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RELIABILITY MODEL USER INTERFACE

Complex technical objects in modern society are extremely important. Such objects belong to the class of recoverable objects of long-term multiple uses. They tend to be expensive and require significant maintenance costs. To ensure the required level of reliability during their operation, maintenance is usually carried out, the essence of which is the timely preventive replacement of elements that are in a pre-failure state.

The problem is that when developing such facilities, all issues related to maintainability and maintenance should be addressed already at the early stages of designing the facility. If you do not provide in advance the necessary hardware and software for integrated monitoring of the technical condition (TC) of the object, do not develop and "embed" the maintenance technology into the object, then it will not be possible to realize in the future a possible gain in the reliability of object due to maintenance. Since all these issues must be resolved at the stage of creating an object (when the object does not yet exist), mathematical models of the maintenance process are needed, with the help of which it would be possible to calculate the possible gain in the level of reliability of object due to maintenance, to estimate the cost costs required for this. Then, based on such calculations, make a decision on the need for maintenance for this type of objects and, if such a decision is made, develop the structure of the maintenance system, choose the most appropriate maintenance strategy, and determine its optimal parameters.

Key words: maintenance, coefficient of variation, object reliability, components.

Introduction. Under complex technical objects refers to objects consisting of a large number of different types of elements (tens, hundreds of thousands), each of which can be a rather complex technical device. Elements can be electronic, mechanical, electromechanical, hydraulic, etc. The heterogeneity of the elements leads to the fact that different elements are characterized by fundamentally different physical processes (and, consequently, speed) degradation, leading to their failure.

The objects under consideration belong to the class of objects to be repaired for long-term repeated use, and during their operation, maintenance is usually provided to maintain the required level of reliability. By maintenance (MS) is meant "a complex of operations or an operation to maintain the health or performance of an object when used for its intended purpose, simple, stored and transported" [1,2]. Further, only MS will be considered when used as intended.

During operation, an object at any time can be in one of the following states: serviceable, workable, inoperable.

The object can be used for its intended purpose only in good or healthy condition. Restoration of a working or working condition is made at the expense of current repair. MS, as a rule, is carried out only when the object is in working condition. If by the moment of the start of the maintenance (or in the maintenance process) there is a complete failure, then at the beginning the object is restored, and then the maintenance is performed.

The essence of the MS is to prevent some part of the failures due to the replacement of individual elements, cleaning, lubrication, adjustment, etc. (therefore, MS is often called prevention). In modern technical objects, in the overwhelming number of cases, maintenance is reduced to the replacement of elements (liquids, oils, etc.) that are in a pre-order condition.

Analysis of recent research. Currently, there is a decline in the number of scientific publications devoted to the issues of maintenance of complex technical objects. One of the reasons for this, in our opinion, is a sharp increase in the level of integration and reliability of components. Thanks to this, the developers of sophisticated equipment were able to solve the problems of ensuring the required level of reliability without significant maintenance costs (or no maintenance at all).

However, the same reason (high integration and reliability of component elements) opened up the possibility of implementing more and more sophisticated equipment with new functions, which was not possible with the old element base. This again leads objectively to the problems of ensuring reliability and, therefore, the question of the need for maintenance and the choice of the optimal strategy for its implementation becomes again relevant.

Unfortunately, the currently known mathematical models and methods for calculating the optimal parameters of the maintenance processes are not very suitable for application to real technical objects. The main disadvantage of these models is that they either do not take into account the complex structure of the object, or it is possible to take into account only some of the simplest structures [3,4]. In [5,6], a comparative analysis of the problems arising in solving problems of maintenance "by resource" and "by state" was made. An overview of the latest at that time work in the field of maintenance and repair of complex systems. In [7], a theoretical generalization of the well-known mathematical models of MS processes was made. However, these models do not allow to build on their basis suitable for practical use of the methodology.

Main part. With the help of MB, information about a real technical object (composition, structural and reliability structures, data on reliability indicators and cost of elements) is presented, which is then converted to the form required for use in IMS. In IMS, process of operation object is simulated, taking into account the maintenance. As a result of the complex application of MB and ISM, results are obtained for a specific type of object, the characteristics of which are specified in the initial data.

MB is developed using well-known concepts and methods of probability theory, reliability theory, graph theory. ISM is based on the application of the statistical modeling method (Monte Carlo method). The use of any analytical method turned out to be impossible due to the complexity of the process being modeled.

MB is implemented in such a way that when the software is launched, all data structures used in the model are immediately (automatically) created in the PC RAM and become available for other models. At the same time, reliability indicators of object and all its elements are immediately formed.

