Formalization of problem and justification of the set of principles of construction of the system of restoration of weapons and military equipment

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Received: August 4, 2020 | Revised: August 20, 2020 | Accepted: August 31, 2020

DOI: 10.33445/sds.2020.10.4.12

Abstract

Analysis of wars and armed conflicts in recent years confirms that the success of mechanized, tank, assault and other military formations (units) will depend on the effectiveness of the system of supply of troops (forces).

The location of military formations (units) engaged in hostilities in a permanent state of combat readiness will depend on the effectiveness of the system of restoration of damaged samples of weapons and military equipment.

Therefore, in this work on the basis of the analysis of the current state of functioning of the system of restoration of weapons and military equipment in the conditions of operation (combat operations) the problem is formulated and the set of principles of construction of the system of restoration of armaments and military equipment is substantiated.

Key words: system of restoration, weapons and military equipment, principles of construction, the complexity of recovery tasks.

Introduction

Currently, one of the main problematic aspects of the functioning of the system of restoration of weapons and military equipment (WME) under certain conditions is a significant excess of the rate of development and use of means of destruction in comparison with means of protection. Low efficiency of means of protection of samples of weapons and military equipment, variety of base chassis, wide nomenclature of spare parts, imperfection of logistics system, namely subsystems of technical reconnaissance, evacuation, repair of damaged samples of weapons and military equipment, provision of material means, structure of mobile and stationary repair bodies leads to untimely return of weapons samples to military formations (units) which conducting hostilities.

With the transition of the Armed Forces (AF) of Ukraine to the logistics system, the tasks that were solved with the help of tools designed to restore damaged samples of weapons and military equipment are changing [1-3]. In turn, this requires the creation of a promising system for the restoration of weapons and military equipment, modernization and development of new means and complexes that would satisfy the conditions for repair of damaged samples of weapons and military equipment during hostilities and the simultaneous need to perform tasks for repair of weapons and military equipment in stationary conditions [4-5]. At present, to solve these problems, the existing weapons and military equipment are used for technical reconnaissance, evacuation, repair of damaged samples of weapons and military equipment, transportation of material resources or in limited quantities purchase means of evacuation, repair, which also increase the range of basic chassis while the functionality duplicates existing or perform a limited range of

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specific tasks. Considering that the means intended for the restoration of damaged samples of weapons and military equipment are an integral part of the weapons system of the Armed Forces of Ukraine, the process of forming their type should be based on a systematic approach.

Material and methods

Sufficient attention is paid to the study of problematic issues of the effectiveness of the functioning of the weapons recovery system, the provision of material resources for the needs of the current group of troops and the course of information flows circulating in the logistics system of the Armed Forces of Ukraine. Also, the issue of weapons and military equipment failure from combat and operational reasons, the need for material resources, the state of staffing of military formations (units) of weapons and military equipment and material resources, the production capacity of repair and rehabilitation military formations (units) is given sufficient attention, both domestic and foreign. However, the subject side for different studies had a different focus. In particular in the work [6] the decision of a problem of synthesis of optimum strategies concerning increase of operational possibilities of repair and restoration bodies of military units is offered. In the work [7] the question of formalization of the decision-making process by the commander on restoration of the damaged elements of weapons and military equipment is considered, and in work [8] the mathematical statement of a problem of distribution of efforts which allows to consider not only the basic elements of plan for fight (operation), but also quality of weapons and military equipment of military formations.

