DOI:10.12845/bitp.32.4.2013.2

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Przyjęty/Accepted/Принята: 25.10.2013;
Zrecenzowany/Reviewed/Рецензирована: 04.12.2013;
Opublikowany/Published/Опубликована: 20.12.2013;

PROJECT-ORIENTED MANAGEMENT OF INDUSTRIAL PRODUCTION OF FIRE AND RESCUE EQUIPMENT BY MEANS OF GEOMETRIC MODELLING

Проекно-орентированное управление промышленным производством пожарно-спасательной техники средствами геометрического моделирования

Zorientowane na projekt zarządzanie produkcją przemysłową wyposażenia przeciwpożarowego i ratunkowego z użyciem modeli geometrycznych

Abstract
Objective: The objective of the research is to develop a method based on the geometric modelling for the purpose of improving the effectiveness of fire protection project management in industrial production of fire protection technology systems.
Methods: The theoretical inheritance mode of effective management in project-organizational structure of fire protection and specialized technical equipment production using geometric modelling.
Results: Mathematical and geometric models of project management describe graphically the process of optimal financial resources allocation in conditions of project-organizational production structure of fire protection and a special type of fire rescue equipment. Methodological basis of the project and program management subject area were enhanced through the introduction of project-oriented management using techniques of geometric modelling in industrial production of fire-rescue specialized equipment. The use of geometric modelling methods in the project-organizational management of specialized technical systems manufacturing and systems engineering provides optimization of whole production process and management automation.
Conclusions: Mathematical and geometrical models of resource management in fire protection and industrial production of specialized equipment were developed. The graphical visualization process of effective project management in the allocation of financial resources for the industrial production of special fire-rescue equipment was constructed; The use of geometric modeling methods in project-organizational management of specialized systems production provides optimization process of whole production process and management automation.

Keywords: geometric modeling, projects, models, resources, fire protection and specialized equipment;
Type of article: review article

Аннотация
Цель: Разработка метода основанного на геометрическом моделировании для целей повышения эффективности управления противопожарной проектной средой при организации промышленного производства технологических систем противопожарного типа.
Методы: Теоретический метод наследования эффективного управления проектно-организационной структурой при промышленном производстве противопожарной и специализированной техники с использованием геометрического моделирования.

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DOI:10.12845/bitp.32.4.2013.2

Результаты: Разработаны математические и геометрические модели графического описания процесса управления проектом оптимального распределения финансовых ресурсов в условиях проектно-организационной производственной структуры промышленного выпуска противопожарной и специального типа спасательной техники; расширена методологическая база из предметной области управления проектами и программами, за счет внедрения проектно-ориентированного управления с использованием методов геометрического моделирования в условиях промышленного производства специализированой техники пожарно-спасательного типа; применения методов геометрического моделирования при проектно-организационном управлении выпуска специализированых технических систем обеспечивает процесс оптимизации всего производственного процесса и автоматизацию управления.
Выводи: Разработанные математические и геометрические модели управления ресурсами в проектах промышленного производства пожарной и специализированной техники; построена модель графической визуализации процессу эффективного управления проектом при распределении финансовых ресурсов для условий промышленного производства спецтехники пожарно-спасательного типа; применение механизмов геометрического моделирования позволило достичь основной цели – синергии элементов конвергируемых методологий при разработке методологии и системы управления проектами, программами и портфелями данного типа предприятия.

Ключевые слова: геометрическое моделирование, проекты, модели, ресурсы, пожарная и специализированная техника;
Вид статьи: обзорная статья

