Implementation of Optimizing Technologies for The Economic Security of Complex Manufacturing Systems

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Abstract— **The article is devoted to the actual problem of economic security of complex production systems. Examined are structure and capabilities of complex production systems that implement complex business processes including research and development, preparation and production process itself and are highly demanding on ensuring economic safety at all these stages.**

The paper highlights main directions and features of the functional components of the economic security of complex production systems. On the basis of the carried-out analysis the priority influence of the technological component featured by optimization of costs of resources and applied technologies is noted.

The model of management of a complex production system is presented where economic safety is considered from a position of functional stability of system.

The approach proposed in the article involves considering the influence of disturbances on the part of the external environment, assessment of dependence of the applied technologies and technological stability.

The obtained results can be used in the selection of technologies to ensure economic security production systems.

Keywords— Complex production systems, optimizing technologies, economic securit

I. Introduction

Political tensions, vague and uncertain relationships between countries, economic sanctions against the Russian Federation have determined the priority of the economic security of our country. The analysis of factual data has shown that the majority of researchers point to the correlation between the economic system's level and the national security, as well as it has become obvious that the economic security relies on the country's material resources.

The Edict of the President of the Russian Federation of 13 May 2017 № 28 «On the National Security Strategies of the Russian Federation for the period until 2030» [1] specifically stipulates that the economic security must be provided though the development of the industrial-technological basis. Consequently, the effectiveness of the economic system is determined to a great extent by the performance of the manufacturing sector. It is also evident that the economic system is secure, if it relies on a powerful industrial-technological basis which comprises complex, technology-intensive manufacturing systems.

The share of technology-intensive enterprises, e.g. complex manufacturing systems, have been growing slightly over the recent years in the overall volume of the GDP: 2013 – 21%, 2014 – 21,6%, 2015 – 21,5%.

Complex manufacturing systems (CMS) involved in the economic system of the country have a great impact on its security. This fact reveals the relevance of the issues discussed by the authors in connection with the technologies applied to ensure and leverage the economic security of CMS.

A large number of prominent scholars have addressed the subject of economic security. The general issues of economic security have been discussed by Oleynikov E.A., Sengagov V.K., Gerasimov K.B.. Nesolenov G.F.; the issue of enterprises' economic security has been studied by Kovalev D.V., Suchorukova T.A., Grounin O.A., Matveev N.V., Samotchkin V.N., Barakhov B.I. The problems of the economic security evaluation procedures have been addressed by Goncharenko L.P., Guilphanova M.T., Kolesnichenko E.A. etc.

The issues of the economic security and the sustainable development of manufacturing systems have been examined by Maleev T.A. Tchuprov S.V., Kanevskiy A.B. have explored the sphere of the manufacturing systems management.

The article is focused on the definition of the optimizing technologies which can be used to provide the CMS' economic security. This problem can be solved though the exploration of the national security's component functions and features and the analysis of the CMS management model, provided that the problem of the economic security is examined from the perspective of the system functional sustainability.

II. Theoretical Part

The interaction between system elements results in a complex system whose current condition can be described with the key parameters $\{x_i\}$, i=1,...n, where

$$\vec{X} = \begin{Bmatrix} X_1 \\ X_2 \\ X_n \end{Bmatrix} [2] \qquad \vec{X}$$

-is the system state vector which represents a number of parameters describing a system.

General characteristics of a complex system include material resources, environment, interaction between units, division between production and management [3]. Modern industrial enterprises which are key development factors are characterized by intensive technological and innovative mobility, complex structure and close interaction between constituent elements.

Consequently, it is of high importance to consider these enterprises as complex manufacturing systems closely interrelated with external and internal contexts. To achieve the goals of the research, i.e. to ensure the economic security, in terms of system management, it is necessary to describe the common patterns of complex manufacturing systems, different processes by means of modern methods and models related to the complex management systems theory.

