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PROGNOSTICATION OF COMPOSITION AND RESOURCE OF GROUPMENT OF OBJECTS MILITARY TECHNIQUE

It is obvious that the component elements of various types have significantly different reliability indicators and various patterns of degradation processes leading to their failures. All these features of the considered objects of technology must be taken into account both in assessing (predicting) their reliability, and in determining the rules and regulations for their technical operation. The specified features of the objects of technology cause considerable difficulties in the construction of mathematical models necessary to evaluate and predict the reliability indicators and the cost of their operation.

In this artide deals has developed a mathematical model of the processes of spending and replenishing the resource of grouping of engineering objects. The model is intended for forecasting the composition and resource of the grouping for the nearest period of planning the operation of technical facilities. The following characteristics have been adopted as forecast indicators: -a vector whose elements are the values of the total residual resource of objects of different types at time t and - a vector whose elements are the number of objects of different types at time t.

This Indicators depend on the actions taken to replenish the group's resource (from supplies to the grouping of new equipment and scheduled repairs that restore the resource of the facilities). The developed mathematical model of the processes of expenditure and replenishment of the grouping resource will allow to implement the optimal software design.

Keywords: groupment of objects military technique, composition and resource, mathematical model, spending and replenishing the resource.

A characteristic feature of the objects of technicab military is the presence in their composition of a large number (tens, hundreds of thousands) of different types of component elements, the work of which is based on different physical principles, having different manufacturers, different levels of reliability, different patterns of wear and aging processes. A significant part of the components is electronic products (microcircuits, semiconductor devices, capacitors, electrical connectors, etc.). The other part of the elements are mechanical and electromechanical units (reducers, electric motors), pneumatic and hydraulic drives, etc. It is assumed that a certain general function is defined for the object of engineering in accordance with its purpose, and signs of the ability (or inoperability) of the object to perform this function are determined.

The considered technical objects belong to the class of recoverable objects of long-term repeated use. As a rule, they are expensive and require significant costs for their operation. To ensure the required level of reliability in the course of their operation, maintenance and repair (ToiR) is usually carried out, the essence of which is the timely restoration of the operable condition of the facility and the preventive replacement of elements that are in the pre-toxic state.

Accession. We arranged under the groupment of objects of technique to understand the great number of technical objects, placed on certain territory and intended for the performance of some general objective. Every object of technique, entering in the complement of groupment there is a difficult technical device, executes certain tasks within the framework of general aims, for achievement of which a groupment is intended. On the level of reliability of separate objects efficiency of functioning of groupment depends on the whole. The examples of groupment can serve as great number of the surface radio-location stations, stations of radio electronic fight, elements of zenithal-rocket complexes, systems of the automated management etc.

All objects, entering in the complement of groupment, have a different remaining resource and, consequently, different level of reliability. After expiration of the set resource an object is subject to the withdrawal from composition of groupment, because the level of his reliability is impermissible subzero.

Us informative and functional connections between the objects of groupment and nature of the tasks decided by them will not interest. For us important will be only two descriptions of groupment is her composition [1,2] and resource of each of objects, included in a groupment [3,4]. Thus we come from that, if composition of groupment corresponds to the required composition, and level of faultlessness of every object of not below set value, then a groupment can execute all tasks in accordance with her destiny with the required quality. It is thus assumed that, if the resource of separate object is outspent, then his indexes of faultlessness dissatisfy to the requirements. Thus, us the concrete tasks of groupment and indexes of her efficiency will not interest, and will interest only the degree of accordance of composition of groupment and resource of her elements to the requirements set for this groupment.

The basic part. In the large systems the groupment of objects of technique usually has a certain organizational structure - can plug in itself the groupments of more low organizational levels. From the point of view of going near development of models for us indifferently, what level this groupment behaves to. Therefore, in further consideration we will not distinguish the levels of groupment, will suppose that the question is about the groupment of any level.

We will enter next denotations:

$\boldsymbol{N}(t) = \{N_i(t); i = \overline{1, N_{ТИП}}\}$ - vector, qualificatory composition of groupment in the moment of time of t, where /- number of objects of technique of i of th type ($N_{ТИП}$ - number of different types of objects);

$\boldsymbol{R}_{\Sigma}(t) = \{R_{\Sigma i}(t); i = \overline{1, N_{ТИП}}\}$ - vector, qualificatory the resource of groupment, in which $R_{\Sigma i}(t)$ - total resource of objects of *i* of th type.

The type of object of technique determines his functional destiny. To one type near on destiny technical objects can be taken. In maximum case all objects of this groupment can be разнотипными. Just can be examined groupment of the same type objects. A division of objects on types is a prerogative of user.

An amount of objects of technique of i of th type $N_i(t)$ is a casual function with single gallops in casual moments of time of changes of composition of groupment (fig. 1). Positive gallops correspond to the moments of entering time groupment of new or returning from repair objects, and negative - to the moments of time of mounting of objects in repair or списания1. A function /can be presented by next expression:

$$N_i(t) = \sum_{j \in \boldsymbol{J}_i} n_j(t), \qquad (1)$$

where $n_j(t)$ - single function, taking on values 1 or 0:

$n_j(t) = 1$- if j a th object in the moment of time of t is in composition a groupment and used on (or is in a state of readiness to application on purpose) purpose; $n_j(t) = 0$ - if j a th object is excluded from composition of groupment for implementation of планового repair or written-off; $\boldsymbol{J}_i$ - great number of numbers of all objects of i of th type, present in composition a groupment.