In the "Database" mode, it is possible to create a database, correct previously entered information. The PC screen in this mode is shown in fig. one.

The tree of the constructive structure of object is displayed on the left side of screen. In this tree, you can collapse or expand the internal structure of any of the elements. When you select (by mouse click) any of the elements in this tree, the tables on the right display information about the elements that make up selected element. The upper table displays data on composite structural elements that make up the selected element. The lower table displays the data on IDI that are directly included in the selected element. You can edit data in these tables.

At the bottom left (under tree) a panel with data is displayed:

- mean time to failure of the selected element (h);
- cost of the element (c.u.);
- number of structural elements included in the selected element;
- total number of elements-INR in the selected element.

At bottom of screen (below tables) a histogram of *DN*-distribution density of the selected element is displayed.

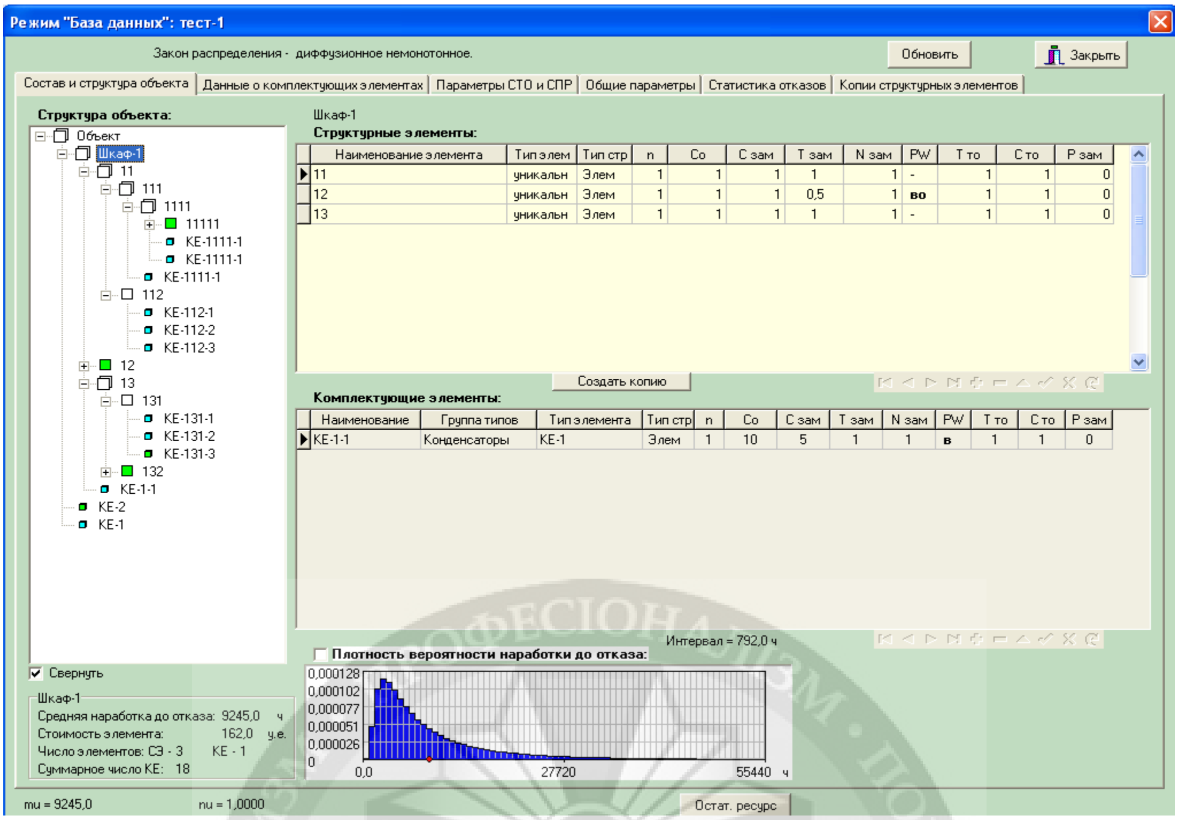

Figura 1 – View of the PC screen in the “Database” mode

To test and study the developed models and methods, test objects with different structures and reliability were used. The characteristics of test objects are selected in such a way as to cover all typical cases of possible real objects encountered in practice. With help of test objects, the following sections demonstrate the features of application developed models and their capabilities. This section presents the main characteristics of test objects, as well as the simulation results obtained for them using MB software.

The Test-1 object is an example of the simplest object that has a consistent reliability structure and a constructive structure that has 6 levels of nesting (Fig. 2). It consists of 20 INR elements that are part of other structural elements of higher levels. INR elements are indicated by circles. All INR have the same reliability characteristics: $T_{ср}$ = 20000 h; ν = 1. The elements included in the set $E_в$ are hatched.