As a result of the designing process, we can observe that the complex manufacturing system is based on the interrelation between the system's input and output. Describing the complex manufacturing system means determining its subsystems and relationships between them, finding out the correlation between the changes of a subsystem's state vector and the growth of another subsystem's ones. This correlation can be presented as a matrix of a subsystem's impact vectors in relation to another one.

$$\overrightarrow{dY} = X_y . \vec{X}$$

X_y - an impact factor matrix including the subsystem X and the subsystem Y [4].

The complex manufacturing system includes two subsystems: the subject to management and the management block.

The internal context is formed by production technologies, an infrastructure, a combination of production components, tasks and other parameters. As for the external context, it may take the form of orders, regulations, legal instruments which have an influence on the system and its input [5].

The management block controls the managed subsystem by means of signals which are transmitted though tasks, plans, regulations. The changes in the system's condition are brought about though the feedback. Consequently, the system's effectiveness can be shown as an equation based on the interrelation of the above-mentioned factors. The input of the system encompasses the indispensible amount of resources, the system's external links, i.e. the environment where the system functions. The output of the system is connected with its outcomes, its impact on the environment.

The internal condition of the system determines its problem-solving abilities.

Thus, managing a complex manufacturing system implies coordinating the interaction between its elements, empowering it to function properly in changing circumstances, preventing conflicts and maintaining its sustainable development which relies on the effective allocation of resources and technologies.

The unique character of the CMS enables it to carry out complicated business processes including scientific and experimental projects, industrial design and operations. We can observe a large variety of technical and economic elements which, taken as a whole, make up a system able to function effectively and provide economic security.

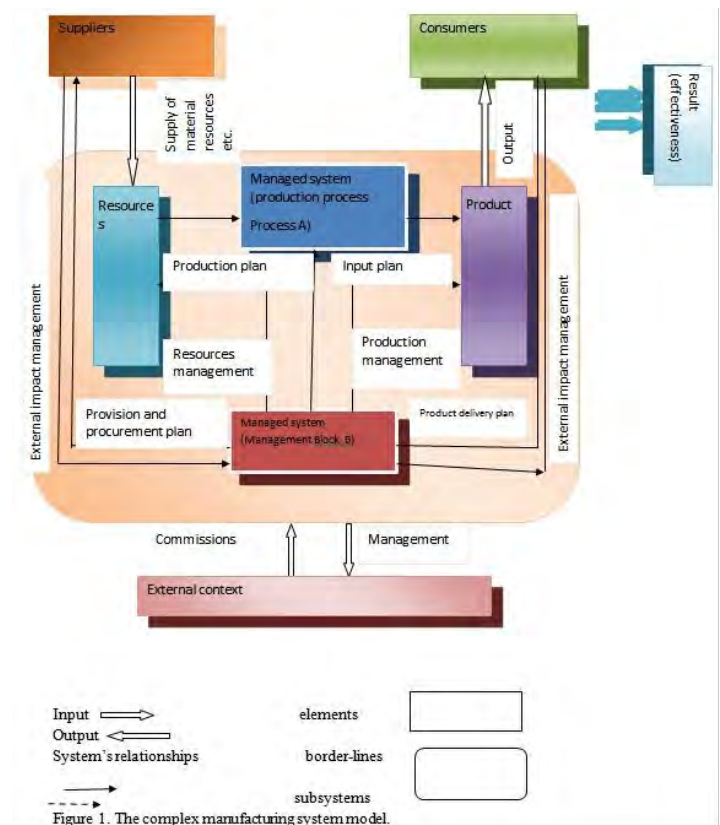Figure 1. The complex manufacturing system model.

Fig.1. The complex manufacturing system model.

