ENGINEERING TECHNOLOGICAL SYSTEMS

Обґрунтовано модель та метод оцінювання ефективності управління фінансовими процесами в логістичних системах промислових підприємств. В моделі враховано параметри фінансових потоків та сукупний вплив на загальну ефективність. Метод розроблено на основі розрахунку інтегрального показника за критеріями ліквідності, збалансованості, інтенсивності, достатності фінансових потоків з урахуванням структури факторних ознак.

Сформовано групи факторів на основі методів стандартизації та актуалізації даних, які визначають ключові критерії управління фінансовими процесами на промислових підприємствах в умовах логістизації економіки. Інтерпретовано економічний зміст кореляційних залежностей між латентними факторами та їх змінними. Визначено рівень впливу ключових критеріїв на загальний стан управління фінансовими процесами в логістичних системах шляхом застосування методів таксономії. Для забезпечення достовірної оцінки кінцевого стану управління фінансовими процесами (високий, середній, низький, досить низький) запропоновано формулу розрахунку інтегрального показника. Встановлено припустимі межі його коливань методом контрольних карт Шухарта.

Застосування моделі забезпечує розробку об'єктивних рекомендацій щодо прийняття рішень з регулювання відповідних показників у розрізі виділених ключових критеріїв.

Для розрахунків використано комп'ютерну програму IBM SPSS Statistics (Росія), що дозволяє аналізувати значний масивів інформації та нівелювати помилки при обґрунтуванні рішень.

Запропонована модель може бути корисною для суб'єктів господарювання у міжнародному форматі. Вона відкриває додаткові можливості оцінки з врахуванням життєвого циклу підприємства, промислових тенденцій, етапу логістизації світової економіки

Ключові слова: логістизація, управління процесами, метод таксономії, інтегральний показник, модель оцінки фінансових процесів

DEVELOPMENT OF A MODEL FOR THE ESTIMATION OF FINANCIAL PROCESSES IN LOGISTIC SYSTEMS AT INDUSTRIAL ENTERPRISES

O. Bondarenko
Doctor of Economic Sciences,
Associate Professor
Department of Finance
Kyiv National University of Trade and Economics
Kyoto str., 19, Kyiv, Ukraine, 02156
E-mail: e95bond@gmail.com

O. Palyvoda
Doctor of Economic Sciences,
Associate Professor*
E-mail: Palyvoda_olena@ukr.net

O. Kyrylenko
Doctor of Economic Sciences,
Associate Professor*
E-mail: ons@ua.fm
*Department of Management
of Foreign Economic Activity of Enterprises
National Aviation University
Kosmonavta Komarova ave., 1,
Kyiv, Ukraine, 03058

1. Introduction

In the global economy, logistic systems play the role of an effective method of management and are recognized as a factor of economic development. Strengthening the tendency of formation of logistic systems by industrial enterprises is characteristic of economies in different countries. A search for additional financial opportunities in logistic systems of industrial enterprises requires optimal solutions that would be based on the logistic methodology of management of financial processes. This results in creating the conditions for minimization of expenditures based on the optimization of the parameters of financial flows, which will ensure the formation of the value of logistic chains and an increase in the cost of enterprises.

The processes of management of material, financial and information flows within logistic systems are widely examined by the global organizations that are members of the European Logistic Association. Its representatives prove that logistic systems must work by the corresponding actual financial structure, show the possibilities of modeling spatial trajectories of movement of financial flows, be actually funded and evaluated, take into account economic, social and environmental aspects. The need to improve the management of financial processes is caused by the development of logistics processes, the desire of countries to integrate into the world economic relations by entering the global logistics systems. In this regard, effective models of management of financial processes should reflect the specifics of functioning of industrial enterprises in the form of logistic systems and be based

on the experience of financial and logistics management. This indicates that the subject of the research into the estimation of managing financial processes in logistic systems of industrial enterprises and the development of solutions to optimize the parameters of financial flows are relevant.

2. Literature review and problem statement

Authors of [1] published a paper, which reveals the features of the management of financial flows in supply chains. Paying attention to feasibility of assessing the impact of management on optimization of the cost of capital, they propose the mathematical model «Supply chain funding», which reveals the relationship between the management of financial flows and net working capital. An important area of subsequent research in the field of supply chain funding is an analysis of the impact of specific market conditions, especially the benefits and risks of supply chains funding for companies during an economic decline.

Researchers [2] prove the need for operative control of financial flows in a supply chain and for development of the ways of risks optimization. The key point of the paper is the method of optimization of supply chain funding based of the improvement of internal processes and development of an approach to liquidity management that is common for participants. Despite the fundamental character of the presented paper, it is important to develop the ways to assess the state of liquidity management by companies-participants of supply chains.

In paper [3], it was indicated that the formation of innovative approaches to the management of financial processes in logistic systems of enterprises requires the development of procedures for acceleration of financial flows, reliability enhancement, improvement of the level of predictability assessment. This approach reflects the key role of financial flows in management of companies in terms of the logistication of economy and determines the feasibility of the search for rational models of ensuring the optimum values of quantitative, spatial and qualitative parameters.

Authors of study [4] developed a stochastic model for dynamic programming to determine the cost of the prepayment program. The positive side of the model is the estimation of future financial flows based of the analysis of a set of movement scenarios. However, the method was developed to manage the relationships with credit institutions, which reveals only one direction of the management of financial processes in logistic systems. It is appropriate for the authors to pay attention to the differential equations for the estimation of the influence of changes in parameters of financial flows on the optimal financing of logistic chains.

Scientific article [5] demonstrates the centralized supply chain model, in which material and financial flows are integrated. Quantitative assessment of the rationality of financial integration is based on the interaction of the monetary mass model with the systems of different levels of financial integration. Proving the effectiveness of the above-mentioned approach, it is important to continue modeling the situation where each participant will choose the first best solution within a decentralized supply chain.

Authors of study [6, 7] define the applied problems of management of financial processes at enterprises under condition of logistication of economy in the framework of the new direction – financial logistics. The papers of researches

reveal the methods of management of the dynamic state of financial resources to increase the value of companies. Despite the development of this direction, the issue of searching for the optimal approaches to evaluation of effectiveness of management of financial processes in logistic systems of industrial enterprises is still unresolved.

In paper [8], the dynamics of financial flows is touched upon in the part of the financial strategy implementation by a logistic system of an enterprise. The author defined the procedure of development of the integrated financial and logistic strategies and identified possible financial risks. Despite the merits of this study, the problem of the development of optimization solutions in management of financial processes in logistic systems of industrial enterprises with the use of the methods of strategic and economic and statistical analysis require further development.

Article [9] determined the conditions for forming a model of management of financial flows in logistic complexes. The order of the rational distribution of funds between activities and the methods of personnel stimulation for the effective use of financial resources were substantiated. The findings presented by the authors can become the basis for evaluation of financial processes in the logistic systems of industrial enterprises, which is necessary in the context of further improvement.

