+_{\text{то}}$.

It is obvious, that at addition in $E^+_{\text{то}}$ new elements the average time between failures T_0 should increase, and as soon as on some step the condition $T_0 \geq T_0^{\text{тр}}$ be satisfied, process of search of the decision stops. Conditionally optimum decision $\text{P}^+_{\text{то}}$ received in last step makes as the optimum decision $\text{P}^*_{\text{то}}$.

Similarly the problem (4.2) is solved also with that only difference, that instead of a private problem (4) on each step the problem is solved

$$K_{\text{ти}}(E^+_{\text{то}}, U^+_{\text{то}}, T^+_{\text{к}}) \to \max_{U_{\text{то}}, T_{\text{к}}} . \qquad (5)$$

Thus, due to such reception we have reduced number of optimized parameters up to two - $U_{\text{то}}$ and $T_{\text{к}}$. However complexities have not disappeared yet as one of the remained parameters is a vector.

The parameter $U^+_{\text{то}}$ is a vector of levels MS set for various served elements. Simple physical reasons speak that optimum values $u^+_{\text{то}i} \in U^+_{\text{то}}$ should be separately for various elements $e_i \in E^+_{\text{то}}$ as likelihood characteristics of process degradation various elements can essentially differ. Thus the greatest influence on a choice of optimum value $u_{\text{то}i}$ the size of factor a variation process of degradation of an element v_{ui}, apparently, should render. On the other hand, optimum values $u_{\text{то}i}$ can depend also on periodicity of the control $T^+_{\text{к}}$. For finding-out of these dependences we shall execute simple research.

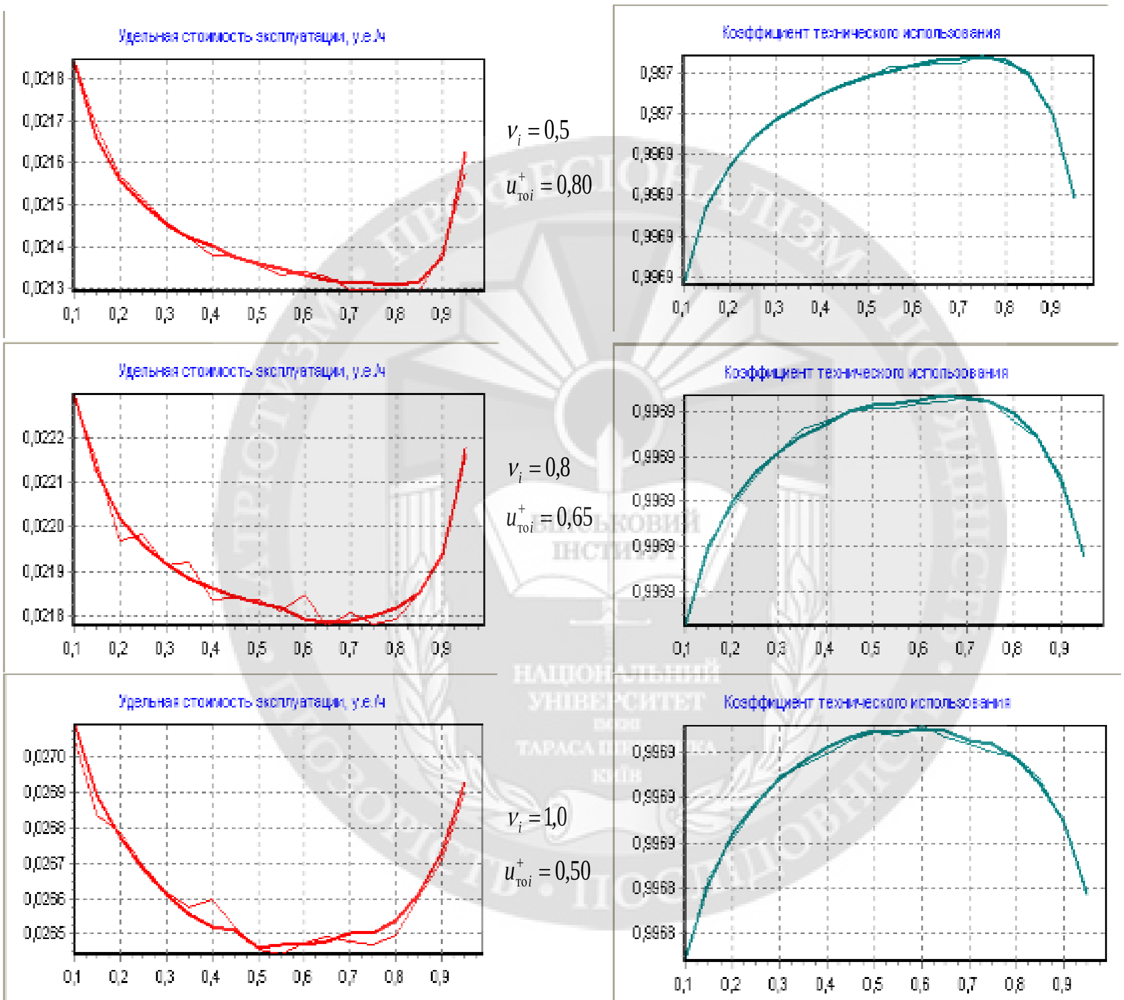
For an example we shall take object Test-1 and we shall make calculations of specific cost of operation $c_{\text{э}}(E_{\text{то}}, U_{\text{то}i}, T_{\text{к}})$ at fixed $E_{\text{то}}$ and $T_{\text{к}}$, and at various values $U_{\text{то}i}$ where $U_{\text{то}i}$ is a vector in which varies *i-th* component $u_{\text{то}i}$: $U_{\text{то}i} = \{u_{\text{то}1}, u_{\text{то}2}, \ldots, u_{\text{то}i}\}$.