Nowadays, scholars tend to consider the CMS's security as a system whose structure includes technological, ecological, economic and information components. The economic security is considered as a condition providing the most effective use of resources and preventing threats, thus maintaining the stable functioning of an enterprise. This condition can be achieved through a combination of resources, funds, personnel, information, technologies and assets [6, 7, 8]. The economic security is determined by the effectiveness of the management model of the CMS and can be achieved through the coordination of various processes and actions which take place at different levels of the system, as well as the interaction with agents set in the external context.

One has to analyze the external links of the system to provide economic security effectively. The analysis is carried out while modeling security processes which may accompany the main production operations of an enterprise, technical development programmes, marketing, innovation and investment activity, business planning, project management and cooperation with other organizations [9].
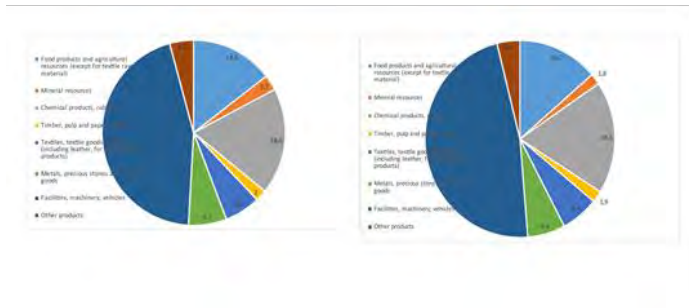
Fig.2. The import pattern of the Russian Federation (in percentage terms) in 2017 [10].

TABLE I.   PERFORMANCE DATA IN THE MACHINERY AND FACILITIES PRODUCTION SECTOR

	2010	2012	2013	2014	2015	2016
Gas turbines , except for ramjet and turboprop engines, mln. kW.	2,1	1,7	1,1	1,4	1,1	1,4
Metal-cutting machines, thous. items.	2,8	3,5	2,9	3,4	3,4	3,9
Compression type machines, thous.items	2218	2098	2162	2336	3200	2423
Furnaces and casting machines, thous.t.	23,9	24,1	21,5	17,2	52,8	31,7

The graphs and tables above clearly demonstrate the reliance of the country on imported facilities, the low absolute value for the facilities produced in Russia and its slight growth over the recent years (the index for the production in 2016 is 103,8%). The data indicates that negative technical and economic factors may affect the secure functioning of the CMS. One has to analyze the main processes and production operations to provide internal security of the CMS.

When the production system functions, negative internal factors may appear and take the form of accidents, delays in the production process, break-downs in the technological cycle, cut-offs of the electricity supply, the lack of instruments and equipment and the extension of the technical support service period.

The technical and technological aspects have the greatest impact on the economic security. They are connected with the supply of facilities, machinery, funds, technologies and information resources.

The analysis of different definitions of the term «economic security» reveals the predominance of the balance between a system and its environment. This fact points to the neoclassical approach to the system sustainability evaluation. The authors stick to the opinion that a system's economic security is determined by its ability to function, i.e. to remain stable. In the framework of the system approach, the term «economic security» is considered as a system's intrinsic quality which ensures its stability in the context of internal and

external threats. We can conclude that the aim of the economic security of the CMS is the system's sustainable and efficient functioning.

The interaction of the system's various elements is based on the coordination of standards and technical solutions, as well as on the analysis of the production output and the evaluation of its adequacy to the technologies and resources. As the classical definition of the term «technology» goes, it is the theory on the methods and processes underlying the treatment of natural resources in order to produce consumer goods and machinery. Nowadays we can notice that the definition above is expanding: the term «technology» denotes an amount of organizational, scientific, experimental and engineering processes which are involved in all production operations.

Thus, the term «technology» refers to all methods and approaches involved in the problem-solving process, the combination of the system's interrelated processes. The ratio between different resources is determined by the technologies involved in the production operations. The technology tends to limit the production process and to determine quantitatively the resources' ratio [11]. The CMS stipulates that different technologies may be used simultaneously during the production process. This situation leads to the generation of a new technology which replaces the previous one without any interruptions in the production process. According to the authors, the CMS's modern technologies include optimization methods which exclude all the circumstances leading to extra expenses and ensure the effective use of a limited amount of resources. The optimization methods comprise economical production, total efficiency of all processes, project management.

