УДК 681.3(07) Ph.D. **Lenkov E.S.** (MITI)

# THE OPTION FOR CALCULATING THE INDICATORS OF THE NEEDLESSNESS OF THE UNBELIEVABLE COMPLEX OBJECT OF TECHNIQUE

***A characteristic feature of complex objects is the presence in their composition of a large number (tens, hundreds of thousands) of various components that have different levels of reliability, different patterns of wear and aging processes.***

***In this article, one of the options for calculating the indispensability of a non-repairable object is presented. It is shown that the adequacy of the simulation simulation model depends on how correctly (adequately) the laws of the distribution of the operating time before the failure of the elements are specified. The variants of serial connection of different types and identical elements, as well as voltage and unloaded redundancy from the DN-distribution are considered. The sequence of connection of different types of elements is analyzed and the reservation of groups of the same type with the E-distribution is analyzed.***

***Keywords: reliability index, non-renewable object, process of wear and aging, imitational statistical model.***

**Accession.** The author of the article has previously studied the maintenance of complex equipment. Mathematical models of the object with the most important of its structural and reliability parameters are constructed, for example [1-3].

The information on properties of non-failure operation of elements in MN is represented functions $P(t/e_i)$ which kind is defined by laws of distribution of a casual operating time to refusal of elements. From that, laws of distribution operating time to refusal of elements are how much correctly (adequately set, adequacy of results modeling imitating statistcal mobel (ISM) depends. In practice of function $P(t/e_i)$ seldom happen are precisely known. At the best first two moments are known and there are certain assumptions of a class of laws of distribution to which function $P(t/e_i)$ probably belongs. As a rule, the estimation of the first moment (a population mean of an operating time to refusal) is known only. At worst – are not known neither function of distribution, nor its moments. Therefore, in practice it is necessary to accept assumptions of a kind of the law of distribution in view of type of the given element and available information on physical laws of occurrence of refusals for elements of this type. The estimation of an average operating time to refusal of elements often should be set according to about elements-analogues.

In this past objects radio-elektronik technic (RET) are assumed growing old, the maintenance of processes maintenanga service and repair (MSaR) is directed on compensating influence of factors ageing and deterioration of objects during their operation. A characteristic attribute of laws the distribution describing refusals of growing old objects, increase of function failure rate (IFF) is. Such laws of distribution name IFF-distributions [4]. IFF-distributions are models of refusals which are generated various degradation (deterioration) by processes in materials of which elements are made. The refusals connected with display of factors deterioration and ageing, it is accepted to name *gradual* [5-7].

**Main material.** In [8] the concept of is *likelihood-physical model* (LP-models) of refusals in which likelihood characteristics of distribution probabilities of refusals contact likelihood characteristics of some parameters of the physical processes generating these refusals is entered. The hypothesis that there is some defining parameter describing a technical condition of an element is accepted. We have defined, that the most comprehensible LP-model for the adequate description of process of occurrence of refusals of objects RET is *DN*-distribution [9].

For *DN*-distribution the density of probability of refusals has a following appearance [10]:

$$f(t) = f(t;\mu,\nu) = \frac{\sqrt{\mu}}{\nu t\sqrt{2\pi t}} \exp\left(-\frac{(t-\mu)^2}{2\nu^2 \mu t}\right), \quad (1)$$

where $\mu$ – parameter of scale (an average operating time to refusal); $\nu$ – Factor of a variation.

Parameters of *DN*-distribution $\mu$ also $\nu$ are connected with corresponding characteristics of the defining parameter $\mu_x$ and $\nu_x$ following simple parities:

$$a_x = 1/\mu;\ \nu_x = \nu, \quad (2)$$

where $a_x$ – average speed of process of degradation (ageing) of the defining parameter $x(t)$; $\nu_x$ – factor of a variation of the defining parameter.

To function of density of probability (1) there corresponds integrated function of *DN*-distribution [10]:

$$F(t) = DN(t;\mu,\nu) = \Phi\left(\frac{t-\mu}{\nu\sqrt{\mu t}}\right) + \exp\left(\frac{2}{\nu^2}\right)\Phi\left(-\frac{t+\mu}{\nu\sqrt{\mu t}}\right) =$$
$$= \Phi\left(\frac{at-1}{\nu\sqrt{at}}\right) + \exp\left(\frac{2}{\nu^2}\right)\Phi\left(-\frac{at+1}{\nu\sqrt{at}}\right), \quad (3)$$

where $\Phi(z) = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{z} \exp\left(-\frac{x^2}{2}\right)dx$ – normalization normal distribution; $a = 1/\mu$.

Simplicity of the parities (2) connecting likelihood characteristics of distribution of a casual operating time before refusal with corresponding likelihood characteristics of the defining parameter, opens greater opportunities for use of *DN*-distribution in problems of modeling of maintenance service.