To make results evident and easily interpreted, we shall extremely simplify a situation. In set $E^+_{\text{то}}$ we shall include a unique element so the vector $U_{\text{то}i}$ turns to a scalar $u_{\text{то}i}$.

On fig.1 results of calculations in the form of schedules dependence parameters $c_э$ and $K_{ти}$ from size $u_{тo\,i}$ are resulted at the fixed periodicity of the control $T_к$ = 1000 ч. The size $u_{тo\,i}$ varies in an interval [0,1; 0,95].

Calculations have been executed for three values of factor of a variation $\nu_{u\,i}$: 0,5; 0,8; 1,0.

Under the received schedules it is well visible, that functions $c_э(u_{тo\,i})$ and $K_{ти}(u_{тo\,i})$ has strongly pronounced extrema which position depends on factor of a variation ν_i. At increase in factor of a variation optimum values of a level MS $u^+_{тo\,i}$ are displaced in area of smaller values, coming nearer to a level 0,5.



а) Графики функции $c_{уд}(u_{тоі})$ б) Графики функции $K_{ти}(u_{тоі})$

Fig.1. Schedules of functions $c_{уд}(u_{тo\,i})$ and $K_{ти}(u_{тo\,i})$ at various values ν_i (Object Test-1, $T_к$ = 1000)

Now it is necessary for us to find out, whether optimum values $u^+_{тo\,i}$ depend on periodicity of the control $T_к$. For this purpose we shall make the same calculations at various values of periodicity $T_к$, and at everyone $T_к$ we shall define optimum values $u^+_{тo\,i}$ and values $c_э(u^+_{тo\,i})$ corresponding them and $K_{ти}(u^+_{тo\,i})$.

Value $T_к$ we shall vary in a range from 500 up to 5000 ч. By results of calculations schedules of dependence on $T_к$ optimum sizes $u^+_{тоi}$ and the values $c_э(u^+_{тоi})$ corresponding them received by criterion $\min c_э$ (fig. 2), and the same schedules for values $u^+_{тоi}$ and $K_{ти}(u^+_{тоi})$, received on criterion $\max K_{ти}$ (fig. 2) have been constructed.