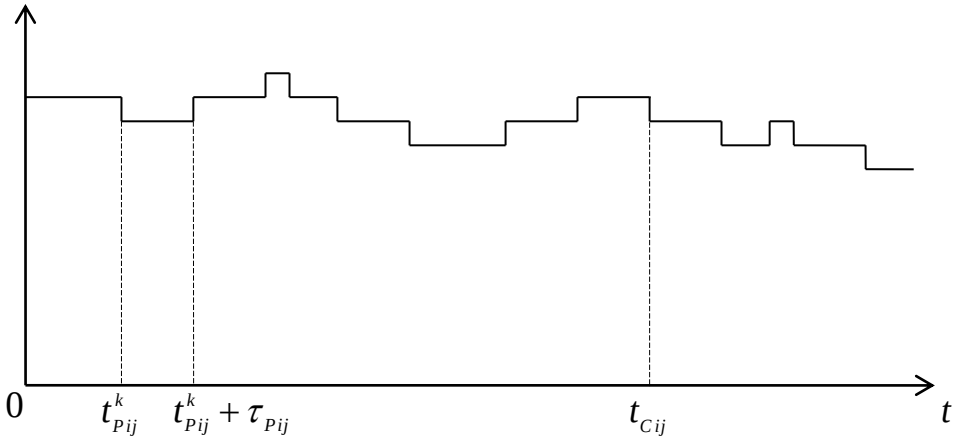

Fig. 1. Characteristic type of function $N_i(t)$

On a fig. 1, which the characteristic type of function $N_i(t)$ is shown on, next denotations are used: t^k_{Pij} - time of dispatch in k th repair; τ_{Pij} - duration of repair; t_{Cij} - time of writing of j of th object.

We will suppose that the moments of time of changes of composition of groupment (gallops of function) are determined by the processes of expense and filling in of resource of separate objects of technique of groupment.

The function of total resource of objects of i of th type $R_{\Sigma i}(t)$ is determined as a sum of next kind :

$$R_{\Sigma i}(t) = \sum_{j \in J_i} R_j(t), \qquad (2)$$

where $R_j(t)$ - resource of *j* of th object in the moment of time of t.

A function $R_j(t)$ is description of process of expense and filling in of resource of j of th object. On a fig. 2 the exemplary type of function is shown $R_{\Sigma i}(t)$. Positive gallops (breaks) of function correspond to the moments of entering time t^k_{Pij} groupment of objects after their repair or new objects of technique.

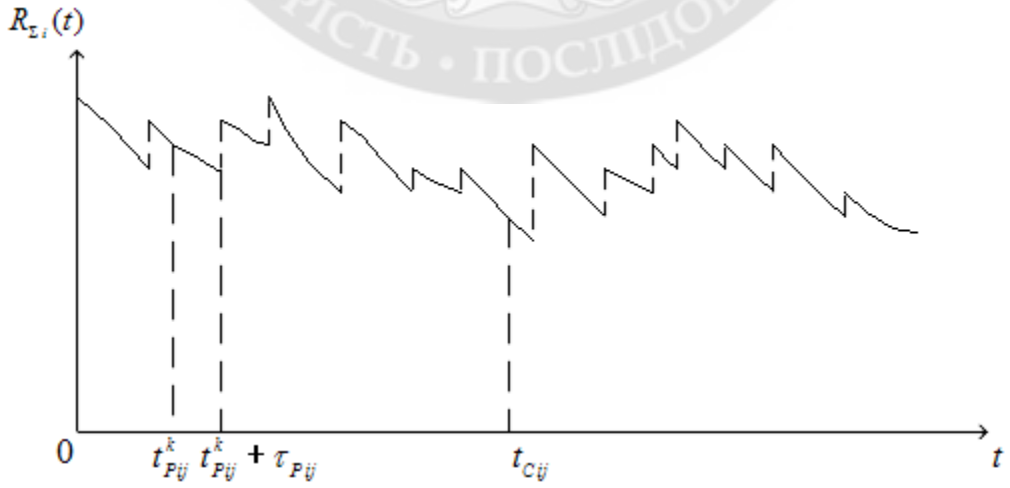

Fig. 2. Characteristic type of function $R_{\Sigma i}(t)$

Speed of decrease of function in intervals between breaks is determined by total intensity of expense of resource of all objects of this type, present at this time crouching.

Requirement to composition and resource of groupment set by such terms:

$$N_i(t) \le N_i^{TP}; \quad (3\ a)$$

$$R_{\Sigma i}(t) \le R_{\Sigma i}^{TP}, \quad (3\ b)$$

where N_i^{TP} and $R_{\Sigma i}^{TP}$ - required values of number of objects of i of th type and their total resource, which the necessary level of efficiency of groupment is provided at.

Clear physical sense has a requirement to composition of groupment (3 a) - if the number of objects of this type crouching will go down below possible, then efficiency of groupment will not correspond required. Therefore there are not questions in connection with determination of value N_i^{TP} - it is a prerogative of the "system" which is provided by this groupment.

