УДС 681.3 Ph.D. **Tolok.V.I.**
(Military institute of Taras Shevchenko National University of Kyiv)

MODELLING THE USEFUL LIFE EXHAUSTION (DEPRECIATION) AND RESTORATION PROCESSES OF THE OF MILITARY EQUIPMENT GROUPAGES

The article deals with the mathematical model of the military equipment (ME) useful life exhaustion and restoration processes. A military equipment groupage is understood as a multitude of various different objects that are used for completing a similar task. Accepted quality measures for the military equipment useful life exhaustion and restoration processes are the quantity of the objects in a given groupage and the total useful life, determined separately for different types of military equipment. Parameters for this model are military equipment maintenance, disposal and procurement plans, as well as established statutory requirements. The concepts of limiting state and useful life of a groupage were introduced.

This model allows to predict the structure and the useful life of the groupage in the forthcoming period of time, evaluate the efficiency of the enacted useful life restoration plans and improve them.

Keywords: military equipment groupage, useful life of a military equipment groupage, maintenance, disposal and procurement plans for the separate items in the equipment groupage.

Introduction and Problem Statement. Sufficient attention was given to the issues of exhaustion and restoration of the useful life of a single military equipment item, e. g. in numerous research projects [1–5], including the works of the author [6–9]. At the same time, it is worth noting that military equipment is usually used to carry out missions, within formations, units and detachments. Therefore, it is important to analyze the useful life of military equipment not by each separate item, but rather of a military equipment groupage as a whole. This type of analysis requires introduction of specific measures that take into account the peculiarities of military equipment useful life exhaustion and restoration processes, with separate ME items being a part of a groupage.

This article elaborates on a mathematical model of the military equipment useful life exhaustion and restoration processes, that allows to predict quantitative and qualitative characteristics of the ME groupage in the forthcoming period of its exploitation, based on enacted statutory maintenance, disposal and procurement requirements for the ME groupage.

The notion of the useful life of a military equipment groupage. *Military equipment groupage* stands for a multitude of similar or different objects, that are connected by a common objective and similar tasks that the groupage is assigned to perform. The objects of the groupage can be located in one settlement, or more often scattered across a certain area, which is considered their zone of responsibility. Examples of military equipment groupages are motor vehicle units or armored formations, fulfilling either combat or combat support missions. In the framework of this model informational and functional connections between the objects, as well as the type of tasks they perform do not matter. Only two characteristics of the groupage are taken into consideration – its structure and *useful life*. If the structure of the groupage meets the corresponding requirements, and the level of reliability of each single object does not fall below a pre–defined value, the groupage is fit for its intended purpose. At the same time, it is understood, that if the useful life of a single object is exhausted, the measures of its reliability do not meet the requirements and such object should be replaced by a new one (with equal functions) or reconditioned to restore its useful life.

In large systems of ME groupages there is usually a certain organizational structure in place, meaning that they include ME groupages of lower organizational levels. It is envisaged that in the future there will be a strong distinction between groupages of different levels.

Let's introduce the following particulars:

$\boldsymbol{N}(t) = \{N_i(t); i = \overline{1, N_{TYPE}}\}$ – the vector, that determines the structure of the military equipment groupage at a given time *t*, where $N_i(t)$ – the number of *i* type ME items (N_{TYPE} – the number of various ME types);

$\boldsymbol{R}_\Sigma(t) = \{R_{\Sigma i}(t);\ i = \overline{1, N_{TYPE}}\}$ – the vector, that determines the useful life of military equipment groupage, where $R_{\Sigma i}(t)$ – total useful life of *i* type ME.

The function $N_i(t)$ can be expresses with the following formula:

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

where $n_j(t)$ – the singular function, that assumes the value of 1 or 0 (1 – if at the time *t* the object is a part of the grouping, 0 – if it is not); J_i – the multitude of numbers (indexes) of the *i* type ME items.

The points in time when the structure of the groupage changes are determined by the useful life exhaustion and restoration processes of separate ME items.

The function of the total useful life of *i* type ME $R_{\Sigma i}(t)$ is defined as the following sum:

$$R_{\Sigma i}(t) = \sum_{j \in \boldsymbol{J}_i} R_j(t), \tag{2}$$

where $R_j(t)$ – the useful life of *j* type ME at the time *t*.

The function $R_j(t)$ describes for the exhaustion and restoration processes of a useful life of a single *j* type ME item.