In paper [10], the need for the use of information technologies in financial management of supply chains was determined. The author of the work is limited to presenting conditional hypotheses of the interaction of information technologies with the efficiency of information exchange, competitive advantages, movement of logistic flows, without revealing the procedure of collection of empirical data. It is important to develop further the economic-mathematical apparatus of using information technologies for ensuring the evaluation of effectiveness of management of financial processes in logistic systems of industrial enterprises.

Authors of study [11] note that financial management of a supply chain appeared in response to the global economic crisis and financial difficulties of companies. Researchers recognize the fact that under conditions of the financial crisis, a lot of logistic networks would be liquidated if powerful companies in their supply chains did not provide an appropriate level of balance and liquidity of monetary flows. Analyzing a wide array of scientific information, they prove that the indicated scientific sphere is characterized by an exponential growth of interest of researchers and practical specialists. Further recognition and interest of researchers to the management of financial processes in logistic systems is determined by a search for the mechanisms of optimization of the parameters of financial flows and assessment of the impact on the overall effectiveness of operation.

Research [12] presents some separate aspects of evaluation of the state of management of financial processes in logistic systems. Taking into consideration the importance of the oil and gas industry, the authors of the article reveal the approach to determining the indicators and factors that affect the management of financial flows, set priorities and indicators of the effectiveness with the use of the Fuzzy ANP method. Despite the significance of the presented models, it is appropriate at the level of the industry, which narrows down the possibilities for its use by an industrial enterprise. Therefore, it is advisable to improve and adapt the presented assessment model to various sectors of functioning.

Functioning of industrial enterprises in the form of logistic systems requires improvement of approaches to the management of financial processes in the part that ensures estimation reliability and formation of systematized models. This is due to the fact that normative values of the indicators do not reflect the relationships in logistic chains and indicators of effectiveness of logistic management do not reflect the specific features of the management of financial processes. As a result, it is almost impossible to establish the optimal values of the parameters of financial flows and to identify the key criteria for management of financial processes. It proves that the existing approaches do not provide a possibility to develop optimal solutions for management of financial processes in the logistic systems of industrial enterprises. This part of the problem can be solved by designing an effective approach, which would ensure generalization of the parameters of financial flows and the criteria for management of financial processes to describe the final state.

3. The aim and objectives of the study

The aim of this study is to develop the model for evaluation of the state of management of financial processes in logistic systems of industrial enterprises, which ensures enhancement of efficiency of economic activities based on making rational decisions.

To achieve the set aim, the following tasks need to be solved:

– to determine the composition of the system-forming factors taking into consideration modern technological tendencies in the industry and identify key criteria for evaluation of the state of management of financial processes in logistic systems of industrial enterprises;

– evaluate taxonomic indicators of the state of management of financial processes in logistic systems of industrial enterprises to assess the impact level;

– to assess the effectiveness of management of financial processes in logistic systems of industrial enterprises by calculating the integral index and identify the possibilities to enhance it.

4. Materials and methods for studying the management of financial processes in logistic systems at industrial enterprises

The information basis of the study included the official statistics [13], [14] financial and management reporting of an enterprise. The methods of information processing comprised abstraction, analysis, synthesis, description, interpretation and others. The methods of statistical-economic analysis were used when exploring the tendencies and systemic factors of the development of logistication processes at industrial enterprises. To support the key criteria of the management of financial processes, we applied the methods of multivariate statistical analysis, sample actualization and factor analysis. The method of taxonomic simulation was applied in assessing the influence of the parameters of financial flows on the overall level of the management of financial processes. The methods of statistical control and graphoanalytic methods were used to determine the limits of fluctuations of taxonomic and integral estimation indicators. The methods of computer processing with the help of IBM SPSS Statistics

Version 22 (Russia) and Microsoft Excel software were used for calculation.

5. Results of implementation of the model for estimation of financial processes in logistic systems of industrial enterprises

5. 1. Establishment of the composition of system-forming factors taking into consideration modern technological tendencies in the industry

Reliability is the basis for effectiveness of functioning of macro- and micro-logistic systems at the national and global levels, which is ensured by the management of financial processes, determined by the value of the formed logistic chains and the impact on the cost of enterprises.

In the logistic systems of industrial enterprises, effective approaches to the management of financial processes must include the indicators that are most sensitive to changes in parameters of financial flows and the importance of key management criteria. Despite this, it is a relevant task to develop of the appropriate evaluation model, which will be based on taking into account the dynamic state (flow) of financial resources and will be acceptable for companies that develop logistic systems or are at primary stages of formation.

As a result, the technology of increasing efficiency of management of financial processes in logistic systems of industrial enterprises should be based on an approach that would allow the combination of indicators of assessment of financial resources, financial flows, and the key management criteria. Its stages must be the following:

1) substantiation of the composition of monitoring and evaluation indicators;

2) calculation, standardization and updating of the system of estimation indicators;

3) construction of Shewhart control charts to determine the limits of indicators' fluctuations;

4) calculation of taxonomic indicators by the key criteria;

5) determining the integral index of estimation of the state of management of financial processes;

6) construction of the graduation scale based of the method of Shewhart control charts and assessment of the state of the management of financial processes at an industrial enterprise.

Indicators of monitoring and evaluation of the state of management of financial processes at industrial enterprises under conditions of logistication of economy should reflect the internal environment of a business entity and industrial tendencies that are characteristic of the external environment. For this purpose, in the process of forming a data array, it is necessary to consider causal and synergistic relationships that arise between elements of a logistic system. In this case, the totality of empirical data must be based on consistency principles. Indicators should be related, but not repeated, which will make it possible to reflect real financial processes in a logistic system of an industrial enterprise. That is why the indicators must be grouped by five directions: finances, a logistic infrastructure, logistic processes, staff, and society [15]. In the framework of the study, empirical indicators were explored for ten studied industrial enterprises for the period from 2009 to 2016.

The stage of actualization is carried out to form the aggregated factors based on correlation relations between partial indicators that characterize the state of the studied

process. These factors reflect the dynamics of the state of management of financial processes. In this case, reliability is determined by the generation of a homogeneous sample and testing it for compliance with the normal distribution law. It uses the criteria of Smirnov-Grubbs, Dickson, Titien-Moor and Kolmogorov-Smirnov, Liliforce and Shapiro-Wilk [16]. Following the position of [17] and with the purpose of maximum preservation of a sample volume, a whole array of indicators was included to the sample within the limits of the proposed model.

It is advisable to perform the process of indicators' actualization based on reduced correlation matrices, calculation of factor loads that are used within the multidimensional statistical analysis [18]. Selection of the method for actualization of the system of indicators of evaluation of the state of management of financial processes in logistic systems of industrial enterprises is based on such conditions of factor analysis:

– it makes it possible to specify the composition of the indicators' system in terms of the determined evaluation aspects under conditions of dynamic changes in a logistic system;

– it does not distort the array of statistical information and makes it possible to draw scientifically reasonable conclusions;

– it synthesizes the system of significant indicators that are inherent to the general tendencies in the management of financial processes at industrial enterprises under conditions of logistication of economy.