A requirement to the total resource of objects (3b) determines the "margin of safety" of groupment the family - determines, сколь long there can be a groupment with the required efficiency. How to set a size $R_{\Sigma i}^{TP}$, strictly speaking, not clear. However and to give it would be not right up the index of total resource $R_{\Sigma i}(t)$, because he carries in itself important information about the supply of "viability" of groupment.

In practice a size $R_{\Sigma i}^{TP}$ is usually set as follows:

$$R_{\Sigma i}^{TP} = R_{\Sigma i}^{ШТ} \cdot \alpha_i, \quad (4)$$

where $R_{\Sigma i}^{ШТ}$ - total resource of all objects of *i* of th type, which must be in composition a groupment according to her regular composition, on condition that all objects new (a size $R_{\Sigma i}^{ШТ}$ is named yet a table resource); α_i - coefficient the size of which determines the relative level of the required supply of resource (a size α_i is determined a posteriori by exploitations and in practice $\alpha_i = 0{,}5$ set usually).

By analogy with LS of separate object of technique will enter the concept of LS for a groupment as follows. Under the maximum state of groupment of objects of technique will understand such her state, at which composition of groupment, including objects, temporally being under плановом repair, went down to the impermissible level which the required efficiency of groupment is not provided at.

Formally the criterion of LS of groupment can be defined by a next condition:

$$\boldsymbol{N}'(t) < \boldsymbol{N}^{TP}, \quad (5)$$

where $\boldsymbol{N}'(t) = \{N_i'(t); i = \overline{1, N_{ТИП}}\}$ - vector in which $N_i'(t)$ - number of objects of i of th type, present in composition a groupment in the moment of time of t, including all objects, being under repair; $\boldsymbol{N}^{TP} = \{N_i^{TP}; i = \overline{1, N_{ТИП}}\}$ - vector in which N_i^{TP} - the required amount of objects of i of th type crouching.

It is assumed that vectorial inequality (8.5) is executed in case that even one of inequalities $N_i'(t) < N_i^{TP}$ ($i = \overline{1, N_{ТИП}}$) is executed.

On the basis of criterion (5) it is possible to enter the concept of resource of groupment as follows. Under the resource of groupment of objects of technique will understand calendar duration of exploitation of groupment to the offensive of (5) on condition of implementation on all objects of all scheduled repairs, foreseen operating scheduled maintebabce systems. The size of resource of groupment will designate $T_{ГР}$. We can say that the resource grouping determines the duration of its existence, provided that new objects of technology in the grouping do not arrive.

Obviously, that can be entered also and concept of resource of groupment on i to the th type of objects of technique, the size of which $T_{ГРi}$ is determined as a decision of next equalization :

$$N_i(T_{ГРi}) = N_i^{ТР}. \quad (6)$$

Taking into account it the resource of groupment $T_{ГР}$ can be defined as follows:

$$T_{ГР} = \min_i T_{ГРi}. \quad (7)$$

The entered concept of resource of groupment is not so synonymous and simple, as a concept of resource of separate object of technique. In most cases groupments stop to exist not because their resource is outspent, and because aims changed, for achievement of which they were created, or technologies of achievement of these aims changed radically.

Nevertheless, the concept of resource of groupment appears useful because the periodic estimation of resource of groupment during her exploitation allows in good time to plan and realize measures on maintenance of some unreduced supply of resource of groupment, due to what to guarantee non-admission in the near future allegedly "sudden" fall-off of efficiency and, possibly, catastrophe related to it. The considered going near determination of resource of groupment was offered before in works [5-7].

Mathematical model of process of expense and filling in of resource of groupment of objects. Now we will pass to consideration of process of expense and filling in of resource at the level of groupment of objects of technique. As it was already certain, this process is described by indexes $N_i(t)$ and $R_{\Sigma i}(t)$, determined separately for the different types of objects [8-10]:

$N_i(t)$ - number of objects of i of th type, present crouching in the moment of time of *t*;

$R_{\Sigma i}(t)$ - total (remaining) resource of objects of i of th type in the moment of time of *t*.

Taking into account the parameters entered higher for functions $N_i(t)$ and $R_{\Sigma i}(t)$ now instead of (1) and (2) will write down such expressions:

$$N_i(t/\mathbf{\Pi}_{Pi}, \mathbf{\Pi}_{Ci}) = \sum_{j \in \mathbf{J}_{0i}} n_{ij}(t/\Pi_{Pij}, \Pi_{Cij});$$

$$R_{\Sigma i}(t/\mathbf{S}_i(0), \overline{\eta}_i, \mathbf{\Pi}_{Pi}, \mathbf{\Pi}_{Ci}) = \sum_{j \in \mathbf{J}_{0i}} R_{ij}(t/S_{ij}(0), \overline{\eta}_{ij}, \Pi_{Pij}, \Pi_{Cij}), \quad (8)$$

where $\mathbf{\Pi}_{Pi} = \bigcup_{j \in \mathbf{J}_{0i}} \Pi_{Pij}$ - plan of repairs of objects of i of th type; $\mathbf{\Pi}_{Ci} = \bigcup_{j \in \mathbf{J}_{0i}} \Pi_{Cij}$ - plan of writing of objects of i of th type; $\mathbf{S}_i(0) = \{S_{ij}(0);\ j \in \mathbf{J}_{0i}\}$ - vector, describing the state of objects of i of th type at the beginning of the examined interval of exploitation [0, $T_э$]; $\overline{\boldsymbol{\eta}}_i = \{\overline{\eta}_{ij};\ j \in \mathbf{J}_{0i}\}$ - vector, presenting intensities of expense of resource of objects of i of th type; $\mathbf{J}_{0i}$ - great number of numbers of all objects of i of th type, which are in composition a groupment in the moment of time of $t = 0$.