Figure 1 is an approximate graph of the function $R_{\Sigma i}(t)$. Positive jumps (discontinuities) of a function correspond the moments in time when the ME groupage receives new procured or old restored equipment.

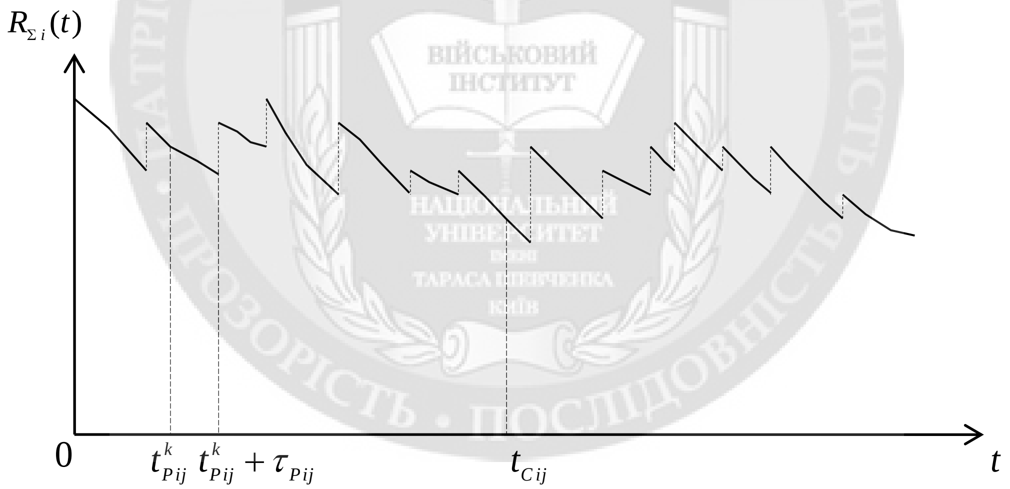

Fig. 1. Typical graph of the function $R_{\Sigma i}(t)$

The rate of the function's decrease in intervals between the discontinuities is defined by the sum intensity of the useful life exhaustion of all the ME, included in the groupage at a given time.

Structural and useful life requirements for a ME groupage are defined by the following formula:

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

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

where N_i^{TP} and $R_{\Sigma i}^{TP}$ – the numbers of *i* type ME items and their total useful life, required for the groupage to be efficient.

Required structure of the groupage (3a) has an obvious physical purpose – if the number of ME items in the groupage drops below the acceptable level, the efficiency of the groupage will not meet the requirements. Therefore there are no issues with the value of N_i^{TP}, since it is the prerogative of an older "system" that formed the groupage.

Required total useful life of the ME (3b) can be viewed as something similar to a "safe load factor" of the groupage that determines how long the groupage can exist with the required efficiency.

As a result *useful life of a ME groupage* can be defined as calendrical duration of the service life of the groupage before it reaches the limiting state, provided that all statutory maintenance measures have been taken. Let's denote the useful life of a groupage by T_{GR}.

The *useful life of the i type ME groupage* T_{GRi} is defined by the following formula:

$$N_i(T_{GRi}) = N_i^{TP}. \tag{4}$$

Therefore the useful life of the groupage T_{GR} can be defined by the formula:

$$T_{GR} = \min_i \; T_{GR\,i}. \tag{5}$$

The next chapter deals with the military equipment useful life exhaustion and restoration processes and explains the functions $N_i(t)$ and $R_{\Sigma i}(t)$.

Useful life exhaustion and restoration model of a single ME item. Useful life function of a separate *j* ME item $R_j(t)$ at the time $t = 0$ and with the object being new (meaning it has not been maintained to restore the useful life) is determined by the following formula:

$$R_j(t) = \begin{cases} R_j^{(0)} - \tau_j(t), \text{ if } \left(\tau_j(t) < R_j^{(0)}\right) \wedge \left(t < T_j^{(0)}\right); \\ 0, \qquad\qquad \text{if } \left(\tau_j(t) \ge R_j^{(0)}\right) \vee \left(t \ge T_j^{(0)}\right), \end{cases} \tag{6}$$

where $R_j^{(0)}$ and $T_j^{(0)}$ – the initial useful life and the initial service life of the *j* ME item;

$\tau_j(t)$ – total operating time of the *j* ME object at the time *t*.