Abstrakt
Cel: Opracowanie metody opartej na modelowaniu geometrycznym w celu zwiększenia skuteczności zarządzania w środowisku projektów ochrony przeciwpożarowej w produkcji przemysłowej technologicznych systemów przeciwpożarowych.
Metody: Teoretyczna metoda dziedziczenia skutecznego zarządzania strukturą projektowo-organizacyjną w ochronie przeciwpożarowej i produkcji wyspecjalizowanego sprzętu technicznego przy użyciu modelowania geometrycznego.
Wyniki: Modele matematyczne i geometryczne zarządzania projektem opisujące w sposób graficzny proces optymalnej alokacji środków finansowych w warunkach projektowo-organizacyjnej struktury produkcji przemysłowej sprzętu przeciwpożarowego i ratowniczego. Podstawa metodologiczna tematyki projektowej i zarządzania programem została rozszerzona o zarządzanie projektami zorientowanymi na zastosowanie techniki modelowania geometrycznego w warunkach produkcji przemysłowej produktów techniki pożarowo-ratowniczej. Zastosowanie metod modelowania geometrycznego w zarządzaniu projektowo-organizacyjnym produkcji wyspecjalizowanych systemów technicznych oraz inżynierii systemów zapewnia optymalizację całego procesu produkcji i automatyzację zarządzania.
Wnioski: Opracowano matematyczne i geometryczne modele zarządzania zasobami do zastosowania w produkcji przemysłowej wyspecjalizowanych produktów technicznych oraz produktów związanych z ochroną przeciwpożarową. Stworzono model graficznej wizualizacji procesu skutecznego zarządzania projektem przy podziale środków finansowych dla warunków produkcji przemysłowej wyspecjalizowanej techniki pożarowo-ratowniczej. Zastosowanie mechanizmów geometrycznego modelowania pozwoliło osiągnąć cel główny – synergię elementów całego procesu produkcji.

Słowa kluczowe: modelowanie geometryczne, projekty, modele, zasoby, technika pożarnicza i wyspecjalizowana;
Typ artykułu: artykuł przeglądowy

1. Introduction

The effectiveness of financial resource management in order to achieve an optimum state of design, production and implementation of fire protection system is possible in case of using models and methods of project-oriented management. Transition to the project-oriented management in sphere of industrial production of fire and specialized equipment requires creation of such project-management methodology that takes into account specificity of measures, aimed to improve significantly fire protection systems at industrial plants and high hazard objects. Such an approach requires transition to a higher level of use of project management methodology when organizing management in all spheres of production and practical activities. This methodology should correspond to effective functioning state of economic activity at the level of design, manufacturing and operating component. Thus, the selected research area is important, especially in terms of environmental degradation in the world.

2. Problem setting

Worldwide complication of environmental situation needs introduction of special requirements to production of industrial fire prevention products. Solving of this problem needs involvement of significant financial resources, management of which requires the use of project-oriented management means. Resource management in projects of industrial production of fire and specialized equipment will ensure the optimization approach to the management of financial flows at the level of design, manufacturing, operation, as well as retraining of fire and rescue service personnel. At the moment there is no structured methodology of project-oriented management of financial resources for organizing design, manufacture and operation of fire protection equipment, developing technologies that take into account the current state of globalization and cybernetization of society.

3. Analysis of recent research

The analysis of research on creation and effective use of technical systems in enterprises of fire protection character and high hazard objects indicates the absence of reasonable methodology of project-oriented management.

The results of the development of scientific fundamentals of project management in industrial technical system production are presented in the works of R. D. Archibald, S.D. Bushuev, Yu.P. Rak, V.A. Rach, M.M. Brushlinskyy, K.V. Koshkin, Hiroshi Tanaka, V.M. Burkov,

 BiTP Vol. 32 Issue 4, 2013, pp. 25-30

 DOI:10.12845/bitp.32.4.2013.2

Thovb O.S.etc. [1, 2, 3]. Scientific reasoning of project management processes of financial resource allocation to organize production of fire protection equipment and specialized systems at all stages of project implementation, taking into account that specificities of operating conditions of such systems are absent.

Improvement of financial resource management in the projects of organization and management of production process is subject to development of methodologies, which are based on design-geometric management methods of fire protection [4].

4. Purpose of research

The aim of the article is to develop a method, based on geometric modelling, for the purposes of fire protection project management for industrial production of fire protection technical systems.

5. Main part of the research

The effective implementation of fire protection projects in organizing production control management (design, industrial production, operation and disposal stages) in the output of fire protection technical systems is achieved through the introduction of project-oriented management involving geometric modeling methodology. The main condition of the implementation of this project is to manage financial resources at all project stages of industrial production. Cost minimizing of industrial production of such systems can be achieved when using methods of geometrical modeling in the allocation of financial resources at all phases of the project life cycle.

Using the method of geometric modeling, we perform some interpretation, characteristic to resource management in projects of industrial production of technical and specialized systems of fire protection type.