Dependences (8) jointly determine the *model of process of expense and filling in of resource of groupment* of objects of technique (for i of th type of objects) on the interval of exploitation [0, $T_э$]. This functions are prognosis estimations of indexes of the state of groupment on a forthcoming period exploitations, depending on parameters $\overline{\boldsymbol{\eta}}_i$, $\mathbf{\Pi}_{Pi}$ and $\mathbf{\Pi}_{Ci}$. Parameter $\mathbf{S}_i(0)$ describes the initial (technical) state of objects and, the same, determines the initial conditions of process of expense and filling in of resource of groupment. A parameter $\overline{\boldsymbol{\eta}}_i$ determines the expected (forecast) external affecting process, and is considered set. Parameters $\mathbf{\Pi}_{Pi}$ and $\mathbf{\Pi}_{Ci}$ are the guided parameters.

Parameters $\mathbf{\Pi}_{Pi}$ and $\mathbf{\Pi}_{Ci}$ will consider normative (and to designate $\mathbf{\Pi}_{Pi}^{H}$ and $\mathbf{\Pi}_{Ci}^{H}$), if for all objects of groupment terms and types of плановых repairs are certain in accordance with the parameters of SRS ($\mathbf{\Pi}_{Pi}^{H} = \{\Pi_{Pij}^{H};\ j \in \mathbf{J}_i\}$ and $\mathbf{\Pi}_{Ci}^{H} = \{\Pi_{Cij}^{H};\ j \in \mathbf{J}_i\}$ set for this groupment.

Beginning to bustle forward, will mark that normative plans Π_{Pi}^{H} and Π_{Ci}^{H}, which on determination are assumed by optimal for every object of technique individually, rarely appear similarly optimal and for a groupment on the whole, and basic destiny of the developed model just and consists of that, with her help to find plans Π_{Pi} and Π_{Ci}, optimal for a groupment.

Until now we examined the process of expense and filling in of resource of groupment in supposition, that new objects groupment do not enter. In actual fact in the real groupments for maintenance of the required composition periodically (according to plan) instead of copied off the new objects of technique are supplied.2 Deliveries in the groupment of new standards of objects instead of copied off are the natural method of extension of resource of groupment.

We will enter denotation $\Pi_{Hi} = \{t_{Hij};\ j \in \boldsymbol{J}_{Hi}\}$ - great number, qualificatory the plan of deliveries in the groupment of new objects of i of th type in which :

t_{Hij} - entering time groupment of j of th new object of i of th type; $\boldsymbol{J}_{Hi}$ - great number of numbers of new objects which it is planned to put in a groupment in the examined period of exploitation.

Taking into account this expression (8), presenting the model of process of expense and filling in of resource of groupment, it is now necessary to rewrite as follows:

$$N_i(t/\boldsymbol{\Pi}_{Pi},\boldsymbol{\Pi}_{Ci},\boldsymbol{\Pi}_{Hi}) = \sum_{j\in\boldsymbol{J}_{0i}\cup\boldsymbol{J}_{Hi}} n_{ij}(t/\Pi_{Pij},\Pi_{Cij}) + \sum_{j\in\boldsymbol{J}_{Hi}} n_{ij}(t/\Pi_{Hij});$$

$$R_{\Sigma i}(t/\boldsymbol{S}_i(0),\overline{\boldsymbol{\eta}}_i,\boldsymbol{\Pi}_{Pi},\boldsymbol{\Pi}_{Ci},\boldsymbol{\Pi}_{Hi}) = \sum_{j\in\boldsymbol{J}_{0i}\cup\boldsymbol{J}_{Hi}} R_{ij}(t/S_{ij}(0),\overline{\eta}_{ij},\Pi_{Pij},\Pi_{Cij}) + \sum_{j\in\boldsymbol{J}_{Hi}} R_{ij}(t/S_{ij}(t_{Hij}),\overline{\eta}_{ij},\Pi_{Hij}), \quad (9)$$

where $\Pi_{Hi} = \bigcup_{j\in\boldsymbol{J}_{Hi}} \Pi_{Hij} = \bigcup_{j\in\boldsymbol{J}_{Hi}} \{t_{Hij}\}$;

$$\boldsymbol{S}_i(0) = \{S_{ij}(0);\ j\in\boldsymbol{J}_{0i}\}\cup\{S_{ij}(t_{Hij});\ j\in\boldsymbol{J}_{Hi}\};$$

$$\overline{\boldsymbol{\eta}}_i = \{\overline{\eta}_{ij};\ j\in\boldsymbol{J}_{0i}\}\cup\{\overline{\eta}_{ij};\ j\in\boldsymbol{J}_{Hi}\}.$$

Expressions (9) are clarification the before brought expressions (8.23) over and are a mathematical model of process of expense and filling in of resource of groupment taking into account supplying with the new objects of technique.