The specific feature of the CMS is the complexity and the prolonged time span of the production cycle. The optimizing technologies include the methods and approaches which lead to the time and risk reduction and to the increased quality at different stages of the production cycle.

III. PRACTICAL RELEVANCE

The practical relevance of the technologies described in the previous part is proved by the experience of the holding company «The Russian Helicopters» where all the data connected with the product's life cycle are used for planning and monitoring. The specialists of the holding company develop both basic and critical technologies including robotics and additive technologies. The innovations are especially remarkable for the extended use of digital data covering all the production process from the model design to the product control. The optimizing technologies stipulate that all the processes are generated by automated systems including CNC machinery: the digital data is transmitted automatically during the production process. The development of the CNC machinery has contributed greatly to the emergence of new technologies [12]. It is worth noting that different stages of the development require the use of specific methods and management tools. The optimized management of the product's life cycle means the use of different management methods (projet/programme management, operational activity

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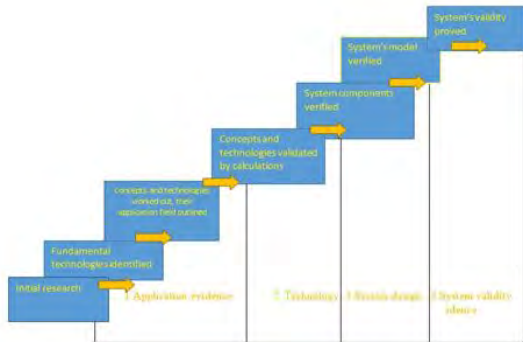

Fig. 3. The technology readiness levels.

Since the implementation of new technologies leads to the risk reduction from 100% (exploratory tests and experiments) to 0% (final tests), the coordination of the production process at different phases and the risk management require a specific approach. The specialists of the Krylov Scientific Centre tend to aggregate separate data to produce system solutions and complex technologies while designing project management technologies. The researches aimed at the formulation of scientific-technical tasks are carried out on the project basis and apply the following model including the stages below [13].

This approach to the implementation of the technology takes into consideration all the constituent elements of the system and ensures its adaptation to the dynamic circumstances of the environment. Thus, it has an impact on the sustainability of the CMS. In these systems the management technologies take the form of methods for forecasting, planning and monitoring.

IV. PROPOSALS AND OUTCOMES

The maximum efficiency of the system is achieved through the optimization aimed at the determination of the system parameters which provide the extremum of the objective function $(F(y) = extr)$ where F is the set of the interrelated functions performed by the system. The difference between the expenses involved in the production and the sale price is also an important indicator. The optimization is aimed at the expenditure reduction. The main purpose of the CMS is the increased efficiency of the production which is both technological and economic function. Taking into consideration the specific virtue of the system, the efficiency indicators may be of different importance, but they are correlated, firstly to reduce the expenses and to raise the

income; secondly to reduce the production time period and to raise the quality. The effective CMS management based on optimizing technologies can be presented in the following way:

$$\Pi(T*, 3c) \rightarrow max$$

$$\frac{d\Pi(T*, 3c)}{d3c} \Big|_{t*=0}$$

where the profit is sufficient and the expenses are at minimum. T – the optimization interval, 3c – expenses, Π – profit [3, p.117].

The authors consider the CMS optimizing technologies as an amount of methods which ensure the expenditure reduction and the increased quality and profit. The effectiveness of the optimizing technologies can be evaluated with the following parameters: S_1 - implementation expenses, $S_2 -$ operation expenses, $S_3 - productivity, S_4 - operation time, C_s$ – overall technology renovation expenses. Each innovation requires the amount of expenses involved in the scientific research to be determined, as well as the output sensitivity to the innovations must be thoroughly studied.