In particular, the cost of the entire project can be formalized in the form of its individual components. An important component of the project is scientific and technical development of its all elements. The cost of performing design studies W_g is determined by the value a_i of materials, wages, etc.:

$$W_g = w(a_i) \tag{1}$$

Resources r_i of implementation i – of that production project include, besides W_g, necessary types of works p_i, aimed at project implementation

$$r_i = r(W_i, p_i) \tag{2}$$

Since W_g covers all element components of i of project elements, their share in each of them is

$$W_g = W_g(\alpha_1, \alpha_2, ..., \alpha_i) \tag{3}$$

where $\sum \alpha_i = 1$.

An important condition of the project implementation is the process of its financing. To consider changes in the allocation of financial resources due to inflation and, therefore, to predict their value at the end of the project implementation is possible on the basis of the known exchange rate ***x, y*** with predicted change in time t:

$$ax^2 + by^2 + dx + ky + mxy = d \qquad 4)$$

where the coefficients of the polynomial are determined for the known dependence $y = y(x)$, obtained by considering time characteristics exchange rates (Fig. 1).

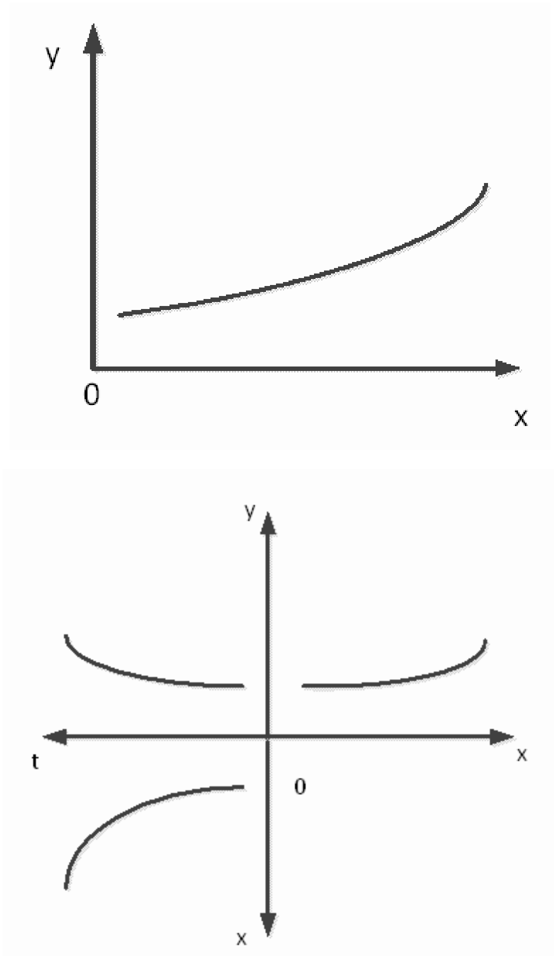


Fig.1. Scheme-model of the distribution of time characteristics of exchange rate changes (of financial resources) in project management by the method of geometric modeling
Рис.1. Модель-схема распределения временных характеристик изменения валют(финансовых ресурсов) в проектном управлении методом геометрического моделирования

A model of resource management in projects of industrial production of fire protection and specialized machinery is implemented by hypersurface G of covering multidimensional phase space $O(a_i, r_i, p_i)$ of its parameters (Fig. 2).

DOI:10.12845/bitp.32.4.2013.2

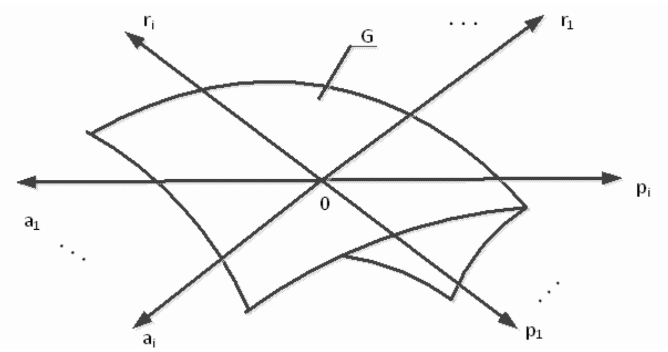


Fig. 2. A model-scheme of resource management in projects of industrial production of fire protection equipment by geometrical modeling
Рис. 2. Модель-схема управления ресурсами в проектах промышленного производства противопожарной техники геометрическим моделированием

Taking into account (1) and (3), we see that W_g for work p_i is determined by the value a_i as a part of value $\alpha_i W_g$. In turn subspace $a_1 ... a_i$ determines the hypersurface W_g, which serves as the subspace of arguments of hypersurface r_i. Subspaces $p_1 ... p_i$ are two-dimensional phase spaces of arguments that form the hypersurface of covering phase space.