The Test-2 facility is an example of a low reliability facility that uses redundancy to improve reliability. The constructive structure of the object is shown in fig. 3. Three least reliable elements have a reserve: 11 (n=3), 12 (n=3) and 131 (n=2). All other elements are consistent (in the sense of reliability) of all the elements included in them. The total number of INR is 900. The elements included in set of recoverable elements are also marked with hatching.

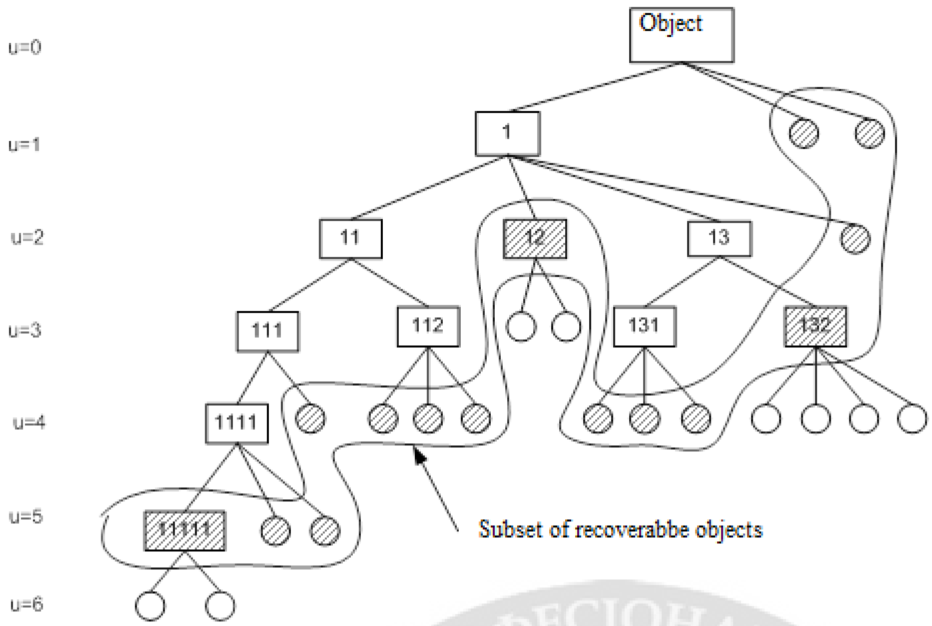

Figura 2 – Constructive structure of object Test-1

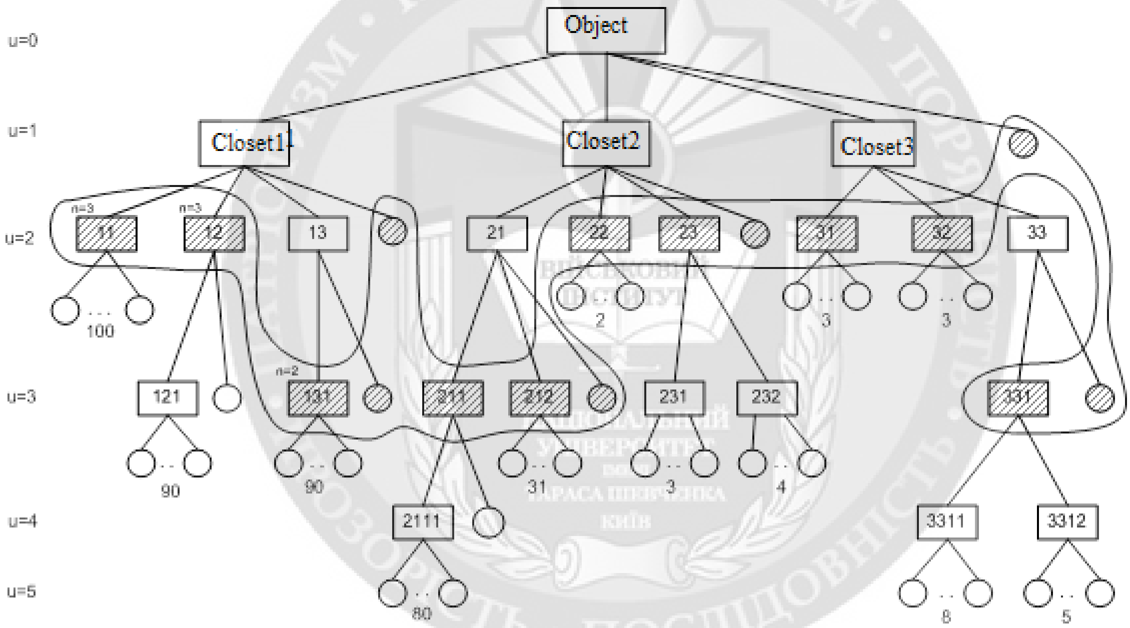

Figura 3 – Constructive structure of the object Test-2

Objects Test-3 and Test-4 are examples of objects that have a single-level constructive structure (Fig. 4). The number of all elements is 50. Elements of