Operating time $\tau_j(t)$ is the random time function:

$$\tau_j(t) = \int_0^t \eta_j(x)\,dx, \tag{7}$$

where $\eta_j(x)$ – the intensity of the useful life exhaustion of the *j ME item*.

In reality there is usually a useful life exhaustion limit in place (e.g. for a year), and during the exploitation the useful life exhaustion process it tweaked in accordance with the limit. That's why for the sake of forecast analysis it is possible to assume that the function $\eta_j(t)$ has a constant value of mathematical expectation $\overline{\eta}_j$, which is defined by the following formula:

$$\overline{\eta}_j = \frac{L_{R\,j}}{T}, \tag{8}$$

where $L_{R\,j}$ – the limit of the useful life exhaustion of the *j ME item*;

T – the exploitation period with the limit of $L_{R\,j}$.

Therefore, the total operating time in the forecast time period [0, *t*] is defined as:

$$\tau_j(t) = \overline{\eta}_j \cdot t. \tag{9}$$

Replacing the former expression (6) with the one mentioned above the new formula is:

$$R_j(t) = \begin{cases} R_j^{(0)} - \overline{\eta}_j \cdot t, & \text{if } \; t \in [0, t_{LS\,j}]; \\ 0, & \text{if } \; t > t_{LS\,j}, \end{cases} \tag{10}$$

where $t_{LS\,j}$ – the time when *j* ME item reaches its limiting state. It is defined by the following formula:

$$t_{LS\,j} = \min\left(\frac{R_j^{(0)}}{\overline{\eta}_j}, T_j^{(0)}\right). \tag{11}$$

The formula (10) is valid for the case when the ME item has not been maintained and is exploited until it reaches the limiting state. However, in case the ME item will be maintained for N_P times during its service life and there are pre–determined maintenance dates and amounts of the useful life restored with each round of maintenance in place, function $R_j(t)$ will no longer be expressed as the one shown above (10), but instead will be defined as:

$$R_j(t)=\begin{cases} R_j^{(0)}-\overline{\eta}_j t, & \text{if } \ t\in[0,t_{Pj}^{(1)}]; \\ R_j^{(k)}-\overline{\eta}_j(t-t_{Pj}^{(k)}), & \text{if } \ t\in[t_{Pj}^{(k)}+\tau_{Pj},t_{Pj}^{(k+1)}];\ k=\overline{1,N_P-1}; \\ R_j^{(N_P)}-\overline{\eta}_j(t-t_{Pj}^{(N_P)}), & \text{if } \ t\in[t_{Pj}^{(N_P)}+\tau_{Pj},t_{Cj}]; \\ 0, & \text{if } \ t>t_{Cj}\vee t\in[t_{Pj}^{(k)},t_{Pj}^{(k)}+\tau_{Pj}];\ k=\overline{1,N_P}, \end{cases} \tag{12}$$

where $R_j^{(k)}$ – the useful life of,;

$t_{Pj}^{(k)}$ – point in time when is maintained for the *k* time:

$$t_{Pj}^{(k)}=t_{Pj}^{(k\text{-}1)}+\tau_{Pj}+\min\left(\frac{R_j^{(k\text{-}1)}}{\overline{\eta}_j},T_j^{(k\text{-}1)}\right); \tag{13}$$

t_{Cj} – disposition time of the *j* ME item:

$$t_{Cj}=t_{Pj}^{(N_P)}+\tau_{Pj}+\min\left(\frac{R_j^{(N_P)}}{\overline{\eta}_j},T_j^{(N_P)}\right); \tag{14}$$

τ_{Pj} – maintenance duration of the *j* ME item;

$T_j^{(k)}$ – the amount of service life of the *j* ME item, restored after maintaining it for the *k* time.

Figure 2 shows graphs that explain the formula (11). To simplify the graphs, in the chosen case the statutory values of the useful life between maintenances $R_j^{(k)}$ and the service life $T_j^{(k)}$ are harmonized, providing $\overline{\eta}_j=R_j^{(k)}/T_j^{(k)}$.

