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COMPLIANCE TECHNOLOGY COMPLEX TECHNICAL NON-RESTORABLE OBJECT

Sophisticated technical objects in modern society are extremely important. This is primarily about various military and special-purpose radio electronic complexes, radar stations, automated control systems (air traffic, energy facilities, etc.). The state of defense of the state, economic security, and the lives of hundreds and thousands of people depend on the level of reliability of such facilities.

The model under development is intended to obtain the probability functions of failure-free operation $P(t)$ (or the distribution function of the time between failures $F(t)=1-P(t)$) for the object as a whole and all its structural elements from the available information on the failure-free indicators of component parts. Functions $P(t)$ and $F(t)$ are indicators of the reliability non-restored objects, therefore we will also call the model the model of non-failure (MN) of an non-restored object.

The constructive structure of a complex technical object is almost always hierarchical. Elements related to different structural levels can be called, for example, units (cabinets), devices (blocks), nodes (boards), etc. Moreover, an object may consist of aggregates, aggregates of devices, devices of nodes, etc.

$$E_{ij\ldots r}^{u}=\{E_{ij\ldots r0}^{u+1},E_{ij\ldots r1}^{u+1},\ldots,E_{ij\ldots rs}^{u+1},\ldots\};\ s=\overline{0,\left|E_{ij\ldots r}^{u}\right|};\ u=\overline{0,U}, \qquad (1)$$

where $E_{ij\ldots rs}^{u+1}$ – is an element of the (u + 1)-th level that is part of the element $E_{ij\ldots r}^{u}$;

U – is maximum level (nesting) of structural elements for a given RET object.

The object as a whole is represented by a list of level 1 elements:

$$E^{0}=\{E_{0}^{1},E_{1}^{1},\ldots,E_{i}^{1},\ldots\};\ i=\overline{0,\left|E^{0}\right|}. \qquad (2)$$

PZR elements are represented by empty lists.

The set of all nested lists of the form (1) is a mathematical model of the constructive structure of an object.

The reliability structure of an object can be an arbitrary series-parallel structure. This means that each structural element $E^{u}_{ij...k}$ can either be an PZR element, or be a series connection of the elements included in it, or be a reserved group of elements – a group elements connected in parallel in the sense of reliability. Elements of a reserved group can only be elements of the same type. Reservation in groups can be loaded (permanent) or unloaded (replacement).

If an element $E^{u}_{ij...k}$ consists of series-connected elements of the (u + 1)-th level, then probability of failure-free operation this elements is defined as the product:

$$P(t / E^{u}_{ij...k}) = \prod_{\forall E^{u+1}_{ij...kr} \in E^{u}_{ij...k}} P(t / E^{u+1}_{ij...kr}), \tag{3}$$

where r – is the number elements of (u + 1)-th level $E^{u+1}_{ij...kr}$ that is part elements of the u-th level $E^{u}_{ij...k}$;

$P(t / E^{u+1}_{ij...kr})$ – probability of failure elements $E^{u+1}_{ij...kr}$.

In practice, functions $P(t / e_m)$ are rarely exactly known. In the best case, the first two points are known and there are certain assumptions about the class of distribution laws to which the function $P(t / e_m)$ possibly belongs. As a rule, only the estimate of the first moment is known (the mathematical expectation of the time between failures). In the worst case, neither the distribution function nor its moments are known. Therefore, in practice, it is necessary to make an assumption about the form of the distribution law, taking into account the type of this element and the available information about the physical laws of the occurrence of failures for elements of this type. The average operating time to failure of the elements must be estimated from the information about the analogous elements.

The model under development is intended to solve the problems of assessing the reliability of aging objects, therefore, we need to use the laws of distribution operating time to failure, taking into account the degradation processes in the materials of heterogeneous elements. Failures generated by various degradation processes are commonly called gradual [1; 3]. Currently, it has become generally accepted that gradual failures occur due to the fact that the value of some determining parameter reaches the maximum permissible value. Failure models based on the concept of the determining parameter are usually called probabilistic-physical (*PF*-models) [2].