objects differ significantly in terms of their reliability. The object Test-3 is an example of an object with a high level of reliability, the object Test-4 is an example of an object with low reliability. Since the structural structure is single-level, all elements are INR, and all of them are recoverable.

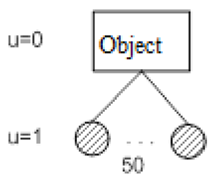

Figura 4 – Constructive structure of objects Test-3 and Test-4

For each of the test objects, a separate database was created, into which the necessary information about the object was entered. For all INR, the coefficient of variation is set to same, equal to 1.

Table 1 presents the main characteristics of test objects.

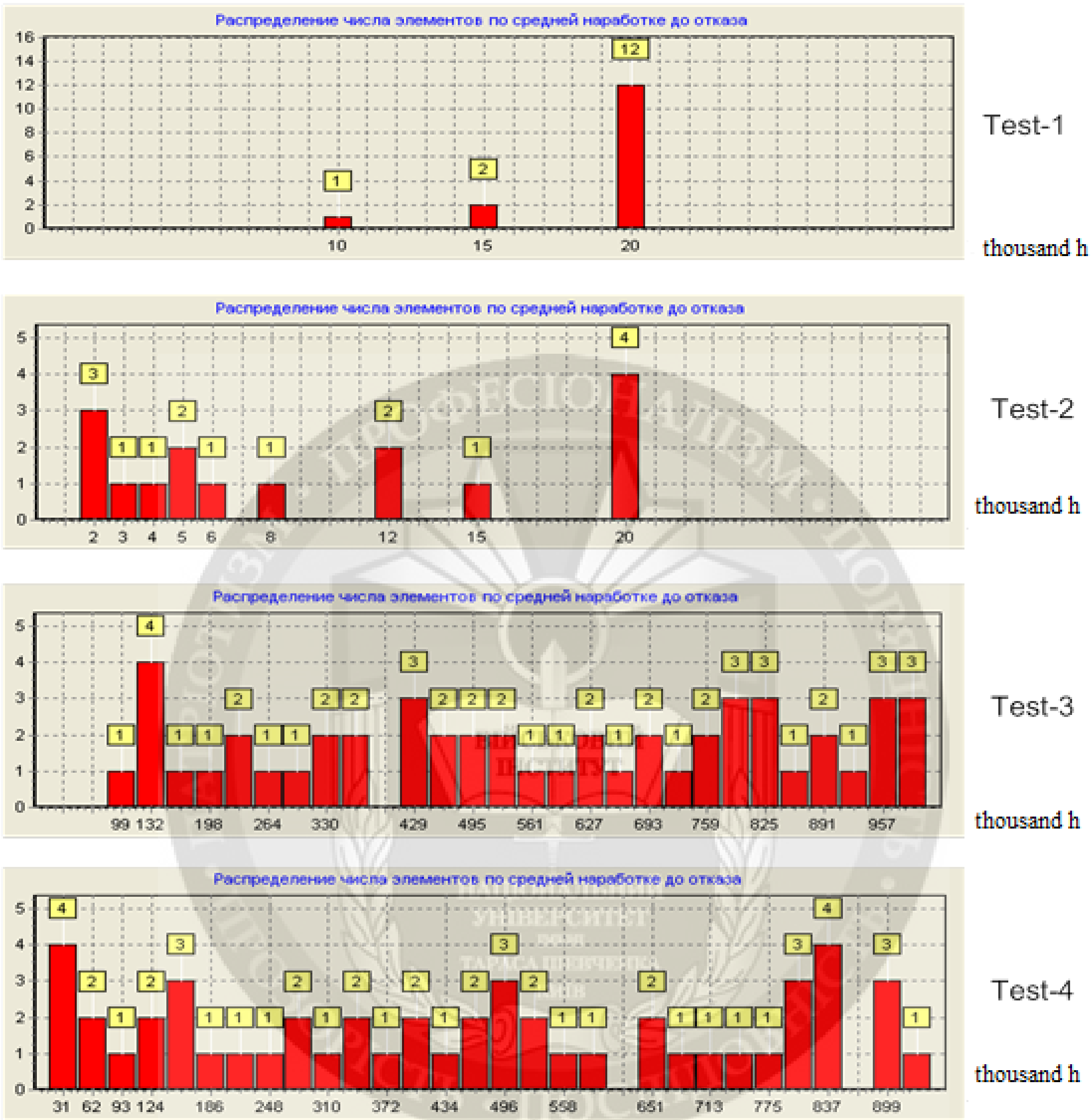

Figura 5 – Distribution histograms of average time to failure restored elements of test objects