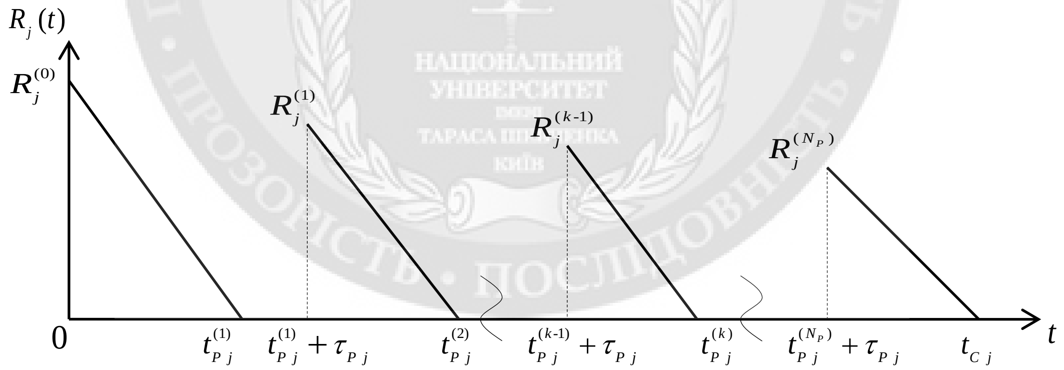

Fig. 2. Useful life function of a *j* ME item, with *t* = 0, since the object is new

In a more general case, when at a time $t=0$ the ME has been maintained n_{Pj} times ($n_{Pj}<N_P$), the useful life function $R_j(t)$ can be defined by the following formula:

$$R_j(t)=\begin{cases} R_j(0)-\overline{\eta}_j t, & \text{if } \ t\in[0,t_{Pj}^{(n_{Pj}+1)}]; \\ R_j^{(n_{Pj}+k)}-\overline{\eta}_j(t-t_{Pj}^{(n_{Pj}+k)}), & \text{if } \ t\in[t_{Pj}^{(n_{Pj}+k)}+\tau_{Pj},t_{Pj}^{(n_{Pj}+k+1)}];\ k=\overline{1,N_P-1}; \\ R_j^{(N_P)}-\overline{\eta}_j(t-t_{Pj}^{(N_P)}), & \text{if } \ t\in[t_{Pj}^{(N_P)}+\tau_{Pj},t_{Cj}]; \\ 0, & \text{if } \ t>t_{Cj}\vee t\in[t_{Pj}^{(n_{Pj}+k)},t_{Pj}^{(n_{Pj}+k)}+\tau_{Pj}];\ k=\overline{1,N_P}, \end{cases} \tag{15}$$

where $R_j(0)$ and $T_j(0)$ – the residual useful life and residual operation life of the *j* ME item at a point in time $t=0$;

$t_{Pj}^{(n_{Pj}+1)}$ – the time of the $(n_{Pj}+k)$ maintenance that is defined by the formula:

$$t_{Pj}^{(n_{Pj}+1)} = \min\left(\frac{R_j(0)}{\overline{\eta}_j}, T_j(0)\right). \tag{16}$$

Quantities $t_{Pj}^{(n_{Pj}+k)}$ when $k=\overline{2,N_P}$ and t_{Cj} are defined by formulas (13) and (14) respectively.

Figure 3 shows the graphs that demonstrate the formula (15).

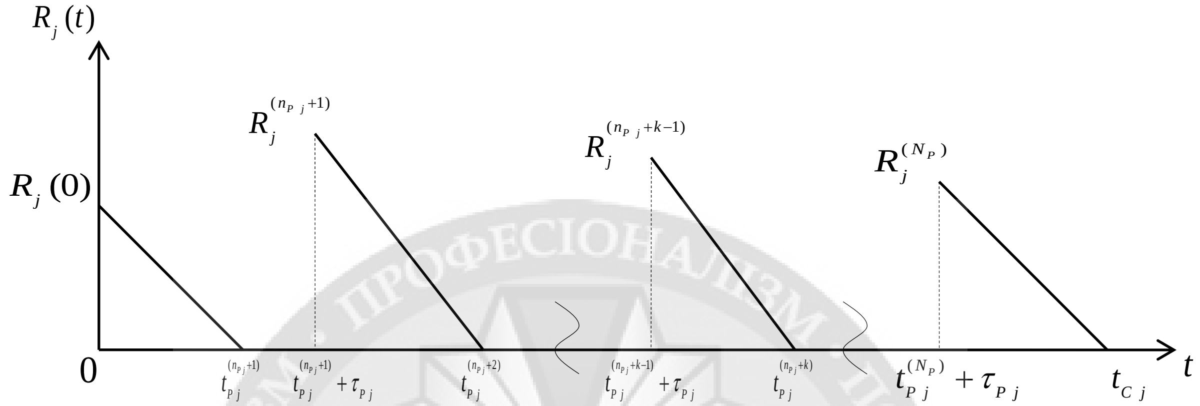

Fig. 3. Useful life function of the *j* ME under the condition that before the point in time $t=0$ the object has been maintained n_{Pj} times

This mathematical model of useful life exhaustion and restoration of a single ME item is at the basis of the useful life exhaustion and restoration model for a ME groupage that is stated below.