The guided parameters of this model are plans Π_{Pi}, Π_{Ci} and Π_{Hi}. Parameter $\overline{\boldsymbol{\eta}}_i$ is partly guided, for example, due to the redistribution of limit of expense of resource between the separate objects of groupment. The non-obvious out of control parameters of model are parameters of SRS, because in her normative requirements to the terms of repairs, degrees of filling in of resource are certain after repair, initial resource for the new objects of technique.

Questions of optimization of plans Π_{Pi}, Π_{Ci} and Π_{Hi} will be considered later.

High-quality analysis of model of process of expense and filling in of resource of groupment of objects. Appears expedient at the beginning to produce the high-quality analysis of the supposed character of dependence of functions (8.24) from parameters $\boldsymbol{S}_i(0)$ and $\overline{\boldsymbol{\eta}}_i$ on condition that the realized plans $\tilde{\Pi}_{Pi}$, $\tilde{\Pi}_{Ci}$ exactly correspond to the normative plans Π_{Pi}^{H} and Π_{Ci}^{H}, and the new objects of technique groupment do not enter ($\tilde{\Pi}_{Hi} = \varnothing$). It will allow to investigate influence of these parameters, as, "in a clean kind", id est, eliminating influence of the guided parameters.

For short of function (8.24) will designate $N_i(t/\ldots)$ and $R_{\Sigma i}(t/\ldots)$.

Parameters $\boldsymbol{S}_i(0)$ and $\overline{\boldsymbol{\eta}_i}$ are vectors and, obviously, it is senseless to try to examine all great number of their possible values. It is expedient to enter some small number of classes of their possible values, having clear physical interpretation, and then at an analysis to operate these classes. We will enter such classes as follows.

For a parameter $\boldsymbol{S}_i(0)$ ***will enter three classes,*** presenting the most characteristic states of resource of groupment. We will name them conditionally "new", "old" and "balanced".

To the class "new" will take such groupments in which the resource of all objects is near to the normative initial resource of new object.

To the class "old" will take a groupment in case that most objects of groupment already practically used up the resource and in the near time subject to repair or writing.

Groupment will arrange to name "balanced", if the resource of objects approximately is evenly up-diffused between the objects of groupment in the range of his possible values, id est from 0 to $R_i^{(0)}$.

The entered classes of the states of resource of groupment formally can be presented by fuzzy sets, and attributing of concrete vector $\boldsymbol{S}_i(0)$ to one or another class can be carried out by an expert. Thus the most informing evident classification sign which an expert can make decision on the basis of is a histogram of corresponding distribution. For presentation of distribution of resource, set by a parameter $\boldsymbol{S}_i(0)$, use a histogram, determined by next values:

$$g_R(R_k) = \frac{\Delta n_k}{n}, \tag{10}$$

where R_k - discrete value of resource, equal $R_k = k \cdot \Delta R$, where ΔR - size of interval, on which the range of definition of histogram is broken [0, $R_i^{(0)}$]

($k = \overline{1, k_{\max}}$, $k_{\max}$ - amount of intervals which a histogram is built on); *n - is a number of objects crouching;* Δn_k - number of objects the resource of which gets in an interval $\Delta R_k = (R_{k-1}, R_k]$ ($\sum_k \Delta n_k = n$).

Amount of intervals which a histogram is built on can be determined the on methods, accepted for the construction of histograms of statistical distributions [11].

On a fig. 8.5 the exemplary type of characteristic histograms $g_R(R_k)$, which can be accepted as standards, presenting entered higher three classes, is shown.

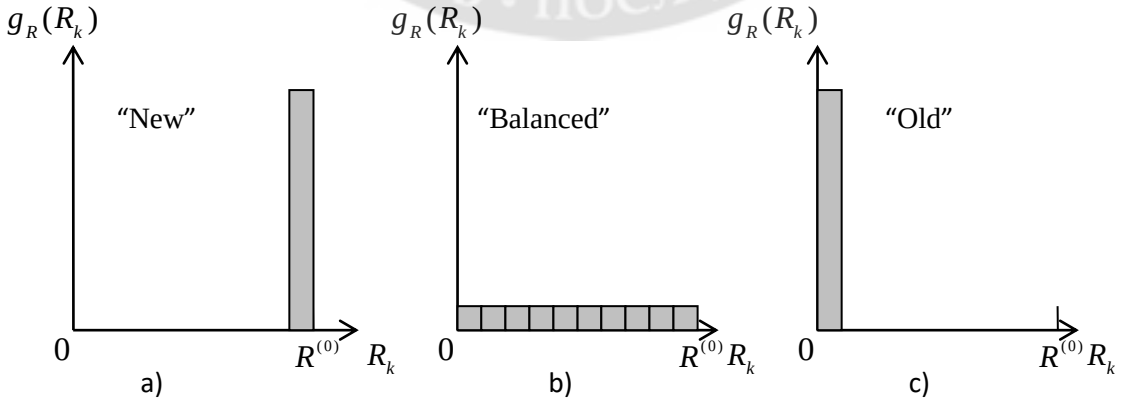

Fig. 3. Exemplary type of standard histograms for three classes of characteristic distributions of resource of groupment of objects of technique

Obviously, that for the real groupments (values of parameter $\boldsymbol{S}_i(0)$) the type of histograms can substantially differ from "standard" and occupy the arbitrary transient state between these standards. In practice most often there are groupments with distributions of resource, which are located nearer to the class "old".