In the work [9] the main problems that are solved in the organization and management of complex organizational and technical systems, as well as the need to use structural synthesis in the formalization of the basic parameters of the recovery system. The work [10] devoted to the analysis of military technical systems in order to identify problematic issues and find ways to solve them. An approach to increase the efficiency of the automotive support system is proposed. In the work [11] the methodical apparatus of optimization of operational and tactical requirements to samples of weapons and military equipment and definition of their conformity to requirements of higher level of hierarchy with application of the theory of difficult systems is considered. In the work [12] a comprehensive approach to determining the priorities for the development of weapons and military equipment in the system of support and management decisions is proposed. In the literature [13] proposed approaches to the formalization of the problem of optimizing the allocation of resources to maintain the level of serviceability of samples of weapons of the Air Force. In the work [14] a method for assessing the balance of development of weapons systems is considered. In the work [15] the possibility of realization of new information technologies at the stage of armament operation, for an estimation of the general condition and quality of functioning of system of intellectual support of process of operation for formulation of principles of technical diagnostics of armament is investigated. Some aspects of this issue are outlined in the work [16], in which the mathematical model of a multicriteria choice of automobile equipment is offered. In the work [17] the approach to the decision of problems of uncertainty at a substantiation of tasks which is based on the complex analysis of processes of functioning is offered. Some issues of this issue are considered in the work [18], which proposes an approach to justify measures to maintain combat readiness and combat capability of weapons and military equipment parks. In the work [19] the issues of improving the information support of a promising automated logistics management system based on the prediction of probable damage to weapons and military equipment samples are considered. A qualitative indicator for predicting the level of a sample of weapons and military equipment is a sign of the degree of its damage,

and as a criterion for determining the degree of damage to a sample of weapons and military equipment selected the number of means of damage that hit. In the work [20] the approach to formalization of the problem of formation of rational technical outline of antiaircraft missile system of new generation taking into account resource limitations is considered and the algorithm of formation of outline which provides performance of functional, technical and constructive synthesis on criteria of a maximum. The literature source [21] analyzes the development of weapons and military equipment in the leading countries of the world and in Ukraine and considers the problems that affect the development of weapons and military equipment. The work [22] is devoted to the problems of development of the air force of Ukraine and the offered ways of improvement on the basis of introduction of means of automation. In the work [23] the approach to formalization of a problem of distribution of technoparks between regions is offered and possible approaches to the decision of this problem are specified. In the work [24] the method of modeling on the basis of the complex approach based on construction and research of mathematical model of system of maintenance of combat capability of park of weapons and military equipment of grouping of armies is offered.

Thus, almost all available sources review the results of studies of the effectiveness of individual processes for the restoration of weapons, methods of evacuation of damaged samples of weapons and military equipment, their repair, provision of material resources, etc., substantiated the requirements for their basic parameters. However, in terms of developing a common methodology based on a systems approach, only partial problems have been solved, which does not allow to fully substantiate the structure and parameters of a promising organizational and technical system for the restoration of weapons and military equipment. These restrictions have exacerbated the scientific and technical problem. The essence of which is to substantiate the set of principles for building a promising system for the restoration of weapons and military equipment and its elements.

Formulation of the purpose of the article

Therefore, the purpose of the article is to formulate a scientific and technical problem and a reasonable set of principles for building a system for the restoration of weapons and military equipment to provide material resources for the restoration of damaged samples of weapons and military equipment.

Results and discussion

Existing means designed to restore damaged samples of weapons and military equipment and currently used in the Armed Forces of Ukraine are a legacy of the former Soviet Union.

Requirements for them were determined by the tasks that corresponded to the military-political, military-strategic views of the leadership on the conduct of armed struggle and the level of development of weapons and military equipment, scientific, technical and production and economic capabilities of the defense industry at that time.

The vast majority of weapons and military equipment recovery equipment in service with repair and recovery formations (units) was developed in the second half of last century. These means are characterized by moral and physical aging of their variety, some tools functionally duplicate others, the lack of ability to carry out repair work on samples of weapons, which over the past five years have been adopted or put into operation in the Armed Forces of Ukraine. According to their mass and size data, the means intended for the evacuation of damaged samples of weapons and military equipment and ammunition are not able to fully perform the task of evacuation of damaged samples of weapons and equipment, and there are no special mobile means of technical reconnaissance. At the same time, a significant part of them were manufactured outside Ukraine, and some were withdrawn from production more than 20 years ago.