Useful life exhaustion and restoration model for a ME groupage. It was previously determined, that the ME groupage characteristics significant to this research are its structure $N_i(t)$ and useful life $R_{\Sigma i}(t)$. To keep these characteristics on the required level for a certain period of time $[0,T_Э]$ the timely maintenance and disposition of single ME items that are in the groupage are needed. There should be a mathematical model in place to efficiently plan these measures. The one that would establish a correlation between the values $N_i(t)$ and $R_{\Sigma i}(t)$ and the parameters of the corresponding plans.

Let's introduce the following plan symbols: $\mathbf{\Pi}_{Pi}$ and $\mathbf{\Pi}_{Ci}$ – for the maintenance and disposition plans, each of these plans is viewed as a union of the corresponding plans for separate ME objects of a certain type.

Maintenance plan is defined as a union $\mathbf{\Pi}_{Pi} = \bigcup_{j\in \boldsymbol{J}_{0i}} \Pi_{Pij}$, where Π_{Pij} – the maintenance plan for the *j* object that is represented by the following union:

$$\Pi_{Pij} = \{\langle t_{Pij}^{(k)}, R_{Pij}^{(k)}, T_{Pij}^{(k)}, \tau_{Pij}^{(k)}\rangle; k=\overline{1,N_{Pj}}\}, \tag{17}$$

where $t_{Pij}^{(k)}$ – the point in time, when the *ij* object is maintained for the *k* time according to plan;

$R_{Pij}^{(k)}$ and $T_{Pij}^{(k)}$ – amounts of the useful life and the operating life, restored after the *k* maintenance;

$\tau_{Pij}^{(k)}$ – duration of the *k* maintenance;

N_{Pij} – total number of maintenances statutory for the *ij* object.

Disposition plan is defined as the unity $\mathbf{\Pi}_{Ci} = \bigcup_{j\in \boldsymbol{J}_{0i}} \Pi_{Cij}$, where $\Pi_{Cij} = \{t_{Cij}\}$ – the disposition plan of the *ij* object is defined by a single value t_{Cij} – the disposition time.

Considering the newly introduced symbols for the functions $N_i(t)$ and $R_{\Sigma i}(t)$, there is a new formula:

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

$$R_{\Sigma i}(t/\boldsymbol{S}_i(0),\overline{\eta}_i,\mathbf{\Pi}_{Pi},\mathbf{\Pi}_{Ci}) = \sum_{j\in \boldsymbol{J}_{0\,i}} R_{ij}(t/S_{ij}(0),\overline{\eta}_{ij},\Pi_{Pij},\Pi_{Cij}), \tag{18}$$

where $\boldsymbol{S}_i(0) = \{S_{ij}(0);\ j\in \boldsymbol{J}_{0\,i}\}$ – vector that describes the state of the *i* type ME at the beginning of considered exploitation period [0, $T_Э$];

$\overline{\boldsymbol{\eta}}_i = \{\overline{\eta}_{ij};\ j\in \boldsymbol{J}_{0\,i}\}$ – vector, that represents the intensity of the *i* type ME useful life exhaustion;

$\boldsymbol{J}_{0\,i}$ – multitude of numbers of all of the *i* type ME items, that are a part of the groupage at the given time *t* = 0.

The correspondences (16) mutually define the useful life exhaustion and restoration model for a ME groupage (for the *i* type ME items) in a period of time [0, $T_Э$].