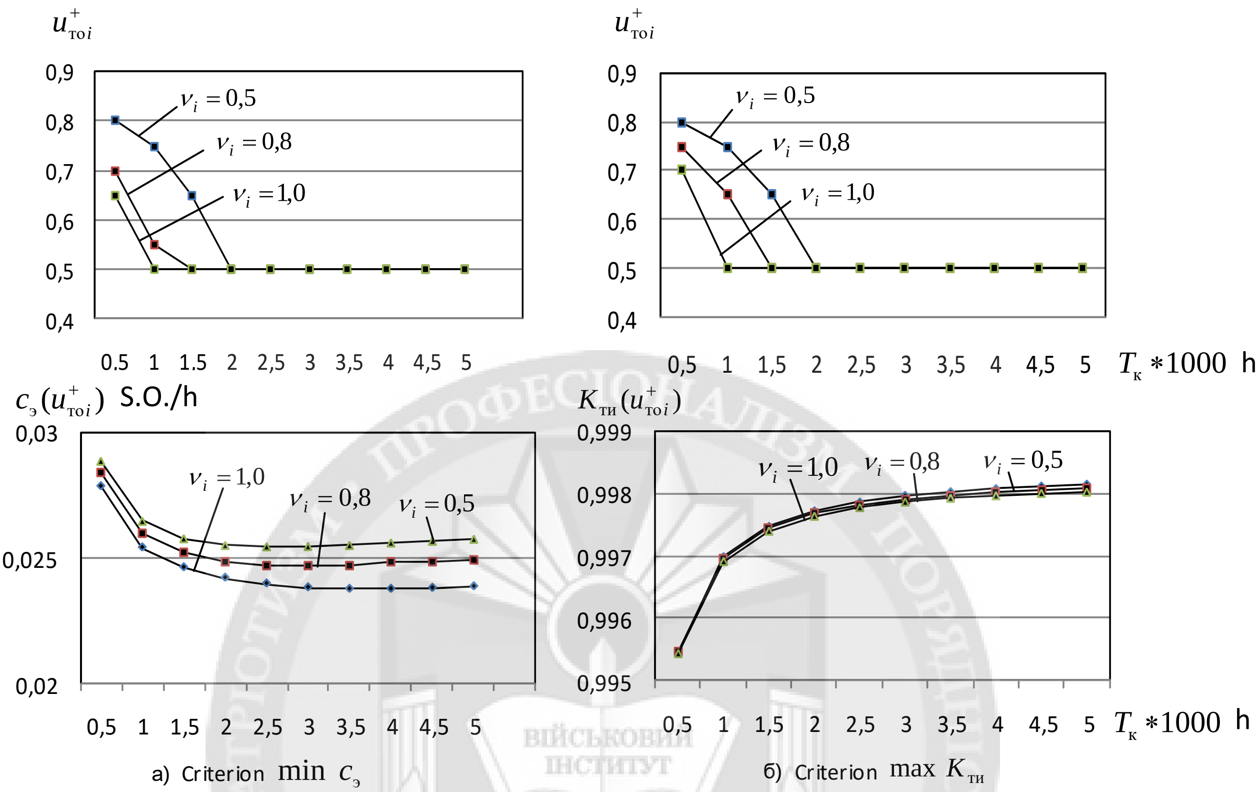


Fig. 1. Schedules of dependences an optimum level MS $u^+_{тоi}$ and corresponding values of criterion functions $c_э(u^+_{тоi})$ and $K_{ти}(u^+_{тоi})$ from periodicity of the control $T_к$ over various values ν_i

The received schedules evidently show the following:

1) conditionally optimum values $u^+_{тоi}$ and corresponding sizes $c_э(u^+_{тоi})$ and $K_{ти}(u^+_{тоi})$ essentially depend on periodicity of the control $T_к$ and, hence, sizes $u^+_{тоi}$ and $T^+_к$ are dependent, and

2) conditionally optimum values $u^+_{тоi}$ also $T^+_к$ depend also on factor of a variation ν_i.

Conclusions. Established facts allow to draw such conclusions.

First, we have received acknowledgement of that by search conditionally optimum vector $U^+_{то}$ it is necessary to carry out separate optimization of each of its elements.

Secondly, by search of conditionally optimum decision in (4.4) it is necessary to search *for in* common optimum values of parameters $U^+_{то}$ and $T^+_к$.

Developed below a technique of optimization of parameters MSC appreciably are based on use of established facts and the conclusions made on them.

REFERENCES:

1. Каштанов В.А. Оптимальные задачи технического обслуживания / В.А. Каштанов – М.: Знание, 1981.

2. Барзилович Е.Ю. Вопросы математической теории надежности / Е.Ю.Барзилович, Ю.К.Беляев, В.А.Каштанов и др.; Под ред. Б.В.Гнеденко. – М.: Радио и связь, 1983. – 376 с.

Ушаков И.А. Вероятностные модели надежности информационно-вычислительных систем / И.А. Ушаков – М.: Радио и связь, 1991. – 132 с.

3. Банзак Г.В. Математическая модель процесса эксплуатации сложного технического объекта / Г.В.Банзак // Збірник наукових праць Військового інституту Київського національного університету імені Тараса Шевченка. – 2011. – № 33. – С. 14 – 20.

4. Банзак Г.В. Определение остаточного ресурса восстанавливаемых технических объектов / Г.В.Банзак // Інформаційна безпека – 2011. – № 1(5). – С.96 – 102.

5. Банзак Г.В. Математическая модель адаптивного технического обслуживания по состоянию // Матеріали 6 Всеукраїнської науково-практичної конференції за міжнародною участю „Інформатика та системні науки". – Полтава, 2015. – С. 43 – 46.

6. Надежность и эффективность в технике. Справочник. Т.10. Справочные данные по условиям эксплуатации и характеристикам надежности. М.: Машиностроение, 1990. – 336 с.

7. Банзак Г.В., Банзак О.В., Лещенко О.И. Сравнительное исследование различніх стратегий технического обслуживания // Збірник наукових праць Одеської державної академії технічного регулювання та якості. - № 1 (6), - Одесса, 2015, - С. 111 – 118.