The sensitivity parameters of the CMS in relation to the technology renovation are indicated by the coefficient which is determined by the ratio of the following variables: Δa_m – resources consumption, $\Delta a_z - depreciation cost, \Delta a_p$ – labour consumption after the technology renovation, C_s — technology renovation expenses . $\frac{\Delta a_m}{C_s}$, $\frac{\Delta a_z}{C_s}$ и $\frac{\Delta a_p}{C_s}$. [2, p.579].

The CMS requires the new technologies to be implemented quickly and to function properly. The CMS is characterized by the producibility and the level of the technological processes is determined quantitatively and qualitatively by the technology level. The producibility level must be described in terms of the technological, industrial and technical sustainability [14]. It is advisable that the producibility level evaluation should be determined by the investment /profit ratio, the share of the technological operations performed by external contractors, the wear coefficient and the capital assets renovation rate.

The system's technology level reflects quantitative changes in the technological production method. All the limitations considered, the maximum level can reach the weighted average of the system's elements:

$$Y_c = \sum_{i=1}^{n} X_i Y_i$$

$$Y_c$$

where c – the system's technology level; Xi – the percentage of the employees in the I system's sector.

$$X_i = \frac{n_i}{\sum_{i=1}^{n} n_i}$$

where ni – the number of the employees in the I technological system's sector; $\sum_{i=1}^{n} n_i$ - the total number of the employees in the technological processes system [15].

This ratio shows the system's technology level and its reliance on the optimized use of resources. The changing external context considered, it is reasonable to use producibility and technology level indicators in order to determine the CMS's adaptation rate and its sustainability, as well as to evaluate the intensity of scientific innovations'implementation in the manufacturing sector. U.V. Gusev and D.V. Mamonov [16] who have explored the problem of sustainability believe that the set $G = \{x\}$ including the conditions which differ in terms of sustainability can be identified among all the system's conditions. The Figure 4 shows that with the time going on the system can undergo certain changes concerning its elements and the relations between them. The system's condition is indicated with the point x (1) at the moment t (1); at the moment t (2) > t (1) the system's condition is indicated with the point x (2). It may occur that x (2) ≠ x(1). If x(t) ∈ G is the system's condition at the moment t, the sequence of the system's conditions x (t) is considered as a process going on during a certain period of time. The system's condition is considered sustainable if the system's behavior pattern starts in a certain phase field and never leaves it (the behavior pattern x (t) refers to the sustainable system) [17, 18, 19].

Thus the technical and technological elements' sustainability is related to the advanced techniques and technological processes, mechanization, implementation of flexible automated production operations and facilities.
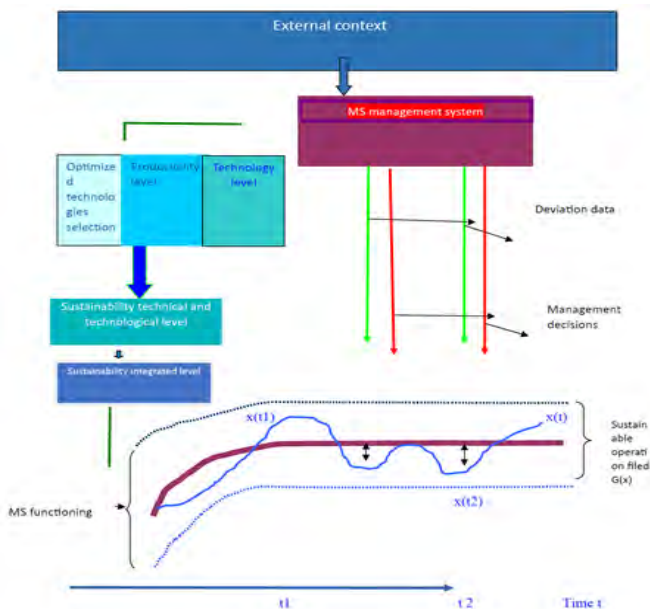

Fig 4. The CMS management chart and the impact of technology on sustainability.