The most universal model of gradual failures is the diffusion nonmonotonic distribution (*DN*-distribution) [1; 2].

DN-distribution has one important property, which consists in the fact that coefficient variation distributions of the mean time between failures coincides with the coefficient of variation of the distribution the random variable of the determining parameter. This property, combined with the fact that mean time between failures is equal to the reciprocal of the average degradation rate determining parameters, opens up great opportunities for using *DN*-distribution in maintenance modeling problems.

The universality of *DN*-distribution lies in the fact that its coefficient of variation (shape parameter) practically coincides with the shape parameters of *DN*-distribution and is approximately equal to the reciprocal of the shape parameter Weibull distribution and alpha distribution [3]. This allows the use of *DN*-distribution as a model of failure of elements of various types having various physical mechanisms of degradation processes. To ensure adequacy of the failure model, it is sufficient to correctly set coefficient of variation.

The choice of the numerical value coefficient variation from the specified range in each case can be carried out taking into account the following general considerations: higher the average ratio of the load to endurance (strength), lower the coefficient of variation, and vice versa, that is, lower the coefficient of loading, greater coefficient variations.

Taking into account everything considered as a model of failures for all structural elements and the object as a whole, we choose *PF* model of *DN*-distribution. The initial information for the MN in this case is a lot of parameter pairs $\langle \mu_i, \nu_i \rangle$ of all elements of PZR. Based on this information, appropriate parameters should be calculated for all other structural elements of senior levels.

In [1], it was proved that if the system consists of elements whose failures are subordinate to the *DN*-distribution, then the system failures are also subordinate to the *DN*-distribution. The parameters of *DN*-distribution the time between system failure (scale parameter μ and shape parameter ν) depending on the method of reliable connection of elements in the system are calculated by the following formulas.

Denote E^u_{ijk} *k*-th element of *u*-th structural level, which is part of the *j*-th element of the (*u*-1)-th level. The *ijk* index in this case indicates a chain of numbers of elements higher levels (including this one) in the sequence of their occurrence in elements of previous (higher) levels. Leveling starts from the top, starting from the level of the object (u = 0). The numbering elements of the u-th level that are part elements of (u-1)-th level is independent within this element. Thus, number of numbers in the subscript is always equal to the value superscript u-the number of structural level.

The object E^0 as a whole is considered as an element of zero level. He is always the only one and is not included in any other elements. Figure 1 shows a fragment of the hierarchical structural structure of an object.

The term structural element will be used in the case when you need to pay attention to the place occupied in the structural structure of the object. The structural elements of the lower level, following the terminology adopted in [1], we agree to call products of zero rank (PZR). PZR can be both a very complex device and consist of a single elementary element (for example, resistor, microcircuit, ransformer, bearing, etc.). PZR is a non-separable element and is always considered as one.

The constructive structure of an object will be formally represented by a hierarchical list structure. Each feature is considewerered $E^u_{ij...r}$ a list.

The prototype of considered MN can be considered the model described in [2]. The main difference between the MN and the prototype is use of the important property of *DN*-distribution to preserve the type of distribution during transformations of the reliability structure of structural elements (when moving from a serial structure to a parallel one, and vice versa).

The model of non-failure (MN) allows you to get estimates of the reliability indicators (RI) of individual structural elements and the object as a whole based on information on the BOP of elements of the lower structural level. In MN, a hierarchical structural structure of an object is presented. The structural elements of a certain u-th structural level are a sequential (in the sense of reliability) connection of the elements of the (u + 1)-th level included in it. Individual structural elements can be a redundant group (parallel connection) of the same type elements. Thus, using MN, the representation of the hierarchical structural structure is combined with an arbitrary series-parallel reliability structure of the object, which is an acceptable representation for most technical objects encountered in practice.

As a model of failures for all elements and the object as a whole, a *DN*-distribution is used. *DN*-distribution is considered an adequate model of gradual failures both for electronic products and for various mechanical components and elements. An important advantage of *DN*-distribution is also that its appearance is preserved during the transformations of the reliability structure of the system. It is this feature of *DN*-distribution that made it possible to apply it to a system with a hierarchical structure.

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