Its basic model is as follows (1):

$$X_1 = a_{11}F_1 + a_{12}F_2 + ... + a_{1i}F_i + ... + a_{1m}F_m + a_1U_1,$$

$$X_j = a_{j1}F_1 + a_{j2}F_2 + ... + a_{ji}F_i + ... + a_{jm}F_m + a_jU_j, \qquad (1)$$

$$X_n = a_{n1}F_1 + a_{n2}F_2 + ... + a_{ni}F_i + ... + a_{nm}F_m + a_nU_n,$$

where $m \leq n$; X_j is the original features; F_i is the general factors; U_j is the specific factors; a_{ji}, a_j are the factor loads (correlation factor of each of the analyzed variables with each of the selected factors).

Given the requirements to construction of correlation matrices [18], in the model of evaluation of the state of management of financial processes in a logistic system of an industrial enterprise, a particular equation of the system takes the form (2):

$$\begin{matrix} X_{1j} \\ X_{2j} = a_{j1} \\ \cdot \\ X_{wj} \end{matrix} \begin{bmatrix} f_{11} \\ f_{21} \\ \cdot \\ f_{w1} \end{bmatrix} + a_{j2} \begin{bmatrix} f_{12} \\ f_{22} \\ \cdot \\ f_{w2} \end{bmatrix} +$$

$$+ a_{ji} \begin{bmatrix} f_{1i} \\ f_{2i} \\ \cdot \\ f_{wi} \end{bmatrix} + ... + a_{jm} \begin{bmatrix} f_{1m} \\ f_{2m} \\ \cdot \\ f_{wm} \end{bmatrix} + a_j \begin{bmatrix} U_{1j} \\ U_{2j} \\ \cdot \\ U_{wj} \end{bmatrix}. \quad (2)$$

Magnitudes X_j, F_i, U_j are variables, in this case, only the values of original features (based on an observation matrix) are known. As a result, the solution to the system of equations is to compute the factor loads, and then factors.

Factor loads, which characterize closeness of relationships between partial features and factors, determine the essential or nonessential relationships. The closer the relationship of a variable with a factor, the higher the value of the factor load. The relationship is considered significant if the correlation factor is higher than 0.7, it is considered nonessential if it is lower. A positive value of load reflects a direct relationship, the negative one reflects an inverse one.

The features that are included in an observation matrix are non-homogeneous, since they describe different properties of the system of evaluation indicators and different units of measurements. That is why within the developed model, it is necessary to perform standardization of features, at which the observation matrix is converted by obtaining standardized values of features.

The standardization of indicators is based on formulas (3) to (5):

$$Z_{ij} = \frac{x_{ij} - \bar{x}_j}{S_j}, \qquad (3)$$

$$\bar{x}_j = \frac{1}{w} \sum_{i=1}^{w} x_{ij}, \qquad (4)$$

$$S_j = \left[\frac{1}{w} \sum_{i=1}^{w} \left(x_{ij} - \bar{x}_j \right)^2 \right]^{\frac{1}{2}}, \qquad (5)$$

where Z_{ij} is the standardized value of the j-th feature for the i-th statistic unit; X_{ij} is the value of the j-th feature for the i-th statistic unit; $j = 1, 2, 3,..., n$; W is the number of units of totality, $\bar{X}_j$ is the arithmetic mean value of the j-th feature; S_j is the standard deviation of the value of the j-th feature j for the i-th unit.

It is advisable to perform standardization of the values of indicators using computer program Excel. A fragment of calculations is presented in Table 1.

Table 1

A fragment of calculation of standardization of elasticity coefficient of incoming financial flow on the example of PAT «Volodarka» (Ukraine)

Years	X_i	$\bar{X}$	$X_i - \bar{X}$	$(X_i - \bar{X})^2$	S_j	Z_i	$(Z_{i1}-Z_o)$	$(Z_{i1}-Z_o)^2$
2009	0.54	0.826	−0.286	0.082	–	−1.329	−1.869	3.492
2010	0.67	0.826	−0.156	0.024	–	−0.725	−1.265	1.600
2011	0.82	0.826	−0.006	0.000	–	−0.029	−0.569	0.323
2012	1.01	0.826	0.184	0.034	–	0.853	0.313	0.098
2013	0.88	0.826	0.054	0.003	–	0.250	−0.290	0.084
2014	0.72	0.826	−0.106	0.011	–	−0.493	−1.033	1.067
2015	0.74	0.826	−0.086	0.007	–	−0.400	−0.940	0.884
2016	1.23	0.826	0.404	0.163	–	1.874	1.335	1.781
Standard	1.00	0.884	0.116	0.014	–	0.540	0.000	0.000
–	–	–	–	–	0.215	–	–	–

After standardization of features, in order to exclude undesirable characteristics of the indicators, it is advisable to convert the correlation matrix into the reduced matrix by including the totality (the part of the variance that is explained by general factors) in it (6):

$$h_j^2 = a_{j1}^2 + ... + a_{jm}^2 \qquad (6)$$

and excluding patterns (part of the variance that remained from the complete variance) of features.

In this case, the variance of a feature will be calculated as (7):

$$S_j^2 = \frac{1}{w} \sum_{i=1}^{w} (z_{ij} - \bar{z}_j)^2. \tag{7}$$

As a result, the obtained reduced correlation matrix, unlike the standard matrix, in which the elements that are equal to unity are on the main diagonal, will take the following form (8):

$$R' = \begin{bmatrix} h_1^2 & r_{12}... & r_{1n} \\ r_{21} & h_2^2... & r_{2n} \\ r_{n1} & r_{n2} & h_n^2 \end{bmatrix}. \tag{8}$$

Its use will make it possible to simplify the procedure of a factor analysis. As a result, the model of factor analysis will be converted into (9):

$$Z_1' = a_{11}F_1 + a_{12}F_2 + ... + a_{1i}F_i + ... + a_{1m}F_m;$$

$$Z_j' = a_{j1}F_1 + a_{j2}F_2 + ... + a_{ji}F_i + ... + a_{1m}F_m; \tag{9}$$

$$Z_n' = a_{n1}F_1 + a_{n2}F_2 + ... + a_{ni}F_i + ... + a_{1nm}F_m.$$

The simplified system of equations predetermines a change in some of the ratios that relate the variance and correlation factors with factor loads. The variance will be equal not to full variance, but rather to the totality of features of factors (10):

$$S_{z_j'}^2 = h_j^2. \tag{10}$$

That is why within the limits of construction of the reduced matrix, it is necessary to use formulas (11) and (12) to calculate the values of correlation factor:

– for $k \neq l$:

$$r_{r,l}' = a_{k1}a_{l1} + a_{k2}a_{l2} + ... + a_{km}a_{lm}; \tag{11}$$

– for $k = l$:

$$r_{r,l}' = a_{k1}a_{l1} + a_{k2}a_{l2} + ... + a_{km}a_{lm}. \tag{12}$$

In the matrix form, these formulas will take the following form (13):

$$\begin{bmatrix} h_1^2 & r_{12........} & r_{1n} \\ r_{21} & h_2^2........ & r_{2n} \\ ..... & ..... & ..... \\ r_{n1} & r_{n2} & h_n^2 \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12........} & a_{1m} \\ a_{21} & a_{22........} & a_{2m} \\ a_{n1} & a_{n2........} & a_{nm} \end{bmatrix} \begin{bmatrix} a_{11} & a_{21........} & a_{n1} \\ a_{12} & a_{22........} & a_{n2} \\ a_{1m} & a_{2m} & a_{nm} \end{bmatrix}. \tag{13}$$

After standardization of features, determining the elements of the matrix and evaluation of totality, factor loads of indicators that reflect correlation level of a separate indicator by the factor were calculated.

Given that the proposed approach to actualization of the indicators' system is iterative, the calculations should be carried out in IBM SPSS Statistics Version 22. The procedure for assigning indicators to parameters and the fragment of calculation of factor loads are shown in Tables 2, 3.

Table 2

Procedure for assigning indicators to parameters in IBM SPSS Statistics

Parameter	Indicator
Coefficient of staff turnover in management of financial processes	VAR00001
Coefficient of social significance	VAR00002
Coefficient if ensuring outgoing financial flows by incoming ones	VAR00003
Coefficient of informatization of management of financial processes	VAR00004
Quality of implemented charity measures	VAR00005
Coefficient of feedback satisfaction of employees	VAR0006
Coefficient of qualification level of management of financial processes	VAR00007
Coefficient of business reputation	VAR00008
Coefficient of expedience of participation in exhibition and fair events	VAR00009
Coefficient of net financial flow per one employee	VAR00010
Coefficient of using logistic infrastructure	VAR00011
Coefficient of elasticity of incoming financial flow by client base	VAR00012
Coefficient of claim	VAR00013
Coefficient of the depth of specialization in management of financial processes	VAR00014
Coefficient of outsourcing impact	VAR00015
Coefficient of profitability of financial flow	VAR00016

Table 3

Matrix of factor loads in IBM SPSS Statistics

Indicator	Factor load characteristics			
	1	2	3	4
VAR00009	0.967	−0.041	0.175	0.016
VAR00008	0.942	−0.036	−0.207	0.023
VAR00010	0.939	−0.043	−0.107	0.054
VAR00002	0.938	−0.037	0.173	−0.020
VAR00016	0.925	0.076	0.084	0.001
VAR00011	−0.031	0.874	−0.169	−0.144
VAR00012	−0.041	0.868	−0.166	−0.191
VAR00007	0.116	0.743	−0.013	0.415
VAR00006	−0.298	0.631	−0.225	0.350
VAR00004	0.189	−0.254	0.533	0.266
VAR00013	−0.164	−0.383	0.513	−0.051
VAR00001	−0.042	0.001	0.461	−0.007
VAR00015	−0.077	−0.069	0.482	0.413
VAR00014	0.207	−0.011	0.148	0.870
VAR00003	0.040	−0.020	−0.375	0.613
VAR00005	0.310	0.090	0.337	0.569

The results of evaluation of the contribution of each indicator to the total variance ensured formation of four system-forming factors. The first factor is 34.8 % of variability. The second and the third factors are explained by 25.4 % and 18.8 % of variability, respectively, the fourth – 11.8 %. In general, the obtained values of total variability suggest that the first four factors at the level of 90.8 % of the totality made it possible to present primary variables that reflect the state of management of financial processes at industrial enterprises. Based on the economic-mathematical content of the factor-forming indicators, the key criteria of management of financial processes in logistic systems of industrial enterprises, it is advisable to determine the liquidity, balance, intensity, and sufficiency of financial flows.

The first factor «Liquidity of financial flows» shows the capability of the financial flow to accelerate the movement rate under conditions of unforeseen situations. The indicators, which determine the capability to ensure the sufficient liquidity level in case of cuts (extension) of logistic chains, are formed in the logistic system of an industrial enterprise. A factor is characterized by the high values of factor logistics on features. Percentage of variability and high loads indicate that at the present stage of economy logistication, liquidity of the financial flow is the main criterion of ensuring a high level of management of financial processes in logistic systems of industrial enterprises. Within the given factor, the main indicators of the influence on liquidity of financial flows of the national industrial enterprises are the following:

– coefficient of expediency of participation in exhibitions and fair events, which describes the conditions for the growth of the amount of incoming financial flows and acceleration of the rate of their movement in the current and future reporting periods due to expansion of selling markets;

– coefficient of business reputation, which assesses the separate features of an enterprise by the criteria of professionalism, reliability, business sense, social responsibility and the formed level of trust of society. Business reputation plays the key role in ensuring liquidity of financial flows, expanding the circle of business partners, which provides the formation of long-term trajectories of movement of financial flows and acceleration of their rate by the specified logistic chains;

– coefficient of a net financial flow per employee reflects the possibilities of using by an enterprise of a net financial flow for the personnel development. His motivation to use creative approaches in management of financial processes determines the acceleration of the rate of movement of financial flows;

– coefficient of social significance, which reflects the value of an enterprise to the society at a particular stage of operation and is calculated as the product of coefficient of brand awareness and coefficient of goods consumption. The impact on liquidity of the financial flow is expressed in its acceleration due to recognition of the given enterprise by the society;

– coefficient of profitability of the financial flow describes the ratio between the net and the outgoing financial flows. To ensure the appropriate level of this indicator, it is required to make business activity of an enterprise more active, and therefore, to form effective mechanisms to accelerate the movement of financial flows.

The second factor is characterized by the same number of parameters as the first factor. It is advisable to define it as «Balance of financial flows», which is capable to optimize incoming and outgoing financial flows and to bring financial flows into conformity with the material flows. The balance is ensured by synchronization, which regulates incoming and outgoing financial flows in terms of logistic chains to optimize the balance of monetary costs and the rhythm, which reflects the movement of same amounts at the same rate. Within this factor, the main indicators on the impact on the balance of financial flows of the national industrial enterprises are the following:

– coefficient of the use of the logistic infrastructure characterizes the conditions of formation by the objectively necessary number of participants. This makes it possible to optimize the amount of net financial flows through the consistency of financial flows, as well as creates the optimal channels of movement of corresponding material flows;

– coefficient of elasticity of incoming financial flow by the client base, which determines the conditions of the gain of the incoming financial flow compared with the gain in the clients of a company. The influence on the balance is pronounced in ensuring the optimal deviations of incoming financial flows from attracting new customers with outgoing financial flows related to the policy of expanding selling markets;

– coefficient of qualification level characterizes ensuring the balance of financial flows through capabilities of employees to apply modern tools of management of financial processes;

– coefficient of feedback satisfaction of staff reflects the level, depth, adequacy of accepting by the managers the decisions made by chief executives and implementation of their cumulative impact on the management of financial processes. Feedback synthesizes the actions of participants of logistic chains, which represent causal relationships during ensuring the balance of financial flows. This reduces entropy, increases the self-organization level and substantiation of decision making.