The Figure 4 shows that the indicators connected with the use of technologies depend on the sustainability's technical and technological components. It also illustrates the influence on the integrated sustainability's indicator.

The proposed approach to the problem of the CMS's sustainability requires the determination of the system's adaptation rate in the context of new technologies. As it has been already said, the system approach stipulates that the economic security is provided by the sustainability amid negative external and internal agents. The system's sustainability determines the level of its economic security and can be reflected in it [20, 21]. In this context the integrated criterion of the economic security is the indicator of the system's sustainability. The same relation is established between management technologies and monitoring. The monitoring study contributes to the development of tactics and strategies, planning, problem-solving and control. The conception developed by S.V. Chuprov and A.B. Kanevskiy stipulates that an enterprise's monitoring can be based on the complex analysis of the enterprise's sustainability and the calculation of the sustainability integrated index by means of the factor analysis and the fuzzy sets theory. The monitoring system is considered as «a black box» which transforms statistic data into latent generalizing factors, complex indicators quality interpretation and the sustainability integrated index «S».
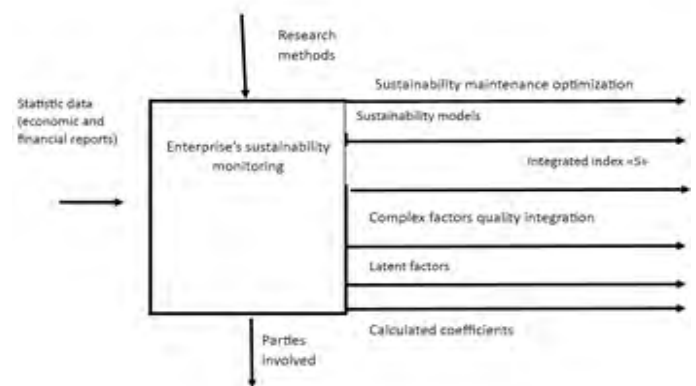

Fig.5. An enterprise's sustainability evaluation model.

Seven steps of the sustainability analysis have been indentified:

- Database building;

- Calculation and selection of specific sustainability indicators;

- Correlation analysis to identify superfluous specific sustainability indicators;

- Identification of complex sustainability indicators by means of the factor analysis;

- Integration of the complex indicators based on generalized factors into the integrated sustainability index «S»;

- Application of the regression and cluster analyses.

The outcomes of the monitoring study promote the management decisions with the view of the enterprise's sustainable and secure functioning. As it has been pointed out, the economic security is conditioned by the effectiveness of the CMS management model which is an important tool in the decision-making process. The processes of this model's life cycle which must be properly designed and comply with the modularity principles implying the interrelation of the functions can ensure the CMS's economic security. The functions performed by the processes are determined by input and output data, technologies and resources.

Ensuring the economic security by means of the processes optimization implies designing a model of the enterprise which may include a structure along with material and information resources. For that purpose Zachman's model may be suggested as it is the most comprehensive model of the enterprise's structure and other models can be integrated in it.

V. CONCLUSION

The specific character of the CMS's activity is proved by the fact that the outcomes of the scientific research and its numerous counterparts are double-purpose objects. The CMS which is aimed at the economic security plays an important role in the country's national security and its defense capability.

The reliance of the Russian economy on the supply of foreign machinery and technologies is a critical factor determining the development of optimizing technologies in the Russian Federation. This fact explains the importance of the technical and technological component of the economic security which is also conditioned by monitoring as a system management technology based on the determination of the sustainability integrated index.

The choice of the optimizing technologies reflects the CMS's ultimate adaptation and fast operation. The studied approach results in the evaluation of the technology's effectiveness and technical and technological sustainability. It also leads to the ongoing improvement of the negative factors mitigation mechanisms and the economic security ensured by means of management decisions.

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