The experience of using means to restore

weapons and military equipment, both in military conflicts of the late twentieth and early twenty-first century, the Joint Forces operation (anti-terrorist operation), peacekeeping operations, and in peacetime, showed the inconsistency of tactical and technical characteristics of certain types of means of repairing damaged weapons, the nature and scope of the tasks that actually arise.

The need to create promising models of weapons and military equipment, on the one hand, and the limited economic capabilities of the state, on the other hand, force the search for the most appropriate in terms of military-technical policy, taking into account the material and economic preconditions. In the current conditions of economic development of the state and the asymmetric advantage of the global pace of development of means of destruction of armored combat vehicles and the use of other weapons, attempts to achieve parity in the development of means of repairing damaged samples of weapons inevitably lead to lag.

The general qualitative characteristic should be considered as an advantage in terms of technical and economic efficiency. An alternative in this case is the principle of asymmetric development of different types of complexes, means of recovery of weapons and military equipment, which in the development of the Armed Forces of Ukraine is to choose different types and introduce them in a rational relationship to a single logistics system [25]. At the same time, to date there is no holistic methodology for structural and parametric synthesis of the weapons and military equipment recovery system, the elements of which would correspond to modern conditions of hostilities, which is one of the key scientific and applied problems. As a result, in the practice of creating promising samples of weapons and military equipment there is a problem of development and production of highly efficient and economically feasible complexes, means of repairing damaged samples of weapons, the use of which in a single organizational and technical system would improve quality, efficiency, safety [26].

Thus, this scientific and applied problem is aimed at resolving the contradiction between modern requirements for the level of functional efficiency of the system of restoration of weapons and military equipment and its elements and the achieved level of development of the theoretical foundations of their construction. The solution of the problem is based on a systematic approach and involves a comprehensive consideration of a wide range of issues.

The analysis of approaches and methods of functioning of the elements of the weapons and military equipment recovery system, distributed in space and time, allows us to conclude that there are sharp contradictions between its capabilities and requirements that are now put forward to this class of systems. The essence of such contradictions is as follows:

there is a need to significantly reduce the time spent on the implementation of applications with the appropriate number of tasks while the existing recovery system is characterized by low response to tasks due to inability to perform tasks with the required performance;

ensuring the reduction of the range of means for technical reconnaissance, evacuation, repair of damaged samples of weapons and military equipment, while the requirement to reduce the cost of operation of the system requires the use of means to restore weapons and military equipment on a single unified base platform;

construction of a system with the use of high-performance means (complexes) of recovery of modular weapons and military equipment, distributed within the areas of hostilities at the same time the impossibility of providing all levels of the recovery system with high-performance, unified means (complexes) of weapons and military equipment recovery due to their large quantity and cost;

the need to take into account the different complexity of the tasks that need to be performed to restore damaged samples of weapons and military equipment with available resources, at the same time there is an irrational use of resources to implement applications of varying complexity;

the need to build an effective structure of repair and restoration units (military formations) while the amount of repair and restoration work at different levels of the hierarchy in terms of labor intensity is different;

there is a need to supply the necessary material resources at a certain time, in a certain place, a certain amount, for repair and restoration work on damaged models of weapons and military equipment, while there is an irrational use of storage resources.

These contradictions necessitate the scientific substantiation of the requirements for the parameters and structure of a promising organizational and technical system for the restoration of damaged weapons and military equipment and parameters of complexes, means of recovery of different types, taking into account the complexity of tasks at different levels of the hierarchy.

This need is complex and combines developments in many fields of science, namely the theory of finding damaged samples of weapons and military equipment, the theory of evacuation (transportation) of samples of weapons and military equipment and their repair, the theory of design of repair and restoration formations (units) repair and restoration military units (subdivisions) material means for carrying out repair work on samples of weapons and military equipment, the theory of complex systems, etc.