Greater advantage of *DN*-distribution as models of refusals is also its universality which consists that its factor of a variation (parameter of the form) practically coincides with parameters of the form of *DM*-distribution and is approximately equal to return value of parameter of the form of distribution Veibulls and an alpha-distribution [8]. It allows using *DN*-distribution as model of refusals of elements of the various types having various physical mechanisms processes of degradation. For maintenance of adequacy of model of refusals correctly enough to set size of factor of a variation. Recommendations at the choice of factor of a variation can be found in [6,11]. In tab. 1. are resulted taken of some data about characteristic values of factor of a variation.

Table 1

The generalized estimations of factors variations of various physical processes

| Kind of process degradation | Factor of variation process of destruction | Name of elements, exposed to destruction |
|---|---|---|
| Weariness (multicyclic) | 0,40 - 1,00 | Case details, bearings rolling, shaft, axes, springs, rods, bolts, etc. |
| Deterioration (mechanic-chemical) | 0,20 - 0,50 | Bearings of sliding, shaft, the axes directing, plugs, etc. |
| Ageing | 0,40 - 1,00 | Elements and details from metals, polymers, rubber technics products, condensation, semiconductors, etc. |
| Electric (electroliz, migration of charges, electrodiffusion) | 0,70 - 1,50 | Semi-conductor devices, integrated schemes, condensers and other products of electronic technics. |

Additional specification of numerical value of factor of a variation from the specified range in each concrete case can be carried out in view of following general reasons: more on average attitude of loading to a limit of endurance (durability), the less size factor of a variation and on the contrary, that is, the factor of loading there is less, the is more factor of a variation.

In [10] it is proved, that if the system consists of elements which refusals are subordinated to *DN*-distribution then also refusals of system also are subordinated to *DN*-distribution. It allows to apply *DN*-distribution as model of non-failure operation for reserve groups of elements. Parameters of *DN*-distribution of an operating time to refusal (parameter of scale $\mu$ and parameter of the form $\nu$ ) depending on a way reliability connections of elements in reserve groups pay off under following formulas.

*Consecutive connection of polytypic elements*:

$$\mu = 1\Big/\sqrt{\sum_{i=1}^{N}\frac{n_i}{\mu_i^2}}\,;\ \nu = \sqrt{\sum_{i=1}^{N}\frac{n_i\nu_i^2}{\mu_i^2}}\Big/\sqrt{\sum_{i=1}^{N}\frac{n_i}{\mu_i^2}}\,, \tag{4}$$

where $n_i$ – quantity of elements of *i*-th type; $\mu_i$ – parameter of scale of *DN*-distribution of an operating time to refusal of elements of *i*-th type (an average operating time to refusal of elements of *i*-th type); $\nu_i$ – parameter of the form of *DN*-distribution operating time to refusal of elements of *i*-th type (factor of a variation); $N$ – number of types of elements in reserve to group.

*Consecutive connection of identical elements*:

$$\mu = \mu_0/\sqrt{n}\,;\ \nu = \nu_0\,, \tag{5}$$

where $\mu_0$ – parameter of scale of *DN*-distribution elements entering in reserve group (an average operating time to refusal of one element); $n$ – number of identical elements in reserve to group.

*The loaded (constant) reservation:*

$$\mu = \mu_0\sqrt{n}\,;\ \nu = \nu_0/\sqrt{n}\,. \tag{6}$$

*Not loaded (replacing) reservation*:

$$\mu = \mu_0 n\,;\ \nu = \nu_0/\sqrt{n}\,. \tag{7}$$

In view of the resulted data as model of refusals for all constructive elements and object as a whole we choose *DN*-distribution.

The initial information for MN is the set of pairs the parameters $\langle \mu_i, \nu_i \rangle$ set for all simple elements (elements of the bottom level). On the basis of this information under formulas (2)–(7) corresponding parameters for all other (compound) constructive elements of the senior levels pay off.

On the parameters $\langle \mu_i, \nu_i \rangle$ received for all elements $e_i \in E$ then functions of probability non-failure operation of elements $P(t/e_i) = 1 - F(t/e_i)$, where $F(t/e_i)$ – the functions of distribution defined under the formula (3) pay off.

In developed below models we shall use also exhibitor distribution (*E*-distribution) for which function of density of probability has a following appearance [12]:

$$f(t) = f(t;\lambda) = \lambda \exp(-\lambda t), \tag{8}$$

where $\lambda$ – parameter of distribution which in problems of reliability interpret as *failure rate* [13, 14].

For *E*-distribution function of distribution casual operating time to refusal is defined by expression [12]:

$$F(t) = F(t;\lambda) = 1 - \exp(-\lambda t). \tag{9}$$

*E*-distribution is one-parametrical with the factor of a variation equal 1. The average operating time to refusal in case of *E*-distribution is equal

$$T_{\text{cp}} = 1/\lambda\,. \tag{10}$$

*E*-distribution is cleanly likelihood distribution (it is not connected in any way with any physical parameters of processes) and is applied in the theory of reliability as ideal model of sudden refusals. Generally speaking, any refusals are sudden and their division on *sudden* and *gradual* is to a certain extent conditional. Under gradual refusals at which laws of occurrence in a greater or smaller measure there is the factor of ageing (deterioration) shown in increase of failure rate in process of increase of an operating time (service life) of object usually are understood. For *E*-distribution by a characteristic attribute the constancy (independence of time) failure rate $\lambda$ is. Therefore, *E*-distribution can be applied as model of refusals only at an assumption that the object is not growing old. It is obvious, that at researches of processes MSaR such assumption is unacceptable.