The functions (18) – are the forecast evaluations of the values that define the state of the groupage of the forthcoming period of time. They depend on the parameters $\boldsymbol{S}_i(0)$, $\overline{\boldsymbol{\eta}}_i$, $\mathbf{\Pi}_{Pi}$ and $\mathbf{\Pi}_{Ci}$. Parameter $\boldsymbol{S}_i(0)$ describes the initial (technical) state of the ME items, thus defining the initial circumstances for the useful life exhaustion and restoration processes of a ME groupage. Parameter $\overline{\boldsymbol{\eta}}_i$ defines expected (forecasted) external influences on the process, and is considered to be pre–defined. Parameters $\mathbf{\Pi}_{Pi}$ and $\mathbf{\Pi}_{Ci}$ are the manageable parameters, since their value at the end is defined by the user.

Parameters $\mathbf{\Pi}_{Pi}$ and $\mathbf{\Pi}_{Ci}$ should be considered *regulatory* (and written as $\mathbf{\Pi}^R_{Pi}$ and $\mathbf{\Pi}^R_{Ci}$), if the dates and types of ME maintenances are set in accordance with the enacted regulations ($\mathbf{\Pi}^R_{Pi} = \{\Pi^R_{Pij};\ j\in \boldsymbol{J}_i\}$ and $\mathbf{\Pi}^R_{Ci} = \{\Pi^R_{Cij};\ j\in \boldsymbol{J}_i\}$).

Regulatory plans $\mathbf{\Pi}^R_{Pi}$ and $\mathbf{\Pi}^R_{Ci}$, that by definition are optimal for each ME item separately, can rarely be optimal for a groupage as a whole, and the main aim of this model is to find optimal plans for groupages $\mathbf{\Pi}_{Pi}$ and $\mathbf{\Pi}_{Ci}$.

Up until this point the research was focused on the useful life exhaustion and restoration processes of a ME groupage, assuming that there was no new equipment procured for the groupage. In reality, the required structure of the ME groupage is maintained by periodically (in accordance with the plan) replacing the disposed items with the new ones. Supplying the groupage with new items to replace the disposed ones is an obvious way of prolonging the useful life of a groupage.

Let's introduce the formula $\mathbf{\Pi}_{Hi} = \{t_{Hij};\ j\in \boldsymbol{J}_{H\,i}\}$ – unity that defines the supply plans for the *i* type ME groupage, where:

t_{Hij} – time when the *j* new equipment items of the *i* type are supplied to the groupage;

$\boldsymbol{J}_{H\,i}$ – multitude of the numbers of new objects, that according to plan are supposed to be supplied for the groupage in its exploitation period.

Therefore the values of $N_i(t)$ and $R_{\Sigma i}(t)$ can be defined as:

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

$$R_{\Sigma i}(t / \boldsymbol{S}_i(0), \overline{\boldsymbol{\eta}}_i, \boldsymbol{\Pi}_{Pi}, \boldsymbol{\Pi}_{Ci}, \boldsymbol{\Pi}_{Hi}) = \sum_{j \in \boldsymbol{J}_{0i} \cup \boldsymbol{J}_{Hi}} R_{ij}(t / S_{ij}(0), \overline{\eta}_{ij}, \Pi_{Pij}, \Pi_{Cij}) + \sum_{j \in \boldsymbol{J}_{Hi}} R_{ij}(t / S_{ij}(t_{Hij}), \overline{\eta}_{ij}, \Pi_{Hij}), \quad (19)$$

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

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

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

The formulas (19) are a more detailed version of the previously stated formulas (16) and represent the mathematical model of useful life exhaustion and restoration processes for a ME groupage, with the regard to new items being supplied.

The manageable parameters of the model are the plans $\boldsymbol{\Pi}_{Pi}$, $\boldsymbol{\Pi}_{Ci}$ and $\boldsymbol{\Pi}_{Hi}$. Parameter $\overline{\boldsymbol{\eta}}_i$ is partially manageable, since the intensity of the useful life exhaustion can be redistributed among single ME items. The non–manageable parameters are the statutory requirements for the maintenance terms, the amount of useful life restored during maintenance, and the initial useful life of new ME items.

Conclusions. The mathematical model for describing the useful life exhaustion and restoration processes of ME groupages has been designed. The model outputs are the structural, quantitative and useful life characteristics of a groupage, forecasted for a given exploitation period. The structure of a groupage is determined by sorting the ME items by types and the useful life of a groupage is defined as the longest time during which the groupage can maintain required efficiency.

Model parameters are the useful life restoration parameters for the ME groupage (maintenance, disposition and procurement plans). This model allows to determine the optimal useful life restoration plans for the ME groupage.

The structure of the model suggests that it is a deterministic simulation model.