Based on the structure of the third factor, it is interpreted as «Intensity of financial flows». The intensity of financial flows is the frequency of movement of incoming and outgoing financial flows in terms of logistic chains and between the elements of the logistic system. Factor logistics indicators are positive and negative in nature. That is why the quantitative increase in of the values that make up the structure of a factor has a stimulatory and non-stimulatory effect on the dynamics of the studied process.

Within the given factor, the main indicators of the impact on the intensity of financial flows of the national industrial enterprises are the following:

– coefficient of digitization of management of financial processes reveals the nature of the use and availability of information and communication technologies. This enhances effectiveness of monitoring the movement of financial flows in the context of logistic chains. As a consequence, the duration of a financial-logistic cycle decreases, which contributes to improvement of intensity of financial flows;

– coefficient of claim describes the impact of claims on the reduction of the frequency of movement of incoming financial flows and emergence of unexpected outgoing financial flows due to the emergence of additional transaction costs;

– coefficient of staff turnover in the management of financial processes, which determines the possibility of ensuring an acceptable level of intensity of financial flows due to creation by managers of their own databases of participants of the logistic infrastructure and formed lasting partnerships;

– coefficient of outsourcing impact characterizes the acceleration of incoming and outgoing financial flows due to reduction in costs of performing operations by outsourcing companies. The intensity of financial flows is ensured by

finding rational ways to optimize incoming and outgoing financial flows.

The fourth factor «Sufficiency of financial flows» includes the indicators that clearly reveal the specifics of functioning of logistic systems of industrial enterprises and display the specifics of the flow management of financial processes based on the principles of social responsibility of business. The structure of indicators reveals the possibilities of net financial flow to meet the needs of an industrial enterprise to implement alternative directions of formation and use of financial resources.

Within the given factors, the main indicators of the impact on sufficiency of financial flows of the national industrial enterprises are the following:

– coefficient of the depth of specialization in management of financial processes reflects the proportion of employees with experience in the management of financial processes of the company. This creates the conditions for ensuring the sufficiency of financial flows during current and future reporting periods;

– coefficient of ensuring outgoing financial flows by the incoming one characterizes the level of the outgoing financial flows being exceeded by the incoming financial flows, which determines the possibility of the development of an enterprise;

– the number of implemented charitable activities determines the possibilities of obtaining sufficient future financial flows due to the formation of new partnerships, which can become a basis for attracting additional investment resources and modern ways of financing, including financing by crowdfunding platforms.

The management of financial processes based on the established indicators of the highest impact on liquidity, balance, intensity, and sufficiency of financial flows can ensure stability of logistic systems of industrial enterprises in long-term prospects. Unlike traditional indicators of ensuring liquidity, balance, intensity and sufficiency, the described indicators of financial flows are more strategically oriented and cover the entire system of the enterprise management.

The next stage is determining the limits of fluctuations in the values of the indicators for key criteria. To do this, we will use the method of construction of the Shewhart control charts [19]. A control chart is a diagram of values of the found characteristics of sub-groups depending on numbers. It reflects the central line, which corresponds to the reference value of the characteristic (arithmetic mean of the indicators of the sample totality of the enterprises in the studied dynamic range) and control boundaries (upper and lower). As a result, the variability cause is the point, which displays on the control card the time and the state of the studied process at some point according to its upper or lower control boundary (permissible magnitude of deviation of a characteristic from its typical value). The control boundaries are at distance of 3σ from the central line, where σ is the standard deviation. Magnitude 3σ indicates that approximately 99.7 % of the values of a characteristic are within the boundaries on condition that the process is in the statistically controlled state. That is, there is a risk, equal to approximately 0.03 %, or an average of three per thousand cases, that the point will be found beyond the control boundaries when the process is in the statistically controlled state. The probability of «breaking» the boundaries is so low that the appearance of a point beyond the boundaries requires immediate actions so as to return to the measures of the typical state. As a result, control boundaries 3σ are called «actions boundaries actions». The boundaries at distance 2σ from the central line display the points that warn about the possibility of the process going beyond the state of statistical control (warning points).

Software interface of implementation of this process by a separate indicator is shown in Fig. 1.
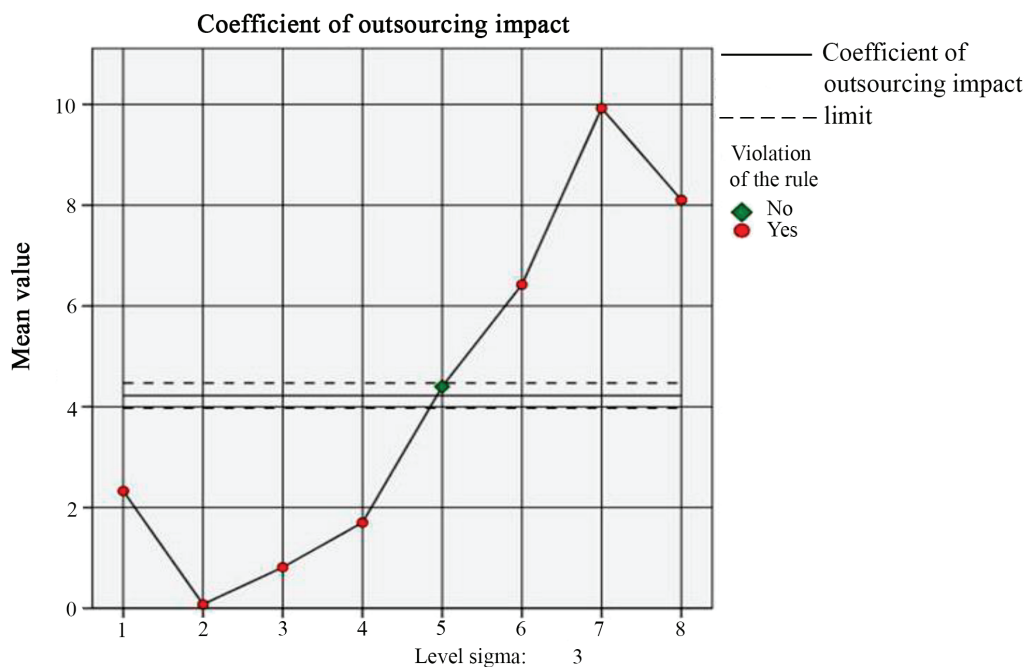

Fig. 1. Software interface of the construction of control charts in IBM SPSS Statistics Version 22 (fragment by a separate indicator)

5. 2. Assessment of the level of impact of key criteria of management of financial processes based on taxonomic indicators

At the next stage, it is necessary to calculate the taxonomic indicators by the key criteria of the management of financial processes in order to assess the level of impact on management processes. A taxonomic indicator is a synthetic magnitude, «resultant» for all features that characterize the studied totality. The main indicator used in taxonomic models is so-called taxonomic distance. It is the distance between the points of a multi-dimensional space that is calculated based on the methods of analytical geometry. Taxonomic distance is calculated between points-features in a multi-dimensional space.

