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SOLVING MILITARY-TECHNICAL PROBLEMS USING INVENTOLOGY

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Abstract: *According to inventology, there are contradictions in the basis of every military-technical problem. They arise when weapons and military equipment (WME) are to be innovated. With the improvement of one WME parameter, the other, which is generically related to it, automatically deteriorates. In order to overcome the contradictions, it is necessary to rename the selected tactical and technical parameters of the WME that are being improved into the most similar mathematical-physical parameters that are in the Spatial-temporal LT-contradiction matrix. The most relevant contradiction in the problem is calculated by the modelling method, using tensor mathematics. Based on the principle of similarity with the X-element, the search of a real X-resource begins. The greater the similarity between the X-element as the basic LT-parameter and the X-resource as an expression of the state, the closer the obtained solution to the military-technical problem is to the notion of ideality.*

Keywords: *military-technical problems, inventology, equipment.*

1. INTRODUCTION

Military-technical problems (MTP) are problems that arise during the research, development and exploitation of weapons and military equipment (WME). Experts who deal with these problems usually try to solve them using methods that belong to the irnative field. However, complex problems such as MTP require individual knowledge from multiple fields of study or a team interdisciplinary approach to be solved. In an effort to improve the creativeability of the person for effective inventive creation, between the 50s and 80s of the XX century, a number of different methods of active creative thinking appeared around the world, such as brainstorming, morphological analysis, synectics, lateral thinking, mind maps and numerous others [1]. In essence, all these techniques are reduced to the method of trial and error, because the yallow a large number of different variants of possible solutions to the problem to be reviewed in a unit of time. That's why the lost their effectiveness when solving complex problems like MTP, but they remained good forgetting ideas [2].

The theory of solving inventive tasks (Russian abbr. TRIZ) is more effective than the mentioned psychological methods in the case of solving MTP because it is based on a scientific, not a psychological approach [2]. It is a heuristic methodology that relies on extracted know-how that exists in the world's patent documentation [3]. TRIZ contains an algorithm that, on a dialectical basis, directs the creative process in the direction of finding the ideal final solution (IFS) of the problem. However, TRIZ very often results in optimal and not desired IFS of problems [4,5]. The reason for this lies in the fact that heuristics are based on empirical, logically described knowledge based on the laws of evolution of technical systems (TS), and not on exact calculation [6]. This means that there is a significant factor of subjective decision-making when choosing an IFS problem.

On a dialectical basis, but completely independently of TRIZ, the spatio-temporal LT-system was developed [7]. Within it, Bartini's LT-table was published as the most famous tool for solving MTP [8,9]. This system is based on the use of natural physical laws, and the solution of MTP is tried to be reached using a mathematical-physical approach. However, the main draw back is the incompleteness of this system, especially in term so fits practical application. Various authors have tried to compensate for this weakness [10-16], but the process has not yet been completed.

Through a critical review of TRIZ and LT-system, a spatial-temporal LT-matrix of contradictions [6, 17-21] was developed with in inventory, as a new tool that can be used to successfully solve various MTP by discover in handover coming their cause.

From the point of view of inventology, all three types of mentioned MTP can be put under the same category as inventive problems, but of different inventive level [22]. They can be classified as MTP of the first, lowest inventive level, to which functional tasks belong. In essence, these are technical improvements, which are achieved with out the help of science.

The second category of inventive problems includes MTP related to the development of WME resources. They comprise the second and third inventive level sand are arrived at using a heuristic methodology. In the third category of inventive problems belong MTP related to applied research. They contain the fourth or fifth, the highest level of inventiveness that represents a scientific-technological breakthrough in a certain field of science and technology.

The aim of this work is to show that MTP can be solved more successfully using inventology and eco-inventology as a science of innovative creativity [3,4,23,24], than in a classical way or using methods of active creative thinking. This means shortening the time necessary for research and development, the expressed need for smaller material and financial investment sand the achievement of better tactical and technical characteristic of newly acquired WME agents.