It is possible to enter the classes of the states analogical character for a parameter $\overline{\boldsymbol{\eta}}_i$ - vector of intensities of expense of resource.

For a parameter $\overline{\boldsymbol{\eta}}_i$ will enter two classes, which will name conditionally "even distribution" and "concentrated distribution", because exactly the degree of equitability of values $\overline{\eta}_i$ can substantially influence on character of functions $N_i(t/\ldots)$ and $R_{\Sigma i}(t/\ldots)$. Information about the degree of equitability appears the histogram of next kind:

$$g_\eta(\eta_k) = \frac{\Delta n_k}{n}, \tag{11}$$

where η_k - discrete value of intensity of expense of resource, equal $\eta_k = k \cdot \Delta\eta$, where $\Delta\eta$ - size of interval, on which the range of definition of histogram [0, η_{max}]. $\eta_{max} = 1$, that corresponds to the mode of continuous operations of object; Δn_k - number of objects for which intensity of expense of resource gets in an interval $\Delta\eta_k = [\overline{\eta}_{k-1}, \overline{\eta}_k]$, where k is a number of interval ($\sum_k \Delta n_k = n$/).

On a fig. 4 the exemplary type of histograms $g_\eta(\eta_k)$ which can be taken for standard distributions is shown.

Position of peak of concentration while will consider not substantial, because it will influence only on distribution of number of objects which arrive at ПС on the sign of exhausting of resource (remaining work) and on the sign of expiration of tenure of employment.

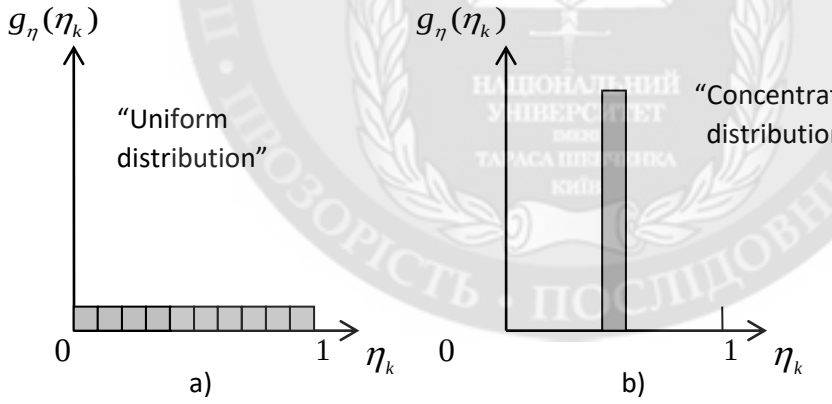

Fig. 4. Exemplary type of standard histograms for two classes of characteristic distributions of intensity of expense of resource

Typical for the real groupments is distribution near to "concentrated".

The entered classification for parameters $\boldsymbol{S}_i(0)$ (and actually - for $\boldsymbol{R}_i(0)$) and $\overline{\boldsymbol{\eta}}_i$ for us is not so important as such, and important only for greater definiteness of the entered concepts (classes) which we will use in a subsequent high-quality analysis. Therefore, we will not build fuzzy sets for presentation of the classes entered higher, and will not deepen in fineness of correct procedures classifications which would require to be used for determination of fuzzy sets (it vast literature is sacred to, for example, [12,13]).

Now we will begin an analysis, the purpose of which consists in that, logically to predict, directly, as will "behave" to the function $N_i(t/...)$ and $R_{\Sigma i}(t/...)$, presenting a process expenses and filling in of resource of groupment, at one or another "standard" states of parameters $\boldsymbol{S}_i(0)$ and $\overline{\eta_i}$.

If at $t=0$ groupment "new" (new are all objects included in a groupment), and intensities of expense of resource of separate objects of groupment are approximately identical ("concentrated distribution" of intensities $\overline{\eta_i}$) here, then character of functions $N_i(t/...)$ and $R_{\Sigma i}(t/...)$ must be approximately such, as it is shown on a fig. 5.

Clear, that in this case all objects of groupment arrive at LS approximately at one and the same time and simultaneous realization of repair is required at once plenty of objects. As a result a groupment becomes disabled (or limitedly capable of working) at this time, because the remaining crouching amount of objects can not provide her normal functioning. Approximately in the same period the total resource of groupment goes down considerably below required.

On a fig. 5 charts resulted for a case, when the parameters of SRS for this type of objects are foresee realization during time of "life" of object of two repairs.