In turn, space dimensionality is determined by the number of features that characterize the studied phenomenon. The calculated taxonomic distance existing in a multi-dimensional space makes it possible to determine the position of each point relative to the others, and as a result, to substantiate the place in the general totality. Due to consideration of complexity of the developed model, the standardization of features was carried out at the first stage. That is why in order to calculate a taxonomic indicator for key criteria of the management of financial processes, it is appropriate to use the information that is grouped at the first stage of implementation of the considered model. Standardization is required in case of a partial use of the model and monitoring the values of taxonomic indicators in each new dynamic range for a particular company.

In this case, it is necessary to calculate the elements of the matrix of distances. To achieve the goal, all features of the matrix of observations should be differentiated. Feature differentiation is the division of the stimulants and destimulant. The basis for feature division into two groups is the nature of the impact of each of them on the management level of the studied object. That is why it is advisable to determine the indicators that make direct impact on the management level within the determined criterion as stimulants. The indicators that make inverse impact are defined as destimulants. Considering a stimulating or destimulating impact of the indicators at the level of management of financial processes in the logistic system of an enterprise, it is proposed to select the highest value as the standard for the indicators in the studied range that are stimulants, and the lowest value – for destimulants.

After studying the coordinates of the standard, the distances between the point and separate units of the studied set are calculated. After calculating the distance between all units of this totality, we obtain the matrix of distances C. It can be written down as (14):

$$C = \begin{bmatrix} 0 & C_{12} & C_{1i} & C_{1p} & C_{1w} \\ C_{21} & 0 & C_{2i} & C_{2p} & C_{2w} \\ C_{i1} & C_{i2} & 0 & C_{ip} & C_{iw} \\ C_{p1} & C_{p2} & C_{pi} & 0 & C_{pw} \\ C_{w1} & C_{w2} & C_{wi} & C_{wp} & 0 \end{bmatrix}, \tag{14}$$

where character C_{ij} means the distance between elements i and j.

The obtained distances are original magnitudes that should be used for calculating the taxonomic indicator for each key criterion of management of financial processes (t_i) (15):

$$t_i = 1 - \frac{C_{io}}{C_o}. \tag{15}$$

Results of calculations of taxonomic indicators of management of financial processes in logistic systems of industrial enterprises are shown in Table 4.

The taxonomic indicator of the management of financial processes for each criterion is interpreted as follows: the closer the value of the indicator to unity, the more this unit influences the level of management of financial processes.

Table 4

Taxonomic indicators by key criteria of management of financial processes in logistic systems of industrial enterprises (Ukraine)

Enterprise	Value of taxonomic indicators			
	Liquidity (TI_{LFF})	Balance (TI_{BFF})	Sufficiency (TI_{SFF})	Intensity (TI_{IFF})
PrAT company «Arsania»	0.019	0.297	0.343	0.275
PAT «Berdichev factory»	0.129	0.157	0.222	0.373
PAT «Volodarka»	0.298	0.442	0.212	0.531
PAT «Grono-Tex»	0.346	0.283	0.275	0.706
PAT «Zorianka»	0.372	0.545	0.468	0.360
PrAT «Santa Ukraine»	0.222	0.251	0.173	0.089
PAT «Siverianka»	0.371	0.136	0.250	0.514
PAT «Trottola»	0.536	0.301	0.021	0.565
PrAT «Uzhgorod sewing factory»	0.247	0.073	0.142	0.698
PrAT «Elegant»	0.317	0.329	0.306	0.151

The level of influence of the key criteria of the management of financial processes by a sample set of enterprises differs significantly. However, the feature for the studied enterprises is a predominant impact of the criteria of intensity and balance, which is quite logical, given the financial capabilities of industrial enterprises, determined by the modern state of development of economy of Ukraine.

5. 3. Calculation of the integral index of evaluation of effectiveness of management of financial processes

It is advisable to calculate the integral index of evaluation of the state of management of financial processes in logistic systems of industrial enterprises based on taxonomic indicators and significance of the generated groups of factors. To calculate the integral index of evaluation of the management of financial processes in a logistic system of industrial enterprises, the following formula is proposed (16):

$$II_{LS}^{MFP} = TI_{LFF} \cdot \lambda_L + TI_{BFF} \cdot \lambda_B + TI_{SFF} \cdot \lambda_S + TI_{FF} \cdot \lambda, \tag{16}$$

where λ displays significance of the key criteria of the management of financial processes in logistic system of industrial enterprise, determined by the structure of factor features.

The calculated values of integral indices for the sample totality of industrial enterprises are shown in Table 5.

The obtained values of integral indices characterize the state of the management of financial processes for a particular industrial enterprise. Along with this, the values of the indices indicate that in the industry it varies from 0.2551 to 0.4085. The economic interpretation of integral index is

as follows: the closer the value to unity, the higher the level of management of financial processes in logistic systems of industrial enterprises.

Integral indices of evaluation of the state of management of financial processes in logistic systems of industrial enterprises (Ukraine)

Enterprise	Value of integral index
PrAT company «Arsania»	0.189
PAT «Berdichev factory»	0.175
PAT «Volodarka»	0.368
PAT «Grono-Tex»	0.351
PAT «Zorianka»	0.408
PrAT «Santa Ukraine»	0.253
PAT «Siverianka»	0.281
PAT «Trottola»	0.390
PrAT «Uzhgorod sewing factory»	0.255
PrAT «Elegant»	0.303

This situation determines the necessity of formation of the corresponding gradation scale. It is advisable to construct it based on the method of Shewhart control charts in software IBM SPSS Statistics Version 22. According to the determined limits, It is appropriate to represent the scale of gradation of the values of integral indices of evaluation of the state of management of financial processes in logistic systems of industrial enterprises as follows (15) to (18):

– high level:

$$\bar{X} + 1\sigma \leq II_{LS}^{MFP} \leq \bar{X} + 3\sigma, \quad 0.419 \leq II_{LS}^{MFP} \leq 0.503; \qquad (15)$$

– medium level:

$$\bar{X} - 1\sigma \leq II_{LS}^{MFP} \leq \bar{X} + 1\sigma, \quad 0.334 \leq II_{LS}^{MFP} \leq 0.419;$$

– low level:

$$\bar{X} - 3\sigma \leq II_{LS}^{MFP} \leq \bar{X} - 1\sigma, \quad 0.250 \leq II_{LS}^{MFP} \leq 0.334;$$