2. PHASES IN SOLVING MILITARY-TECHNICAL PROBLEMS

Each WME agent has its own life cycle. It consists of origin, growth, climax and obsolescence. This process can be represented by Gaussian curvatures (Fig. 1) [4]. In Phase I, while the growth rate of the new TS is hampered by the old system as its predecessor in the market, there are strong contradictions between them. In that phase, the TS is designed, refined, prototyped, and prepared for mass production. In phase II, the contradictions were overcome, which is why the accelerated growth of the new system occurs. In this phase, the "flourishing" of the TS occurs, during which it becomes more and more powerful and productive. Such TS enters the phase of serial production, its quality improves and the demand for it grows rapidly. In phase III, the system becomes older, and growth slows down. After some time, the improvement of TS becomes more and more difficult and it less and less meets the growing needs of man. At that stage TS starts doing more harm than good. This means that it is necessary to switch to the new system as soon as possible. The transition to a new TS at the end of the III phase can be viewed from a mathematical point of view as a disaster [4]. Disaster prevention can be temporarily postponed by technical improvement of TS (further movement along branch 3) or by shifting the sigmoid curve in the direction of innovative processes and technologies (movement along branch 1-2). In this way, new features of the TS will be obtained, which are at a significantly higher production and economic level than the old TS. Then with the new TS, the life cycle is repeated in the same way from beginning to end.

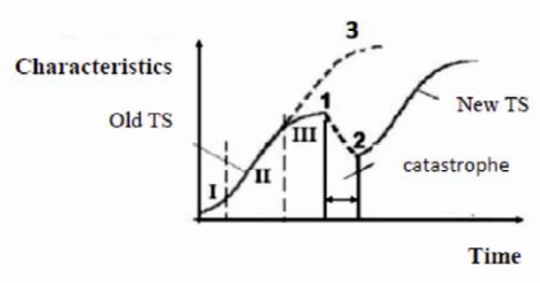

Figure 1. Life cycle of a WME agent

2.1. Functional problems or technical improvement of WME agents

One of the best systems of technical improvement in the world is implemented within a process called kaizen (Japanese for continuous improvement). Kaizen management represents an element of comprehensive management quality control, and refers to a continuous long-term approach to changes, with respect for human needs and quality [25]. If the problem is not recognized, there is no recognition of the need for improvement. Once identified, the problem must be solved. Kaizen requires the use of a variety of tools to solve problems. After each solved problem, the upgrades reach higher levels. Improvement must be standardized to establish a new level. Kaizen, therefore, requires standardization. The word quality can be interpreted in many different ways and there is no agreement on the content of this term. In the broadest sense, quality is anything that can be improved. This means that quality can be associated not only with products and services, but also with how people work, how machines work and how work systems and procedures are implemented. It includes all aspects of human behavior. The Western expression of improvement more often refers to the improvement of devices and equipment. In contrast, kaizen is a generic term that can be used in any aspect, in any activity, including in the field of technical improvement of WMEs.

2.2. Developmental problems

A technical system can produce a useful function, while simultaneously creating a harmful function. The goal is to eliminate the negative characteristic. Based on the analysis of hundreds of thousands of patents, the TRIZ contradiction matrix was derived, with 40 inventive principles that are most likely to solve the formulated technical contradiction (TC). Although not all cells of the matrix are filled, the matrix contains principles for solving more than 1.200 different types of TC. This significantly reduces the scope of research and it is reduced only to appropriate concepts of possible solutions. For users of the matrix, it is therefore recommended to formulate several TCs for one problem situation [1, 3-5]. The next step is to use those principles that have been recommended 3 or more times. The principle that is recommended only once should be ignored. In any case, this approach helps to understand and document a number of basic TCs in the system that can be of great importance for problem analysis.
In addition to the described TRIZ contradiction matrix, a contradiction matrix based on TRIZ standards was developed within inventory [4]. Also, there are other heuristic tools such as the Algorithm for Solving Inventive Tasks (Russian abbr. ARIZ), Functionally Oriented Search (FOS) and others, which can also be used to find the MTP solution on a heuristic basis.