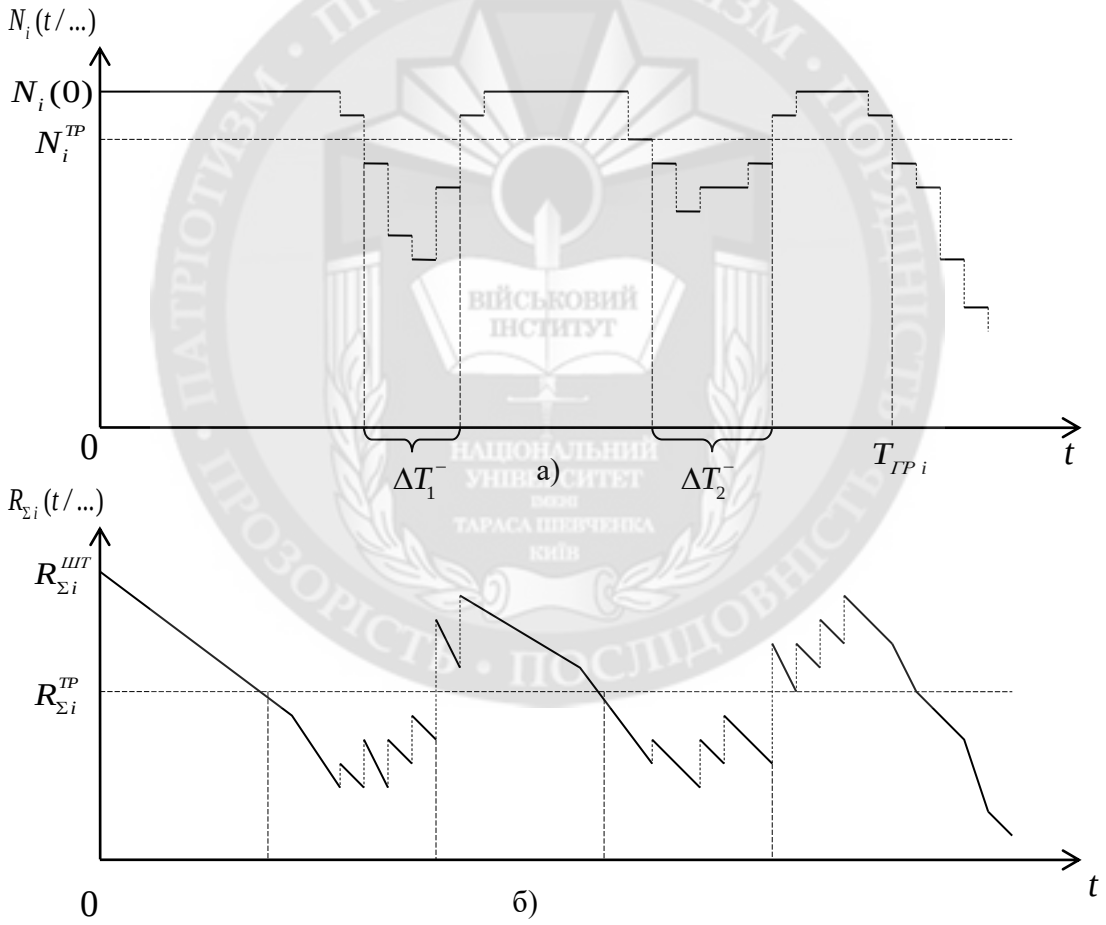

Fig. 5. Type of functions $N_i(t/...)$ and $R_{\Sigma i}(t/...)$ in case if at $t=0$ a groupment is "new" and intensities of expense of resource of objects are approximately identical

If a groupment is similarly "new", but intensity of expense of resource is up-diffused between separate objects approximately evenly ("even distribution" of intensities $\overline{\eta_i}$), then functions $N_i(t/...)$ and $R_{\Sigma i}(t/...)$ will have such kind approximately.

Obviously, that during organization of exploitation of groupments it is necessary to aspire to such state of resource of groupment, at which the number of capable of working objects crouching and middle level of total resource is supported on the average approximately by permanent [14]. Such process of expense and filling in of resource of groupment state will arrange to name "balanced". In this state a dynamic equilibrium comes between the process of expense and process of filling in of resource.

If a groupment is "old", then a process of expense and filling in of resource, as a rule, is "unstable".

The resource $T_{ГР\,\text{і}}$ of "old" groupment always substantially less than, than resource of "new" groupment. In the case of "unstable" process of expense and filling in of resource of groupment the concept of resource, in general speaking, loses primordial strict sense, because it appears that within the limits of resource ПС can come and "keep" oneself aloof several times.

Therefore at the estimation of the state of resource of groupment the not so much estimation of size of resource $T_{ГР\,\text{і}}$ is important, how many estimation of degree of her mental instability and prognosis of "dangerous" time domains in which composition of groupment of c will go down large probability (or with inevitability) to the impermissible low level.

The produced short high-quality analysis of model shows, to what anomalies or even catastrophic consequences would bring an out-of-control process over of expense and filling in of resource of groupment. An obvious conclusion ensues from all сказанного, that for providing of normal operating of groupment conditions the optimal planning of measures done early and periodically specified is required on filling in of resource of objects of groupment.

Development of algorithms, realizing the considered mathematical model of processes of expense and filling in of resource of groupment is assumed in subsequent, it will allow with the use of such model to decide the practical tasks of management composition and resource of groupments of technical objects.

Conclusions

1. A mathematical model, intended for prognostication of processes of expense and filling in of resource in the groupments of objects of technique, is worked out in article. As indexes of the state of groupment two vectorial descriptions are certain:

$\boldsymbol{N}(t/\boldsymbol{\Pi}_P,\boldsymbol{\Pi}_C,\boldsymbol{\Pi}_H)$ - composition of groupment, and

$\boldsymbol{R}_\Sigma(t/\boldsymbol{S}(0),\overline{\eta},\boldsymbol{\Pi}_P,\boldsymbol{\Pi}_C,\boldsymbol{\Pi}_H)$ - resource of groupment,

2. A parameter $\boldsymbol{S}(0)$ imagines information current technical status of objects of groupment (related to the moment of time $t=0$). A parameter $\overline{\eta}$ is the partly guided parameter of model, her values are mainly determined by external (in relation to a groupment) factors Forming of optimal plans $\boldsymbol{\Pi}_P$, $\boldsymbol{\Pi}_C$ and $\boldsymbol{\Pi}_H$, in fact, and there is destiny of the created model.