The analysis of the problems of restoration of damaged samples of armaments and military equipment and existing theoretical studies showed that the contradictions between the theoretical foundations of the structure and parameters of the system of restoration of weapons and military equipment and its elements and current requirements are not resolved.

Thus, the urgency of the issue under consideration is due to the inconsistency of the scientific and methodological apparatus of the description of the processes of restoration of damaged samples of weapons and military equipment and the need to solve the scientific problem of developing the theory of structural-parametric synthesis and principles of organizational and technical system of repairing damaged samples of weapons and military equipment.

To formalize the scientific problem on the basis of the theoretical-multiple approach model of the system of restoration of damaged samples of weapons and military equipment, as

$$SV = \langle V, D, F, Z, Pr, Sp, Ck, N, Q(Z), C(Z), t((Z)\rangle, \quad (1)$$

where SV– system for restoration of damaged samples of weapons and military equipment;

V – many elements of the system of restoration of damaged samples of weapons and military equipment;

D– set of connections between elements;

F – functions that are intended for elements of the system of recovery of damaged samples of weapons and military equipment;

Z – set of tasks of the system of updating damaged samples of weapons and military equipment;

Pr – set of processes in the restoration system of weapons and military equipment;

Sp – the area of the operating area where the samples of weapons and military equipment fail from combat and operational damage;

Ck – difficulty of process of restoration of weapons and military equipment;

N – probable failure of weapons and military equipment samples from combat and operational damage;

$Q(Z)$– performance indicators of the task;

$C(Z)$– indicators of the cost of the weapons and military equipment recovery system;

$t(Z)$– time spent on tasks to restore weapons and military equipment.

The operation of the weapons recovery system and military equipment (1) can be presented as a reflection

$$V \times D \times F \times Pr \times Sp \times Ck \to Z^{**}$$

One of the main requirements for the system of restoration of weapons and military equipment is the requirement for its operability (functioning). That is, the amount of performed tasks Z, which are implemented by the relevant

processes Pr, should be maximized in compliance with the requirements for maintaining their required quantity and quality of their implementation $Q(Z)$, in terms of resource and time constraints.

That is, in formalized form the problem can be presented as

$$W(N_{OVT}; C_k) \to max; \quad (2)$$

on

$$Z \in Z^*, Q(Z) \geq Q^*(Z), C(Z) \leq C^*(Z), t(Z) \leq t^*, Ck_{ij} \geq Ck_j^*, Ck_i = \langle k, h, g \rangle$$

where $Q^*(Z), C^*(Z), t^*, Ck_j^*$ – some thresholds set by operational and tactical requirements;

$\langle k, h, g \rangle$ – parameters of the complexity of the processes of restoration of weapons and military equipment (k – the number of weapons and military equipment samples that received combat (operational) damage, unit; h– labor intensity of works on repair of the damaged sample of weapons and military equipment, people/hour; g– nomenclature of samples of weapons and military equipment that have failed).

Therefore, detailing the formulated scientific problem, it is necessary to define such structure of system of restoration of the weapons and military equipment at which the target function of its application acquires the maximum value among all possible options of its construction.

$$\alpha = \langle v, d, f \rangle : arg\, max\left[W\left(N_{OVT_i} Ck_i\right)\right]$$

In order to increase the efficiency of the process of restoration of damaged samples of weapons and military equipment at all levels of the recovery system, it is proposed to use its elements in accordance with the scope of tasks of varying complexity, taking into account resource constraints. The construction of this system is proposed to be carried out on the basis of adaptation to the conditions of hostilities modernized existing and created new means (complexes) of weapons and military equipment, as well as through the implementation of reasonable requirements for parameters and structure of the system of weapons and military equipment, the operation of which can be represented as a canonical model (Fig.).