2.3. Research problems

Within the search for a solution to research MTP, the goal is to discover the cause or mechanism of the occurrence of a phenomenon or process. This can be done using ARIZ or relying on some other scientific methods. As part of the inventory, for this purpose a space-time LT-matrix of contradictions was developed, which can be used to solve over 3.000 different TC. It was designed by combining TRIZ's contradiction matrix and Bartini's LT-table [20]. Thus, 64 parameters were obtained in the LT - matrix of contradictions. Each of them can be seen as a parameter that is fixed, corrupted, and can also represent a solution of the TC. If the obtained LT-parameter is not among the 64 listed LT-parameters (e.g. $L^{20}T^{-17}$), then this value L^mT^n shows that the solution to the contradiction is in the genetic trend whose value is 3 (m+n=20-17=3) and IFS of the problem in the form of the required X-element can be any member of that genetic group. Parameters belonging to a special genetic group are indicated by the sum of exponents (m+n): -3, -2, -1, 0, 1, 2 and 3.

3. CASE ANALYSIS

The Serbian Armed Forces has adopted the Filterable Protective Suit (FPS), which is intended to protect soldiers from highly toxic substances (HTS) or chemical (C) agents. It consists of a blouse and trousers (Fig. 2). The calculated ideality of this WME agent is 69% [26]. This means that there is a lot of room for improving its design in terms of approaching ideality. One of the goals of this paper is to propose a new FPS design whose ideality would be higher than the one mentioned.

Figure 2. Constituent parts of FPS

If the purpose of FPS-C is expanded so that it effectively protects not only from chemical (C) agents, but also from radioactive (R) and biological (B) agents, but with the same production cost, then it is obvious that this will achieve a higher ideality. The need for FPS-RCB construction is evident. Nowadays, insulating agents are most often used to protect the body from radioactive contaminants such as depleted uranium, as well as biological agents such as the coronavirus. These are different types of overalls. However, wearing them for longer periods of time can cause physiological unfitness, including heat stress, and even death in the user. However, since the FPS-RCB is expected to protect the soldier simultaneously from RCB agents, it is obvious that this increased level of protection will adversely affect his physiological suitability. Namely, it is assumed that due to the provided protection against RCB agents, it is necessary to insert additional protective layers into the FPS-C design, which would increase its mass. This would have a negative impact on the physiology of the user. This situation leads to the emergence of an inventive problem that requires an adequate solution. Details on the structure and design of the outer and inner layers of FPS-C, as well as on the mechanism of protection against C agents are given in the literature [27, 28]. The decisive factor for the comfort of FPS-C is the water vapor permeability. In the case of spherical carbon materials, water vapor permeability is good, and water vapor molecules in spherical adsorbers are weakly bound. Therefore, a slight desorption occurs and a normal pressure gradient is established relatively quickly as soon as the relative humidity on the outside of the FPS-C decreases. In addition, thin-film spherical carbon materials possess good flexibility, which gives them good load-bearing properties.

4. RESULTS AND DISCUSSION

The main problem is how to make an FPS-RCB from the existing, two-layer FPS-C, without increasing its mass. In order to design a two-layer FPS-RCB, it is essential to consider the interrelationships of the following physical parameters: permeability, stationary object mass loss, absorption rate, and stationary object mass. All those parameters are listed in the segment of the space-time LT-matrix of contradictions (tab. 1) [20].