As parameters of reliability for groups with consecutive and parallel connection of elements are rather simply defined.

1. At consecutive connection of polytypic elements in case of *E*-distribution of an operating time to refusal following expressions [12] are fair:

$$\lambda = \sum_{i=1}^{n} \lambda_i\,;\; T_{\text{cp}} = 1/\sum_{i=1}^{n} 1/T_{\text{cp}\,i}\,, \tag{11}$$

where *n* – number of elements in group; $\lambda_i$ and $T_{\text{cp}\,i}$ – failure rate and an average operating time to refusal of *i-th* element ($i = \overline{1,n}$).

In case of the same elements:

$$\lambda = n\lambda_0\,;\; T_{\text{cp}} = T_{\text{cp}\,0}/n\,, \tag{12}$$

where $\lambda_0$ and $T_{\text{cp}0}$ – parameters of reliability of the element entering into group.

From (11) and (12) it is visible, that a property exhibitor distribution of an operating time to refusal at consecutive connection of elements is kept. At parallel connection of elements, unfortunately, it not so. The law of distribution of an operating time to refusal reservation groups nonexhibitor in spite of the fact that the operating time to refusal of each separate element in group is subordinated to *E*-distribution.

2. For reservation groups of the same elements in case for separate elements the operating time to refusal is subordinated to *E*-distribution, following expressions for an average operating time to refusal [12, 14] are fair:

for the loaded reservation:

$$T_{\text{cp}} = T_{\text{cp}\,0} \sum_{i=1}^{n} 1/i\,; \tag{13}$$

for replacing reservation:

$$T_{\text{cp}} = nT_{\text{cp}\,0}. \quad (14)$$

The parameter $\lambda$ for reservation groups of elements becomes dependent on time (operating time).

**Conclusions.** In this part of paper present, what in [10] it is proved, that if the system consists of elements which refusals are subordinated to *DN*-distribution then also refusals of system also are subordinated to *DN*-distribution. It allows to apply *DN*-distribution as model of non-failure operation for reserve groups of elements. Parameters of *DN*-distribution of an operating time to refusal (parameter of scale $\mu$ and parameter of the form $\nu$) depending on a way reliability connections of elements in reserve groups pay off under following formulas.

Remarkable property of *E*-distribution is simplicity of mathematical expressions for parameters of reliability that allows defining their exact theoretical values simply.

Owing to simplicity of mathematical expressions for parameters of reliability *E*-distribution is convenient for using for check of accuracy and adequacy of developed models of processes MSaR. But, unfortunately, not always it is possible to take advantage of this opportunity. For example, in case of carrying out MS property exhibitor operating time between refusals is broken.

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## ВАРИАНТ РАСЧЕТА ПОКАЗАТЕЛЕЙ БЕЗОТКАЗНОСТИ НЕВОССТАНАВЛИВАЕМОГО СЛОЖНОГО ОБЪЕКТА ТЕХНИКИ

***Характерной особенностью сложных объектов является наличие в их составе большого количества (десятки, сотни тысячи) разнотипных комплектующих элементов, которые имеют различный уровень надежности, различные закономерности процессов износа и старения.***

***В данной статье представлен один из вариантов расчета показателей безотказности невосстанавливаемого объекта. Показано, что от того, насколько правильно (адекватно) заданы законы распределения наработки до отказов элементов, зависит адекватность моделирования имитационно статистической модели. Рассмотрены варианты последовательного соединения разнотипных и одинаковых элементов, а также напряжение и ненагруженное резервирование с DN-распределения. Проанализированы последовательность соединения разнотипных элементов та резервирование групп однотипных элементов с Е-распределением.***

***Ключевые слова: показатель безотказности, невосстанавливаемый объект, процесс износа и старения, имитационно статистическая модель.***

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## ВАРІАНТ РОЗРАХУНКУ ПОКАЗНИКІВ БЕЗВІДМОВНОСТІ НЕВІДНОВЛЮВАЛЬНОГО СКЛАДНОГО ОБ’ЄКТУ ТЕХНІКИ

***Характерною особливістю складних об'єктів є наявність в їх складі великої кількості (десятки, сотні тисячі) різнотипних комплектуючих елементів, які мають різний рівень надійності, різні закономірності процесів зносу і старіння.***

***У даній статті представлений один з варіантів розрахунку показників безвідмовності невідновлюваного об'єкта. Показано, що від того, наскільки правильно (адекватно) задані закони розподілу напрацювання до відмов елементів, залежить адекватність моделювання імітаційно статистичної моделі. Розглянуто варіанти послідовного з'єднання різнотипних і однакових елементів, а також напруга і ненавантажений резервування з DN-розподілу. Проаналізовано послідовність з'єднання різнотипних елементів та резервування груп однотипних елементів з Е-розподілом.***

***Ключові слова: показник безвідмовності, невідновлюваний об'єкт, процес зносу і старіння, імітаційно статистична модель.***