According to the figure shown in Fig. of the scheme, in order to achieve the goal of restoring damaged samples of weapons and ammunition, the minimum required number of means of restoration, which are used with different temporal and spatial scope, should be used. This will significantly reduce the number of recovery tools required to achieve the set level of functional efficiency and justify the required type for different levels of the hierarchy.

The above factors are directly related to the peculiarities of the functioning of the system of recovery of weapons and military equipment and do not require a separate justification. At the same time, the functioning of this system should correspond to the general purpose and tasks that are solved during the battle (operation), and its structure – to ensure the greatest effect from the use of promising means of repairing damaged samples of weapons and military equipment. Therefore, there is a need to substantiate the set of basic principles for building such a system, while for preliminary evaluation of its effectiveness it is possible to use the results presented in the works [27-28].

It should be noted that in general, these principles are based on the general principles of the system of recovery of weapons and military equipment [29].

For adequate formulation of the principles, consider space X external factors that affect the functioning of the recovery system of weapons and military equipment. According to the works [30-33] it is possible to distinguish the following groups of such indicators: physical and geographical indicators $x_{фг}$; indicators that characterize the group, the nature of the enemy's actions $x_{пр}$, and its ability to damage samples of weapons and military equipment; indicators that characterize the group, the nature of the actions of their troops, as well as the ability to restore damaged samples of weapons and military equipment $x_{св}$.