Given the subspace $a_1 ... a_i p_1 ... p_i$ serves as the only subspace of arguments, hypersurface of phase space can designed in the direction, which is orthogonal to the subspace $r_1 ... r_i$ (Fig.3).

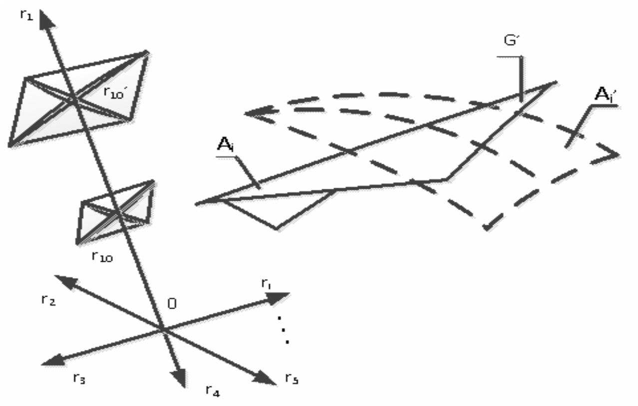


Fig. 3. Scheme-model of subspace of resource management in projects of industrial production of fire protection and specialized equipment
Рис. 3. Модель-схема подпространства управления ресурсами в проектах промышленного производства противопожарной и специализированной техники

Projection of hypersurface G' of subspace $r_1 ... r_i$ contains points A_i as parameters of the process, the coordinates of which are determined by numerical values of all measurements of covering multidimensional space (see Fig. 3).

Hypersurface projection (see Fig. 4) can be described by the dependence, in particular

$$r_1 = r\,(r_2, r_3, ..., r_i) \tag{5}$$

Extremum (5) can be determined by setting hyperplane G' with a mark r_{10}, parallel to subspace r_2, $r_3 ... r_i$ (see Fig.4). Smoothly changing r_{10}, setting its other numerical parameters, in particular r'_{10}, we find the point A_i' of extremum, coordinates of which determine the volume of resources for the implementation of the project portfolio.

A model of resource management implies simultaneous change of a parameter or several project parameters of industrial production of fire protection and specialized equipment, that is accompanied by shape changes of hypersurface G and, therefore, location of extremum point A_i. Managing numerical values of parameters for a given direction of hyperplane with variable mark r_1, the coordinates points A_i are received, as parameters that determine efficiency of resource management in projects.

Example of determination of optimal and compromise values of variable parameters is carried out for the case of two optimization functions under arbitrary number of parameters for compromise optimization of specialized fire and rescue equipment micro transformer (SFREMT) having power P_2 by two parameters: volume V and weight D according to dependences [5]:

$$P_2 = \frac{\left(4.44 k_c f B 10^{-2}\right)^2 \left(1+\varepsilon_u\right)\left(1-U\right) U k_{ok} y^2 x z a^2}{p k_{T\omega}\left(1+\varepsilon i_1\right)\left(1+\varepsilon_u\left(1-U\right)^2\right)\left(z+zy+\pi x_k\left(1+2\varepsilon i_1\right)/\left(1+\varepsilon i_1\right)\right)},$$

$$V = 2\left(x+1\right)\left(y+2x_k\right)\left(z+1\right)a^3, \tag{6}$$

$$D = \left[k_c y_c y\left(2\left(x+z\right)+\frac{\pi}{2}\right)+k_o y_k k_{T\omega} z_k\left(x_k - x\Delta\right)\left(2+xy+\pi x_k\right)\right]a^3,$$

where x,y,z – dimensions of SFREMT;
$k_c, f, B, \varepsilon, k_{ok}, a, k_{T\omega}, i_1, k_o$ – calculation parameters.

Hyperplane G' in the case of dependence $\frac{P_2}{D} = f\left(\frac{P_2}{V}\right)$ is set in coordination system $O\frac{P_2}{V}\frac{P_2}{D}$ by a segment:

$$\frac{P_2 / V}{\lambda_V} = \frac{P_2 / D}{\lambda_D} = 1, \tag{7}$$

where λ_D and λ_V - optimality balance according to volume and weight.