The technical contradiction (TC) that is created by crossing parameter no. 42 – Mass of a stationary object (x) and parameter no. 29 – Loss of mass of a stationary object (y) is represented by the following expression [21]:

$$x=\begin{bmatrix} L^3 & 0 \\ 0 & T^{-2} \end{bmatrix},\ y=\begin{bmatrix} L^3 & 0 \\ 0 & T^{-2} \end{bmatrix}$$

TC in the form of a product xy is obtained using the expression:

$$TC_{(x,y)}=xy=\begin{bmatrix} L^3 & 0 \\ 0 & T^{-2} \end{bmatrix}\times\begin{bmatrix} L^3 & 0 \\ 0 & T^{-3} \end{bmatrix}=\begin{bmatrix} L^6 & 0 \\ 0 & T^{-5} \end{bmatrix} \quad (1)$$

The resulting product is called the determinant $D_{(x,y)}$, and is displayed using the expression:

$$D_{(x,y)}=L^6\times T^{-5} \quad (2)$$

Power $TC_{(x,y)}$ is calculated using the expression:

$$R_{(x,y)}=\sqrt{(6)^2+(-5)^2}=\pm\sqrt{61}=\pm 7.81 \quad (3)$$

If TC is created by transforming the expression $\frac{x}{y}$, then it follows:

$$TC_{(x-y)}=\frac{x}{y}=\begin{bmatrix} L^3 & 0 \\ 0 & T^{-2} \end{bmatrix}\times\begin{bmatrix} L^3 & 0 \\ 0 & T^{-3} \end{bmatrix}^{-1}=\begin{bmatrix} L^0 & 0 \\ 0 & T^1 \end{bmatrix} \quad (4)$$

Determinant $D_{(x-y)}$ is obtained by the expression:

$$D_{(x-y)}=L^0\times T^1 \quad (5)$$

Power $TC_{(x-y)}$ is calculated using the expression:

$$R_{(x-y)}=\sqrt{(0)^2+(1)^2}=\sqrt{1}=\pm 1 \quad (6)$$

Physical contradiction $PC_{(x,x)}$ for parameter x is obtained like this:

$$PC_{(x,x)} = x \times x = x^2 = \begin{bmatrix} L^3 & 0 \\ 0 & T^{-2} \end{bmatrix}^2 = \begin{bmatrix} L^6 & 0 \\ 0 & T^{-4} \end{bmatrix} \quad (7)$$

Its determinant $D_{(x,x)}$ is achieved using the following expression:

$$D_{(x,x)} = L^6 \times T^{-4} \quad (8)$$

Power $PC_{(x,x)}$ is obtained with the expression:

$$R_{x,x} = \sqrt{(6)^2 + (-4)^2} = \sqrt{52} = \pm 7.21 \quad (9)$$

Given that TC contains PC, their power ratio can be calculated via the ratio of the determinants given in the expressions:

$$D_{(x,x)} - D_{(x,y)} = x + x - (x + y) = D_{(x-y)} = x - y \quad (10)$$

By introducing a standardized value R_n of the relationship intensity between $TC_{(x-y)}$ and $TC_{(x,y)}$ a more objective assessment of the state of the forces that exist in TC are achieved:

$$R_n = \frac{R_{(x-y)}}{R_{(x,y)}} = \frac{1}{7.81} = 0.128 \quad (11)$$

From tab. 1 can be seen to be the greatest intensity is in the contradiction of R_n in TC which consists of parameters no. 42 and 29 with value R_n = 0.128 This means that in the case of a reduction in the mass of a stationary object (FPS-RCB), there is inevitably a loss of the mass of the stationary object. Since FPS-C consists of an inner layer impregnated with spherical granules of activated carbon, and an outer layer of woven material with an impregnated protective layer showing oleophobicity and hydrophobicity, this means that the thickness of the inner layer is reduced. This will weaken the FPS's protection against RCB agents. The structure of the contradiction is such that the intensity of the contradiction $R_{(x,y)}$ = 7.81, which was obtained by multiplying two chosen parameters of $TC_{(x,y)}$, displays a stronger intensity than $R_{(x-y)}$ = 1, which is obtained by dividing two parameters of $TC_{(x-y)}$. By multiplying parameters 42x29, parameter no. 39 is achieved - Using the energy of a moving object (L^6T^5). That moving object that releases energy could be the Sun that releases heat and electromagnetic radiation. That energy should somehow be used at FPS-RCB. If we assume that the FPS-RCB should have two layers (inner and outer), then the inner layer should remain unchanged, i.e. it should retain a layer of spherical activated carbon that will absorb the C agent that penetrates to it in vapor form. The outer layer of FPS-CB should be made of woven material on which a thin layer of TiO_2 (alternatively: Ag) is applied. In contact with sunlight, the decontamination of C and B agents that reach the surface of FPS-RCB occurs.