Table 1

Characteristics of test objects

Object	Number of INR	Number of elements to be restored	Mean time to failure, h	Coefficient of variation
Test-1	20	15	4472,1	1,0
Test-2	900	16	745,8	0,726
Test-3	50	50	29930,7	1,0
Test-4	50	50	1783,2	1,0

The values of the reliability indicators given in table (mean time to failure and coefficient of variation) are formed automatically when DB program is launched and displayed on PC screen (Fig. 1). For object Test-2, the resulting coefficient of variation is not equal to 1 due to the presence of redundant groups elements in the object.

The most important characteristic of object, which affects the operational indicators of reliability and cost of the object, is distribution of reliability indicators object by its elements. On fig. 5 shows the distribution histograms of the mean time to failure elements of test objects. Grouping intervals are plotted horizontally, and the number of elements in the intervals vertically.

The histograms shown in the figures were formed using the model software in the “Database” mode.

Conclusions

1. The reliability model (RM) makes it possible to obtain estimates of the reliability indicators (RI) of individual structural elements and the object as a whole based on information about the RI of the elements of the lower structural level. The RM represents the hierarchical constructive structure of object. Structural elements of a certain *u*-th structural level are a sequential (in terms of reliability) connection of the elements of (u+1)-th level included in it. Separate structural elements can be a redundant group (parallel connection) of the same type of elements. Thus, with the help of RM, representation of a hierarchical structural structure is combined with an arbitrary serial-parallel reliability structure of an object, which is an acceptable representation for most technical objects encountered in practice.

2. *DN*-distribution is used as a failure model for all elements and the object as a whole. *DN* -distribution is considered to be an adequate model of gradual failures both for electronic products and for various mechanical units and elements. An important advantage of *DN*-distribution is also that its form is preserved during 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 that has a hierarchical structure.

3. The software implementation of RM was developed in the Delphi programming system. The hierarchical constructive structure of an object is programmatically represented using list data structures (TList lists are used). List elements are objects (instances of Delphi classes) representing individual structural elements of a technical object. Such objects encapsulate all the necessary data related to individual structural elements, including the parameters of *DN*-distributions of the time of failure.

Information about the composition, structure and reliability indicators of the elements of the object is stored in the database of the model built using tables of the InterBase DBMS format.

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ІНТЕРФЕЙС, ЩО ВИКОРИСТОВУЄТЬСЯ В МОДЕЛІ БЕЗВІДМОВНОСТІ

Складні технічні об'єкти у суспільстві мають виключно важливе значення. Такі об'єкти належать до класу об'єктів, що відновлюються тривалого багаторазового застосування. Вони, як правило, є дорогими та потребують значних витрат на їх експлуатацію. Для забезпечення необхідного рівня безвідмовності в процесі їх експлуатації зазвичай проводиться технічне обслуговування (ТО), суть якого полягає у своєчасній запобіжній заміні елементів, що знаходяться в стані перед відмовою.

Проблема полягає в тому, що при розробці таких об'єктів усі питання, пов'язані з ремонтопридатністю та технічним обслуговуванням, повинні вирішуватися вже на ранніх етапах проектування об'єкта. Якщо не передбачити заздалегідь необхідні апаратні та програмні засоби вбудованого контролю технічного стану (ТС) об'єкта, не розробити і не вбудувати в об'єкт технологію проведення ТО, то реалізувати в майбутньому можливий виграш у безвідмовності об'єкта за рахунок проведення ТО не вдасться. Оскільки всі ці питання повинні вирішуватися на етапі створення об'єкта (коли об'єкта ще немає), необхідні математичні моделі процесу ТО, за допомогою яких можна було б прорахувати можливий виграш у рівні безвідмовності об'єкта за рахунок проведення ТО, оцінити вартісні витрати. Потім на підставі таких розрахунків прийняти рішення про необхідність проведення ТО для даного типу об'єктів і, якщо таке рішення прийнято, розробити структуру системи ТО, вибрати найпідходящу стратегію, визначити її оптимальні параметри.

Ключові слова: технічне обслуговування, коефіцієнт варіації, безвідмовність об'єкта, комплектуючі елементи