– rather low level:

$$0 < II_{LS}^{MFP} \leq \bar{X} - 3\sigma, \quad 0 \leq II_{LS}^{MFP} \leq 0.250.$$

Approaches to improvement of effectiveness of management of financial processes in logistic systems of industrial enterprises are also determined for each enterprise by a situational combination of the values of the value of taxonomic and integral indicators. The calculations show that it the lack of a high level of management of financial processes is characteristic for Ukrainian industrial enterprises. The medium level of management of financial processes is characteristic of PAT «Volodarka», PAT «Grono-Tex», PAT «Kirovogradska SF «Zorianka», PAT «Trottola». The enterprises PJSC PAT «Siverianka», «Santa» Ukraine, PAT «Uzhgorod sewing factory», PAT «Chernigov SF «Elegant» have a low level of management of financial processes. The value of the integral index for PAT company «Arsania», PAT Berdichev factory» go beyond the lower boundary of the Shewhart control chart, which reflects a rather low level of management of financial processes. It is appropriate to determine the measures for improvement of the effectiveness of the management

of financial processes for a particular industrial enterprise taking into consideration taxonomic indicators according to the established criteria and the impact of decisions on the indicators that belong to each of them. In particular, for the PAT «Volodarka», intensity and balance are the most significant criteria of the management of financial processes. It is appropriate to make decisions on the transition from the medium level to the high level through the influence on the indicators of these factors. A similar algorithm in decision-making for improvement of the management of financial processes is used for other businesses.

6. Discussion of the results of implementation of the model for evaluation of financial processes at industrial enterprises

The advantage of the proposed model is to provide a reliable assessment of the effectiveness of the management of financial processes in logistic systems of industrial enterprises based on the methods of mathematical statistics. Developing the scientific approach [5] regarding the financial integration of the participants of logistic chains, the proposed model creates a basis for the formation of logistic networks and generation of extra value by them.

In contrast to study [12], which propose a model for evaluation of the management of financial processes at the level of the industry, the developed model can be applied both at the level of various industries and at the level of businesses.

The presented model also improves the approaches [10] concerning the necessity of the management of financial processes in supply chains. In particular, the financial flows that circulate not only in a supply chain, but also in the entire logistic system of an industrial enterprise are taken in consideration within its boundaries.

The author [2] demonstrates the key role of the operative control of the management of financial flows in supply chains, which limits the possibilities for strategic management. The presented model is aimed at the regulation of the operative indicators that ensure the strategic prospects of the development of an enterprise and cover all of the systems of control of an industrial enterprise. In addition, in the technique of the researcher [2], the emphasis is on the management of liquidity. The developed model provides an assessment of the effectiveness of the management of financial processes in logistic systems of industrial enterprises by four key criteria – liquidity, balance, intensity, and sufficiency.

The problem of the vast majority of existing scientific research is that the normative value of the indicators, which are used in the management of financial processes, do not reflect the specificity of the flow management. Trying to solve the specified problems, the study proposed an integrated approach based on the financial, logistic and social indicators.

The disadvantage of the presented model is, first of all, that it is applicable only to the specified sample of enterprises or the corresponding stage of functioning of the economic system. A change in industrial or technological tendencies leads to reviewing the scale of gradation of values of integral indicators, and hence the need to calculate new values of indicators, formation of new groups of factors and to substantiate the key criteria. Secondly, in the determined dynamic series, the indicators can be formed by other latent factors, which will determine the need for substantiation of their causation. Thirdly, the economic-mathematical content of each selected

factor can be subjectively interpreted by the financial manager, based on the analysis of a particular situation.

The subsequent development of the model must focus on the formation of a unified approach to the selection of indicators and criteria for the management of financial processes at industrial enterprises. The presented model can also be developed in the direction of searching for the ways of their adapting to the dynamic conditions of functioning of the economies of various countries.

The possible difficulties in the development and practical application of the model is the occurrence of contradictions, which lies in simultaneous application of the unified approach corresponding to digitalization of the economy, and the differentiated approach, caused by different dynamic states of the business environment. The application of simulation can probably be one of the ways of overcoming the described problem.

7. Conclusions

1. The system-forming factors of the influence on the management of financial processes in logistic systems of industrial enterprises were determined based on the application of standardization procedure and actualization of the system of indicators. Taking into consideration the modern technological tendencies in the industry, the economic and mathematical content was revealed and the key criteria of the management of financial processes in the logistic systems of industrial enterprises were substantiated. It was established that at the present stage of functioning of the industry, it is advisable to carry out the study by such key criteria as liquidity, balance, intensity and sufficiency.

2. The level of the influence of the key criteria on the general state of the management of financial processes in logistic systems of industrial enterprises was determined. To do this, the taxonomic indicators of the management of financial processes by key criteria in the context of the studies industrial enterprises were calculated. The impact of the liquidity criterion is characterized by the values of the taxonomic indicators in the range from 0.019 to 0.536, of balance criterion – from 0.073 to 0.545, of sufficiency criterion – from 0.021 to 0.468, of intensity criterion – from 0.089 to 0.706. It was proved that under modern conditions, the intensity criterion and the balance criterion have prevailing influence on the management of financial process in the industry, which is explained by the limited financial capabilities of the Ukrainian industrial enterprises.

3. The state of the management of financial processes in logistic systems of industrial enterprises was estimated based on the proposed method for calculation of the integral index. The result of the evaluation is the establishment of the boundaries of the fluctuations in the values of integral index for each of the studied companies. Numeric boundaries of the fluctuations are:

– for the high level – $0.419 \leq II_{LS}^{MFP} \leq 0.503$;
– for the medium level – $0.334 \leq II_{LS}^{MFP} \leq 0.419$;
– for the low level – $0.250 \leq II_{LS}^{MFP} \leq 0.334$;
– for a rather low level – $0 \leq II_{LS}^{MFP} \leq 0.250$.

The gradation scale was established based on using the method of Shewhart control charts. It was emphasized that the numeric boundaries can change under the influence of economic and technological changes in the industry. It is appropriate to develop practical recommendations for each company with respect to the situational composition of the indicators of aggregated groups of factors and values of taxonomic indicators by the key criteria.

References

1. Pfohl H.-C., Gomm M. Supply chain finance: optimizing financial flows in supply chains // Logistics Research. 2009. Vol. 1, Issue 3-4. P. 149–161. doi: https://doi.org/10.1007/s12159-009-0020-y

2. Kristofik P., Kok J., Vries S. de, Hoff J. van S. Financial supply chain management – challenges and obstacles // ACRN Journal of Entrepreneurship Perspectives. 2012. Vol. 1, Issue 2. P. 132–143.