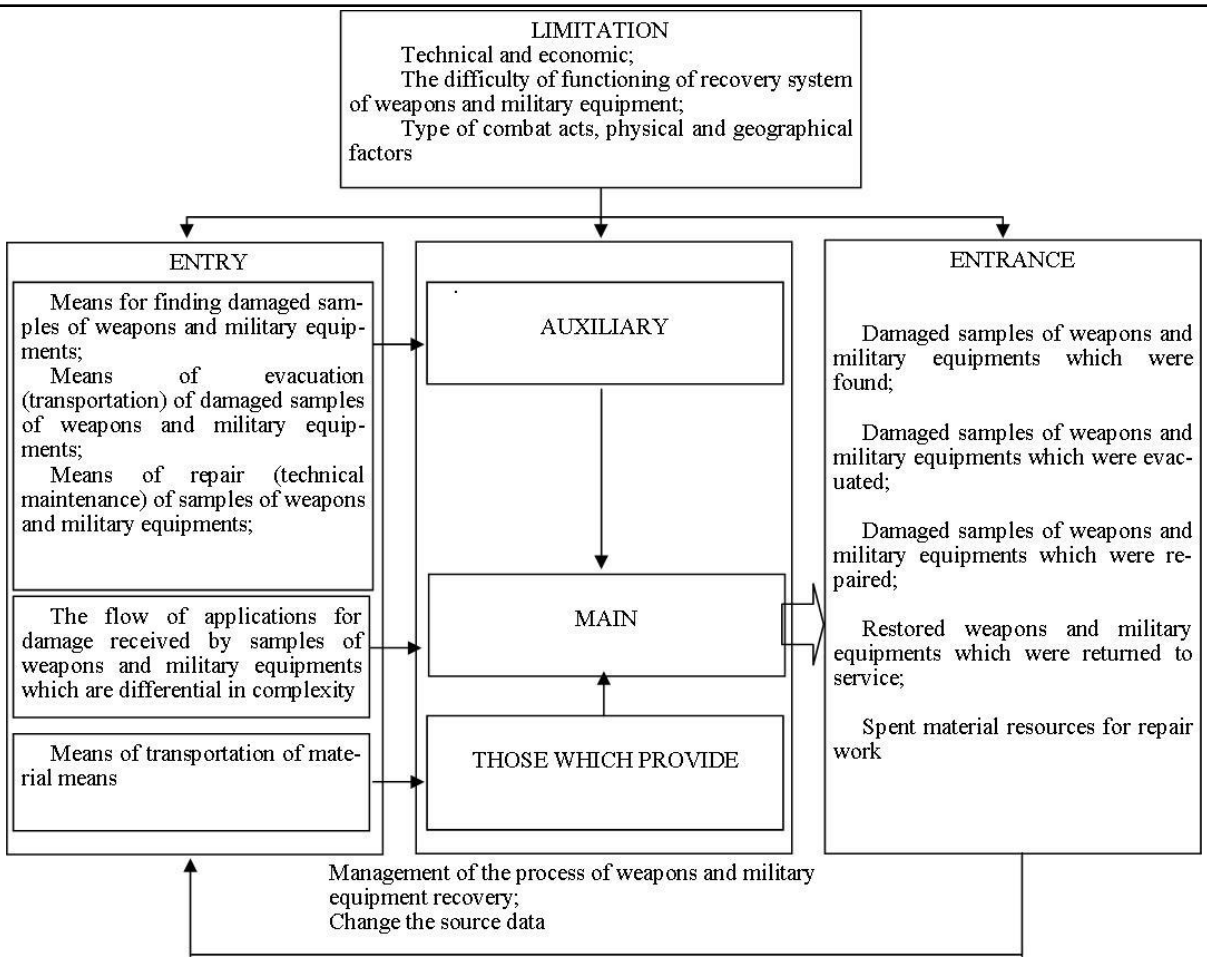

Fig. Functional diagram of weapons and military equipment recovery processes

In turn, given the dynamic nature of modern military conflicts, it is possible to note that in the time interval T, during which the operation of the weapons and military equipment recovery system is considered, these factors may take the form of a tuple:$x = \langle x_{фг}, x_{пр}, x_{св}, t \rangle$, characterizing the current state of external factors that affect the functional efficiency of the system as a whole.

Then the indicator of functional efficiency is generalized W weapons and military recovery systems can be represented as $W = W(\alpha, x)$, and the choice of the best variant of the structure of the specified system – to carry out on the criterion of maximization of the generalized indicator.

The proposed formalized description of the problem makes it possible to formulate the basic principles of construction and operation of the weapons and military equipment recovery system in the context of the operation (combat).

First of all, it is necessary to determine the principle of conformity of the structure of the weapons and military equipment recovery system to the current state of external factors:

$$\forall \alpha, x_k : W(\alpha_i, x_k) \rightarrow max, \qquad (3)$$

where α_i – one of the options for the structure of the system of restoration of weapons and military equipment

x_k, x_j – options for the current state of external factors affecting the efficiency of the system $k, j \in 1, |x|$.

As the next principle of construction of system of restoration of the weapons and military equipment we will consider the principle of modularity. This principle provides for the presence of structural elements, the possibility of their interchangeability, as well as increasing the overall efficiency of the system in case of increasing the efficiency of its individual

modules. Fulfillment of the first of these conditions follows from the formalization of the system (the presence of the plural V). Consider certain subsets (modules) $p, q \subseteq V$ and display W– generalized indicator of the effectiveness of the elements of the structure of the recovery system of weapons and military equipment, then:

$$\left.\begin{matrix} v_1 = \langle p \rangle \\ v_2 = \langle p, q \rangle \end{matrix}\right\} \Rightarrow v_1 < v_2 \rightarrow C(\alpha_1) < C(\alpha_2)$$
$$W(\alpha_2\langle v_1, d, f\rangle, x) \geq W(\alpha_1\langle v_1, d, f\rangle, x) \qquad (4)$$

where v_1 – a set of means to perform tasks at the lower level of the hierarchy;

v_2 – a set of means for performing tasks at the highest level of the hierarchy.