In this way, this outer layer becomes a mechanical obstacle for the passage of contaminant droplets, but also a reactive layer. The external resource is the Sun, which enables this outer layer to turn from passive protection to active protection.

It was established that by modifying standard military textiles with TiO_2 nanoparticles, textile substrates with self-decontamination properties are obtained [26-28]. To solve the problem of protection against aerosol B and R agents, Functional Oriented Search (FOS) was used as one of the most powerful TRIZ tools for solving innovation problems on a heuristic basis [4].

Table 1. Calculation of the strength of contradictions R_n, $R_{(x,y)}$, $R_{(x-y)}$ respectively, in the inventive FPS-RCB design problem

Improvement	**22**	Permeability (**$L^{-2}T^{1}$**)	*PC*	2.864; 2.236; 6.403	3.606; 1;3.606	4.135; 1.41; 5.831
	29	Loss of mass of a stationary object (**$L^{3}T^{-3}$**)	2.864;2.236; 6.403	*PC*	0.499; 5.657; 2.828	0.128; 7.81;1
	31	Speed (**$L^{1}T^{-1}$**)	3.606;1; 3.606	0.499; 5.657; 2.828	*PC*	0.447; 5; 2.236
	42	The mass of a stationary object (**$L^{3}T^{-2}$**)	4.135;1.41; 5.831	**0.128; 7.81; 1**	0.447; 5; 2.236	*PC*

The main idea of FOS is to use existing technology from a different field of science and engineering to solve a specific innovation problem, in relation to the field to which the initial problem belongs. As it was determined in research [29-31] that the materials from which the protective half-masks are made successfully protect the respiratory organs from the aerosols of B agents, and the filter of the protective mask M3 from the aerosols of depleted uranium [32], then by analogy it was concluded that the same will apply and in the case of percutaneous protection of the human body. Namely, the structure of filters used in respiratory protection is in principle similar to the structural design of FPS-RCB, as respiratory protection is largely similar to percutaneous body protection. Therefore, it was concluded that the conceptual design of the double-layer FPS-RCB will effectively protect the user from all three types of contaminants, which should be confirmed experimentally. In wartime conditions, especially in conditions of imminent RCB danger, instead of wearing the classic war uniform, it is suggested to wear only the FPS-RCB.

5. CONCLUSION

Inventology combines functional, developmental and research problems treating them as inventive military technical problems from the first to the fifth level of inventiveness. At the same time, when searching for the ideal final solution to military technical problems, inventory relies on dialectics, mathematical-physical modeling and heuristics.

Functional problems are problems of technical improvement, and they are solved without the help of science and are of the first inventive level. A significant role in overcoming them is played by the application of kaizen and standardization.

Development problems are successfully solved by applying heuristic scientific methodology. They contain a second or third level of inventiveness. When solving them, the tools of inventory and TRIZ are used.

Research problems are solved by the combined application of mathematical-physical modeling in order to determine the cause of the problem and heuristics in order to find an adequate resource, the introduction of which in the system results in solving the problem. They contain a fourth or fifth level of inventiveness. To solve them, inventory tools such as the LT-matrix of contradictions and TRIZ tools are used in combination.

On the example of the new conceptual design of the FPS-RCB filtering protective suit that should successfully protect against radioactive, chemical and biological (RCB) agents, the successful application of inventory to solve the military technical problems that arise was demonstrated.

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