LITERATURE:

1. Lenkov S.V., Lenkov Ye.S. Formalized procedures for optimizing the maintenance parameters based on the useful life of complex items of long exploitation // “Contemporary special equipment” magazine, Kyiv, 2016. – 4(47). – P.3 – 8.

2. Lenkov S.V., Banzak G.V., Tsytsariev V.N., Protsenko Ya.N. Algorithms for predicting reliability and exploitation cost of the EW items// Ivan Kozhedub Kharkiv University of Air Force magazine “Information processing systems”. – Kharkiv, – 2016. – №9(146). – P.28 – 30.

3. Lenkov S.V., Pashkov S.A., Osypa V.A., Tsytsariev V.N. On the influence of rational structure of the renewable object on its reliability // Collected volume of scientific papers of Ivan Kozhedub Kharkiv University of Air Force. – Kharkiv, – 2014. – Issue 2(39). – P.127 – 131.

4 Lenkov S.V., Tsytsariev V.N., Hunchenko Yu.A., Boriak K.F., Koltsov R. Yu. Evaluating the reliability of complex technical objects with the regard to their hierarchic structure// Collected volume of Odessa State Academy of Technical Regulation and Quality. – Odesa, 2012. – №1. – P.65 – 70.

5. 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, etc.; under edition S. V. Lenkov. – Odessa: Publishing house “BMB”, 2014. – 252 p.

6. Tolok I.V. Defining the vehicle maintenance system at the establishments of the Ukrainian Ministry of Defense and the criteria for its efficiency// Control, navigation and communication system. – K.: Central Research Institute of Navigation and Control, 2008. – Issue 4(18). – P. 95 – 97.

7. Tolok I.V. Building a database of vehicle maintainance // Collected volume of scientific papers of Ivan Kozhedub Kharkiv University of Air Force. – Kharkiv, 2008. – Issue 3(18). – P.146 – 148.

8. Tolok I.V. Improving the process of maintenance of complex renewable vehicles and armored equipment with the statistic simulation model // “Contemporary specialized equipment” magazine, Kyiv, 2016. – 4(47). – P.90 – 95.

9. Tolok I.V. Certain aspects of determining and restoring the useful life of complex renewable technical equipment // “Contemporary specialized equipment” magazine. – Kyiv, 2017. – 1. – P.41-44.

REFERENCES:

1. Ljenkov S.V., Ljenkov Je.S. (2016). Formalizovana metodyka optymizacii' parametriv strategii' tehnichnogo obslugovuvannja za resursom skladnyh vyrobiv tryvaloi' ekspluatacii'. *Zhurnal «Suchasna special'na tehnika»*. Kyi'v. 4(47). 3 – 8.

2. Ljenkov S.V., Banzak G.V., Cycarjev V.N., Procenko Ja.N. (2016) Algorytm prognozuvannja dlja pokaznykiv nadijnosti i vartosti ekspluatacii' ob'jektiv radioelektronnyh zasobiv ozbrojennja. *Zhurnal Harkivs'kogo universytetu Povitrjanyh Syl im..I.Kozheduba «Systemy obrobky informacii'»*. Harkiv. №9(146). 28 – 30.

3. Lenkov S.V., Pashkov S.A., Osypa V.A., Cycarev V.N. (2014). O vlijanii konstruktivnoj struktury vosstanavlivaemogo ob#ekta na ego pokazateli nadezhnosti. *Zbirnik naukovih prac' Harkivs'kogo universitetu Povitrjanih Sil*. Harkiv. 2(39). 127 – 131 (In Russian).

4. Lenkov S.V., Cycarev V.N., Gunchenko Ju.A., Borjak K.F., Kol'cov R.Ju. (2012). Ocenki nadezhnosti slozhnyh tehnicheskih ob#ektov s uchetom ih ierarhicheskoj konstruktivnoj struktury. *Zbirnyk Odes'koi' derzhavnoi' akademii' tehnichnogo reguljuvannja ta jakosti*. Odesa. №1. 65 – 70(In Russian).

5. Sergey Lenkov, Konstantin Borjak, Gennady Banzak, Vadim Braun, etc.; under edition S. V. Lenkov. Forecasting to reliability complex object radio-electronic technology and optimization parameter their technical usage with use the simulation statistical models: [monography]. Kyiv. Odessa: *Publishing house «BMB»*. 252 (in English).