Having accepted for received dependences $\frac{P_2}{D} = f\left(\frac{P_2}{V}\right)$ optimality balance λ_D and λ_V accordingly, we conduct tangent G'_p and, therefore, define necessary geometrical dimensions of SFREMT. In the case of compromise optimization and, for example, calculated optimality balance $\lambda_V = 1$, $\lambda_D = -0.4$ dependence (7) is presented by a segment in the plane $O\frac{P_2}{V}\frac{P_2}{D}$.

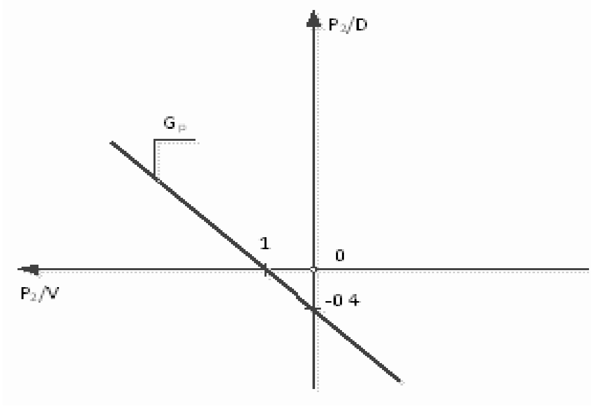


Fig. 4. Graph of dependence of a segment in the plane for the optimality balance condition calculation under compromise optimization and project management
Рис. 4. График зависимости отрезка в плоскости для условия расчета весов оптимальности при компромиссной оптимизации и проектном управлении

We build graphical dependencies $\frac{P_2}{D} = f\left(\frac{P_2}{V}\right)$ when resizing x, y, z of SFREMT, which present projection G in the two-dimensional plane.

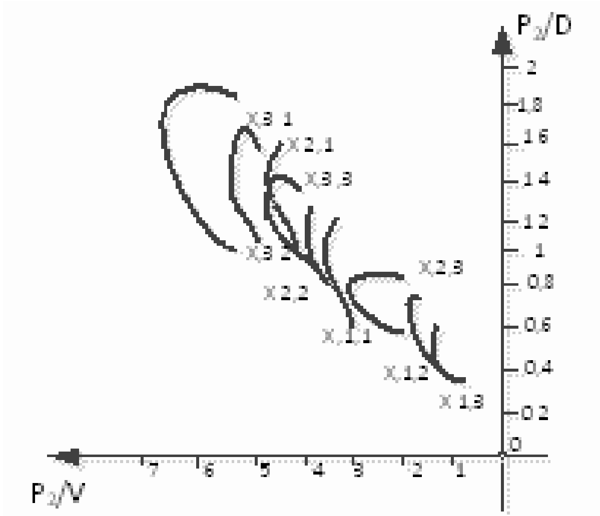


Fig. 5. Graph of dependencies of optimality determination when calculating geometric dimensions of SFREMT and project management
Рис. 5. График зависимости по определению оптимальности при расчете геометрических размеров СМТПРТ и проектном управлении

Putting a tangent in parallel to the segment G'_p, we define calculated dimensions of SFREMT $x = 0{,}7$; $y = 3$; $z = 1$ (Fig. 6).

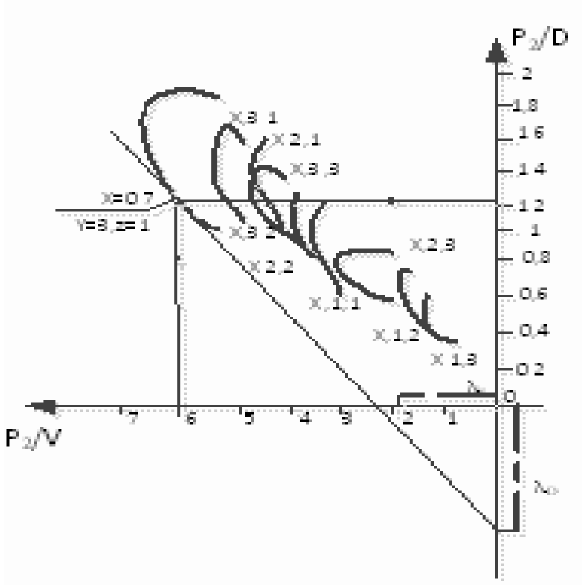
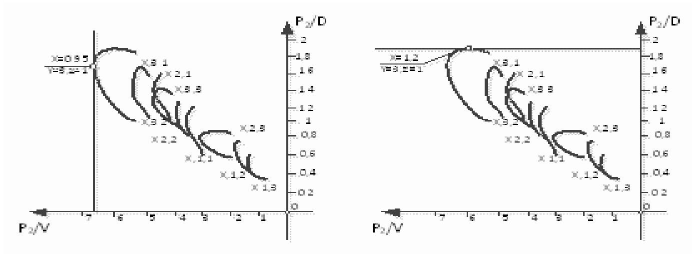