On the method of construction this model behaves to the class of the determined simulation models. Software, realizing this model development is presently produced.

3. High-quality research of the expected conduct of functions $\boldsymbol{N}(t/\boldsymbol{\Pi}_P,\boldsymbol{\Pi}_C,\boldsymbol{\Pi}_H)$ and $\boldsymbol{R}_\Sigma(t/\boldsymbol{S}(0),\overline{\eta},\boldsymbol{\Pi}_P,\boldsymbol{\Pi}_C,\boldsymbol{\Pi}_H)$ is produced and /at the different characteristic states of parameters $\boldsymbol{S}(0)$ and $\overline{\eta}$ on condition that the guided parameters (plans) $\boldsymbol{\Pi}_P$, $\boldsymbol{\Pi}_C$ and $\boldsymbol{\Pi}_H$ determined strictly in accordance with the norms of SRS. A concept is entered the "balanced" state of resource of groupment, at which provided the most favorable terms of providing of exploitation of objects of groupment.

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ПРОГНОЗУВАННЯ СКЛАДУ І РЕСУРСУ УГРУПОВАННЯ ОБ'ЄКТІВ ВІЙСЬКОВОЇ ТЕХНІКИ

Характерною особливістю об'єктів військової техніки є наявність в їх складі великої кількості (десятки, сотні тисяч) різнотипних комплектуючих елементів, робота яких заснована на різних фізичних принципах, що мають різних виробників, різний рівень надійності, різні закономірності процесів зносу і старіння. Значна частина комплектуючих елементів є виробами електронної техніки (мікросхеми, напівпровідникові прилади, конденсатори, електричні роз'єми і т.д.). Інша частина елементів - це механічні та електромеханічні вузли (редуктори, електродвигуни), пневматичні і гідравлічні приводи і т.п. Передбачається, що для об'єкта

військової техніки визначена деяка загальна функція відповідно до його призначенням, і визначені ознаки працездатності (або непрацездатності) об'єкта щодо виконання цієї функції.

Наведено докладні приклади розв'язання обох задач.

У даній статті розроблена математична модель процесів витрачання та поповнення ресурсу угруповання об'єктів військової техніки. Модель призначена для прогнозування складу та ресурсу угруповання на найближчий період планування експлуатації технічних об'єктів. Як прогнозованих показників прийняті такі характеристики:

вектор, елементами якого є значення сумарного залишкового ресурсу об'єктів різних типів в момент часу; вектор, елементами якого є кількість об'єктів різних типів в момент часу. Дані показники залежать від дій, що робляться по заповненню ресурсу угруповання (від поставок в угруповання нових об'єктів техніки і проведення планових ремонтів, відновлюють ресурс об'єктів). Розроблена математична модель процесів витрачання та поповнення ресурсу угруповання дозволить здійснювати оптимальне планування забезпечення ЗІПом.

Ключові слова: угруповання об'єктів військової техніки, склад і ресурс, математична модель, витрачання та поповнення ресурсу.

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ПРОГНОЗИРОВАНИЕ СОСТАВА И РЕСУРСА ГРУППИРОВКИ ОБЪЕКТОВ ВОЕННОЙ ТЕХНИКИ

Характерной особенностью объектов военной техники является наличие в их составе большого количества (десятки, сотни тысяч) разнотипных комплектующих элементов, работа которых основана на различных физических принципах, имеющих различных производителей, различный уровень надежности, различные закономерности процессов износа и старения. Значительная часть комплектующих элементов является изделиями электронной техники (микросхемы, полупроводниковые приборы, конденсаторы, электрические разъемы и т.д.). Другая часть элементов – это механические и электромеханические узлы (редукторы, электродвигатели), пневматические и гидравлические приводы и т.п. Предполагается, что для объекта военной техники определена некоторая общая функция в соответствии с его предназначением, и определены признаки работоспособности (или неработоспособности) объекта относительно выполнения этой функции.

Приведены подробные примеры решения обеих задач.

В данной статье разработана математическая модель процессов расходования и восполнения ресурса группировки объектов военной техники. Модель предназначена для прогнозирования состава и ресурса группировки на ближайший период планирования эксплуатации технических объектов. В качестве прогнозируемых показателей приняты такие характеристики:

вектор, элементами которого являются значения суммарного остаточного ресурса объектов различных типов в момент времени; вектор, элементами которого является количество объектов различных типов в момент времени. Данные показатели зависят от предпринимаемых действий по восполнению ресурса группировки (от поставок в группировку новых объектов техники и проведения плановых ремонтов, восстанавливающих ресурс объектов). Разработанная математическая модель процессов расходования и восполнения ресурса группировки позволит осуществлять оптимальное планирование обеспечение ЗИПом.

Ключевые слова: группировка объектов военной техники, состав и ресурс, математическая модель, расходование и пополнение ресурса.