As noted earlier, in the conditions of the operation (combat) may be a variety of values of indicators of external factors, which characterize, in particular, different situations for the restoration of weapons, and so on. Accordingly, low efficiency and poor recovery of weapons and military equipment will not allow to ensure a high level of efficiency of the existing group of troops as a whole. The transition to a recovery system that adapts to certain situations will provide the necessary flexibility in the use of recovery tools of different types. At the same time, it is possible to create and maintain a part of the structure of the weapons and military equipment recovery system in advance α^{min} based on the introduced principle of minimum sufficiency. This principle requires ensuring a minimum sufficient level of system efficiency W^{min} for any possible values of indicators of external factors:

$$\forall a_i \rightarrow \alpha^{min} \text{ on } W(a_i, x_k) \geq W^{min}. \quad (5)$$

If there is a sufficiently effective weapons and military equipment recovery system, the enemy will take appropriate measures to counter it, and therefore, certain elements of the weapons and military equipment recovery system will be disabled. It is also possible failure of system elements for other reasons (operational reasons). In addition, it is necessary to provide the opportunity to increase the structure of the system of recovery of weapons and military equipment in accordance with the external conditions prevailing at a certain point in time t.

In accordance with the above, define the principle of redundancy of a certain part of the elements of the weapons and military equipment recovery system for their further use:

$$t < t\langle v, d, f\rangle'\langle v', d', f'\rangle_{max},$$
$$\text{on}$$
$$v' > v; d' > d; f' > f, \qquad (6)$$

where t_{max} – final application time of the system.

Then, based on the description of the previous (5), (6) two principles for the moments t_1, t_2 of operation of the system of restoration of weapons, we formulate the principle of restoration and building of the structure:

$$W(a_i, x_k) \geq W^{min_{t_1 t_2}}; t_1 < t_2 \qquad (7)$$

where α_{t_1} – dynamics of change of an interval in time of the first task;

α_{t_2} – dynamics of change of an interval in time of the subsequent task.

According to expression (7) after some time there is a use of previously reserved elements of the structure of the recovery system of weapons and military equipment. In this case, on the one hand, supports part of the system structure, which corresponds to the principle of minimum sufficiency (5), on the other – the overall structure of the system increases (6).

During the consideration of the previous principles of construction of the weapons and military equipment recovery system, the presence of destabilizing effects on the system has already been determined, which lead to the failure of certain of its elements and a corresponding decrease in its functional efficiency. Accordingly, during the structural-parametric synthesis of such a system, the property of functional stability is considered - as a property of the system, which is the ability to perform at least a set minimum of its functions

under the influence of external factors provided by operating conditions.

The above makes it possible to put forward the principle of functional stability of the weapons recovery system, the general idea of which is to create the necessary redundancy $(\Delta v, \Delta d, \Delta f)$ and ensure its applicability to localize and correct emergencies that arise during the operation of the system. The principle of functional stability of the weapons recovery system can be formulated as

$$\left.\begin{array}{l}\forall v \subseteq V \exists v^+, v^- \\ \forall d \subseteq D \exists d^+, d^- \\ \forall f \subseteq F \exists f^+, f^- \\ \langle \Delta v, \Delta d, \Delta f \rangle \neq \end{array}\right\} \Rightarrow \alpha\langle \Delta v, \Delta d, \Delta f \rangle \rightarrow W(a_i, x_k) \geq W^{min} \quad (8)$$

Conclusions

Thus, the formalization of the scientific-applied problem based on the set-theoretic approach considered in the article is a new conceptual approach in the field of building complex organizational systems, in particular, the system of restoration of damaged weapons and military equipment. The set of principles of construction of this type of system was further developed in the work, which additionally includes the principles of minimum sufficiency formulated on the basis of the canonical model, the principle of modularity, the principle of conformity of structure of weapons and military equipment recovery system to the current state of external factors the principle of redundancy of a certain part of the elements of the system of restoration of weapons and military equipment, the principle of restoration and expansion of the structure, the principle of functional stability of the system of restoration of weapons and military equipment.

The direction of further research is to substantiate the requirements for the basic parameters and structure of the organizational and technical system for the restoration of weapons and military equipment and its elements.

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