8. Банзак Г.В. Алгоритмы моделирования процесса технического обслуживания «по состоянию» // Збірник наукових праць Військового інституту Київського національного університету імені Тараса Шевченка. – К., 2015. – № 49. – С.96 – 103.

9. Банзак Г.В. Математическая модель адаптивного технического обслуживания по состоянию // Матеріали 6 Всеукраїнської науково-практичної конференції за міжнародною участю „Інформатика та системні науки". – Полтава, 2015. – С. 43 – 46.

10. Прогнозирование надежности сложных объектов радиоэлектронной техники и оптимизация параметров их технической эксплуатации с использованием имитационных статистических моделей: [монография] на русском языке / С.В. Ленков, К.Ф. Боряк, Г.В. Банзак, В.О. Браун [и др.]; под ред. С.В. Ленкова. – Одесса: Изд-во «ВМВ», 2014. – 256 с.

11. Прогнозування надійності складних об'єктів радіоелектронної техники та оптимізація параметрів їх технічної експлуатації з використанням імітаційних статистичних моделей: [монографія] на українській мові / С.В. Лєнков, К.Ф. Боряк, Г.В. Банзак, В.О. Браун [и др.]; під ред. С.В. Лєнкова. – Одеса: Вид-во «ВМВ», 2014. – 248 с.

12. Forecasting to reliability complex object radio-electronic technology and optimization parameter their technical usage with use the simulation statistical models: [monography] in English / Sergey Lenkov, Konstantin Borjak, Gennady Banzak, Vadim Braun, ets.; under edition S.V. Lenkov. – Odessa: Publishing hous «VMV», 2014. – 252 p.

Рецензент: д.т.н., проф. Лєнков С.В., головний науковий співробітник науково-дослідного центру Військового інституту Київського національного університету імені Тараса Шевченка

к.т.н. Банзак Г.В., к.т.н. Цицарєв В.М., к.т.н. Лещенко О.І., Бондаренко Т.В.

ТЕХНІКА ОПТИМІЗАЦІЇ ПАРАМЕТРІВ СТРАТЕГІЇ РЕГУЛЮВАННЯ ТЕХНІЧНОЇ СЛУЖБИ

В статті проводиться аналіз змісту процесу технічного обслуговування (ТО) об'єкта радіоелектронної техніки та обґрунтована необхідність вибору найкращої стратегії ТО, що відповідає надійно-вартісним характеристикам об'єкта. Показано, що для складних об'єктів радіоелектронної техніки потенційно найбільш ефективною є стратегія ТО «за станом». Розроблена загальна математична модель процесу ТО та її часткові представлення для наступних стратегій ТО: ТО за станом з постійною періодичністю контролю (ТОС); ТО з адаптивним зміною періодичності контролю (АТО); ТО по ресурсу (ТОР). Показова обмеженість побудованої аналітичної моделі процесу ТО, неможливість врахувати в ній реальну конструктивну та надійну структуру складного об'єкта радіоелектронної техніки. Розроблена аналітична модель, яка використовується як вихідне формальне опис процесу ТО при розробці імітаційної статистичної моделі (ІСМ) процесу технічного обслуговування та ремонту.

Ключові слова: бездоглядність об'єкта, технічне обслуговування, оптимальні параметри, періодичність контролю, технічний стан.

к.т.н. Банзак Г.В., к.т.н. Цицарев В.Н., к.т.н. Лещенко О.И., Бондаренко Т.В.

ТЕХНИКА ОПТИМИЗАЦИИ ПАРАМЕТРОВ СТРАТЕГИИ РЕГУЛИРОВАНИЯ ТЕХНИЧЕСКОГО ОБСЛУЖИВАНИЯ

В статье произведен анализ содержания процесса технического обслуживания (ТО) объекта радиоэлектронной техники и обоснована необходимость выбора наилучшей стратегии ТО, соответствующей надежностно-стоимостным характеристикам объекта. Показано, что для сложных объектов радиоэлектронной техники потенциально наиболее эффективной является стратегия ТО «по состоянию». Разработана общая математическая модель процесса ТО и ее частные представления для следующих стратегий ТО: ТО по состоянию с постоянной периодичностью контроля (ТОС); ТО с адаптивным изменением периодичности контроля (АТО); ТО по ресурсу (ТОР). Показана ограниченность построенной аналитической модели процесса ТО, невозможность учитывать в ней реальную конструктивную и надежностную структуру сложного объекта радиоэлектронной техники. Разработана аналитическая модель, которая используется как исходное формальное описание процесса ТО при разработке имитационной статистической модели (ИСМ) процесса технического обслуживания и ремонта.

Ключевые слова: безотказность объекта, техническое обслуживание, оптимальные параметры, периодичность контроля, техническое состояние.