3. Hausman W. H. Financial Flows & Supply Chain Efficiency. URL: https://www.visa-asia.com/ap/sea/commercial/corporates/includes/uploads/Supply_Chain_Management_Visa.pdf

4. Basu P., Nair S. K. Supply Chain Finance enabled early pay: unlocking trapped value in B2B logistics // International Journal of Logistics Systems and Management. 2012. Vol. 12, Issue 3. P. 334. doi: https://doi.org/10.1504/ijlsm.2012.047605

5. Luo W., Shang K. Joint Inventory and Cash Management for Multidivisional Supply Chains // Operations Research. 2015. Vol. 63, Issue 5. P. 1098–1116. doi: https://doi.org/10.1287/opre.2015.1409

6. Holofaieva I. P. Finansovi potoky v lohistychniy diyalnosti pidpryiemstva // Biznes inform. 2013. Issue 8. P. 248–252.

7. Harafonova O. I. Osoblyvosti potokovoho upravlinnia v lohistychnykh systemakh promyslovykh pidpryiemstv // Naukovyi visnyk Polissia. 2015. Issue 4. P. 51–55.

8. Melnykova K. V. Finansova skladova stratehiyi rozvytku lohistychnykh system // Biznes inform. 2017. Issue 8. P. 237–241.

9. Negreeva V. V. Upravlenie finansovymi potokami v logisticheskih Kompleksah // Nauchniy zhurnal NIU ITMO. Seriya: Ekonomika i ekologicheskiy menedzhment. 2016. Issue 3. P. 71–78.

10. Aldakhil A. M. Effective Financial Management of Supply Chain through the Use of Emerging Technology // International Journal of Financial Research. 2015. Vol. 7, Issue 1. doi: https://doi.org/10.5430/ijfr.v7n1p189

11. Vousinas G., Ponis S. T. Financial Supply Chain Management – A review. URL: https://www.researchgate.net/publication/320196808_Financial_Supply_Chain_Management_-_A_review

12. Bahremand M., Karimi R. Providing Financial Flow Management Strategies in Supply Chain Projects // Industrial Engineering & Management Systems. 2018. Vol. 17, Issue 1. P. 155–163. doi: https://doi.org/10.7232/iems.2018.17.1.155

13. Holovne upravlinnia statystyky Ukrainy. Ekonomichna statystyka. Ekonomichna aktyvnist. Promyslovist. Indeksy promyslovoi produktsiyi za vydamy diialnosti v 2018 rotsi. URL: http://www.ukrstat.gov.ua

14. Ahentsiya rozvytku fondovoi infrastruktury Ukrainy (SMIDA). Finansovi zvity pidpryiemstv. URL: https://smida.gov.ua/

15. Bondarenko O. S. Systema otsinky efektyvnosti upravlinnia finansamy pidpryiemstva u suchasnykh umovakh // Investytsiy: praktyka ta dosvid. 2016. Issue 16. P. 18–21.

16. Ayvazyan S. A. Prikladnaya statistika: Osnovy modelirovaniya i pervichnaya obrabotka dannyh. Moscow: Finansy i statistika, 1983. 471 p.

17. Gribovskiy S. V. O povyshenii dostovernosti ocenki rynochnoy stoimosti metodom sravnitel'nogo analiza // Voprosy ocenki. 2002. Issue 1. P. 2–10.

18. Plyuta V. Sravnitel'niy mnogomerniy analiz v ekonomicheskih issledovaniyah. Metody taksonomii i faktornogo analiza / V. M. Zhukovskaya (Ed.). Moscow: Statistika, 1980. 151 p.

19. Vydannia ofitsiyne. Statystychnyi kontrol (kontrolni karty Shukharta) // Derzhstandart Ukrainy No. 69 vid 01 liutoho 2002 r. Kyiv, 2002. 32 p.

IMPROVING THE QUALITY OF FORGINGS BASED ON UPSETTING THE WORKPIECES WITH CONCAVE FACETS

O. Markov
Doctor of Technical Sciences, Professor,
Head of Department*
E-mail: oleg.markov.omd@gmail.com
V. Zlygoriev
PhD
Private Joint Stock Company
«Novokramatorsky Mashinostroitelny Zavod»
Ordzhonikidze str., 5, Kramatorsk,
Ukraine, 84305
E-mail: zvn@nkmz.donetsk.ua
O. Gerasimenko
PhD*
E-mail: profalliance@i.ua
N. Hrudkina
PhD**
E-mail: vm.grudkina@ukr.net
S. Shevtsov
PhD**
E-mail: sheser.ssa1@gmail.com
*Department of Metal Forming***
Department of Higher Mathematics*
***Donbass State Engineering Academy
Akademicheskaya str., 72, Kramatorsk,
Ukraine, 84313

Запропоновано спосіб кування поковок, який полягає в осаджені заготовок з увігнутими гранями. Розроблено методику теоретичних досліджень, яка полягала в дослідженні механізму закриття штучних осьових дефектів в заготовках. Дослідження проводилися на основі методу скінчених елементів. Основним параметром дослідження була глибина увігнутих граней заготовки. Цей параметр варіювався в діапазоні 0,75; 0,80 і 0,85. Кут увігнутих граней становив 120°. Результатами теоретичних досліджень були розподіли: деформацій, температур і напружень в тілі заготовки в процесі осадження заготовок з увігнутими гранями. На основі цих параметрів встановлювався показник напруженого стану в осьовій зоні заготовки.

Для перевірки отриманих теоретичних результатів була розроблена методика експериментальних досліджень. Дослідження проводилися на свинцевих і сталевих заготовках. В результаті теоретичних досліджень було встановлено, що ефективною глибиною увігнутих граней є співвідношення діаметрів виступів і уступів рівних 0,85. Для цього співвідношення відбувається інтенсивне закриття осьового дефекту. Це пояснюється високим рівнем стискають напружень при осаджені заготовок з увігнутими гранями. Встановлена ефективна ступінь деформації, при якій відбувається інтенсивне закриття дефектів. Встановлені розподіл деформацій за перерізом і висоті заготовки, а також зміна показника напруженого стану в процесі осадження заготовок з увігнутими гранями. Закриття осьових дефектів було підтверджено експериментальними дослідженнями на свинцевих і сталевих зразках.

Було здійснено впровадження нового способу осадження заготовок з увігнутими гранями. Результати ультразвукового контролю дозволили встановити, що отримані деталі не мають внутрішніх дефектів, які перевищують вимоги європейського стандарту SEP 1921. Проведені дослідження дозволили зробити висновок про високу ефективність запропонованого нового способу осадження заготовок з увігнутими гранями, яка полягала у підвищенні якості осьової зони крупних поковок з використанням цього способу

Ключові слова: увігнуті грані, осадження, напружено-деформований стан, осьові дефекти злитка, високоякісні поковки

1. Introduction

All machine parts in heavy industry and energy engineering refer to the products that have special purposes and are manufactured using the techniques of hot plastic deformation. The dimensions and weight of these parts imply their fabrication by forging. Billets for forging are typically ingots. Forge ingots are characterized by low quality due to