Fig. 6. Graphs of dependencies of determining Compromise extremum for calculated dimensions of SFREMT
Рис. 6. Графики зависимости определения компромиссного экстремума для расчетных размеров СМТПРТ

Absolute extremum according to volume V or weight D is defined, by drawing a tangent to the projection G of hyperplane in parallel to the axis $O\frac{P_2}{D}$ and $\frac{P_2}{V}$ (Fig. 7a, b).



a) b)

Fig. 7. Graphs of dependencies of determining compromise extremum for the case of two functions and project management when calculating SFREMT dimensions
Рис. 7. Графики зависимости определения компромиссного экстремума для случая двух функций и проектного управления при расчете размеров СМТПРТ

Problem of compromise extremum determination for the case of two optimization functions under arbitrary number of independent arguments is solved by the above method. Increasing the number of optimization functions with the same number of arguments requires use of numerical methods of calculation. Increasing number of optimization functions, up to three:

$$\frac{P}{D} = D(x, y, z, a)$$
$$\frac{P}{V} = V(x, y, z, a) \qquad (8)$$
$$\frac{P}{W} = W(x, y, z, a)$$

DOI:10.12845/bitp.32.4.2013.2

leads to phase space dimensionality increase of its implementation:

$$\frac{P}{D} = f\left(\frac{P}{V}, \frac{P}{W}\right) \quad (9)$$

and tangent hyperplane serves as a two-dimensional plane of the three-dimensional phase space (Fig. 8):

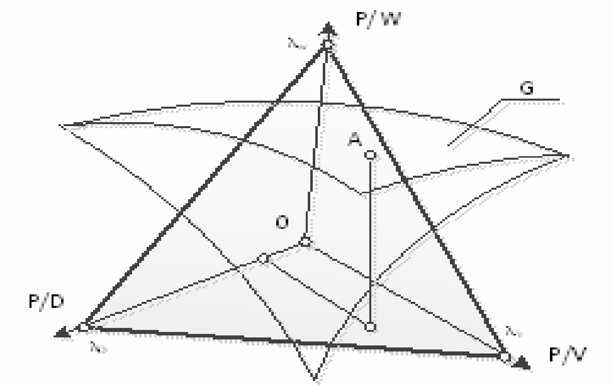


Fig. 8. Graphs of dependencies of determining three optimization functions of geometrical parameters of SFREMT in three-dimensional phase space of project management
Рис. 8. Графики зависимости определения трех функций оптимизации геометрических параметров СМТПРТ в трехмерном фазовом пространстве проектного управления

$$\frac{P/D}{\lambda_D} + \frac{P/V}{\lambda_V} + \frac{P/W}{\lambda_W} = 1 \quad (10)$$

Point *A* coordinates of their contact is the value of the desired ratios and, therefore, geometrical parameters of SFREMT.

Compromise values of geometric parameters of SFREMT correspond to the contact point of these geometric patterns.

Values of geometrical parameters of SFREMT having power of 50W are determined by consecutive comparing of compromise values of optimization functions as contact point coordinates of equivalent manifold and a plane (10). Obtained values $x = 1, y = 2, z = 2{,}5$ with a standard value $a = 25$ *mm* of closed armor belt core are within the boundaries of SFREMT parameters for calculated optimality balance $\lambda_D = 4,\ \lambda_V = 1,\ \lambda_W = 8$.

6. Conclusions

On the basis of the research analysis of realization of the project-oriented management of industrial production of fire protection and specialized equipment it was suggested:

- A scheme-model of project management of efficient allocation of financial resources for industrial production conditions and use of geometric modeling methods.
- Mathematical and geometric models of resource management in production projects of fire and specialized equipment.
- Project task was implemented introducing geometric modeling and project management in the calculation of optimal parameters of SFREMT in industrial production and obtaining numerical values of geometrical parameters of the closed armor belt core.
- The results of experimental researches will be resulted in future in the extended interpretation of this article.

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