6. Tolok I.V. Opredelenie sistemy tehnicheskogo obsluzhivanija i remonta avtomobil'noj tehniki na predprijatijah Ministerstva oborony Ukrainy i ee kriterii jeffektivnosti. (2008). Systema upravlinnja, navigacii' ta zv’jazku. Kyiv. *Central'nyj naukovo-doslidnyj instytut navigacii' i upravlinnja*. 4(18). 95 – 97 (In Russian).

7. Tolok I.V. Postroenie informacionnoj bazy sistemy tehnicheskogo obsluzhivanija i remonta avtomobil'noj tehniki (2008) *Zbirnyk naukovyh prac' Harkivs'kogo universytetu Povitrjanyh Syl im.I.Kozheduba.* Harkiv. 3(18). 146 – 148 (In Russian).

8. Tolok I.V. (2016). Udoskonalennja procesu tehnichnogo obslugovuvannja skladnyh vidnovljuvanyh ob’jektiv avto – ta bronetehniky za dopomogoju imitacijnoi' statystychnoi' modeli. *Zhurnal «Suchasna special'na tehnika»*. Kyi'v. 4(47). 90 – 95.

9. Tolok I.V. (2017). Dejaki aspekty vyznachennja ta popovnennja resursu skladnyh tehnichnyh ob'jektiv, shho vidnovljujut'sja. *Zhurnal «Suchasna special'na tehnika»*. Kyi'v. – 1. – 41-44.

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

к.пед.н. Толок І.В.

МОДЕЛЮВАННЯ ПРОЦЕСІВ ВИТРАТ І ВІДНОВЛЕННЯ РЕСУРСУ УГРУПОВАННЯ ОБ'ЄКТІВ ВІЙСЬКОВОЇ ТЕХНІКИ

У статті розглядається математична модель процесів витрачання та поповнення ресурсу угруповання об'єктів військової техніки (ОВТ). Угруповання ОВТ розуміється як безліч різнотипних об'єктів, призначених для вирішення спільних для угруповання завдань і цілей. Показниками якості процесів витрачання та поповнення ресурсу прийняті кількісний склад угруповання і сумарний ресурс, що визначаються окремо за типами ОВТ. Параметрами моделі є плани ремонту, списання та поставок ОВТ, а також встановлені нормативні вимоги по їх здійсненню. Введено поняття граничного стану і ресурсу угруповання.

Застосування моделі дозволяє прогнозувати склад і ресурс угруповання на майбутній період часу, оцінювати якість діючих планів поповнення ресурсу і здійснювати їх оптимізацію.

Ключові слова: угруповання об'єктів військової техніки, ресурс угруповання об'єктів військової техніки, план ремонту, списання та поставки об'єктів в угруповання.

к.пед.н. Толок И.В.

МОДЕЛИРОВАНИЕ ПРОЦЕССОВ РАСХОДОВ И ВОССТАНОВЛЕНИЕ РЕСУРСОВ ГРУППИРОВКИ ОБЪЕКТОВ ВОЕННОЙ ТЕХНИКИ

В статье рассматривается математическая модель процессов расходования и восполнения ресурса группировки объектов военной техники (ОВТ). Группировка ОВТ понимается как множество разнотипных объектов, предназначенных для решения общих для группировки задач и целей. Показателями качества процессов расходования и восполнения ресурса приняты количественный состав группировки и суммарный ресурс, определяемые раздельно по типам ОВТ. Параметрами модели являются планы ремонта, списания и поставок ОВТ, а также установленные нормативные требования по их осуществлению. Введены понятия предельного состояния и ресурса группировки.

Применение модели позволяет прогнозировать состав и ресурс группировки на предстоящий период времени, оценивать качество действующих планов восполнения ресурса и осуществлять их оптимизацию.

Ключевые слова: группировка объектов военной техники, ресурс группировки объектов военной техники, план ремонта, списания и поставок объектов в группировку.

ВІЙСЬКОВИЙ ІНСТИТУТ НАЦІОНАЛЬНИЙ УНІВЕРСИТЕТ ІМЕНІ ТАРАСА ШЕВЧЕНКА КИЇВ ПАТРІОТИЗМ • ПРОФЕСІОНАЛІЗМ • ПОРЯДНІСТЬ • ПОСЛІДОВНІСТЬ • ПРОЗОРІСТЬ